Social and behavioural questions associated with automated vehicles

Scoping study by UCL Transport Institute

Final report - January 2017

Tom Cohen, Peter Jones and Clémence Cavoli

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Foreword

The UK is increasingly seen as one of the best places in the world for connected and autonomous vehicles (CAVs) due to our world leading approach to regulation, culture of innovation and strong emphasis on research and development. CAVs have the potential to deliver significant social benefits to the UK: fewer crashes on our roads; freedom to travel for those who currently find that difficult; and more efficient transport networks that are safer, smoother, and swifter.

But we cannot be complacent. Understanding the attitudes, behaviour and wider public acceptability of transport users will be critical to the success of this technology. So it's vital that transport users, stakeholders and the wider public are at the heart of the design, development and deployment of CAVs.

It is important for those developing the technology to engage with the public openly and honestly. The four cities government funded trials currently underway will enable the public to see the vehicles up close and provide some evidence to support the growing understanding of the social and behavioural aspects of CAVs.

There is much left for the sector to understand now and in the future on the social and behavioural implications of CAVs for transport and beyond. We commissioned this scoping study to map out some of the main social and behavioural considerations in relation to CAVs and as a starting point for a wider social and behavioural programme that the Department for Transport is undertaking. The study has made some recommendations for future research not just for Government but for the entire CAV sector to engage with. Government cannot do it alone and we anticipate contributions towards the social and behavioural agenda from academia, industry and other stakeholders.

John Hayes MP – Minister of State

Executive summary

The UCL Transport Institute (UCLTI) was commissioned by the Department for Transport to conduct a scoping study to identify the key social and behavioural questions that should be addressed relating to automated vehicles (AVs).

The study consisted of: a literature review; a series of group events and interviews with stakeholders; and a workshop with representatives of the government-funded "four cities driverless vehicles" trials[1] in the UK, which was followed up by visits to these trials.

The research recommendations include:

- A **scenarios exercise**. Drawing on best practice in 'futures' work and embracing a wide range of themes, this would produce a manageable number of plausible scenarios of future technologies and usage patterns that could then act as a reference for a range of other research, including into consequences/wider impacts.
- **Deliberative exercise with citizens and organisations to investigate attitudes and likely behavioural responses to the technology**. This project could serve four purposes: to assess the value of work done to date on attitudes; to test the validity of the scenarios developed in the project described above, including the behavioural responses component; to gauge general attitudes to those scenarios and their likely social impacts; and to provide a foundation for detailed research concerning wider impacts.
- **Scoping work on the interaction between AVs and road users (including AV users themselves)**. This project would explore in greater detail than has been possible in this project the state of knowledge in this area and the nature and quality of research work currently being undertaken. This would enable the identification of a number of research projects that would complement existing work and inform, amongst other things, vehicle standards and a Highway Code of the future.
- **Exploration and appraisal of the potential role of the public sector.** Reflecting the prominence of the role of the public sector amongst the research questions generated, this rigorous exercise would be designed to map out the range of paths available to government at all levels to influence positively the development of the technology and its impacts.
- **Transport network simulation exercise**. Ideally drawing upon the scenarios exercise to provide a set of well-rounded and plausible combinations of technology and behavioural responses to it, this simulation would assist in identifying likely first-order network effects of the advent and use of AV technology.

In addition, the following complementary recommendations are made:

- Cross-government AV research panel
- Summit of major funders of transport research
- Deliberative events for officials that draw on the engagement tools used with stakeholders as part of this study

The main findings from the **literature review** include:

- There is a strong focus amongst published research upon the more technical aspects of the subject, with social and behavioural issues receiving much less attention. The

[1] Greenwich GATEway, UK Autodrive (Milton Keynes and Coventry) & Venturer (Bristol)

subject of the potential impacts of automated vehicles in general appears under-researched, with very few topics studied in any depth and some, such as health impacts, barely acknowledged.

- Though some researchers display a concern about the technology's potential for creating wider negative impacts, the majority of the literature appears positive about AVs.
- There is relatively little empirical work, most writing on the subject being speculative in nature.
- The research on the whole is either not academically rigorous, or rather narrowly focused, with authors not tending to consider a sufficiently wide range of possible futures in arriving at their conclusions, or focusing on a very specific aspect. This may stem in part from the lack of inter-disciplinary research in the literature, with most work coming from a single discipline, predominantly engineering or computer science.

This study generated a set of 384 **questions** relating to automated vehicles and these broadly fit with the four areas identified below. These are large research areas in their own right; it is not imagined that all associated research questions can be answered in the immediate term.

- The interaction between the user/driver and highly automated/'driverless' car
- The interaction of other road users, including pedestrians with the 'driverless' car
- The attitudes of the general public towards 'driverless' cars, including public acceptability
- The wider, longer-term social, economic and environmental impacts of autonomous vehicles

These four areas were useful but, to provide further structure and support thinking about current and future research needs in this area and manage the complexity of the topic, a **conceptual framework** was developed, consisting of five main categories (see Page 19, Figure 2).

Technological & market developments are the set of actions that will determine the AV "offer" (for example, what vehicles will look like, how users will operate them, how quickly they will travel)

Use of & response to AVs are the set of reactions from individuals and organisations to the technologies that are offered by the market(s) (for example, how AVs will be deployed, what uses they will have, who will use them and for what purposes)

Consequences/wider impacts are the set of effects that are propagated by the pattern of AV uptake and use (for example, the impacts of AV use on congestion and the environment; and public health implications)

Both **stakeholders' awareness & attitudes** and the **public sector's role** interact with each of these three steps. For example, the nature of the AV offer will be significantly influenced both by consumer perceptions and attitudes, and the regulations imposed by governments.

The principal relationships within the conceptual framework are linear[2] and demonstrate that, in order to draw conclusions concerning consequences/wider impacts of AVs, it is necessary first to have made at least working assumptions concerning both of the preceding categories: technological & market developments; and use of & response to AVs.

Acknowledgments

UCL Transport Institute thanks the many individuals and organisations that contributed their time to the work reported here.

[2] *Use of & response to AVs* are to a large extent a function of *technological & market developments*; in turn, *consequences/wider impacts* are largely a function of *use of & response to AVs*.

Introduction

The UCL Transport Institute was appointed by the Department for Transport to conduct a scoping study "to identify the key social and behavioural questions associated with autonomous vehicles (AVs)". It specified three goals:

- "Map out the key social and behavioural research questions associated with autonomous vehicles.
- Assess the extent to which the current Government-funded "four cities" driverless vehicle trials in the UK can provide evidence on the research questions identified, both individually and in a co-ordinated way.
- Determine what, if any, additional research would be required to answer the social and behavioural research questions identified and outline a suggested approach to this research."

The project brief originally made the focus of the work "primarily on drawing out research questions applicable to fully autonomous vehicles" though it was always understood that research questions relating to the transition towards full automation would also be included. It was also understood that this research would be limited to vehicles travelling on roads (including freight), thereby excluding automation on the train network and in the maritime and aviation sectors.

In the event, it has proved difficult to isolate "social and behavioural" aspects from those of other kinds. Social and behavioural questions arise in relation to all aspects of AVs, even those that superficially seem wholly technical. For example, it is impossible to say whether full automation will happen (ostensibly a technical question) without asking at the same time whether there would be a substantial consumer interest in purchasing/using such products and whether widespread deployment would be societally acceptable. Hence, almost all useful questions about AVs have at least a social or behavioural component.

There are strong methodological arguments for tackling certain social and behavioural research questions that relate to the nature of the technology as a priority, since assumptions about the types of technology are needed in order to undertake research into the impact of technology. In particular, the wider and indirect effects of AVs cannot be predicted with any certainty without there first being a clear position concerning what form the technology might take and how it might be used. Given current uncertainties, it might be useful to develop a set of technology scenarios to assist with impact assessment. Questions relating to the nature of the technology must encompass considerations of what producers are motivated to do and what consumers and stakeholders more generally might want or tolerate – all manifestly social and behavioural issues.

This approach is in contrast with the bulk of research carried out to date on AVs, as shown by the literature review. Here, there is a strong focus on technology and what might be characterised as a sense of "technological determinism" – AVs will become commonplace within a relatively short time period, with the assumption that any social concerns or behavioural issues will be readily ameliorated, if/when they arise. Material gathered in the course of this project suggests many stakeholders believe that social and behavioural issues are of central importance and may in turn influence the development and take-up of the technology.

Report structure

This main report is accompanied by a report of the literature review carried out as part of the project (described below).

This report has the following structure:

- A short section, *Core concepts*, sets out some simple points concerning the ways in which certain terms are used in this report.
- *Description of activities* explains the work done as part of this project.
- In *The four cities UK trials*, the work of UK Autodrive, GATEway and Venturer is briefly described and examined for the extent it can provide evidence on the social and behavioural impacts of AVs.
- In *Findings & recommendations*, a set of research topics and questions is presented in accordance with a conceptual framework, after which certain specific recommendations (research and other) are set out.

There are six appendices:

A Description of stakeholder events
B Stakeholder events: “Mapping the Territory” materials
C Stakeholder events: scenes including questions
D List of participating organisations
E Workshop with four city trials
F Full List of Questions

Core concepts

Since the technology is developing quickly and, with it, the terms used to describe it, this section is intended to reduce the scope for misinterpretation of what follows.

In this report, the term *automation* is used to describe the extent to which a vehicle is equipped to carry out the driving task, and *full automation* implies that the vehicle can carry out all aspects of the driving task in any environment (thus being equivalent to SAE's Level Five) (SAE International 2016), see Table 1.[3]

Table 1 – Levels of automation. Extract from SAE International (2016), slightly modified for clarity.

SAE level	**Name**	**Narrative definition**
Driver performs part or all of the *dynamic driving task (DDT)*		
0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.
1	Driver Assistance	The *sustained* and *ODD*[4]-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.
2	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *object and event detection and response* (*OEDR)* subtask and *supervises* the *driving automation system*.
Automated Driving System (*ADS)* performs the entire *DDT* (while engaged)		
3	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.
4	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.
5	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.

Autonomy describes the extent to which a vehicle "makes decisions" on its own. A *fully autonomous* vehicle assesses its environment and selects a course of action in accordance with what it finds. In principle, an autonomous vehicle could carry out the driving task in its entirety without communicating with other vehicles or roadside infrastructure. Autonomy is here contrasted with *control:* a *fully controlled* vehicle in effect acts out instructions set

[3] It should be noted that, whilst these are a helpful guide to what the technologies can do, the UK government and the UN Economic Commission for Europe's World Forum for Harmonization of Vehicle Regulations have not endorsed these levels.

[4] ODD: operational design domain

outside it. One example of this is a following lorry in a platoon[5], where both steering and speed have been ceded to the lead vehicle: it has a high level of automation, in that it does not depend upon a human driver inside the vehicle, but its movements are largely determined by the leading vehicle and so it is controlled rather than autonomous. The term *control* has been preferred to *connectedness* because of the use of the latter word also to describe the extent of communication between the vehicle and its environment (notably other vehicles and road-side infrastructure).[6]

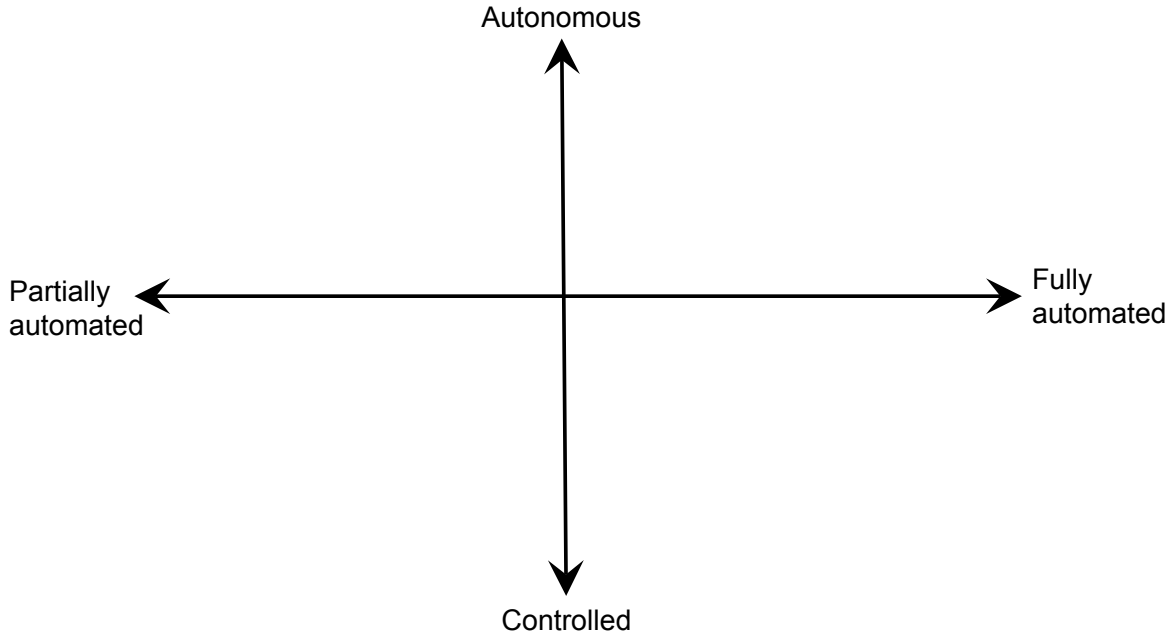

Figure 1 - Automation, autonomy, control

As Figure 1 is intended to show, automation and autonomy/control are distinct axes and vehicles will occupy quite different points on the graph. For example, the following lorry in a platoon would probably lie in the bottom-right quadrant, whilst cars in the fleet today that offer "advanced driver assistance" will lie in the top-left.

One consequence of this approach is that the term "connected and autonomous vehicles" (CAV) which is widely used does not appear in this report. Instead, *automated vehicle* is the general term, abbreviated to AV. Unless the level of automation is specified (e.g. full or partial), the reader should assume that text refers to any point on the range from partial to full automation. Equally, unless a point or range on the autonomy-control axis is specified, the reader should assume the text refers to any point on that range.

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[5] Platooning (also known as electronic coupling) is the use of advanced vehicle technologies to control the longitudinal (and potentially the lateral) position of vehicles following at a closer distance to each other than would normally be permitted without these safety systems. A *following vehicle* in a platoon is electronically coupled to the *lead vehicle*. The drivers of following vehicles will, as a minimum, cede longitudinal (speed) control to the lead vehicle. Lateral control (steering) may also be ceded in more advanced platooning systems.

[6] A highly connected vehicle may actually have no automation: it may simply have extensive data-sharing arrangements such as those that enable a human driver to remain very well informed about traffic conditions ahead, for example.

Though these clarifications will hopefully be useful, it must be pointed out that they alone cannot capture adequately the *experience* of travelling in an AV. There is a great difference, for example, between travelling in a fully automated "pod" which will not exceed 15mph, say, and in a partially automated conventional car at motorway speeds. Where appropriate, therefore, additional information about the nature of the travel experience will be specified. Where it is not, it should be assumed that the speed and comfort of an AV journey are at least *comparable* with those of journeys made currently using motorised transport.

Description of activities

The project has involved four main strands of activity:

1 Literature review
2 Stakeholder events
3 Expert interviews
4 Workshop with and visits to the “four cities" trials

They are briefly described in turn in this section.

1 Literature review

A comprehensive review of the literature relating to social and behavioural aspects of AVs, both academic and “grey” literature, has been carried out and is reported fully in the companion document. The process is briefly summarised here.

A variety of documents was already available to the research team or supplied by the client. A set of search terms was then applied to the following bibliographic databases: Scopus, Transport Research International Documentation (TRID), International Bibliography of the Social Sciences (IBSS), ProQuest Social Sciences, and PsycINFO. This produced approximately 50,000 items which were filtered down in two stages to 432 references, including the most relevant items from the initially held set.

Coding of the 432 sources led to the selection of 62 documents for more detailed analysis. Findings were collated thematically and reflect the top-level structure of the conceptual framework (see *Findings & recommendations*).

2 Stakeholder events

Two day-long workshops were held in London in May 2016 and were attended by a broad range of stakeholders with an interest in the topic, from government, industry, academia and NGOs, including both those working directly in transport and others working in associated fields.

During the sessions, participants were taken through two deliberative tasks:

- An exploration of the likely form of the take-up of AV technology and the environment in which it may develop
- Examination of use cases designed to confront participants with some of the dilemmas and opportunities that may arise from the development and adoption of AVs

The transcripts of the group and plenary discussions were subsequently trawled for research topics and questions.

A fuller explanation of the workshops is provided at Appendix A, and materials from the events are at Appendix B and Appendix C.

3 Expert interviews

Not all those who were invited were able to take part in either workshop, and certain individuals identified as potentially helpful sources of intelligence are based outside the UK. A set of nine expert interviews was therefore carried out, in person where possible. Some generic questions were asked of all interviewees (e.g. to identify what the interviewee

thought the mature form of the technology would be) but discussion guides were tailored to the individual's role and sector.

As with the stakeholder events, the interviews were recorded. The recordings were then analysed to identify research topics and questions. See Appendix D for a list of organisations represented.

4 Workshop with and visits to the "four cities" trials

A half-day workshop took place in London in May 2016. Consortia from each of the four cities driverless car trials (UK Autodrive, GATEway and Venturer) was represented, along with the Department for Transport and the Centre for Connected and Autonomous Vehicles.

Each project gave a short presentation on the work it was doing, with particular reference to the social and behavioural elements of the project. The remainder of the time was devoted to discussion in groups of a set of relevant questions relating to research into AVs.

A short note of the event was subsequently produced (Appendix E).

In addition to the workshop, the UCL Project Manager also visited the projects in July 2016. The aim of the visits was to further explore I how the work being done as part of the trials might contribute to answering a wide range of social and behavioural questions associated with AVs.

All discussions were recorded and the recordings subsequently analysed to identify research topics/questions and other relevant material.

Aggregation and analysis

All of the four strands generated a set of ideas, questions and challenges. These have been subsequently drawn together, grouped and honed (see *Findings & recommendations*, below).

The four cities UK trials

Activities

The activities of the 4 cities driverless vehicle projects are summarised very briefly here, with an emphasis on aspects of the project that can be expected to capture or predict social and behavioural impacts. Further information can be obtained directly from the consortia's websites.[7]

UK Autodrive

This consortium will run trials of two types of vehicles:

- Low-speed Autonomous Transport System (L-SATS), a demand-responsive four seater shuttle, running predominantly on footways in central Milton Keynes
- M1 (passenger) cars, initially on closed roads, graduating to the public highway

Autodrive is conducting an attitudinal survey on-line, at a national level (though seeking a sufficient level of response in Milton Keynes) and a series of connected discussion workshops in cities both in the UK and overseas. The survey will be run at two points – Autumn 2016 and two years later, in order to capture change. The question set is "what are the current public attitudes towards driverless cars, and will they change over the lifetime of this project?" The survey builds upon that used by the Transport Systems Catapult in its *Traveller Needs and UK Capability Study* (Wockatz & Schartau 2015).

Complementing the attitudinal survey and discussion workshops is a modelling/simulation exercise intended to help establish the business case for driverless technology. Members of the consortium will attempt to model the operations of AVs in a conventional traffic environment in order to understand what operating speeds might in time be feasible. Information concerning consumer expectations will then be used to estimate what level of demand for the technology could be expected.

Venturer

The Venturer Project is looking to understand the factors relevant to wide scale adoption of AV capability and part of this includes a dedicated work package examining social and behavioural aspects of AVs. The project is looking at:

- Expectations/acceptance of the AV concept and market opportunities
- Handover from AV to human driver in the urban context
- Interactions on urban roads between AVs and other road users

The Venturer team has carried out a literature review for each of the three (Morgan et al. 2016; Parkin et al. 2016; Clark et al. 2016).

As part of the first area, the team will be conducting interviews with expert stakeholders in the Bristol area and beyond. They will also carry out an internet-based survey (focusing on recruitment in the Greater Bristol area). Key themes for the survey are willingness to pay for AV services and willingness to share AV vehicles. A further element, which will build on the

[7] https://www.gateway-project.org.uk/; http://www.ukautodrive.com/; http://www.venturer-cars.com/

survey findings, is a set of "lightly moderated" online debates, which will use visual stimuli including video to provide participants with a representation of AVs to which they will then be asked to react. In the latter stages of the project, it will be running public trials of "pods" and will carry out observations and qualitative research as these take place.

The first trial in the Venturer project examined 'handover' between autonomous and human driven modes. This tested on the handover process, first using a STISM simulator then in a Wildcat AV. The tests involved a number of members of the public with the Wildcat vehicle operating on closed roads (within the campus of University of the West of England). The report on the handover trials will be available in early 2017.

The second and third sets of Venturer trials will begin in 2017 and are currently envisaged to include:

- Trials at T-junctions and roundabouts (Venturer Simulator and Wildcat on campus roads, possibly followed by use of the public highway) to establish whether there are important differences between AV and human driver behaviour.
- Trials of interactions between AVs and other road users – stationary vehicles, pedestrians, cyclists – (Venturer Simulator then Wildcat on campus roads, possibly followed by use of the public highway)
- This element of the work will be to conduct the experimental aspects of the trials. Focus groups with users of different social groups and of the various modes involved will be undertaken to support development of the experimental conditions and aid interpretation.

GATEway

The element of GATEway's project of greatest relevance to this exercise is its trial of a shuttle fleet to demonstrate 'last mile' automated transportation in an urban environment. Shuttles will provide a demand-responsive collective transport service in two Greenwich locations using pedestrianised spaces. It has two other trials planned: one to explore opportunities and overcome barriers associated with automated vehicle technologies for people with additional travel needs; the other of automated urban deliveries.

Various research activities have been taking place or are planned as part of the project:

- Sentiment mapping and collection of views concerning likely good and bad locations for driverless technology[8]
- Workshops with citizens who have a Greenwich connection – enthusiasts, sceptics and the undecided
- Simulator research to explore how drivers react in traffic situations where they are sharing the road with automated vehicles
- Surveys and video analysis of pedestrian behaviour with regard to risk perception in the vicinity of fully automated vehicles
- Surveys of shuttle passengers and bystanders to understand better their interactions with the automated vehicles

The workshops take participants through a series of exercises, first identifying possible advantages and disadvantages of AVs, then exploring how AVs might alleviate unpleasant aspects of hypothetical journeys, before participants are invited to design an ideal AV. The workshops' stated research questions are:

[8] https://gateway.commonplace.is/comments (accessed 31st August 2016)

- "What are people's perceptions and attitudes towards autonomous vehicles that will be important when designing for acceptance and adoption?
- How might the design of autonomous vehicles influence people's perceptions and attitudes to make acceptance and adoption more likely?" (Phillips 2016).

The simulator research will involve people recruited from Transport Research Laboratory's research database being set a task of driving a vehicle in a mixed traffic environment including AVs (which, they will be told, drive cautiously). The research is designed to establish whether drivers behave differently towards AVs than manual vehicles and, if so, in what ways.

An on-line survey[9] has been used to gather perceptions of safety of AVs in the context of a more general picture of the respondent's attitude to risk.

When the shuttle trials take place, some passengers will be interviewed to gauge their views of the experience as well as their more general attitudes to travel by various modes. During the course of the trials, pedestrians who have interacted with the shuttles by crossing the shuttle path will be surveyed to understand their behaviours and attitudes. If resources permit, manual analysis of video footage will also be conducted to understand gap acceptance and tolerance more accurately. The duration of the shuttle trials should provide opportunities for longitudinal surveys to reveal any change as the shuttles become more familiar.

Insights from the workshop and visits

One question set by the project brief was the extent to which the trials "can provide evidence on the research questions identified".

All of the trials are conducting experiments that are necessarily bounded: they depend on the technology that is currently available, are mindful of the need to maintain acceptable levels of safety for all concerned, and are constrained by limited time. The experiments also need to keep the number of variables under control in order to arrive at robust results.

Subject to these restrictions, all of the trials can be expected to produce highly relevant and useful evidence to support the growing understanding of the social and behavioural impacts of AVs. But, like most research, it will add usefully to knowledge without definitively answering the core questions. In part this is because the technology is developing rapidly and respondents are being asked to envisage a future situation rather than react to an existing one. The standard responses are to articulate a future and invite people to react to it, or to attempt to simulate the future, hoping that the assumptions made in constructing the simulation are sound. The trials are all doing both of these to some extent.

Lying beneath the trials' work is a methodological question: whether to attempt to give people a real experience of something that may not be representative of future reality or instead an artificial experience of what (it is predicted) will actually come about? The vehicle-based aspects of the trials are examples of the first category and it is impossible to say at present whether they will deliver more insightful knowledge than research of a more hypothetical nature. There is good reason to believe that they will reveal accurately people's attitudes to the technology as it is today, such as the shuttles that travel slowly and with

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[9] https://fseg.gre.ac.uk/surveys/projects/index.php?r=survey/index/sid/998821&lang=en&newtest=Y (accessed 31st August 2016)

inevitable timidity. But whether they will assist or hinder people in their ability to picture a quite different future is hard to say. Venture's decision to use imagery unconnected with the Wildcat trials for its on-line debates shows that the team is attempting to engage people in debates that go beyond the limits of current technology. However, since the two different approaches to exposing people to possible future technology will lead to different yet complementary knowledge being developed, there are benefits to using both of them where possible.

The trials are engaged, first and foremost, in testing the technology as it is; it seems fair to describe these as "research and development projects". So the investigation of more speculative aspects (such as a world in which the technology is mature) comes across in each case as secondary to the central task. The evidence suggests that close collaborations between trials across all elements of their project or sharing of their research activities has been limited so far, for several reasons. First, the projects are business-led and will be generating intellectual property which the consortia may well look to exploit further. This and the broader competitive environment may prevent the blanket sharing of information or close collaboration. Representatives of one trial were open in their reasons for not sharing their research instrument: they considered it to include intellectual property which they were anxious not to lose. Second, the trials are working in different environments, with different technologies, to very challenging deadlines and may be attempting to address research questions which are not necessarily comparable. So, to return to the question posed, any evidence emerging from the trials on the social, behavioural and wider acceptability issues will need to be considered within the context of each individual trial.

Findings & recommendations

All of the four activity streams in this project have produced useful findings which have been collated and synthesised to inform what is reported in this section. The literature review, though, stands out as discrete and deserves some individual attention since it provides an overview of the accumulated published work on social and behavioural aspects of AVs. Its principal conclusions are therefore summarised below. Following these, this section continues as follows:

- Conceptual framework – this introduces a pragmatic way of thinking about the research terrain
- Research topics – this is the result of gathering the long list of research questions generated by this project and placing them under a manageable number of headings according to the structure of the conceptual framework
- Research methods – some brief comments about ways in which research questions may be addressed
- Research recommendations – a small number of recommendations for research to be undertaken in the short term
- Other recommendations – suggested actions that would complement the research activity discussed

Literature review – summary of conclusions

The literature review reveals a strong focus amongst published research upon the more technical aspects of the subject; this is more pronounced in the academic literature than the grey literature. Social and behavioural issues are in comparison heavily under-researched.

Amongst the non-technology aspects, very few topics are studied in any depth and some, such as health impacts, are barely acknowledged. This is perhaps unsurprising given that this is a young topic but the balance of attention is still noteworthy.

Though some researchers display a wariness about the technology's potential impacts, the majority appear positive about AVs. And much of the research appears narrow: an unhelpfully small number of variables are considered; or authors work with only one or two scenarios which cannot be expected to map out the full range of possible futures. Perhaps connected to this is a lack of inter-disciplinary research on AVs, with most work strongly located in a single discipline and therefore limited in the conclusions that can be drawn from it.

Conceptual framework

There are two main characteristics that contribute to the complexity of this subject:

- The extent of uncertainty
- The multiple links between factors (for example, attitudes informing government action, thereby influencing technological development and hence uptake, and thus leading back to attitudes etc.)

In order to make progress towards a research agenda, it has been necessary to simplify these relationships significantly. The resultant conceptual framework represents an attempt to capture the strongest relationships between factors and, at the same time, provide a pragmatic way of dealing with uncertainty.

Development

The brief for this project suggested that the social and behavioural research questions would "broadly fall within three areas":

- The interaction between the user/driver and highly automated/'driverless' car
- The interaction of other road users, including pedestrians with the 'driverless' car
- The attitudes of the general public towards 'driverless' cars, including public acceptability

The project team proposed that a fourth area should be added:

- The wider, longer-term social, economic and environmental impacts of autonomous vehicles

Useful as this set of four was, it became apparent as the project progressed that a different framework was needed to support thinking about research in this area. The final version of this framework (following iteration with the on-going literature review, feedback from the client and other groups) is introduced below, after which the relationship between it and the initial set of four areas is explained.

The categories within the framework

The core of the framework (see Figure 2) has five categories:

- **Technological & market developments** – the set of actions that will determine the AV "offer"
- **Use of & reaction to AVs** – how AVs will be purchased or accessed; in what ways and by whom they will be used; and how other road users will respond
- **Consequences/wider impacts** – the range of first- and higher-order impacts of AV use, ranging from network performance to wellbeing, many involving consideration of social and behavioural issues
- **Stakeholders' awareness & attitudes** – the role of belief and opinion on the part of individuals and organisations, users and non-users of the technology, in shaping the technology, its uptake and the various consequences of uptake
- **Public sector's role** – the scope for government at all levels (whether explicit or implicit) to affect the forms of technology, their uptake and the consequences of uptake; and the policy issues that are likely to arise

Outside the core are **Global trends/drivers**, serving to demonstrate that the AV "system" is subject to a wide range of external influences;[10] and **Monitoring & consequential actions** which represent the element of the feedback process in which actors seek to correct relationships that are perceived to be leading to unwelcome outcomes.

[10] The examples in the diagram are *localisation* (a trend of people living less dispersed lives), *globalisation* (the opposite) and *digital lives* (an increasing role for technology in people's lives).

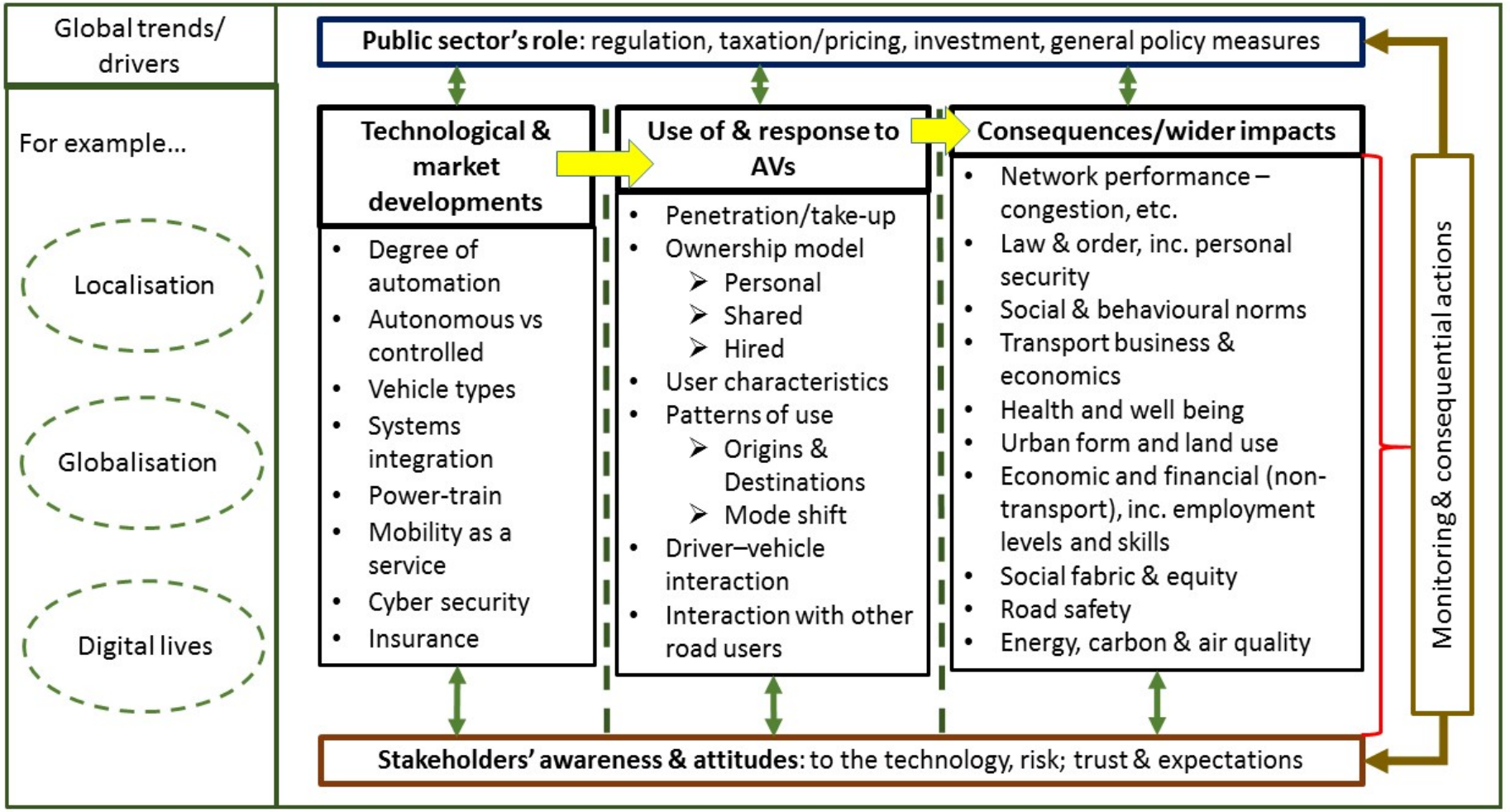

Figure 2 - Conceptual framework

Interactions within the framework

Whilst, in reality, there is a highly complex set of interactions within and between the categories, the principal flows within the framework are *linear*, represented by **large yellow arrows**, with feedback loops:

Technological & market developments is the first step, (of course influenced to some extent by external factors). **Use of & response to AVs** covers the set of reactions to what technologies are offered by the market(s). Finally, **consequences/wider impacts** are the set of effects that are propagated by the pattern of AV uptake and use. The diagram shows both **Stakeholders' awareness & attitudes** and **Public sector's role** as interacting with each of these three steps: for example, the nature of the AV offer will be significantly influenced by the regulations imposed by governments; equally, the extent to which AVs are taken up will be a function of stakeholder beliefs concerning their desirability, affordability, safety, and so forth.

This logic has a significant implication for the planning and execution of research relating to AVs:

Any conclusions concerning consequences and wider impacts can only be drawn by making assumptions concerning *technological & market developments* and *use of & response to AVs*. Whilst any study of consequences/wider impacts could make its own assumptions, it would seem to be more cost-effective and consistent if there was a degree of common understanding about possible AV futures across different research projects.

There is therefore a natural chronological order to the research programme relating to AVs. There is also an efficiency argument for making early progress on the first two categories in the core of the conceptual framework (including the associated social and behavioural aspects): if this does not happen, all research projects relating to wider impacts will require a significant proportion of resources to be devoted to establishing a working position on technological & market developments and use of & response to AVs.

This being said, it must be acknowledged that the research gaps relating to the first two categories are extremely large. It is therefore unrealistic to expect all research questions in these categories to be answered definitively before research can commence on the health impacts of AVs, say. This points to pragmatic efforts to advance understanding of the first two categories, as addressed below in *Research recommendations*.

Relationship between the framework and the initial set of four areas

Returning to the set of four areas with which the project commenced, **the interaction between the user/driver and highly automated/'driverless' car** is largely captured in *Technological & market developments* and *Use of & response to AVs*. This is also true of **the interaction of other road users, including pedestrians with the 'driverless' car**. In both cases, the interaction will be a function of the nature and operation of the technology, as well as the individual response to it. **The attitudes of the general public towards 'driverless' cars, including public acceptability** fall into the category of *Stakeholders' awareness & attitudes*. Finally, **the wider, longer-term social, economic and environmental impacts of autonomous vehicles** for the most part fall within *Consequences/wider impacts*.

This set of relationships is illustrated using a colour scheme in the following section.

Research topics

The project's various activities generated approximately 384 research questions, ideas and challenges. After some distillation, most of the remaining questions have been associated with one of the categories in the conceptual framework. The questions associated with each category were then analysed and a set of sub-categories created which appeared to reflect satisfactorily the range of themes arising. This process is inevitably subjective: most questions have links to more than one category so each question was placed on the basis of what was perceived its strongest association. By implication, it is often the case that two similar-sounding questions appear in the set, associated with different categories and sub-categories. For example, questions of data security appear under both "Public sector's role" and "Stakeholders' awareness & attitudes".

The edited set of questions remains large but it contains much useful detail. It is therefore included as Appendix F[11]. In this section, each of the sub-categories (grouped by category) is represented by a short written description intended to summarise the scope of research questions associated with it.

A colour coding system is used to demonstrate the relationship between the sub-categories and the four initial themes, as follows:[12]

- The interaction between the user/driver and highly automated/'driverless' car is represented by a green background
- The interaction of other road users, including pedestrians with the 'driverless' car is represented by a blue background
- The attitudes of the general public towards 'driverless' cars, including public acceptability are represented by a red background
- The wider, longer-term social, economic and environmental impacts of autonomous vehicles are left uncoloured

As can readily be seen in the tables below, the majority of topics fall under the fourth theme. This is understandable, given its breadth. It also reflects the fact that a deliberately open and inclusive approach was taken to gathering evidence: for example, whilst stakeholders

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[11] Appendix F presents the full set of research questions generated during the study, ordered first by category then by sub-category. The origin of each question is recorded using the following abbreviations:

Mapping	Mapping the Territory exercise at stakeholder events
Scenes	Scenes exercise at stakeholder events
Lit review	Literature review
Experts	Expert interviews
Other	Generated through discussion within the study team

In several cases, similar questions have been generated from two or more distinct sources. It was decided to retain these rather than seek to remove the duplication, in order that readers will be able to identify recurring themes.

[12] This mapping is not precise, since most of the topics below contain elements of more than one of the four initial themes.

were free to raise issues relating to the first three themes (and most did), they tended also to raise a large number of other issues.

Range of question types

Research questions take various forms (University of Twente Faculty of Behavioural, Management and Social Sciences 2013). The majority of those generated by this project are either predictive ("what will happen?") or normative ("what should X do?"); normative questions are distinguished by having implicit underlying values. Apart from "pure" normative questions there are remedial questions ("which interventions might most effectively limit negative/unwanted event Y?") and back-casting questions ("given desired outcome Y/agreed goal of achieving Y, what does agent X need to do?"). The bulk of normative questions that have been gathered in this project (pure, remedial and back-casting) relate to government influence.

Technological & market developments

Sub-category	Description
Business case & competition	Crucial to the prospects of AVs is their business case: how will they be used? Will consumers (individuals and organisations) want to purchase them at the price offered, or will they rent them on a trip-by-trip basis, and will suppliers be able to profit from them? On the assumption that the private sector will lead the development process, what might be the different effects of lighter or heavier regulation on government's part? Given that the vehicle manufacturing market is highly competitive, how will this affect the capacity for co-operation (e.g. with respect to voluntary codes of practice), particularly given much-discussed new entrants?
Technological advance	The "transition phase" preceding the maturity of the technology will be crucial: the nature of changes in technology and their distribution in the fleet will greatly affect the performance of AVs over time and will help to determine the form of that technology once it matures. The timing and shape of the transition, including whether retro-fit is possible and how technology will cascade down from high-value vehicles, will both have major impacts.
Vehicle characteristics & performance	There is a wide variety of visions of AVs, relating to size, shape, speed and general function. These factors, as well as the nature of the AV experience, will both be fundamental to determining consumer response. The ways in which AVs might be used are also an important consideration: a taxi model may imply different characteristics than a conventional owner-user model. And the idea that vehicles will be able to learn introduces numerous questions about practical implications and how they might be regulated.
Technological pluralism	Many of the benefits claimed for AVs assume the ubiquity of full automation, but manual vehicles are likely to remain for a long time and, some people may never want to surrender control of their car. Different questions arise depending on the prevalence of the various levels of automation in the fleet – when fully automated vehicles are a small minority or when manual cars are. Questions of pluralism also arise in the degree to which vehicles are autonomous or controlled, and in the degree to which they share or withhold data.
Infrastructure supporting AVs	Whether autonomous or controlled, AVs will rely on some infrastructure outside the vehicle to operate and may function better in some environments than in others. A further set of infrastructure may enable vehicles to operate more efficiently or satisfactorily. But such infrastructure would need to be provided somewhere and be paid for by someone: how might the inevitable compromises be negotiated and how might this play out in terms of wider impacts?
Inclusion & diversity	There is no guarantee that a market-led development process will deliver technology that is either universally affordable or inclusive in its functioning. In fact, it is entirely possible that different "classes" of AV will come into being and that substantial segments of the community will be priced out. The likely outcomes under different regulation scenarios need to be better understood.

Sub-category	Description
Contingencies	Both the perception of technology and the extent to which it is used will be in part functions of how it performs in an emergency – how safe is the failsafe? A good understanding is required of how AVs will behave in response to internal anomalies and failures and to external contingencies. This extends to a vehicle being "out of range" during a software update and failure of external systems such as global navigation satellites. A crucial consideration is the extent to which users might be able to "take back control" in such situations.

Use of & reaction to AVs

Sub-category	Description
Vision, AVs & other modes	Whilst the potential benefits of AVs have been extensively articulated at the level of the individual, it is less clear how this technology might fit into the existing transport and planning environment, particularly with respect to existing modes that already carry large volumes efficiently. Given that they will need space to operate, an understanding is required concerning how public space is to be shared amongst AVs and other modes. At the highest level, how do AVs fit with a local authority's vision of future transport and land use?
Appeal, cost & demand	Propensity to adopt AV technology will greatly influence its wider operational and societal effects. In the simplest sense, this is a matter of whether the new option represents (or is perceived to represent) an improvement on the options people currently have, but beneath this lie numerous complexities: the aesthetic appeal of a new option, spatial and socio-demographic distribution of demand and uptake, whether appeal will increase or decrease with market penetration, and acceptance or not of new "costs" (e.g. data vulnerability). There are associated questions of who represents the "near market" for AVs and who, in contrast, might wish to hold on as long as possible to manual driving.
The range of road users	How will others in the road environment feel about increased automation and how will they respond to it? Whilst the full range of road users includes those driving manual vehicles in a mixed-fleet scenario, there is a natural focus here on vulnerable road users: if the safety claims for AVs are sound, pedestrians and cyclists will have nothing to fear. But this may have unexpected and perhaps unwelcome effects, as other road users take advantage of AVs' "timidity". It also assumes that people's perception matches reality, which is by no means guaranteed. The topic as a whole is influenced by debates about the fallibility of sensing systems, what will be an acceptable speed for AVs in a mixed-traffic environment, and "trolley" questions of how AVs will deal with no-win situations.
Environmental & spatial variation	Motorways are often cited as a natural environment for AVs, given they are relatively closed and simple systems. But, if the full benefits of AVs are to be reaped, they must operate more widely and this raises questions about types of environment and the vehicles' characteristics – level of automation and whether autonomous or controlled. There are associated questions about the management of differences across boundaries at all spatial scales – how will vehicles adapt to moving from one jurisdiction to another within a country? Will vehicles be able to operate in multiple countries?

Sub-category	Description
Ownership, sharing & trust	The conventional model of owning a car is already under threat from the growth of the sharing economy and the more transport-specific phenomenon of mobility-as-a-service. Whether people own or share AVs or simply use them as they might a taxi will have large implications for the journeys that are made and, as a consequence, the size and nature of the fleet, spatial planning etc. Propensity to own an AV may also vary spatially: the availability of on-demand services may be higher in urban areas than rural areas, thereby making the possession of a vehicle less relevant. The "taxi" model brings interesting new questions given the potential absence of the driver as figure of authority etc: will travelling with strangers necessarily become less attractive?
Mobility	AVs (certainly if fully automated) can be expected to lead to quite major changes in mobility but a predicted growth in vehicle-km is dependent on the capacity of the network to sustain it at acceptable speeds. Nonetheless, the likely convenience and accessibility of AVs could introduce or reintroduce sizeable segments of society to private motorised travel with possibly significant consequences. Questions to be addressed embrace the total volume of movement, vehicle occupancy, mode choice (including the role of wealth in determining how people travel) and time of travel.
New behaviours	Partial automation implies handback in some form, whereas full automation would change profoundly the role of "the driver". This implies that new behaviours associated with AV travel will arise. Under partial automation, there is the question of whether drivers can learn to be ready to take back control and whether consumers will accept the new reality; under full automation, the questions are more open: how will in-vehicle time be spent? Will former drivers find new ways of deriving the positive experiences that driving gave them?

Consequences/wider impacts

Sub-category	Description
Network performance	Proponents of AV technology cite possibly large increases in effective network capacity and reductions in delay. Performance will depend on the nature of the fleet and operating regime – some hoped-for benefits will only come about with full automation and/or high levels of control, and may rely on segregation of automated vehicles from other traffic. Network performance, however, will probably be the largest single determinant of the uptake of AVs and extra capacity could easily be absorbed by increased demand, if AVs prove affordable to most. What might any future "equilibrium" between transport supply and demand look like?
Transport business & economics	If drivers are no longer required (or their driving duties substantially reduce), this means major changes for the transport sector. And, alongside the immediate employment impacts, connected industries such as parking and vehicle repair may see profound change, whilst fewer crashes and a more intensive use model may also imply a smaller manufacturing sector. There are connected questions of how AVs might affect established transport sectors such as rail, in terms of both the continuation of existing operations and new initiatives.

Sub-category	Description
Road safety	A reduction in crashes is often presented as the primary benefit of AV technology but the extent of any reduction is extensively debated in the literature. Though human error causes the majority of crashes, good decisions mean a great many more crashes do not occur. And the topic is made more complex when vulnerable road users are introduced into calculations: can the safety of pedestrians and cyclists be guaranteed at the same time as ensuring an acceptable AV running speed? All of these questions are highly sensitive to the prevailing level of automation, fleet composition, operating environment, user interaction and regulatory context.
Energy, carbon & air quality	The potential impact of AVs on energy use and emissions is complex: it is claimed by some that AVs will be lighter than and will be able to drive more smoothly than manual vehicles, thereby saving energy. And a more intensive use pattern and optimised routing may imply reduced emissions per passenger-km. But a predicted increase in overall mobility might offset these gains partially or completely. A connected consideration is that, if the typical AV in future is electrically powered, this implies significant changes in terms of battery technology and recharging infrastructure.
Law & order	Discussion in this area has tended to concentrate on cyberterrorism and data security in the context of asking where liability will lie when the role of the user diminishes. But this should not distract attention from a range of less prominent issues relating to crime and judicial processes: a potentially changed role for the police; the possibility of cowboy practices in the manufacturing sector; new opportunities for crimes against or by the AV user; perhaps even social unrest, if the impacts of AVs aggravate social disparities.
Urban form & land use	Full automation appears to suggest radical changes to the structure of our urban spaces, not least as the need for parking may change dramatically. More widely, as mobility patterns respond to different opportunities and costs, the distribution of people and activity in space may change greatly: in particular, the classically very different accessibility patterns of urban and rural areas may begin to converge, removing one of the differentiators between town and countryside as places to live and work. Do AVs imply sprawl?
Social & behavioural norms	It is hard to exaggerate the extent to which driving has both influenced and come to reflect our norms. The driver of a manually-driven vehicle is a responsible individual (to a greater or lesser extent) and norms surrounding travel on the highway reflect this. The prospect that some or all of that responsibility might shift to third parties, not present at the scene, suggests profound changes to how people might behave when travelling and what will be deemed socially desirable or acceptable. The literature contains much debate about whether AVs should protect person A or person B but there is a more important underlying question about whether automating such decisions can ever be socially acceptable.
Health & well being	Set against potential road safety benefits of AVs are questions about levels of active travel in a world where door-to-door motorised transport may become more feasible. But there is a wider debate to be had about the possible gains in quality of life (and, by extension, mental health) from expanding the travel horizons of those who may experience very limited accessibility at present.

Sub-category	Description
Social fabric & equity	Just as the internet has changed the way people conduct their lives and interact with each other, so might AVs, with immediate questions about how time might be used and whether people will lose something of value when they stop driving. There are broader questions about whether AVs can and will be used to address social problems, and about the distribution of costs and benefits: it is assumed that AVs will benefit some, but will there be losers and, if so, what future will be socially acceptable?
Economic & financial effects (not directly transport)	Whilst there will undoubtedly be financial benefits for companies that lead the development of AV technology, what will be the wider economic impact of its adoption and use? Can any specific responses be predicted, for example in terms of how employers might in future view the time their staff spend travelling? In addition to sector-based questions, there is uncertainty about aggregate effects on GDP and employment, in the light of the fact that a step-change in mobility may alter certain "laws" concerning the relationship between transport and the wider economy. And thinking of AVs as a "disruption" implies any number of market innovations that it is hard to foresee at present.

Stakeholders' awareness & attitudes

Sub-category	Description
The public sector & its intervention	Whilst consumers may be happy to see this technology being led by the private sector, they may also expect government (at all levels) to ensure the necessary protections. But it is more complicated than this: the nature and extent of regulation will affect what AVs can do. More specifically, some journeys may be slowed or even prevented "for the greater good". Apart from the safeguards mentioned, what will citizens accept from government in terms of managing the operations of AVs and how should government respond?
Risk	Perceptions of and attitudes to risk will be very important to adoption and use of AVs. There is a complex relationship between type of risk (of injury, financial loss, embarrassment, for example), its level and its acceptance by consumers, and this relationship changes over time, reflecting broader norms. Close attention can be expected to be paid by consumers to questions of risk as AV technology develops, but the intervention of third parties (e.g. the media) is bound to influence what may not be a wholly rational process in the first place. In particular, since no system can be 100 per cent safe, how will citizens react to the (inevitable) first and subsequent casualties of collisions involving AVs?
Trust, acceptance & resistance	Use of an AV may imply the surrender of data and the giving of consents, both of which are increasingly familiar in the context of using computers/the internet. And, whether directly or indirectly, AV users will be placing their trust in software (and, by association, the software's author) when they embark on journeys. An important complicating factor is the mixed role of the public and private sectors in this process. What will consumers accept and what will they require in order to feel they trust the technology? How will answers to these questions change over time as the technology develops and people become more familiar with it? And what of those who object to it?

Sub-category	Description
Review tasks	A variety of research into attitudes has already been carried out but it is of mixed quality and, in order to extract full value from it, some additional analysis is required: how have participants been sampled? How have topics and questions been presented? What has been done to understand what image(s) of automation the participant has in mind when answering?

Public sector's role

Sub-category	Description
Principles of governance	What future is desired? It is easy to dodge this question by assuming that the technology will develop and government's job will be to intervene as necessary to prevent harm. But it may be both wiser and more beneficial for government to take a more active role from the outset. At the highest level, if something is to be maximised (capacity, speed, throughput, equality, say), which is it to be? Beneath this is a series of questions about priority for vehicle types, journey types and users, all of which will vary in pertinence as the market develops. And to what extent should government itself be a user of this technology, in its role as provider of public transport?
Practicalities of governance	If AVs represent a genuine shift in the nature of transport, this may mean that their governance will need to reflect this. How will licensing and regulation work with devices that are continuously learning and therefore changing? Can government ensure adequate standards of inclusion and data protection and control monopolistic behaviours? Beyond these specifics are more fundamental questions about the tools of governance and whether they will remain fit for purpose.
Influencing & managing industry behaviour	On the assumption that the private sector will continue to lead development, the public sector may need to intervene if market failure occurs in the form of a mismatch between supply and demand. It also faces a challenge to encourage the positive aspects of competition, such as innovation, whilst containing its negative aspects. And what level and type of regulation will enable different technologies successfully to co-exist?
Influencing & managing travel behaviour	The advent of AVs may, if unmanaged, lead to an increase in travel demand and reduced active travel but the sophistication of the technology may at the same time provide government with a wider range of policy levers such as smart pricing. This implies a series of decisions concerning whether and how to intervene in order a) to achieve optimal operational conditions and/or b) to pursue certain social objectives relating to inclusion, public health etc.
Keeping people & possessions safe	AVs appear to present numerous new opportunities to criminals and terrorists; they may also provide a foundation for new antisocial behaviour. In addition to the presumption that government will promote road safety, it may be expected to manage these threats to personal and financial security. But its scope to act is not yet clear; nor is it obvious whether intervening for the sake of safety and security implies limiting the operations of AVs.

Sub-category	Description
Management of producer & consumer diversity	A mixture of vehicles can be expected to share the highway for a long time to come, even if full automation comes about. Some users may always reject automation and some manufacturers may wish to offer products that reflect this preference. It is easy to imagine that the first fully automated vehicle on the network will be expected to “fit in” with the rest of the traffic. But what of a time when such vehicles are half of the fleet? Ninety per cent of it? Is segregation inevitable? Will manual vehicles eventually be excluded from the general road system?

Research methods

It is worth making a distinction between social or behavioural *questions* and social or behavioural research *methods*. The emphasis in this project and in this report has been on the former, notwithstanding the fact that social and behavioural issues permeate most questions relating to AVs. With respect to methods, it is best to leave the matter of how to carry out research until the research question(s) has/have been sufficiently developed. This is because methods are not neutral: how research is conducted can constrain both the nature and extent of feasible inferences. Once the scope of a research question is understood, it should be possible to select the research method or methods that will be likeliest to deliver the knowledge sought.

A more general point is that there is a complex relationship between social or behavioural questions and social or behavioural research methods. In particular, certain social or behavioural research questions will best be answered using techniques that lie outside the conventional set of social and behavioural research methods. In the case of AVs for example, a modelling/simulation exercise is recommended below as an effective way of exploring the likely behavioural impacts of distinct "versions" of the AV offer and associated operating regime.

Good research relies not just upon making sound decisions about method but also on competent execution. In fact, much of the AV research encountered in the literature review has not impressed in this regard: examples include small and sometimes biased samples and poorly designed survey instruments, a point picked up below under *Research recommendations*.

What is abundantly clear, from analysis of the topic of AVs in general and from the literature review in particular, is that the full range of research methods should be in contention as work progresses. If AVs are thought of as a "socio-technical system" (Nye 2007) (and there is very good reason to do so), this helps to emphasise that technology and human behaviours are very much interwoven and reinforces the significant future role of multi-disciplinary research.

Research recommendation

Once an initial version of the conceptual framework had been developed, some effort was given to prioritising themes for research but this proved challenging. Three reasons for this offer themselves:

- As already identified, there is an interdependency between categories in the conceptual framework such that research into, say, environmental impacts cannot be conducted without first making assumptions about the nature of the technology and its uptake
- Different individuals have distinct interests and priorities and there is no natural means of arriving at a "winner" from a disparate set of preferences (despite the well-intentioned use of multi-criteria decision analysis)
- The division of the subject into discrete categories (whilst necessary) can only be partially successful as the vast majority of research projects relating to AVs would embrace multiple categories. Prioritising one category over another is therefore difficult.

For these reasons, the following recommendations do not include a prioritisation of either the categories or sub-categories. Instead, reflecting observations made in the *Conceptual framework* section about the sequential relationships between categories, a small number of research projects is proposed (containing appropriate work on social and behavioural

factors) which can be expected to provide a common foundation for future investigations of the wider social and behavioural consequences and impacts of AVs.

It is therefore not appropriate to specify at this stage a wider set of research projects. Instead, the question of which research to prioritise should be revisited after this first wave of work has been carried out.

Development of scenarios for technological & market developments, use of & response to AVs

This report argues that research into the consequences/wider impacts of AVs relies on having at least a working position on the nature of the technology and its use. Given that there is no immediate prospect of *knowing* how these will develop, it is desirable to develop a set of scenarios in the short term that, between them, map out the more plausible combinations of technology and behaviour.

Whilst some work has been done on scenarios (see the Literature Review), it has so far tended not to embrace a sufficient number of variables to be useful; authors envisage what the technology might be able to do but do not explore fully whether it would be taken up, say. The work has also tended to reflect an enthusiasm for the technology which limits the extent to which the conclusions can be relied upon as objective evidence.

What is required is a rigorous exercise, drawing on best practice[13] in scenario planning, which addresses all of the sub-categories under these two categories to at least some extent. The exercise should produce a manageable number of well-defined scenarios which can then be referred to by subsequent research. For example, future research into the energy impacts of AVs could model the energy implications of each scenario arising from the project described here. If there was some consistency of impacts across the scenarios, this would be a useful finding. If not, this would suggest that, for the time being, it was not possible to draw robust inferences on this topic. This scenarios exercise would enable conclusions of this kind to be reached without having first devoted considerable effort to addressing questions about what the technology would be and how it might be used.

Deliberative exercise with citizens and organisations to investigate attitudes and likely behavioural responses to the technology

The literature review has identified a range of work in the area of attitudes but its quality is in general low. In part, this is because researching attitudes to a technology that is in its infancy is inherently difficult. But the work has tended to be harmed by partiality (the authors having an apparent enthusiasm for AVs), small or biased samples and/or poor instrument design. A particular challenge (reflecting that this is a new technology) lies in ensuring that participants have in mind the concepts that the survey designer wishes them to have. Phrases such as “driverless car” are imprecise and can conjure up a wide range of mental images, which will lead to unreliable results if not effectively managed.

Nevertheless, the fact (as identified by the literature review) that research in the AV field has so far been predominantly technological in focus makes a strong case for high-priority work of a good standard on attitudes. And the task relating to scenarios above should provide a sound platform for such work, in that it should offer a range of plausible, well-defined

[13] Examples of scenario planning include the work of Shell which continues to be consistently cited (Wack 1985b; Wack 1985a)

pictures of potential future market offerings and responses, attitudes to which can be investigated. Previous work on attitudes has often presented participants with a single view of the future, and one that does not embrace a sufficiently large number of variables to be complete in any sense.

What would such a research project be designed to investigate? It seems it could have four primary purposes:

1 To assess the value of work done to date on attitudes
2 To test the validity of the scenarios developed in the project described above, including the behavioural responses component
3 To gauge general attitudes to those scenarios and their likely social impacts
4 To provide a foundation for detailed research concerning wider impacts

With respect to the second of these, the scenarios are expected to combine a picture of the AV "offer" with a prediction of the behavioural response (in terms of uptake, use patterns, etc). Responses to this deliberative exercise would be useful as a sense-check of the scenarios, enabling some refinement where appropriate. The third reflects the fact that how people *feel* about the technology is distinct from how they *respond* to it and is an important issue in itself. Widespread adoption of a technology does not imply satisfaction with or enthusiasm for it. And the fourth would represent a tentative step towards learning about the nature and magnitude of likely wider impacts. Whilst this exercise could not be expected to answer any questions about wider impacts definitively, it would provide early indications and, more important, inform the design of more detailed investigations. If the exercise were seen to have been useful, it could be repeated periodically (as a whole or in part) in order to track change in awareness and attitudes over time.

At the risk of overly prejudging the scope and methods of such a project, it is suggested that it should be extensive and should take a deliberative form. It needs to be extensive because small samples introduce uncertainties and potential biases and because there are many distinct groups whose opinions may differ considerably. It should be deliberative because this is new technology and participants therefore need to be familiarised with the possible ramifications of its introduction in order to arrive at a "mature" view. This is not to say that surveys gathering instinctive responses could not complement the deliberative element but that such surveys alone could not be relied upon to provide a robust picture.

A possibly useful starting point is the existing Sciencewise programme[14], which has a strong track record in engaging stakeholders in deliberative exercises, particularly those relating to emergent and/or controversial technology against a background of policy questions for government.

Amongst other aspects, particular care needs to be taken over recruitment. With respect to individuals, it is easy to imagine the following factors being relevant:

- Where home location lies on the urban-rural spectrum (and location of key destinations such as workplace)
- Whether a driver/access to a vehicle
- Attitudes to cars and driving
- Age
- Gender

[14] http://www.sciencewise-erc.org.uk/ (accessed 5th October 2016)

- Wealth
- Household structure
- General attitudes to technology, risk, privacy and government

With respect to organisations, a sufficiently broad range of organisation types would need to be captured, including private, public and third sectors. A range of organisation sizes would also need to be sampled. And it may prove desirable to create a distinct sample of organisations operating in the transport sector. Identifying an appropriate "representative" of the participating organisation will not be discussed here but is an important element of the process.

Scoping work on the interaction between AVs and road users (including AV users themselves)

Certain aspects of this topic, such as handback, have received extensive attention, whilst others, such as the ways in which AVs will interact with pedestrians or cyclists in future, have been researched to only a limited extent to date. The topic includes both "human-machine interaction" as it is classically understood to apply to the AV user's relationship with the vehicle, and relationships between AVs the set of other road users who are likely to share space with them. It encompasses communication (e.g. how the AV will tell other road users about its manoeuvres and how will other road users signal their intentions to AVs); negotiation (e.g. how, in situations where priority is not clear, joint decisions will be made); and the practicalities of operating an AV, ranging from the nature of any user interface to the feasibility and safety of handback.

This exercise would establish in greater detail than has been possible in this project the state of current understanding and the nature and quality of research work currently being undertaken. This would enable the identification of a number of research projects that would complement existing work and inform, amongst other things vehicle standards and a Highway Code of the future.

Exploration and appraisal of the potential role of the public sector

As previous remarks show, there is a strong emphasis in the questions generated by this project on the role of the public sector and its ability to influence the development and use of AV technology to maximise benefit and minimise potential harm. This exercise would be intended to advance the debate by scoping as exhaustively as possible the range of interventions available to government (at all levels): infrastructure delivery/modification; regulation and legislation; financial incentives; social marketing etc. As well as identifying which options were available to government, an initial appraisal would be conducted, tentatively to identify the possible costs and benefits of implementation, drawing on the impact assessment process. As with most research relating to AVs, there would be large unknowns so the assessment would need to allow for ranges of possible impact (perhaps drawing on the scenario exercise described above if it had concluded).

Transport network simulation exercise

Of the many sub-categories under *consequences/wider impacts*, network performance stands out for several reasons:

- Many of the claims made for AVs relate to their likely effects on congestion, capacity and journey speed
- Whereas some of the wider impacts may take years to come about, network performance impacts are likely to be seen relatively quickly

- Network performance will have a very strong feedback effect on user behaviour and, to a lesser extent, technological and market developments

Put another way, network performance could be considered to be one of the "acid test" of AVs and the most significant impact area in terms of informing the actions of the public sector at this stage. It is also of great interest to the Department for Transport, because one of its priorities is "improving journeys" (GOV.UK n.d.).

It is therefore proposed that a detailed simulation exercise be carried out to test the effects of AVs on the network.[15] As with the exploration of potential government interventions, the unknowns are many so it would again be useful to be able to draw on the outcomes of the scenario-planning work identified earlier in order to test network performance against a credible range of combinations of technology and user behaviour.

Various sophisticated models exist of transport networks, particularly those of cities. It should therefore not be necessary to develop a new model, but sufficient to make limited amendments to one already in operation.

Other recommendations

Cross-government AV research panel

It is striking that officials from the Department of Health and the Home Office devoted a day to attend stakeholder events as part of this project. This is probably the most effective demonstration that AVs are seen as potentially having a significant impact far beyond transport. Also, it does suggest that there would be benefits in gathering views across government concerning research priorities and approaches to its execution. A side-benefit of doing this would probably lie in discovering relevant work commissioned by departments other than Transport and it is conceivable that additional funds would appear.

Summit of major funders of transport research

Apart from the Department for Transport, the Engineering and Physical Sciences Research Council and Economic and Social Research Council should both have a strong interest in AVs. Outside the public sector, trusts such as the Rees Jeffreys Road Fund could also be expected to be interested. This suggests there is potential benefit in gathering these and other such stakeholders to discuss the range of possible research relating to AVs and, where, possible to co-ordinate activity.

Deliberative events for officials

The methods used in this project's stakeholder events were designed to challenge participants' preconceptions and to encourage them to think more broadly about a world including AVs in terms of both positive and negative aspects. Comments received after the events indicated that participants had found the experience very useful.

Given that AVs constitute a new technology whose impacts could be extensive and profound, circumspection amongst the widest range of officials is desirable. With slight modifications, the methods from the events could be used as part of shorter events or "self-

[15] To an increasing extent, it is possible to forecast collisions using transport models so this could be included amongst the items being tested.

administered" in one's own time.[16] It might be considered desirable for all officials working on AVs to have undergone an exercise of this sort as part of their AV "induction".

[16] Officials could, for example, be presented with one or more of the "scenes" and asked to respond to the associated questions. They could also go through the "Mapping the Territory" exercise, if provided with a fuller guidance note.

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Appendices

Appendix A: Description of stakeholder events

Two day-long workshops were held (on 19th and 27th May 2016) at the offices of the Department for Transport. An effort was made to attract a wide range of interested individuals to participate (see Appendix D for a list of organisations represented).

Each workshop began with introductory material including a presentation about "game changers": advances in technology that have significantly altered the ways individuals behave and society operates. Two specific examples were discussed – the automobile and the internet – and, in each case, evidence was provided that predictions made as these technologies were first emerging turned out to be inaccurate, and sometimes wildly so. A short time was also spent discussing supersonic travel, as an example of a technology that, despite widespread predictions that it would become ubiquitous, did not. The general aims of this section were to remind participants of the tendency for assumptions about technological development to prove false.

After this, there were two facilitated discussions in small groups. The first, *Mapping the Territory* (see Appendix B), presented participants with a series of tools designed to support them in thinking about how AV markets might develop, with explicit reference to external factors that might promote or inhibit the development process. The second was based on discussing a set of twelve "scenes" (see Appendix C), with each group discussing two or three from the set. Each scene was a vignette or use case, representing a possible future where the introduction and/or adoption of AVs had led to unexpected and, in some cases, controversial events. Facilitators were provided with a set of questions for each scene which they were able to use as necessary to prompt discussion. Each group discussion session was followed by a plenary during which groups were able to share their thinking about the tasks they had undertaken.

Mapping the territory

27th May 2016

VISION

- One assumption is that we all share the same view of what the technology will be like when it’s mature

- However, competing visions are likely - for instance video recorders were perceived by the media industries as a method of distributing content and by users as a way of time-shifting content. The two visions eventually proved compatible

VISION – *facilitators' notes*

- *Facilitators - please elicit from the table their views of the ultimate state of the technology - and collect and collate those views.*

VISION

Type of innovation	Vision of technology's role at maturity

Background assumptions – *facilitators' notes*

- We've listed some background dimensions and specified two time horizons. The first we call '**immediate**', ie between product launch and main market acceptance; the second relates to when the technology is **at maturity**

- What are people assuming about the demographic structure, economic status and general functioning of society etc at this point?

- We've started with some suggestions for "immediate", but provide a second - blank - slide on which you can add further dimensions if they arise.

Background assumptions – *facilitators' notes*

- Once you have run through the list for “immediate”, adding any that arise in discussion, ask your group which, if any, of these dimensions would look different “at maturity”. Record those answers on the “at maturity” sheet(s).

Background assumptions – “immediate”

Dimension	Summary
Demography	
Status of economy	
Population mobility	
Size & density of cities; level of urbanisation	
Technology use model (eg ownership vs pay for use/leasing)	
Energy availability and cost	
Political situation (stable/unstable)	
Public attitudes to technology	
Consumer spending power	

Background assumptions – “immediate”

Dimension	Summary
Complementary technologies	
Production conditions	
Role played by technology	

Background assumptions – “at maturity”

Dimension	Summary

Background assumptions – “at maturity”

Dimension	Summary

THE DEPLOYMENT CURVE

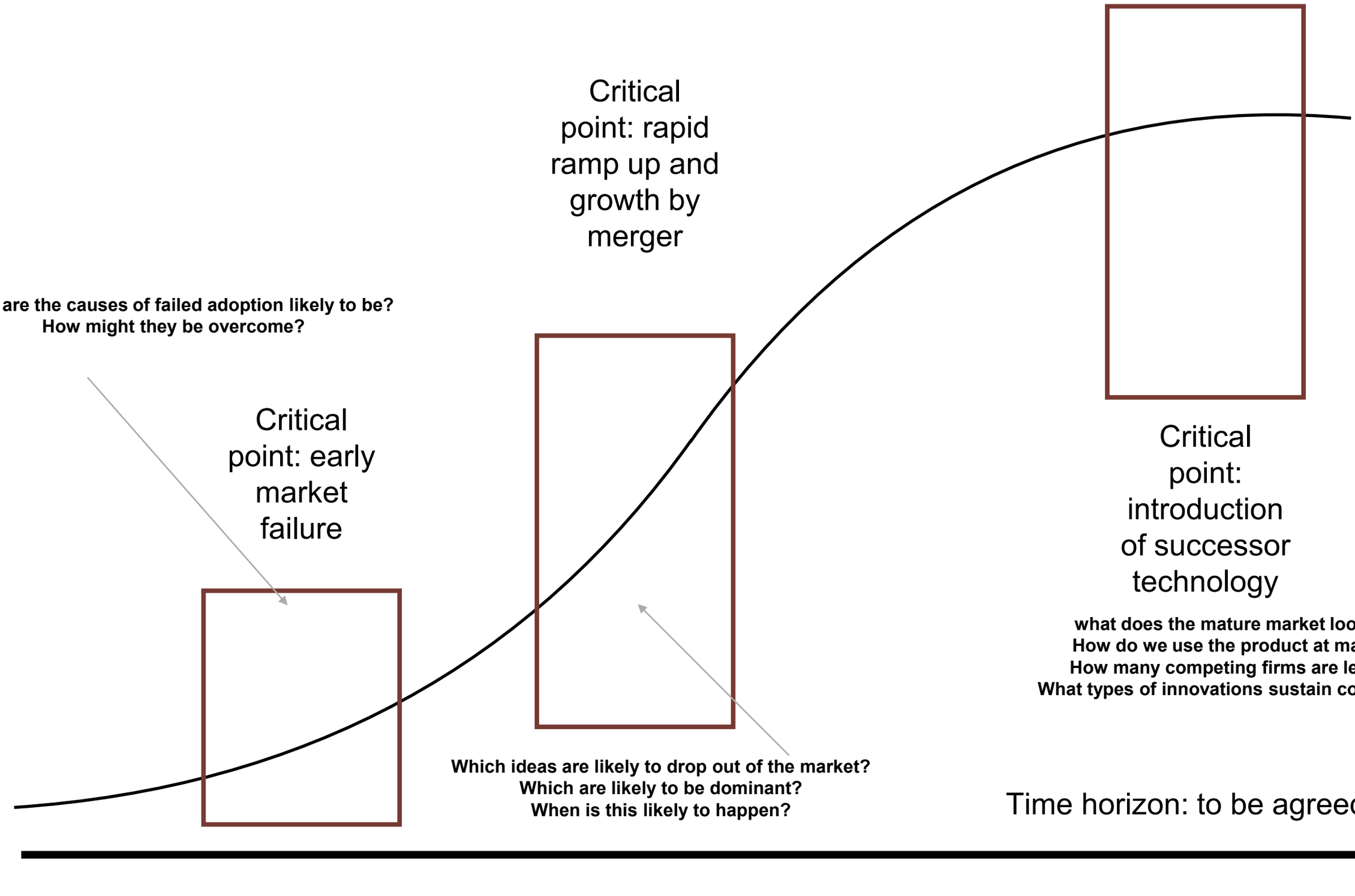
- The trajectory we have found for the penetration of earlier technologies follows, broadly, an S curve.

- However, within that, there tend to be points of risk and opportunity, that lead to runaway growth for successful technologies and failure for less successful ones.

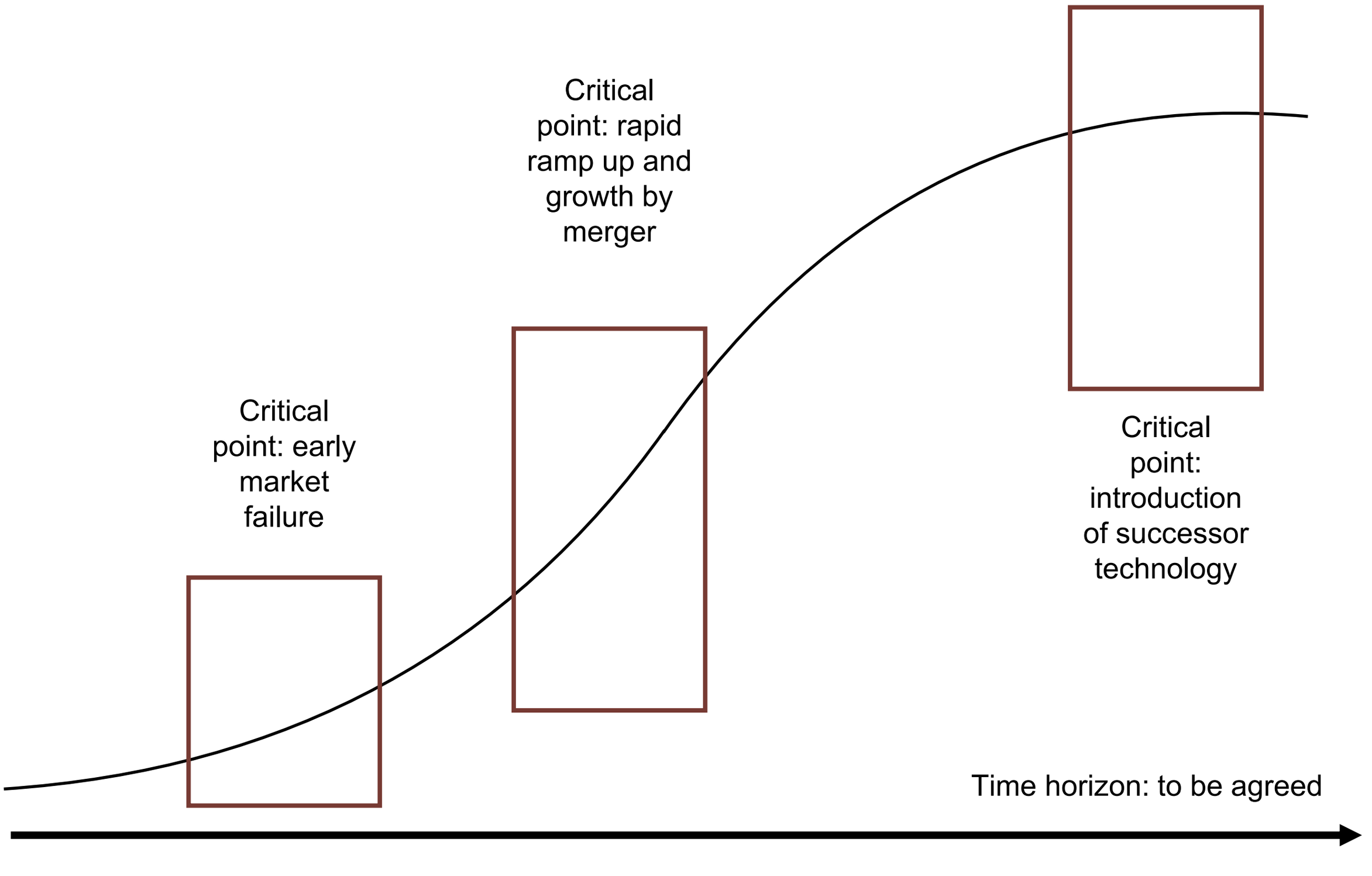
- The deployment curve we are using adapts an S curve to think about ‘places’ where there are significant risks and opportunities.

- Use it to ‘map’ likely issues onto the technology trajectory - as you see fit.

THE DEPLOYMENT CURVE – *facilitators' notes*



THE DEPLOYMENT CURVE



THE ROLE OF MARKETS

- This deals with the *degree to which we prefer, as a society, the use of markets when introducing a technology*

- There are several possible dimensions -

  - Whether we prefer markets **in general** to a more regulated environment

  - The choice of how much of a new technology is privately developed and how much directed or mandated via standards

  - The advantages and disadvantages of each approach

THE ROLE OF MARKETS - example

- Standard setting -
    - A high level of regulation avoids the duplication costs inherent in standards battles (think VHS vs Betamax)
    - Markets may not develop working systems in cases where standards compete
    - However, mandating a ‘best’ solution may stop us benefitting from a ‘better’ solution that might be found only through market experimentation

THE ROLE OF MARKETS - *Facilitators' note*

- The next slide is for mapping the degree to which your table thinks the ‘world’ in which the AV will be launched is ‘state controlled’ or ‘market centred’

- Ask the table to think about what the dimensions of each might be - might the state mandate technical standards or might it be more directive? Might it use ‘rules’ or ‘incentives’ to achieve those ends?

THE ROLE OF MARKETS

STATE CONTROL	MARKET

Knock-on consequences: *Facilitators' notes*

- Innovations such as AVs tend to have consequences both for obviously close substitutes (eg other forms of transport) and, via re-allocation of budgets, for less obvious products.

- Mapping the path to the maturing of a product involves thinking about what is displaced along the way.

- In the next slide, please think about how AVs and associated technologies (eg highway infrastructure) will be challenged, create benefit or be blocked by factors **after they enter the market**.

Knock-on consequences

Technology	Creates benefit for	Challenges	Is blocked by

Force fields - return to top level *(facilitators' notes)*

- This final exercise is intended to draw together the previous elements, so some repetition of earlier points can be expected. The aim is to identify which themes are the most significant.

- Returning to a top-level view, elicit from participants their views of what will drive the technology and what they think will be resisting or blocking the introduction of the technology, using the preceding tables and pictures as a reference.

Force fields

DRIVERS	BLOCKERS

SCENE A: A CLASH OF IDEAS

News Report, R4 Today .
14/09/2021

Public health campaigners are queuing up to condemn the recent offering by an East Midlands brewery of a free ride home in one of the new ‘Hail and Ride’ autonomous vehicles to any customer spending more than £30 in one of its pubs.

The Campaign against Alcohol Misuse said “this drives a coach and horses through the national alcohol strategy, and encourages irresponsible drinking.” Meanwhile Citizens Action on Social Health pointed to the estimated £60bn cost to the public that it blames on ‘problem drinking’. “We know how much alcohol misuse costs to society and we’re frankly quite disappointed that anyone would think it was a good idea to subsidise inappropriate behaviour”.

In reply, the brewery in question, Red Goblin, said “in many rural areas consumers have poor social and transport options. Pubs are often the only meeting place, but are hard to get to and have been closing as stricter drink driving laws have bitten hard. Most pubs now will have deals with taxi firms, and we’re only doing exactly what other ride schemes have been doing.” Asked about whether its actions are an invitation to problem drinking they replied “nobody said that an individual pays £30 for their own drinks - they may well have bought for others - and at today’s prices that’s barely a round.”

Campaigners are not satisfied, and have called on the government to make such offers illegal under the Alcohol Strategy Framework.

SCENE B: OF YOUTH AND AGE

Today's Phone-in Debate
SHOULD WE SUBSIDISE RIDES FOR PENSIONERS?

Today, the National Pensioners' Foundation produced evidence showing that widespread adoption of driverless car technologies would prevent social isolation in older people and called for the government to subsidise rides in the new driverless Urban Transit cars for the elderly, but should it and, if so, who should pay?

Tracey in Bolton says "Of course they should. They should make it cheap for old people without cars to get around."

Ilyas in London says "Why can't the companies just offer cheaper rides themselves? Why does the government need to get involved in this - taxpayers are already squeezed hard enough."

Jenson in Birkenhead emails to say "We give pensioners free travel now - they have Freedom Passes and whatnot, so what's the difference here?"

Alina in Guildford chimes in with "Pensioners aren't the poor now, it's young people who pay their pensions. And anyway, why are we helping car manufacturers get their products on the market?"

Keep the calls and emails coming in, we'll be back after the break.

SCENE C: What's my job worth?

London Radio News
January 15th 2022

It's already been described as the biggest local story of the year, and it's been the biggest phone-in we've had in the past five. The complaints of delivery driver Aldus Marsh went viral after he took to the airwaves to talk about how tedious and boring his job has become since his employer automated their delivery fleet.

"I turn up and I do nothing now, bruv. Turn the key. Listen to the radio. Drop the package, Log the package, turn the key, listen to the radio. The van knows where it's going, I've got nothing to do but sit half the day. You can't work like this, can't call it a decent job or nothing! Once they figure out how to make a robot knock on a door, then I'm there doing nothing."

The old switchboard lit up with people agreeing. "It's a shame that he has to be there at all, it's not really a job is it?" "Why does he have to be there at all?" "People used to have decent jobs, but now, it's all automated. First the warehouses, but at least drivers had to do something. Now why's he behind the wheel at all? Bet only for Health and Safety or something."

We'll be taking more calls on the topic this afternoon. Are you a driver in a driverless van? Give us a ring. You can't be arrested for not driving without care and attention, can you?

SCENE D: ZERO DAY

AV Dashcam exploit: Police Issue Warning

The Bugle, 23/11/2021

Police today issued a warning following the discovery of a zero-day exploit in the firmware of the recent line of Wu Ming autonomous vehicles.

The exploit came to light with hackers' release of data giving the location of reality TV star Emma Dale's vehicle, which was uploaded to several social networks last night.

Ms Dale, who is currently married is rumoured to be having an affair with celebrity superstar, Justin Rees and the allegation from the hackers is that she was headed to his home.

Wu Ming has, as yet, not provided an update for the insecure software. Solicitors for Ms Dale announced that they are suing Wu Ming for facilitating what they call a 'gross invasion of privacy'. Representing Ms Dale, Penny Rose, said "this is a violation of her rights to privacy. We are troubled by the cavalier way in which the essential expectation of privacy has been treated."

A spokesman for Wu Ming said "we naturally take any breach of customer privacy very seriously and are looking into the precise nature of the breach. Beyond that, we have no comment for the moment."

Note: "A zero-day vulnerability is a disclosed computer-software vulnerability that hackers can exploit to adversely affect computer programs, data, additional computers or a network. It is known as a "zero-day" because once the flaw becomes known, the software's author has zero days in which to plan and advise any mitigation against its exploitation." (https://en.wikipedia.org/wiki/Zero-day_%28computing%29)

SCENE E: IT SHOULD NEVER HAVE HAPPENED

WENDY

"We cross live now to our transport correspondent, Richard Westplot, who is in central Surbiton. Richard…?"

RICHARD

"Thanks Wendy. You join me in Surbiton, an ordinary London suburb if it's fair to use that term. Two days ago, right where I'm standing, something that should never have happened, happened. Thirteen-year old Peter Leicester was struck by one of the new wave of fully autonomous cars of which we've heard so much. The vehicle's user had passed control to the onboard *Robodriver*. Witnesses say that Peter and friends had been playing "chicken", each taking turns to step out in front of an autonomous vehicle in order to force an emergency stop. In fact, there have been three airbag injuries to vehicle users arising from pedestrian-related stops in this area over the past month. What happened in Peter's case? Did he step out so late that the vehicle was unable to stop? Did the vehicle suffer a failure of some kind? The user was operating the vehicle on a section of highway rated for self-driving so appears to be in the clear. Police will say no more than that they are investigating and in touch with Wu Ming, the vehicle's manufacturer.

This is the first UK accident involving an autonomous vehicle that's led to hospitalisation and it's a mercy that Peter is in a stable condition. But his parents are unlikely to be impressed by claims of an 80% fall in accidents thanks to this technology. Back to you, Wendy."

SCENE F: TRUNK ROAD CONVERSION

Planning Inspectorate bulletin 2027.1203

Case 72s

Application to convert A3 between Chessington and Guildford to exclusive use of AV vehicles conforming to ISO93241

The proposer, SERCO, on behalf of Highways England and the AUTO Manufacturers' Consortium, seeks an order under the Town and Country Planning Act 2025, to convert the above section of the strategic road network to use exclusively by vehicles conforming to ISO93241. In particular:

- 2m guard-railing along both sides of the carriageway as required by the Act in respect of 180kmh operating speed
- Reconfiguration of major junctions to "gated" status for entry to the converted section of highway
- Closure of four minor junctions and associated works to provide access to the frontage properties of Jelton village from the east

Order of business, 13th June 2027

Oral representations will be heard from:

- Surrey County Council
- Guildford Borough Council
- Dream Vehicles *(whose "family vans" are designed in accordance with ISO93226)*

SCENE G: AUTOMATED MUGGING

Local Transport Today, Issue 13227, February 4-17 2026

Transport Select Committee announces inquiry on personal security and autonomous vehicles

The Transport Select Committee yesterday announced the launch of a new inquiry on personal security and autonomous vehicles, reflecting serious concerns raised by a wide range of motoring and consumer group organisations (see LTT passim). These relate to the vulnerability of occupants of fully autonomous vehicles following a series of high profile vehicle-jackings and personal muggings in wealthy, low-density areas at night – throwing into question the whole idea of 'hands-free' driving.

AVs travelling down residential streets have been suddenly surrounded by groups of young men, wielding bars and bats. The vehicles come to a halt, to avoid causing injury, and then remain immobile while windows are smashed and occupants are threatened. Having suffered the fear and humiliation of the attack, the occupants are further angered by the vehicle's monitoring systems identifying damage and thereby refusing to restart so they can resume their journey.

The *Mail on Sunday* has added its weight to the campaign for action. As it reported last month, Sue Brown was returning home from a night out with friends and while her vehicle was passing a local park something was thrown in front of her car, which made an emergency stop. Immediately she was surrounded by four youths; one smashed a side window and demanded her necklace, watch and purse. "What could I do?" she recalls. "If I'd had my old manual car I'd have driven at them and they would have soon scattered! We bought this car as we were told it was a lot safer – my husband had an accident a few years ago and injured a cyclist – but this is just exchanging one type of danger for another. We traded it in the next day for a 'proper' car."

The inquiry is open to written submissions until 31st May

SCENE H: COMMUTERS WELCOME THE 25+ HOUR DAY

From the Sunday Times Lifestyle Section, 3rd August 2028

Car commuters, on average, spend an hour a day driving to and from work - and quite a number drive for two or more hours each day. Those who have switched to autonomous driving are reporting major benefits for their working lives and in their personal lives.

From a business perspective, they are arriving at work less tired and less stressed, and many can work effectively on the journey to and from the office – to such an extent that some employers are starting to count AV travel time as part of the working day (if verified by email trails, etc), in the same way that a few companies have counted rail commuting time as 'productive time'.

Seen from a personal point of view, AV users also arrive home feeling more refreshed, and if they don't choose to work can communicate with their children using Facebook, chatting via a direct video link, or sharing a computer game. Alternatively they can complete on-line household chores (on-line shopping, banking, etc), thereby releasing more time for family social activities.

"Either way", as George noted enthusiastically, "it's like gaining an hour a day; either I save an hour at work by using my commuting time for office work, or I get an extra hour's interaction with my kids on the way to and from the office. This is a bonus I did not expect when I got my first AV car!"

SCENE I: MAYOR “ROBUSTLY CONFRONTED”

From the Borchester Argus, November 13th, 2026

By L Snell

We reported last week (edition of 6th November) on Borchester Borough Council’s decision to drastically cut back on parking provision, in the light of large forecast increases in self-driving vehicles (AVs). This provoked an angry reaction from the Borchester AV Owners Society, culminating in a scuffle outside the council chamber on Thursday. The council’s press team has described the event as a “robust confrontation”, though no injuries were reported.

The council had argued that the takeover of car mobility by AVs will almost completely remove the need for parking spaces, as they will become automated taxis and so will be in almost constant use. This makes most parking spaces redundant, thereby enabling the council to sell off valuable land taken up by the existing off-street car parks, and to increase road capacity for the additional numbers wanting to use auto-taxis by removing on-street parking spaces.

According to the AV Owners Society website, they have several objections to this:

- This will discriminate against AV car owners, who feel strongly about having their own car - and who help to support the UK car industry
- Retailers are also worried that the loss of parking will reduce the attractiveness of their shops for tourists and residents visiting from the surrounding rural areas – where giving up personal car ownership is seen as a less likely outcome
- There were suggestions of ‘good relations’ between the mayor and Tungsten, the construction company that has been named as ‘preferred bidder’ for the first of the off-street car parks to be sold off
- The idea that removing on-street parking would enable more car taxi traffic to flow through the town was not welcomed by pedestrian and cycling groups

We attempted to speak with the mayor’s office concerning the claim relating to Tungsten but were told that no one was available.

SCENE J: EMERGENCY MEETING CALLED BY MINISTER

Local Transport Today, Issue 2338, April 12-23, 2024

Minister announces new legislation requiring compatible AV responses to emergency vehicles

A meeting took place at the Department for Transport's headquarters last week, called by a reportedly "angry" Selwyn James, Minister for Roads, with the heads of the UK emergency services and the leading car manufacturers and distributors. This followed a leading article in the *Daily Mail* which, after a 'Freedom of Information' request, had found that emergency vehicle response times had increased in cities pioneering the introduction of AVs. The paper estimated that, in the previous 12 months, these delays had led to several 'unnecessary deaths' and hundreds of millions of pounds in extra fire damage.

An industry source, who asked not to be named, said that the problem arose from two factors. First, the software on some imported AVs cannot identify signals sent out ahead of them by emergency vehicles in the UK, as there is no international standard. And, second, each company has developed its own automated response algorithms to deal with the presence of an emergency vehicle; some come to a safe halt, some pull as far as possible to the left, others pull as far as possible to the right. As the spokesperson noted: "Each of these strategies is fine if there is only one AV impeding the path of an emergency vehicle, but when a busy road is full of AVs each adopting a different response, it can lead to a total road blockage."

The minister has since announced that new legislation will be introduced, as a matter of urgency, to ensure that all AVs sold in this country have compatible vehicle emergency recognition and avoidance strategies – although the car industry is likely to argue as to which maker's standards are the ones to be universally adopted. Academics have been contracted to use the latest micro simulation traffic assignment models to see which would be the optimal strategy, at a network level.

As one frustrated political adviser noted, on condition of anonymity: "we were led to believe that it was best to 'leave it to the market' and that any regulation would hinder not help. That might be true for the individual vehicle user, but when it comes to running a road network with thousands of interacting vehicles of all shapes and sizes, this approach has clearly failed – I dread to think what other problems might lie in wait!".

SCENE K: ETHICAL DILEMMAS

Jilly Toynbee writes in the Guardian:

Who would have thought that the application of philosophy to public policy would become so acrimonious?

We remember the so-called Star Chamber consisting of the world's most renowned moral philosophers that held a three-year inquiry to support the development of ISO94622. Their brief: to agree on principles that would determine how autonomous vehicles would deal in real time with a series of ethical dilemmas. This most public of inquiries not only took evidence from a host of eminent experts but was played out on social media. So we should perhaps have been amazed that any decisions were reached at all.

But now, Professor Harry Stottle who, as chair of the Chamber, became something of a celebrity during the early 20s, has lately been the subject of anonymous death threats, culminating last week in the firebombing of his home in Summertown, north Oxford. And why? Because Belinda Graham, a 78-year-old with 13 grandchildren, was the loser as the behavioural algorithm of a *Wu Ming X42* decided in favour of a four-year old boy with a degenerative disease that is likely to mean he will die before the age of ten.

We can only speculate about why this example has ignited the tinder of public opinion; there have, after all, been similar cases over the five years since ISO94622 gained approval and vehicles rolled onto our highways. Perhaps it's the sense that the standard's inevitably simplistic decision-making heuristics ignored the additional details that would, many argue, have reversed the standard prioritisation in favour of a woman whose life was, on balance, more valuable. But Pandora's Box has truly been opened now: the Campaign for a Cyber-Free Environment has renewed its calls for the standard to be revoked and all vehicles operating its algorithms to be recalled. *The New Saboteurs* are claiming responsibility for increasing numbers of "AV-cides", where vehicles are put beyond use in sometimes rather spectacular ways. This movement seems to enjoy increasing cross-party support. As for Professor Stottle, he might be forgiven for wishing that he'd stayed in the world of tutorials, papers and conferences.

SCENE L: SYSTEM FAILURE

JOIN MY CAMPAIGN FOR MANUAL OVERRIDE TO BE MADE MANDATORY

I was more excited than most to take delivery of my new Wu Ming *X36* a few months ago. I've been an "early adopter" all along, had a TESLA with Autopilot and got the first Wu Ming with *SitBack* technology. I was a bit worried by the complete absence of a steering wheel in the X36 but decided to believe Wu Ming and the government, who said it would all be fine.

Then I spent two nights locked inside a stationary car in the Highlands with no light or warmth, wondering if I'd ever see my family again. The car had suffered a complete systems failure and I mean "complete". Not only could I not get out; I had no comms either. Maybe manual override wouldn't have made much difference in my case but I can think of lots of people who would want the option for when the system goes down *and it will*.

I say that all road vehicles should have manual override. And I say that there should always be a trained, capable driver in any road vehicle. With luck, they can *SitBack* and relax but they might be very glad they had a steering wheel and knew how to use it. Better safe than sorry, I say.

So please sign here to tell the government to revise all relevant standards to stipulate that all road vehicles have manual override

And sign here to make it a requirement for all road vehicles in motion to contain at least one individual competent to drive.

And please "like" my campaign on Bookface

Thanks

Gerald Costorphine

UCL TRANSPORT INSTITUTE

Scene	Questions
A	**Immediate (Scene) questions** 1) Is there any way to resolve the issue? 2) Is social connection important enough to allow it to trump the public health concerns? 3) How might this scene play out in the short term? What steps might be taken to assuage concerns? **Wider (Sectoral) questions** 1) What balance might there be between competing concerns such as in this case? 2) In which way would the public mood lie when confronted with an impasse? What are the implications for AV services/ manufacturers? 3) What effects might the introduction of AVs have on rural communities? Or on other areas less well served by public transit systems. 4) Who might be called upon to take such decisions? What might the consequences be? 5) What method might be chosen to decide between the merits of claims that address competing harms or benefits, and how might this affect the choices of consumers around autonomous vehicles. 6) What does being a 'responsible' AV user entail?
B	**Immediate (Scene) questions** 1) Could a scheme like this be conceived of in practice? 2) How would funding for such a regime take place, practically? 3) Aside from the trade-offs mentioned in the scene, are there any others that come to mind? 4) Would funding, whether through tax breaks or through direct subsidy, be considered as part of a migration towards autonomous vehicles? **Wider (Sectoral) questions** 1) Are there implications for government support for the adoption of autonomous vehicles in their widest sense? 2) What factors would need to change around the autonomous vehicle sector in order to support such a migration? 3) What other jobs, business models or technologies would get displaced or otherwise challenged by a social support system for autonomous vehicles? How would people doing those things react? 4) What government entities - local, national or supra-national - would be held to be stakeholders in a scheme of this kind? How would they react to the changes?

Scene	Questions
C	**Immediate (Scene) questions** 1) How far away in technological terms do you think we are from a scene like this occurring in practice? 2) Do you see resistance from workers in traditionally low skilled industry to such a technology or would they welcome it? 3) Would widespread automated delivery have consequences for other parts of the economy, and if so what are those consequences likely to be? **Wider (Sectoral) questions** 1) What are the implications of moving to a driverless world for the wider economy, and for work and occupations within the economy? Would disengagement lead in time to unemployment? 2) Beyond the delivery industry, which industries or activities do you see as most likely to be affected by the changes? 3) What happens to workers in those industries? What possibilities will there be for redeployment? 4) Beyond the possible health and safety concerns alluded to in the discussion, what purpose will humans fulfil in this sector of the economy? 5) What effects will there be on wider participation in labour and on productivity? 6) Which areas of the employment market will grow as a result of AVs? Who will the winners be?
D	**Immediate (Scene) questions** 1) Upon whom does any liability fall? 2) What steps could the manufacturer take to deflect liability for any breach? 3) How might this particular scene play out in the short term? What steps are likely to be demanded or taken in response to the breach? **Wider (Sectoral) questions** 1) What balance should there be between the needs for notification of misbehaviour and the reasonable expectation of privacy in an AV? 2) Supposing an AV would be broadcasting its location at all time, where would the public mood lie on the questions of privacy surrounding the use of an AV? 3) To what extent are breaches like this, should they occur, going to affect the demand for and use of AVs? 4) How can a system be built that is trusted, safe and balanced for all stakeholders? What compromises might there be? 5) Assuming that to some extent breaches of AV software take place, what is the order of priority for dealing with risks? What protocols ought to be in place to deal with such breaches should they occur?
E	1 Is this something that we would get used to? What if such collisions did indeed happen a great deal less frequently than in the days of human-operated vehicles? 2 What difference, if any, does the suggestion that the pedestrian had been playing “chicken” make and why? 3 Would full automation ever be permitted on roads shared with vulnerable users? 4 At this stage in the technology’s development, autonomous vehicles will be comparatively expensive, implying a wealth gap between the vehicle user and the pedestrian. How relevant is this?

Scene	Questions
F	**Immediate (Scene) questions** 1. Would segregation be necessary in certain locations in order for the full benefits of autonomous vehicles to be obtained? 2. If so, how would such issues be weighed? 3. Is it likely that automation will gravitate towards a single protocol? If not, how will government work with multiple variants? **Wider (sectoral questions)** 1. How will the interests of AV users be balanced with those of other users – non-AV users, cyclists, pedestrians? 2. The scene assumes private interests will drive (some) changes to infrastructure and operations. Is that likely? Is it desirable? 3. Does the likely advent of AVs imply a different relationship between users of transport infrastructure and those living in its vicinity? 4. What would people living in the area and other road users think of this? How would they be affected?
G	**Immediate (Scene) questions** 1) Is this likely to be a serious enough problem to change public sentiment and halt the AV expansion? How could public fears be assuaged? 2) Could algorithms be modified to override normal obstruction avoidance strategies if, for example, a panic button was activated? But, if this led to a collision, what would be the legal situation? 3) Vehicles could be designed to withstand such low level attack, but at the expense of weight and cost – does this stack up commercially? **Wider (Sectoral) questions** 1) How might we deal with moral dilemmas, where personal safety is at odds with personal security? 2) Does it make sense to give type approval where the occupant has no control over the actions – or inactions - of the vehicle?
H	**Immediate (Scene) questions** 1) Are employers likely to embrace AVs as a source of productivity increase? 2) Is the increased option to carry out personal chores on-line while commuting likely to displace this activity from working time and so increase productivity? 3) Will the 'mobile office' take off on a large scale, or will car sickness become a more serious problem? 4) Will 'engagement at a distance' strengthen or weaken child/parent ties? **Wider (Sectoral) questions** 1) What kinds of sectors will see the widespread use of AVs as an opportunity to increase consumption (e.g. entertainment, retail)? 2) Will any employer concessions to AV commuters discriminate against users of healthy active travel modes?

Scene	Questions
I	**Immediate (Scene) questions** 1) Would the widespread adoption of the car taxi remove the need for most parking – or would people be likely to rent a vehicle for an hour or two, to wait for them while they shopped, etc? 2) Would policy makers want to encourage increased use of cars in urban areas? If not, what might they do to stop it? 3) Could space no longer needed for parking be used more imaginatively? (e.g. widening footways, creating pocket parks) **Wider (Sectoral) questions** 1) How much are people likely to be willing to give up personal car ownership, given that cars may still be linked to personal identity and equipped for a range of customised uses – from a mobile office to a crèche? 2) Could we face major problems by over-relying on automated taxis for personal mobility – what if the employees of the company owning the vehicles went on strike? 3) Were the need for parking spaces to reduce dramatically, should we use this as an opportunity to throw out existing design codes and start again?
J	**Immediate (Scene) questions** 1) How might we go about identifying vehicles with priority use on the road network? 2) Would it be simple to identify a set of agreed autonomous responses for conflict or emergency situations? 3) What 'other problems might lie in wait?' **Wider (Sectoral) questions** 1) Does this mark the death knell for the fully autonomous vehicle? 2) How might we identify situations where 'connectedness' overrides the individually optimised autonomous performance of AVs? 3) What other areas might raise issues about standardisation?' 4) 'How will the authorities manage a road network with thousands of different interacting vehicles of different types?'
K	1) Can we ever get used to the notion of setting rules that place higher value on some lives than others? 2) If we did, could we accept that such rules, as generalisations, would inevitably mean the "wrong" decision was sometimes made? 3) Given that we expect many fewer people would be dying than is currently the case without autonomous vehicles, would that make a difference? 4) What might be a reasonable response to the public outcry described here? 5) The natural alternative to addressing these so-called "trolley problems" is to place AVs in a closed system. Is that viable? Is it desirable?

Scene	Questions
L	**Immediate (Scene) questions** 1) What degree of support might be expected for his campaign? 2) Would such a campaign, if widely publicised, affect interest in AVs? 3) What would the retention of manual override mean for highway operations (assuming that some sections might otherwise be given over to fully automated vehicles)? 4) Assuming the risk of complete systems failure, what level of protection for occupants might be expected? **Wider (Sectoral) questions** 1) Will "full automation" including the absence of any manual controls ever be publicly acceptable? Under what circumstances? 2) Proponents of full automation would argue that the benefits would more than compensate for the costs such as reported here. Would they be right?

Appendix D: List of organisations participating in the study

Organisations participating in stakeholder workshops

AA (Automobile Association)

Addison Lee

Bournemouth Borough Council

Bristol City Council

BVRLA (British Vehicle Rental and Leasing Association)

Campaign for Better Transport

Carplus

College of Policing

Confederation of Passenger Transport

Cycling UK

Department for Business, Innovation and Skills

Department for Transport

Department of Health

Freight Transport Association

Frost and Sullivan

Government Office for Science

House of Commons

Ipsos MORI

London Councils

Milton Keynes Council

National Composites Sector

Nesta

RAND Europe

Rees Jeffreys Road Fund

Road Safety Trust

Royal Town Planning Institute

Steer Davies Gleave

Telent

Thatcham Research

Transport for Greater Manchester

Transport for London

Transport Systems Catapult

TRL (Transport Research Laboratory)

University of Greenwich

University of Leeds Institute for Transport Studies

University of Westminster

University of York

Urban Transport Group

Weightmans

Welsh Government

WSP

Organisations participating in expert interviews

Age UK

Future Cities Catapult

HORIBA MIRA

ITS International

Northamptonshire County Council

RAC Foundation

Toyota Research Institute

Transport Systems Catapult

University of Leeds Institute for Transport Studies

Social and Behavioural Impacts of Autonomous Vehicles – Scoping Study

Summary of workshop with trial representatives, 5th May 2016

Background

The Department for Transport commissioned UCL Transport Institute to carry out a project with the following three goals:

1. Map out the key social and behavioural research questions associated with autonomous vehicles (AVs);
2. Assess the extent to which the current 'driverless cars' trials in the UK can provide evidence on the research questions identified, both individually and in a co-ordinated way across the trials; and
3. Determine what, if any, additional research would be required to answer the social and behavioural research questions identified and set out a suggested approach to this research.

One strand of the project is engagement with the four cities autonomous vehicles trials, summarised here. The other principal strands are a literature review and engagement with the wider community of experts and stakeholders.

The main aims of the workshop with trial representatives were to share knowledge about the activities of each trial relating to social/behavioural aspects of AVs and to identify future opportunities for collaboration and information sharing.

At the workshop, each trial's consortium gave a short presentation on the social/behavioural aspects of its work within the wider project context. Following some general discussion, participants were assigned to groups in which they discussed three connected questions relevant to the scoping project and its second goal in particular.

Summary of group discussions

Bridging to reality

Can we (how can we) extrapolate from limited trials to a world in which AVs are ubiquitous?

The group identified four categories of likely benefit: safety; mobility; efficiency; and economic benefit.

With respect to safety, and claims that accidents would be cut by x%, the group asked what might be the prevailing environment – would regulators have access to data in the event of accidents similar to the aviation sector? This might be more compatible with a world in which government was leading the development process but what if the private sector has greater autonomy than where aviation is concerned? A probable "period of pain" was predicted, when accidents occur in which AVs are held wholly/partially responsible, possibly leading to a backlash prompted by negative media coverage. This will need careful management.

Turning to efficiency, the group asked what might be the underlying governance structure. If AVs are delivered almost as a local bus service (i.e. regulated by government in some way), it seems likely that network management can develop in tandem. But if the system develops in a bottom-up way, with AVs at first owned by affluent individuals, this points to incremental automation of parts of the network. This may mean an interim period during which expected (or claimed) network benefits do not immediately materialise and there is increased

congestion. A connected question related to the partial visibility of potential benefits: if, for example, AVs are for the most part "clean", the resultant air quality benefits may not be apparent to all beneficiaries.

Research gaps

What significant research areas are not being investigated by any of the trials? And is there scope/desire to expand accordingly?

The group identified the following:

- The trials' time and budget restrictions force a focus on *components* of the journey rather than end-end
- There is limited study of interaction between AVs and passenger experience thereof; there is equally little focus on social aspects of driving, e.g. interactions between drivers of vehicles (rules of the road)
- Various "cultural" issues deserve closer scrutiny across a range of road environments: how AVs will respond to aggressive (human) driving, road rage and traffic violations; the range of approaches to priorities at junctions and gap acceptance; and how AV passengers will respond to their vehicles' treatment of these situations
- In light of the speed of technological change (e.g. there are numerous people effectively driving vehicles with low levels of automation on the motorway already), there is a growing cohort of people who have had live experience of the technology and who could be studied
- The ethical issues (e.g. how an AV should prioritise individuals if a collision is unavoidable) may be usefully investigated through a "democratic process" of some kind.

Specific additional themes for research were also suggested:

- Capturing the need to update theories of social/technological change (perhaps through a longitudinal study)
- Better understanding of consequences of mass take-up, especially privately owned AVs
- Trust issues

An associated point made was that it should be accepted that it is not possible to make questions neutral. A pragmatic response is to ask a "cloud" of survey questions (and get a cloud of responses).

Citizen viewpoint

What can we do to help citizens of the present imagine/experience a world with AVs and how best do we capture their responses?

The principal conclusion was that this is hard to do.

The group thought it important to be clear whether we are trying to get people to understand full automation or points in the transition. Perhaps going straight to full automation would ask too much of citizens, suggesting instead a staged process.

It is necessary to provide people with a certain amount of information in order that they can understand the nature of the product/experience (as distinct from what the media may have led them to believe) but there is a risk that this will condition them such that their responses are unreliable. Vignettes and scenarios can help people to put themselves in an unfamiliar place; and there are various real AVs which people can experience now, e.g. DLR and the Heathrow pods.

Qualitative research was thought best for grasping people's current understanding (baseline). A mix of qualitative and quantitative research could follow to track change.

Given that the media may emphasise the negative (scare stories), it was felt desirable to sell the benefits of AVs to promote a more balanced grasp of likely impacts. To this end, the inclusion benefits of AVs, especially given the growing number of older and mobility-impaired people, were a useful aspect to promote.

Concluding thoughts

The impression is that the workshop provided a useful means for the trials to share information about their activities. The DfT and CCAV anticipate that it will stimulate the trials to initial further interactions as they continue their activities.

Full set of research questions

(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
65	Mapping	How does data openness (and its opposite) affect a) what is possible, b) how technology might develop and c) what response it might elicit?	Technological & market developments	Business case & competition
82	Mapping	How large a role will the insurance industry have in determining what technology emerges when (by deciding which risks it is prepared to insure and at what price)?	Technological & market developments	Business case & competition
98	Mapping	Can vehicle manufacturers be relied upon to adopt voluntary codes such as NCAP?	Technological & market developments	Business case & competition
101	Mapping	How will competition between traditional OEMs and Google/Apple affect the AV development process?	Technological & market developments	Business case & competition
164	Scenes	What would development in a largely unregulated market look like?	Technological & market developments	Business case & competition
169	Scenes	Who will own the data?	Technological & market developments	Business case & competition
203	Scenes	Is there a business case for platooning (freight vehicles)?	Technological & market developments	Business case & competition
250	Lit review	What is/are the benefit-cost ratio(s) of the introduction of AVs?	Technological & market developments	Business case & competition
304	Experts	What would be the true benefits (if any) of mixed fleet operation?	Technological & market developments	Business case & competition
309	Experts	What is AVs' commercial proposition?	Technological & market developments	Business case & competition
26	Mapping	How will software update fit with individuals' travel schedules?	Technological & market developments	Contingencies
41	Mapping	What about a fundamental system failure such as loss of GNSS following a solar flare?	Technological & market developments	Contingencies
50	Mapping	Since software updates take time, will vehicles be unavoidably "out of service" at inconvenient times?	Technological & market developments	Contingencies
239	Other	Might emergency override be limited to enabling the occupant(s) to leave the vehicle?	Technological & market developments	Contingencies
261	Lit review	If all software has bugs, what is the worst-case scenario for failure and how "safe" is the failsafe?	Technological & market developments	Contingencies
68	Mapping	Will (and, if so, when will) AVs be an affordable option for more than the hyper-rich?	Technological & market developments	Inclusion & diversity
69	Mapping	Would a market-led development process be bound to exclude certain user groups?	Technological & market developments	Inclusion & diversity
72	Mapping	Will the technology be developed with disabled people in mind?	Technological & market developments	Inclusion & diversity
76	Mapping	Will there be, in effect, different "classes" of AV travel?	Technological & market developments	Inclusion & diversity
107	Mapping	How can technology be made accessible to (nearly) all?	Technological & market developments	Inclusion & diversity
312	Experts	What will be the user interface (for requesting a trip, say) and will it be designed inclusively?	Technological & market developments	Inclusion & diversity
334	Experts	What can increased (as opposed to full) automation do for those with (all types of) mobility impairments?	Technological & market developments	Inclusion & diversity
377	Lit review	Will elder persons, disabled and non-drivers, such as underage children, have the capacity to use these vehicles?	Technological & market developments	Inclusion & diversity
8	Mapping	What if demand for AV mobility cannot be accommodated within the existing highway footprint?	Technological & market developments	Infrastructure supporting AVs
15	Mapping	How compatible is current infrastructure with the requirements of AVs?	Technological & market developments	Infrastructure supporting AVs
16	Mapping	What communication infrastructure is required to enable AVs to operate and how disruptive and costly would its implementation be?	Technological & market developments	Infrastructure supporting AVs
17	Mapping	Would communication infrastructure be "future proofed"?	Technological & market developments	Infrastructure supporting AVs
62	Mapping	Who would pay for the on-road communication infrastructure?	Technological & market developments	Infrastructure supporting AVs
185	Scenes	Will infrastructure supporting AV operation develop at the same rate as the AVs themselves?	Technological & market developments	Infrastructure supporting AVs
308	Experts	What will happen to "the ride" with increasing autonomy – heave, jerk, bumps etc? Is a change in the condition of the highway network likely/affordable/desirable?	Technological & market developments	Infrastructure supporting AVs
335	Experts	What environments are best suited to the operation of AVs and why (eg campuses, places with very low parking provision)?	Technological & market developments	Infrastructure supporting AVs
341	Lit review	Do AVs require large scale infrastructure to function safely and effectively?	Technological & market developments	Infrastructure supporting AVs
342	Lit review	What infrastructure is required to support different type of AVs and roll-out scenarios (e.g. connected or non-connected AVs, urban or rural set up, type of vehicle, segregated lanes, etc.)	Technological & market developments	Infrastructure supporting AVs
343	Lit review	Who should pay for the new infrastructure?	Technological & market developments	Infrastructure supporting AVs
57	Mapping	What will be the impacts on privacy, security and responsibility during a transitional phrase (ie before any technology is "proven")?	Technological & market developments	Technological advance
73	Mapping	How might technology respond to differences of environment? (eg if it takes 18 months to adapt a left-hand drive system to a right-hand drive environment)	Technological & market developments	Technological advance
153	Mapping	What is the relationship between advances in AI and AV development? (Will the first wave of fully automated vehicles be only "quite" clever?)	Technological & market developments	Technological advance
160	Scenes	Can an incremental transition towards automation co-exist with a direct step to automation? How would this play out in the market?	Technological & market developments	Technological advance
199	Scenes	What if the technology halts short of full automation?	Technological & market developments	Technological advance
207	Scenes	Supposing driver-support systems will continue to feature at first on the most expensive vehicles, what is the likely cascade pattern?	Technological & market developments	Technological advance
284	Lit review	If full automation is the "destination", what is the optimal pathway to it?	Technological & market developments	Technological advance
285	Other	Will retrofitting (introducing technology into "conventional" vehicles") increase the speed of AV deployment?	Technological & market developments	Technological advance
299	Other	Will teething troubles mean that things get worse before they get better?	Technological & market developments	Technological advance
301	Experts	What are the potential timelines for the development and adoption of technological developments?	Technological & market developments	Technological advance
58	Mapping	Will those who insist on data privacy/anonymity be excluded or is there an AV-light for them?	Technological & market developments	Technological pluralism
59	Mapping	Could there be a range of control in a fully automated fleet? (ie some vehicles are more autonomous than others.)	Technological & market developments	Technological pluralism
63	Mapping	How might AV technology preserve "the driving experience" for those who want it?	Technological & market developments	Technological pluralism
67	Mapping	Can increasing automation cater to a multiplicity of cultures and visions? (eg if City A wants high-tech and City B wants a focus on arts and culture)	Technological & market developments	Technological pluralism
75	Mapping	If manual driving remains possible when the bulk of vehicles are fully automated, how would this work in traffic management terms and would the driver be expected to pay for the privilege (and the safety cost they impose)?	Technological & market developments	Technological pluralism

Full set of research questions
(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
77	Mapping	If manual vehicles remain the dominant form, what role will fully automated vehicles play and where will they be used?	Technological & market developments	Technological pluralism
84	Mapping	Might problems of a mixed fleet put an end to automation?	Technological & market developments	Technological pluralism
86	Mapping	Would differential insurance rates enable a mixed fleet to work?	Technological & market developments	Technological pluralism
89	Mapping	How best to respond to the desire to retain the joy of driving?	Technological & market developments	Technological pluralism
246	Lit review	Is "old technology" bound to be edged out in time? Will it be edged out by being made difficult to use?	Technological & market developments	Technological pluralism
24	Mapping	In a highly (but not fully) automated car, does the need to be able to respond at short notice in an emergency imply a different skillset for the driver than hitherto?	Technological & market developments	Vehicle characteristics & performance
39	Mapping	How might AVs "learn" of incidents such as temporary closures and how would this answer differ depending on the level of a vehicle's connectedness?	Technological & market developments	Vehicle characteristics & performance
42	Mapping	How much will efficiency determine the dominant technology and regime?	Technological & market developments	Vehicle characteristics & performance
46	Mapping	Will a person inside an AV have exactly the same value as a person outside an AV?	Technological & market developments	Vehicle characteristics & performance
52	Mapping	What does the notion of machine learning imply for compliance with regulations (eg will cars through learning develop new approaches that go beyond what is set out in regulations)?	Technological & market developments	Vehicle characteristics & performance
54	Mapping	If an AV learns a useful lesson (about interpreting particular visual information, say), how widely and by what means would this knowledge spread?	Technological & market developments	Vehicle characteristics & performance
55	Mapping	How "smooth" can the ride in an AV become?	Technological & market developments	Vehicle characteristics & performance
71	Mapping	Will there be a hierarchy of journey types and, if so, how will that hierarchy operate?	Technological & market developments	Vehicle characteristics & performance
78	Mapping	If the fleet delivers sufficient capacity to meet peak demand, does this mean that there will be significant unused capacity at other times? Where will the vehicles go?	Technological & market developments	Vehicle characteristics & performance
116	Mapping	Might there be large AVs that provide extra space for those that want and can afford it?	Technological & market developments	Vehicle characteristics & performance
187	Scenes	If AVs operate as taxis, how will this play out in terms of needing to deliver in the centre and collect from the centre but (presumably) be somewhere other than the centre during the day?	Technological & market developments	Vehicle characteristics & performance
193	Scenes	Could vehicles be designed to carry people some of the time and freight the rest of the time?	Technological & market developments	Vehicle characteristics & performance
208	Scenes	What will be the drive train of AVs and, if it's electricity, how will that be serviced?	Technological & market developments	Vehicle characteristics & performance
230	Scenes	If people no longer need to buy a vehicle that satisfies peak demand (eg a holiday trip involving all family members and their possessions), what does this imply for the future size distribution of the fleet?	Technological & market developments	Vehicle characteristics & performance
298	Other	Should AVs be differentiable from manual vehicles?	Technological & market developments	Vehicle characteristics & performance
307	Experts	Will there be three distinct types of vehicle – for one-off trips, for commuting, and for long-distance (ie motorway)?	Technological & market developments	Vehicle characteristics & performance
321	Experts	What would full automation mean for the design and form of vehicles?	Technological & market developments	Vehicle characteristics & performance
338	Experts	In the absence of driver gesture, how should (fully automated) AVs communicate with other road users?	Technological & market developments	Vehicle characteristics & performance
374	Lit review	To what extent AVs have the potential to be low emission vehicles?	Technological & market developments	Vehicle characteristics & performance
28	Mapping	What is true willingness to pay for automation a) as an additional feature of an owned vehicle, b) as a characteristic of a journey?	Use of & response to AVs	Appeal, cost & demand
38	Mapping	How will international variations in infrastructure (extent and quality) influence use of AVs?	Use of & response to AVs	Appeal, cost & demand
49	Mapping	How might the perceived benefits/costs of AVs affect the balance of business/personal a) vehicle ownership and b) use?	Use of & response to AVs	Appeal, cost & demand
53	Mapping	What will using AVs cost?	Use of & response to AVs	Appeal, cost & demand
70	Mapping	What benefits will people expect to receive in order to be prepared to surrender personal information?	Use of & response to AVs	Appeal, cost & demand
87	Mapping	What benefits will people expect to receive in order to accept the risk that their personal information may be misused in some way?	Use of & response to AVs	Appeal, cost & demand
108	Mapping	If those who find driving annoying or unpleasant are the "near market" for AVs, how many are there and how near are they?	Use of & response to AVs	Appeal, cost & demand
117	Mapping	How will international variations in culture influence use of AVs?	Use of & response to AVs	Appeal, cost & demand
118	Mapping	If it becomes possible to "convert" a manual car to full automation, what would be the results?	Use of & response to AVs	Appeal, cost & demand
143	Mapping	Might AVs be adopted at different rates in urban, peri-urban, rural areas?	Use of & response to AVs	Appeal, cost & demand
165	Scenes	What is the role of premium marques (Rolls Royce etc) in an AV world?	Use of & response to AVs	Appeal, cost & demand
190	Scenes	How alluring will AVs be?	Use of & response to AVs	Appeal, cost & demand

Full set of research questions

(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
200	Scenes	Is the probably limited space within an AV (in contrast with a train, say) likely to limit enthusiasm for this form of travel?	Use of & response to AVs	Appeal, cost & demand
202	Scenes	Will those who enjoy the sense of control they derive from driving be prepared to give it up?	Use of & response to AVs	Appeal, cost & demand
222	Scenes	Will those who choose to own vehicles prefer to own manual vehicles and, if so, for how long?	Use of & response to AVs	Appeal, cost & demand
229	Scenes	How will international variations in wealth influence use of AVs?	Use of & response to AVs	Appeal, cost & demand
286	Lit review	Would the attraction of AVs diminish as they became more widely available? (eg if the efficiency benefits experienced by early adopters were not matched once the roads were full of AVs)	Use of & response to AVs	Appeal, cost & demand
330	Experts	What happens to consumer enthusiasm between being told of the concept and experiencing the technology?	Use of & response to AVs	Appeal, cost & demand
350	Lit review	What will the cost of AV travel be according to the different 'roll-out scenarios'	Use of & response to AVs	Appeal, cost & demand
361	Lit review	How will AVs interact with other road users, in particular car drivers, pedestrians and cyclists, under different 'use scenarios', including in urban areas?	Use of & response to AVs	AV's interactions with other road users
362	Lit review	Could AVs interact with other road users lead to unsafe situations?	Use of & response to AVs	AV's interactions with other road users
363	Lit review	Could AVs interact with other road users negatively affect traffic flow?	Use of & response to AVs	AV's interactions with other road users
356	Lit review	Under what conditions to allow AV users to engage in non-driving tasks in partially or highly automated vehicles?	Use of & response to AVs	Driver's interaction with AVS
357	Lit review	What solutions, such as training, should be implemented to keep the driver engaged and maintain/adapt driving skills?	Use of & response to AVs	Driver's interaction with AVS
358	Lit review	To what extent will drivers be able to/want to work whilst in AVs?	Use of & response to AVs	Driver's interaction with AVS
359	Lit review	Could motion sickness issues prevent most drivers from engaging in non-driving tasks? To what extent will AVs reduce drivers' stress?	Use of & response to AVs	Driver's interaction with AVS
360	Lit review	To what extent could drivers' attachment to driving can affect AV adoption?	Use of & response to AVs	Driver's interaction with AVS
163	Scenes	Does the historic dichotomy between American and European car standards predict a similar situation for AVs?	Use of & response to AVs	Environmental & spatial variation
220	Scenes	Are urban areas the least well suited to fully automated vehicles?	Use of & response to AVs	Environmental & spatial variation
227	Scenes	How will AVs deal with local variations (eg different road-lining practices between municipalities)?	Use of & response to AVs	Environmental & spatial variation
236	Scenes	Will different levels of automation and/or forms of technology be naturally better suited to some spatial and highway environments than others? (eg will full automation fare better in a rural environment or on a motorway?)	Use of & response to AVs	Environmental & spatial variation
237	Lit review	Will AVs be more appropriate to some settings than others? (eg contrasting Singapore which has sought to reduce car use with other jurisdictions that have tolerated it)	Use of & response to AVs	Environmental & spatial variation
238	Other	Can controlled operation ever be realistic in remote areas?	Use of & response to AVs	Environmental & spatial variation
240	Lit review	What are the critical thresholds of settlement size that make different patterns of AV operation feasible/desirable?	Use of & response to AVs	Environmental & spatial variation
241	Lit review	Are AVs bound to be more successful in relatively closed highway environments such as motorways and, if so, does this imply that they will be most prevalent in such environments?	Use of & response to AVs	Environmental & spatial variation
242	Lit review	Is there scope for developing nations to "leapfrog" countries with a highly developed infrastructure geared to manual vehicles and, if so, what would this imply?	Use of & response to AVs	Environmental & spatial variation
302	Experts	How will developments play out in the different transport markets, eg east Asia, Africa, as well as the more developed economies?	Use of & response to AVs	Environmental & spatial variation
355	Lit review	What shape a connected and integrated automated freight and delivery system could take?	Use of & response to AVs	Freight
364	Lit review	To what extent negative externalities linked to the use of AVs could lead to a market failure?	Use of & response to AVs	Market uptake
365	Lit review	What are the opportunities and challenges of introducing AVs in non-Western countries?	Use of & response to AVs	Market uptake
12	Mapping	Will mass transit be/remain the poor person's choice?	Use of & response to AVs	Mobility
37	Mapping	Will AVs remove walk stages to and from public transport?	Use of & response to AVs	Mobility
51	Mapping	How would the impacts of retrofitting differ from those of "new-build" AVs?	Use of & response to AVs	Mobility
106	Mapping	Will AVs replace journeys made by active travel?	Use of & response to AVs	Mobility
144	Mapping	If "peak car" is real, what do AVs mean for that phenomenon?	Use of & response to AVs	Mobility
145	Mapping	What might AVs do to the balance of journey purposes?	Use of & response to AVs	Mobility
146	Mapping	Will AVs enable "time shifting" of journeys to take place?	Use of & response to AVs	Mobility
147	Mapping	Will safety gains from AVs be converted into increased speed?	Use of & response to AVs	Mobility
154	Scenes	Will AVs herald an increase in vehicle-km?	Use of & response to AVs	Mobility
166	Scenes	Will full automation lead to increased aggregate mobility (eg, instead of driving two children to a single school, the parent will despatch each to a different place of learning and make a separate trip to the gym)	Use of & response to AVs	Mobility
167	Scenes	If the usage pattern is predominantly not based on personal vehicle ownership, how will the lack of a sunk cost affect travel behaviour?	Use of & response to AVs	Mobility
176	Scenes	What will happen to the ratio of passenger-km to vehicle-km?	Use of & response to AVs	Mobility

Full set of research questions
(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
188	Scenes	How would different models of ownership/use affect a) total vehicle-km and passenger-km, b) need for parking, c) replacement frequency, d) congestion, e) cost per unit distance, f) number of vehicles required to meet demand?	Use of & response to AVs	Mobility
189	Scenes	If a presumption to avoid harm meant that AVs would travel at a uselessly low speed in urban areas, what would happen?	Use of & response to AVs	Mobility
268	Lit review	What will be the aggregate effect on vkm?	Use of & response to AVs	Mobility
317	Experts	What would happen if the sum currently devoted to concessionary fares were reallocated to subsidised AV trips?	Use of & response to AVs	Mobility
2	Mapping	Can routine ("planned") handback be made sufficiently safe?	Use of & response to AVs	New behaviours
233	Scenes	Can emergency handback work?	Use of & response to AVs	New behaviours
258	Other	How will the negotiation between road users (eg through eye contact) be modified by the advent of AVs?	Use of & response to AVs	New behaviours
260	Other	If override is possible, will drivers who become frustrated at the timidity of their automated vehicle simply wrest back control? Does the answer depend on what the occupant is doing during the journey?	Use of & response to AVs	New behaviours
25	Mapping	Will those who own and share AVs be able to trust other users and can this be influenced by reputational tools?	Use of & response to AVs	Ownership, sharing & trust
27	Mapping	Will we ride in AVs with strangers in the future?	Use of & response to AVs	Ownership, sharing & trust
29	Mapping	How many AVs will be owned and used exclusively by their owners?	Use of & response to AVs	Ownership, sharing & trust
34	Mapping	Will the usage pattern (eg owned/hired) differ by location (eg urban/rural)?	Use of & response to AVs	Ownership, sharing & trust
35	Mapping	Are some ownership/use models more socially desirable and, if so, which and why?	Use of & response to AVs	Ownership, sharing & trust
295	Lit review	If a taxi model became prevalent, who would own the vehicles?	Use of & response to AVs	Ownership, sharing & trust
310	Experts	Will people want to use lots of different vehicle types, reflecting their different needs/aspirations? (eg 2-seater sporty number for fun, estate for holidays)	Use of & response to AVs	Ownership, sharing & trust
352	Lit review	What impact different AV uptake scenarios might have on modal share, in particular on the use of public transport and walking?	Use of & response to AVs	Ownership, sharing & trust
353	Lit review	To what extent public authorities should invest/support automated mobility on demand systems?	Use of & response to AVs	Ownership, sharing & trust
354	Lit review	What are the practicalities of establishing shared AV systems, including forecasts of market penetration, system design, implementation and operation?	Use of & response to AVs	Ownership, sharing & trust
243	Lit review	How might urban form accommodate AVs in line with different mobility/environment visions? (eg how would a prioritisation of walking and public space affect the provision of infrastructure on which AVs would operate?)	Use of & response to AVs	Vision, AVs & other modes
244	Lit review	How will mass transit and individual transport interact in an AV world?	Use of & response to AVs	Vision, AVs & other modes
290	Lit review	How can AVs contribute to or undermine the achievement of a given vision for an area (urban or otherwise)?	Use of & response to AVs	Vision, AVs & other modes
19	Mapping	What will be the impact on software development and associated industries?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
104	Mapping	What will be the net impact upon employment?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
109	Mapping	How gradual or sudden might economic adjustments arising from AVs be?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
151	Mapping	What will be the net impact on GDP at a global, UK and UK-region level?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
174	Scenes	What will be the net combined financial impact of AVs on a) individuals, b) society, c) the national economy?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
175	Scenes	What will be the life cycle of AVs – when people replace their vehicles, who will inherit them and with what consequences?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
192	Scenes	How productive will people actually be in an AV?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
214	Scenes	How productive will in-vehicle working time be?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
223	Scenes	Instead of a parking place, might accommodation in future be bundled with a “mobility package”?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
228	Scenes	Will private-sector organisations such as retailers use AVs to bring customers to their outlets?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
254	Other	Would employers ascribe the same value to in-AV time as time spent in a fixed location?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
328	Experts	What might a truly "mobile office" mean for economic impacts such as agglomeration benefits?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
329	Experts	Could freight reap early rewards of automation in terms of night-time deliveries without flouting driver-hour restrictions?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
367	Lit review	How many jobs directly and indirectly related to AVs, across sectors, could be at risk?	Consequences/wider impacts	Economic and & financial effects (not directly transport)

Full set of research questions
(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
368	Lit review	How many jobs directly and indirectly related to AVs, across sectors, could be generated?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
379	Lit review	To what extent will mass AV market penetration will lead to desirable socioeconomic outcomes?	Consequences/wider impacts	Economic and & financial effects (not directly transport)
170	Scenes	What will be the short- and long-term effects of AV introduction on a) total energy use and energy consumed per vehicle-km/passenger-km?	Consequences/wider impacts	Energy, carbon & air quality
195	Scenes	What will be the net effect of AV introduction on greenhouse gas emissions?	Consequences/wider impacts	Energy, carbon & air quality
255	Other	Will AVs operate more efficiently, therefore (in the case of ICE) leading to improved air quality?	Consequences/wider impacts	Energy, carbon & air quality
372	Lit review	To what extent could AVs contribute to energy and emission reduction - under which use scenario?	Consequences/wider impacts	Energy, carbon & air quality
373	Lit review	Under which scenario could AV use lead to an increase in vehicle emission and energy consumption?	Consequences/wider impacts	Energy, carbon & air quality
5	Mapping	Would the “working commute” discourage commuting by physically active modes?	Consequences/wider impacts	Health & well being
14	Mapping	What will increasing automation mean for drivers’ stress levels?	Consequences/wider impacts	Health & well being
32	Mapping	Can increasing automation make driving possible at a later age than currently?	Consequences/wider impacts	Health & well being
61	Mapping	Is the last-mile model of AV use socially desirable (eg in terms of public health)?	Consequences/wider impacts	Health & well being
157	Scenes	What will AVs do to public health?	Consequences/wider impacts	Health & well being
168	Scenes	Might AVs reduce older people’s risks of falling?	Consequences/wider impacts	Health & well being
196	Scenes	Can AVs slow the transition from independent living to residential care?	Consequences/wider impacts	Health & well being
314	Experts	What are the potential social benefits of reversing "circumscribed mobility" on the part of older people and others whose travel is limited under present circumstances?	Consequences/wider impacts	Health & well being
315	Experts	What would be the net health impact (physical and mental) of increased mobility through AVs (with particular reference to older people)?	Consequences/wider impacts	Health & well being
376	Lit review	Will the mass use of AVs shift travel patterns and reduce the share of walking and cycling?	Consequences/wider impacts	Health & well being
378	Lit review	To what extent do AVs have the potential to improve the life of non-drivers, in particular the elderly and the disabled?	Consequences/wider impacts	Health & well being
13	Mapping	will corporate prosecution grow in prevalence?	Consequences/wider impacts	Law & order
30	Mapping	What are the real risks to AV users of cyber-terrorism?	Consequences/wider impacts	Law & order
66	Mapping	What will the implications of increased automation be for policing (eg reduced fine income but also reduced need for enforcement)?	Consequences/wider impacts	Law & order
152	Mapping	If AVs were perceived as the plaything of the rich, would this lead to social unrest?	Consequences/wider impacts	Law & order
209	Scenes	Whilst major organisations involved in AVs will have a global brand to protect, smaller operators may not be thus motivated. Can they be expected to behave with propriety or might “cowboy” practices be seen?	Consequences/wider impacts	Law & order
256	Lit review	If I own an automated car in/by which a third party is injured, what is my liability?	Consequences/wider impacts	Law & order
269	Lit review	How might unions react in respect of industries most affected by increased automation?	Consequences/wider impacts	Law & order
40	Mapping	What will be the true journey-time reliability impacts of AVs?	Consequences/wider impacts	Network performance
64	Mapping	Is a reduction in congestion dependent on full automation? On high levels of control?	Consequences/wider impacts	Network performance
186	Scenes	What will traffic density be in future and how much will this vary across the day/week/year?	Consequences/wider impacts	Network performance
257	Other	What will be the aggregate area of the highway network?	Consequences/wider impacts	Network performance
275	Lit review	What does the optimal operation of AVs mean for congestion?	Consequences/wider impacts	Network performance
276	Lit review	If the demand for on-street parking in urban centres diminished, how would the highway space released be used?	Consequences/wider impacts	Network performance
319	Experts	What would be the consequences of allocating certain lanes on carriageways to AVs?	Consequences/wider impacts	Network performance
366	Lit review	What impact will different Avs roll-out and adoption scenarios have on traffic flow in different environments (e.g. urban areas)?	Consequences/wider impacts	Network performance
206	Scenes	How soon and with what confidence can it be known whether AVs represent a road safety improvement?	Consequences/wider impacts	Road safety
211	Scenes	What are the unforeseen consequences with respect to road safety?	Consequences/wider impacts	Road safety
331	Experts	What are the plausible safety outcomes of different automation, adoption and regime scenarios?	Consequences/wider impacts	Road safety
332	Experts	What can the aviation sector tell us about near misses?	Consequences/wider impacts	Road safety
375	Lit review	To what extent are manufacturers addressing driver's reengagement with the vehicle and interaction with other road users issues? To what extent should the government further support research and development in this field?	Consequences/wider impacts	Road Safety
3	Mapping	How will social norms change in response to the advent of AVs?	Consequences/wider impacts	Social & behavioural norms
6	Mapping	In a mixed-fleet scenario, will some of those travelling by means other than AV deliberately bait the automated vehicle?	Consequences/wider impacts	Social & behavioural norms
7	Mapping	Will people see time spent within AVs as leisure time?	Consequences/wider impacts	Social & behavioural norms
9	Mapping	If humans need to hold someone responsible, who will be responsible when automated vehicles are involved in collisions in future?	Consequences/wider impacts	Social & behavioural norms
20	Mapping	What happens in collective transport when we remove the figure of authority (driver)?	Consequences/wider impacts	Social & behavioural norms
21	Mapping	What will AVs do to the meaning of “personal responsibility” on the part of other highway users, in the case of jaywalkers, for example?	Consequences/wider impacts	Social & behavioural norms
22	Mapping	What will AVs mean for the use of alcohol and other intoxicants?	Consequences/wider impacts	Social & behavioural norms
23	Mapping	What are the possible implications of full automation for people not old enough to have a conventional driving licence?	Consequences/wider impacts	Social & behavioural norms
91	Mapping	Even if developed rigorously and with the best intentions, can an algorithm that chooses person A over person B ever be acceptable?	Consequences/wider impacts	Social & behavioural norms
92	Mapping	If AVs bring greater accessibility for some at the cost of increased inequality (of accessibility), what is an acceptable balance?	Consequences/wider impacts	Social & behavioural norms
99	Mapping	Will experience of near/full automation change people who drive manual vehicles?	Consequences/wider impacts	Social & behavioural norms
221	Scenes	What does a predicted blurring of private and public transport imply in terms of social attitudes?	Consequences/wider impacts	Social & behavioural norms

Full set of research questions
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Reference	Source	Question	Category	Sub-category
259	Lit review	Can society accept a computer making a life/death decision?	Consequences/wider impacts	Social & behavioural norms
296	Other	Is there a legitimate case for driving at an individual in “self defence” and does the answer to this question change with increased automation?	Consequences/wider impacts	Social & behavioural norms
305	Experts	How would citizens feel about the relative attractiveness of control and autonomy?	Consequences/wider impacts	Social & behavioural norms
18	Mapping	Will access to the highway cease being democratic (ie equally available to all whose vehicle complies)?	Consequences/wider impacts	Social fabric & equity
45	Mapping	How will the digital divide be manifested as AVs develop? (eg wrt to elderly)	Consequences/wider impacts	Social fabric & equity
47	Mapping	Will the “productivity benefits” of AVs be limited to white-collar workers?	Consequences/wider impacts	Social fabric & equity
79	Mapping	What are the distributional impacts of AVs?	Consequences/wider impacts	Social fabric & equity
83	Mapping	What might be the overall effect of AVs on accessibility (eg increasing it for some and possibly reducing it for others)?	Consequences/wider impacts	Social fabric & equity
129	Mapping	How do private and social benefit interact a) at the various levels of automation and market penetration, b) in urban, peri-urban, rural areas?	Consequences/wider impacts	Social fabric & equity
213	Scenes	Will AVs lead to social fragmentation as people spend more time closeted away?	Consequences/wider impacts	Social fabric & equity
224	Scenes	If people no longer receive a “buzz” from driving, how else will they meet that need?	Consequences/wider impacts	Social fabric & equity
225	Scenes	Can personal ratings be an effective way of ensuring good conduct? What of those who are excluded by such a system?	Consequences/wider impacts	Social fabric & equity
226	Scenes	Could a longer-term impact be availability of certain services (eg doctors' surgeries) for more hours per day?	Consequences/wider impacts	Social fabric & equity
231	Scenes	Do AVs herald the end of peripatetic service delivery (eg district nurses), it being more efficient to “bus” patients to a central point?	Consequences/wider impacts	Social fabric & equity
232	Scenes	Might the idea of a “working commute” further erode boundaries between work and home?	Consequences/wider impacts	Social fabric & equity
234	Scenes	How feasible will it be to work, read etc in an AV?	Consequences/wider impacts	Social fabric & equity
291	Lit review	What will be the distribution of any benefits and will that distribution be acceptable?	Consequences/wider impacts	Social fabric & equity
303	Experts	What will increasing detachment from driving mean for drivers?	Consequences/wider impacts	Social fabric & equity
318	Experts	What impact (if any) will AVs have upon intergenerational fairness?	Consequences/wider impacts	Social fabric & equity
327	Experts	How might AVs be used to improve the life chances of disadvantaged people?	Consequences/wider impacts	Social fabric & equity
371	Lit review	"To what degree should AVs prioritize minimizing injuries to their occupants, versus other crash-involved parties? And should owners be allowed to adjust such settings?" (Fagnant et al, 2015)	Consequences/wider impacts	Social fabric & equity
380	Lit review	Will the uptake of AVs widen inequity? Or, on the contrary, will it improve accessibility for all through shared mobility?	Consequences/wider impacts	Social fabric & equity
90	Mapping	Will AVs “generate high-skilled jobs” (Cable) and, if so, how?	Consequences/wider impacts	Transport business & economics
113	Mapping	How might value of time be affected by the potential release of driving time?	Consequences/wider impacts	Transport business & economics
114	Mapping	How might the relative costs of other modes (eg train) be affected by AVs?	Consequences/wider impacts	Transport business & economics
115	Mapping	What will happen to the parking industry if fully automated vehicles are adopted largely on a taxi use model?	Consequences/wider impacts	Transport business & economics
120	Mapping	Will vehicles be more expensive to repair in future?	Consequences/wider impacts	Transport business & economics
121	Mapping	Do AVs mean fewer vehicles will be produced?	Consequences/wider impacts	Transport business & economics
122	Mapping	What will happen to the non-driving aspect of the professional driving role (managing luggage, helping individuals into/out of vehicles)?	Consequences/wider impacts	Transport business & economics
124	Mapping	What will be the impact on the professional driving sector?	Consequences/wider impacts	Transport business & economics
125	Mapping	What will be the impact on the insurance industry?	Consequences/wider impacts	Transport business & economics
128	Mapping	What will be the impact on the parking industry?	Consequences/wider impacts	Transport business & economics
130	Mapping	What will be the impact on the vehicle repair industry?	Consequences/wider impacts	Transport business & economics
131	Mapping	To what extent and in what ways will freight/logistics be affected by AVs?	Consequences/wider impacts	Transport business & economics
134	Mapping	Will AVs damage the business models of conventional public transport?	Consequences/wider impacts	Transport business & economics
135	Mapping	Does increasing automation harm the case for high-speed rail or other major public transport initiatives?	Consequences/wider impacts	Transport business & economics
351	Lit review	What effect will AV used in the context of shared mobility have on the insurance industry?	Consequences/wider impacts	Transport business & economics
81	Mapping	If moving to the city is in part a function of poor transport links in rural areas, what might AVs do for land use?	Consequences/wider impacts	Urban form & land use
85	Mapping	Is it conceivable that the advent of AVs will lead to an increase in highway infrastructure?	Consequences/wider impacts	Urban form & land use

Full set of research questions
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Reference	Source	Question	Category	Sub-category
138	Mapping	If the demand for off-street parking in urban centres diminished, what would happen to the land released and who would benefit?	Consequences/wider impacts	Urban form & land use
142	Mapping	What are the likely effects of increased automation on land use, especially density?	Consequences/wider impacts	Urban form & land use
215	Scenes	What might AVs mean for the design of new urban areas?	Consequences/wider impacts	Urban form & land use
216	Scenes	Will automated parking enable many more vehicles to fit into a typical car park?	Consequences/wider impacts	Urban form & land use
217	Scenes	In a world of full automation, what does a pedestrian crossing look like?	Consequences/wider impacts	Urban form & land use
219	Scenes	What might increasing automation mean for a) vehicle design and b) highway form?	Consequences/wider impacts	Urban form & land use
369	Lit review	To what extent could shared mobility scenarios save parking spaces in cities? How will the freed space be used?	Consequences/wider impacts	Urban form & land use
370	Lit review	To what extent could AV use increase urban sprawl? How might one prevent this development?	Consequences/wider impacts	Urban form & land use
384	Lit review	To what extent can AVs contribute to urban areas and improve urban mobility systems?	Consequences/wider impacts	Urban form & land use
172	Scenes	How have agenda-setting, priming and framing contributed to the results of attitudinal research conducted to date?	Stakeholders' awareness & attitudes	Review tasks
173	Scenes	What can be inferred from spatial and socio-demographic differences in the results of attitudinal surveys conducted to date?	Stakeholders' awareness & attitudes	Review tasks
180	Scenes	What pictures of the technology and its functioning do respondents have in their minds when they answer questions about attitudes to AVs?	Stakeholders' awareness & attitudes	Review tasks
197	Scenes	What will be an acceptable level of risk (eg with respect to cyber security) as AVs develop and how will this change over time?	Stakeholders' awareness & attitudes	Risk
201	Scenes	What does the aviation industry (pilots present but largely overseeing an automated system) tell us about risk and acceptance in AVs?	Stakeholders' awareness & attitudes	Risk
322	Experts	What level of safety will be acceptable in AVs?	Stakeholders' awareness & attitudes	Risk
333	Experts	What are public attitudes to privacy as opposed to anonymity?	Stakeholders' awareness & attitudes	Risk
110	Mapping	How should government and citizen opinion interact in determining the development and deployment of this technology/these technologies?	Stakeholders' awareness & attitudes	The public sector & its intervention
140	Mapping	What is the relationship between style of governance ("light touch", interventionist) and public trust in the technology?	Stakeholders' awareness & attitudes	The public sector & its intervention
306	Experts	How would people feel (in a "connected" world) about having their journey plans frustrated by the central control system that is "smoothing" demand?	Stakeholders' awareness & attitudes	The public sector & its intervention
156	Scenes	What does familiarity with technology mean for its acceptance and adoption? (eg can we assume that millennials will automatically be more comfortable with AVs than their parents?)	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
158	Scenes	How significantly could a major incident (such as multi-fatality crash) affect popular attitudes about AVs?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
161	Scenes	How likely is that attitudes will turn against the technology?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
177	Scenes	Will people trust automated public transport vehicles, such as a bus?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
178	Scenes	How strong might opposition to AVs be and how might it be manifested?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
182	Scenes	How sophisticated can sensing and recognition systems become? Can their imperfections be tolerated?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
183	Scenes	Is data privacy likely to be as significant in determining attitudes to AVs as personal safety/security?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
191	Scenes	Will we feel safe if sharing a vehicle with strangers but without a driver?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
194	Scenes	Would a large, relative decrease in road fatalities answer concerns about the deaths that might still occur with AVs?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
210	Scenes	What is the relationship between public trust, singularities (such as severe collisions) and familiarity?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
212	Scenes	Some models of AV operation assume the equivalent of an air traffic controller, guiding operations at a network area level. Do people feel more/less comfortable with this than a wholly automated system? How would liability be decided in the event of a crash?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
235	Scenes	How will people react to losing the ability to practise a skill (driving), the pleasure of doing it well and the sense of having some control/impact on the world?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
252	Other	Will AVs constitute a case of needing to "keep up with the Jones's"?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
253	Lit review	Might some groups (eg older citizens) reject driverless technology?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
262	Other	What will be the appeal of owning a vehicle once the owner no longer drives it?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
263	Lit review	Will people accept the encroachment on data privacy that highly connected systems appear to imply?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
264	Other	What is a socially acceptable approach to pricing AV use so as not to worsen transport network performance?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
278	Lit review	Will people's acceptance of sharing data be a function of whether they are sharing with a private company or government in some form?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
294	Lit review	What level of surveillance within AVs will be necessary/justifiable?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
297	Lit review	What level of surveillance around AVs (ie data collected by the vehicle concerning its surroundings) will be necessary/justifiable?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
344	Lit review	Who should own and control data generated by AVs?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
345	Lit review	For what ends will the data be used?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
381	Lit review	Under what conditions and scenarios the public would be most likely to use and accept AVs?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
382	Lit review	How do non-drivers perceive Avs and what do they expect from AVs?	Stakeholders' awareness & attitudes	Trust, acceptance & resistance
1	Mapping	What are the prospects for a unified communications protocol to support highly connected vehicles and who would own such a code?	Public sector's role	Influencing & managing industry behaviour
4	Mapping	Can the influence of vested interests be prevented from distorting the role of government in the development process?	Public sector's role	Influencing & managing industry behaviour
10	Mapping	How can government prevent the unwanted consequences of competition between developers without at the same time losing the benefits?	Public sector's role	Influencing & managing industry behaviour

Full set of research questions
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Reference	Source	Question	Category	Sub-category
11	Mapping	Can innovation be encouraged?	Public sector's role	Influencing & managing industry behaviour
31	Mapping	How can a need for interoperability best be met whilst still allowing individual players to develop novel technological approaches? Is a common data dictionary part of the answer?	Public sector's role	Influencing & managing industry behaviour
33	Mapping	If supply of AVs cannot meet demand at some stage in the development process, is there a role for government to support production?	Public sector's role	Influencing & managing industry behaviour
36	Mapping	How to promote data sharing by companies to enable connectivity?	Public sector's role	Influencing & managing industry behaviour
44	Mapping	Can/should government act to prevent market failure "killing off" the technology?	Public sector's role	Influencing & managing industry behaviour
300	Other	How successful will OEMs and big tech firms be in resisting regulation?	Public sector's role	Influencing & managing industry behaviour
348	Lit review	How to ensure that data is shared by companies to enable connectivity?	Public sector's role	Influencing & managing industry behaviour
126	Mapping	Can smart pricing discourage certain trips (eg AV replacing a short walk to school) whilst also enabling others (access for someone with a mobility impairment)?	Public sector's role	Influencing & managing travel behaviour
132	Mapping	How might demand for automated mobility be managed to avoid a damaging excess of demand over supply?	Public sector's role	Influencing & managing travel behaviour
133	Mapping	Does greater connectedness imply greater scope for (government to) influence travel decisions and behaviour?	Public sector's role	Influencing & managing travel behaviour
149	Mapping	How might road pricing fit into an AV world and would it be more/less acceptable with the new technology?	Public sector's role	Influencing & managing travel behaviour
179	Scenes	If AVs are to be associated with reduced congestion, what operational rules will need to prevail?	Public sector's role	Influencing & managing travel behaviour
184	Scenes	Could and should government promote a more desirable ownership/use model?	Public sector's role	Influencing & managing travel behaviour
204	Scenes	What can/should government do to minimise the extent that AV use is associated with crime and/or anti-social behaviour?	Public sector's role	Keeping people & possessions safe
205	Scenes	How will customers' data be protected?	Public sector's role	Keeping people & possessions safe
336	Experts	What is the need for driver monitoring at the various levels of automation (short of full)?	Public sector's role	Keeping people & possessions safe
337	Experts	How is "safe resumption of control" to be defined and catered for?	Public sector's role	Keeping people & possessions safe
340	Experts	How can risk of cyber-crime be minimised?	Public sector's role	Keeping people & possessions safe
346	Lit review	Which safeguards (e.g. standards) should be established to prevent the misuse of data?	Public sector's role	Keeping people & possessions safe
347	Lit review	How will customers' data be protected?	Public sector's role	Keeping people & possessions safe
349	Lit review	With whom should the data be shared?	Public sector's role	Keeping people & possessions safe
103	Mapping	How will highway use be defined? Might the carriageway be delineated between AVs and other vehicles? Might there be zones in which AVs are the only vehicles permitted?	Public sector's role	Management of producer & consumer diversity
123	Mapping	If future regulations require vehicles to have certain functionality, what will this mean for those whose vehicles don't comply?	Public sector's role	Management of producer & consumer diversity
136	Mapping	Can (manual) driving for pleasure (eg through the Scottish glens) be accommodated in a world of AVs?	Public sector's role	Management of producer & consumer diversity
48	Mapping	How can/will multi-level governance work with regulation re AVs? (eg, in the UK, might there be regional or local variations in how AVs could behave?)	Public sector's role	Practicalities of governance
56	Mapping	How could different approaches to regulation (eg laissez-faire, interventionist) affect the development of AVs and their impacts?	Public sector's role	Practicalities of governance
60	Mapping	If big tech firms (Apple, Google) are pushing the development of this technology, what is the role for government?	Public sector's role	Practicalities of governance
74	Mapping	Given a typical fleet renewal period of 15 years, what is a realistic profile of fleet mix over time? Does this lag imply that government should regulate sooner, rather than later?	Public sector's role	Practicalities of governance
88	Mapping	Does this process require a central regulatory body?	Public sector's role	Practicalities of governance

Full set of research questions

(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
94	Mapping	Do speedy software updates imply a need for a different approach to type approval?	Public sector's role	Practicalities of governance
95	Mapping	Can conventional appraisal methods capture the costs and benefits of AVs – technology and regime?	Public sector's role	Practicalities of governance
96	Mapping	Can regulation successfully stipulate minimum standards or must any standard specify fully how AVs will operate?	Public sector's role	Practicalities of governance
97	Mapping	What will encourage/force those working with personal data to maximise its security?	Public sector's role	Practicalities of governance
111	Mapping	Should regulation of AVs be at arm's length from government?	Public sector's role	Practicalities of governance
248	Other	How will licensing work with AV use?	Public sector's role	Practicalities of governance
265	Lit review	Can regulation anticipate AV developments?	Public sector's role	Practicalities of governance
266	Other	If people have personal care budgets, will they be able to spend some of the money on transport?	Public sector's role	Practicalities of governance
316	Experts	What would be the impact of setting standards relating to AVs' user interface?	Public sector's role	Practicalities of governance
320	Experts	When MaaS and AVs reach their maturity, what role will the public sector play in delivery?	Public sector's role	Practicalities of governance
324	Experts	What would path dependency in regulation (government not straying from familiar areas) mean for development and adoption?	Public sector's role	Practicalities of governance
339	Experts	What forms of regulation will actually prove effective?	Public sector's role	Practicalities of governance
93	Mapping	In a world where full automation works, how will governments weigh a presumably non-zero desire for manual driving with a presumably significant safety benefit from its prohibition?	Public sector's role	Principles of governance
102	Mapping	Should a bus enjoy priority over a taxi (in an autonomous-controlled scenario)?	Public sector's role	Principles of governance
105	Mapping	How should safety impacts be weighed with, say, economic impacts?	Public sector's role	Principles of governance
112	Mapping	Would the state choose to provide or subsidise AV transport for certain individuals? In other words, might AVs become the new community transport?	Public sector's role	Principles of governance
119	Mapping	Why shouldn't long-distance (eg overnight) travel be normal for AVs? What would stop this?	Public sector's role	Principles of governance
127	Mapping	If development continues to be twin-track (OEMs making conventional cars more automated whilst Google etc aim straight for Level 5), will one type of vehicle be accorded an advantage by the traffic management system?	Public sector's role	Principles of governance
137	Mapping	Will the regime allow different marques to impose different driving styles on AVs?	Public sector's role	Principles of governance
139	Mapping	What are appropriate traffic management regimes associated with various levels of automated vehicle penetration, eg 5%, 10% etc?	Public sector's role	Principles of governance
141	Mapping	Would current norms concerning leaving minors unaccompanied translate to AVs?	Public sector's role	Principles of governance
148	Mapping	What will AVs mean for the status quo with respect to subsidised transport for certain individuals?	Public sector's role	Principles of governance
150	Mapping	Will AVs become the means by which Dial-a-Ride and equivalents operate?	Public sector's role	Principles of governance
155	Scenes	Would pricing in future take account of vehicle size?	Public sector's role	Principles of governance
159	Scenes	In a mixed fleet, should AVs be differentiable from driven vehicles?	Public sector's role	Principles of governance
171	Scenes	If individual preference with respect to AV use (eg not riding with strangers) is not optimal with respect to, say, traffic operation, energy use, what will determine the trade-off?	Public sector's role	Principles of governance
247	Other	In a highly "automated-controlled" regime, who would decide the hierarchy of journey importance and how would it be implemented?	Public sector's role	Principles of governance
249	Lit review	Will public transport authorities adopt AVs as part of their offering?	Public sector's role	Principles of governance
251	Lit review	If freight vehicles become automated, will staff be needed to accompany the vehicle?	Public sector's role	Principles of governance
311	Experts	In an "automated-controlled" world, how might trips be prioritised by the central control system?	Public sector's role	Principles of governance
383	Lit review	What role should AVs play in cities?	Public sector's role	Principles of governance
267	Other	How will social norms change with the passing of time?	Global trends/drivers	
270	Other	What does increasing urbanisation imply for the distribution of urban trip lengths?	Global trends/drivers	
271	Other	How will the general cost of mobility change over time?	Global trends/drivers	
272	Lit review	What is the future of people's desire to *own* things?	Global trends/drivers	
273	Other	How much *space* will the average person have in future?	Global trends/drivers	
274	Other	Will transport continue to become depoliticised?	Global trends/drivers	
277	Lit review	What if the widespread strategic objective of removing traffic continues?	Global trends/drivers	
279	Lit review	Is the attraction of a car as status symbol fading in the developed west?	Global trends/drivers	
280	Lit review	What will be the distribution of wealth as time passes?	Global trends/drivers	
281	Other	Can we assume that those born with technology will always embrace it? Why shouldn't people's attitude to technology change as they age?	Global trends/drivers	
282	Other	Can the much reported lack of interest in driving amongst young people be relied upon?	Global trends/drivers	
288	Lit review	What will be the style of government in future (eg localism, centralism?) and how might this affect AV development?	Global trends/drivers	
289	Other	Is the future one of continuing austerity?	Global trends/drivers	
292	Lit review	Will funding in future be more in control of municipalities/city regions etc?	Global trends/drivers	
293	Other	Will integration of funding allow government to move money more readily between transport and other areas?	Global trends/drivers	
313	Experts	Does an ageing population imply an ever-increasing number of people having their licences taken away?	Global trends/drivers	
323	Experts	How will the wider sharing economy play out?	Global trends/drivers	
43	Mapping	Do we need the benefits of AVs to be articulated? If so, what are they?	Uncategorised	
80	Mapping	Are AVs the latest example of boys and their toys (ie something liked because it appeals in a primal way without necessarily being strategically necessary?)	Uncategorised	

Full set of research questions
(ordered by category and sub-category)

Reference	Source	Question	Category	Sub-category
162	Scenes	How local are ethical questions relating to AVs?	Uncategorised	
181	Scenes	Can there be a shared vision for this technology?	Uncategorised	
198	Scenes	What is the role of AVs in the Department for Transport's strategy?	Uncategorised	
218	Scenes	Is there a "desirable" volume of movement? Or "desirable" volumes of movement by given means, eg motorised?	Uncategorised	
245	Other	Transport practitioners tend to expect an innovation to be a response to a need or problem. AVs can be characterised as merely an opportunity. What might be the policy implications?	Uncategorised	
325	Experts	Can current appraisal tools handle AV-related interventions and, if not, what is required?	Uncategorised	
326	Experts	How would AV-related schemes (funded by government) compare in terms of value for money with standard transport interventions?	Uncategorised	