Planning and Preparing for Connected and Automated Vehicles

TECHNICAL REPORT

MARCH 2016

CONTENTS

DISCLAIMER

ACRONYMS

ACS	Automated Control Systems
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
ABS	Anti-Lock Brakes
ACC	Adaptive Cruise Control
AV	Automated Vehicle
AVP	Autonomous Valet Parking
BIS	Business Innovation and Skills
C-ACC	Cooperative Adaptive Cruise Control
CAV	Connected Automated Vehicles
CEF	Connecting Europe Facility
CEO	Chief Executive Officer
CIO	Chief Information Officer
C-ITS	Co-operative ITS
CODECS	Cooperative ITS Deployment Coordination Support
DCMS	Design Manual for Roads and Bridges
DfT	Department for Transport
DMRB	Design Manual for Roads and Bridges
DoT	Department of Transportation
DSRC	Dedicated Short-Range Communications
DVLA	Driver and Vehicle Licensing Agency
ERTICO	European Road Transport Telematics Implementation
Euro NCAP	European New Car Assessment Programme
HMI	Human Machine Interfaces
ISA	Intelligent Speed Adaption
ITS	Intelligent Transport Systems
I2V	Infrastructure to Vehicle
JLR	Jaguar Land Rover
LUTZ	Low-carbon Urban Transport Zone
OBD	On Board Diagnostic
OEM	Original Equipment Manufacturer
NHTSA	National Highway Traffic Safety Administration
PRT	Personalised Rapid Transit
RoSPA	Royal Society for the Prevention of Accidents
SMMT	Society of Motor Manufacturers and Traders
TfL	Transport for London
TSC	Transport Systems Catapult
UDRIVE	European naturalistic Driving and Riding for Infrastructure and Vehicle safety and Environment
V2I	Vehicle to Infrastructure
V2X	Vehicle to everything

1. INTRODUCTION

1.1 Overview

This document has been prepared by the Transport Systems Catapult (TSC) for the Department for Transport (DfT) and represents the deliverable of the Project – 'Planning and Preparing for Connected and Automated vehicles'.

This study has focussed on potential public sector interventions that could help to promote and realise the early benefits of Connected and Automated Vehicles (CAVs). The ultimate output of this work is a prioritised list of interventions which could be considered by the various public sector authorities.

The following methodology was employed to produce this report:

- 1 to 1 interviews with 25 industry experts, including researchers (academics, consultants, legal experts), vehicle manufacturers and suppliers, highways authorities, mobile network operators, personal rapid transit operators and mapping providers.
- An in depth literature review which extracted key recommendations

1.2 What problem are we trying to solve?

As a starting point, it is important to consider what issues are being addressed by CAVs. Figure 1-1 outlines the process of identifying and addressing issues by setting out the context, inputs, outputs and outcomes.

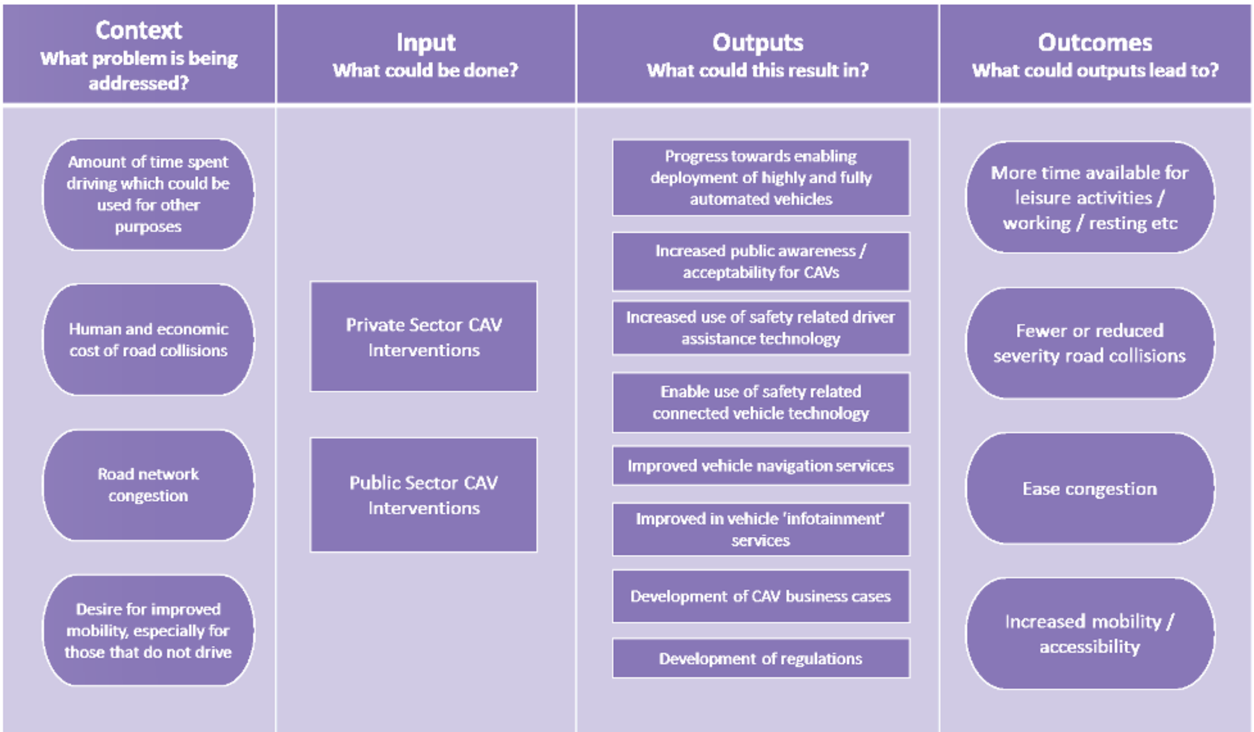


FIGURE: 1-1: Examples of Context, Input, Outputs and Outcomes

Introduction

The potential benefits (or outcomes as described above) and the problems being addressed (or context) were taken from various literature sources including DfT's document: 'Pathway to Driverless Cars: A detailed review of regulations for Automated Vehicle (AV) technologies'[1], which highlights these four benefits in relation to AV technology. Connectivity will also have a role in addressing at least two of the four problems above; namely the human and economic cost of road collisions and road network congestion and it could also lead to more productive use of time. Perhaps more fundamentally, connectivity is seen by some experts as a key enabler for automation, so the two are closely linked and the four problems listed above are considered relevant for both the area of AVs and connected vehicles.

For example, if the intervention promotes the testing and deployment of an automated demand responsive bus service, then this might have an impact on the following aspects highlighted in Figure 1-2 below:

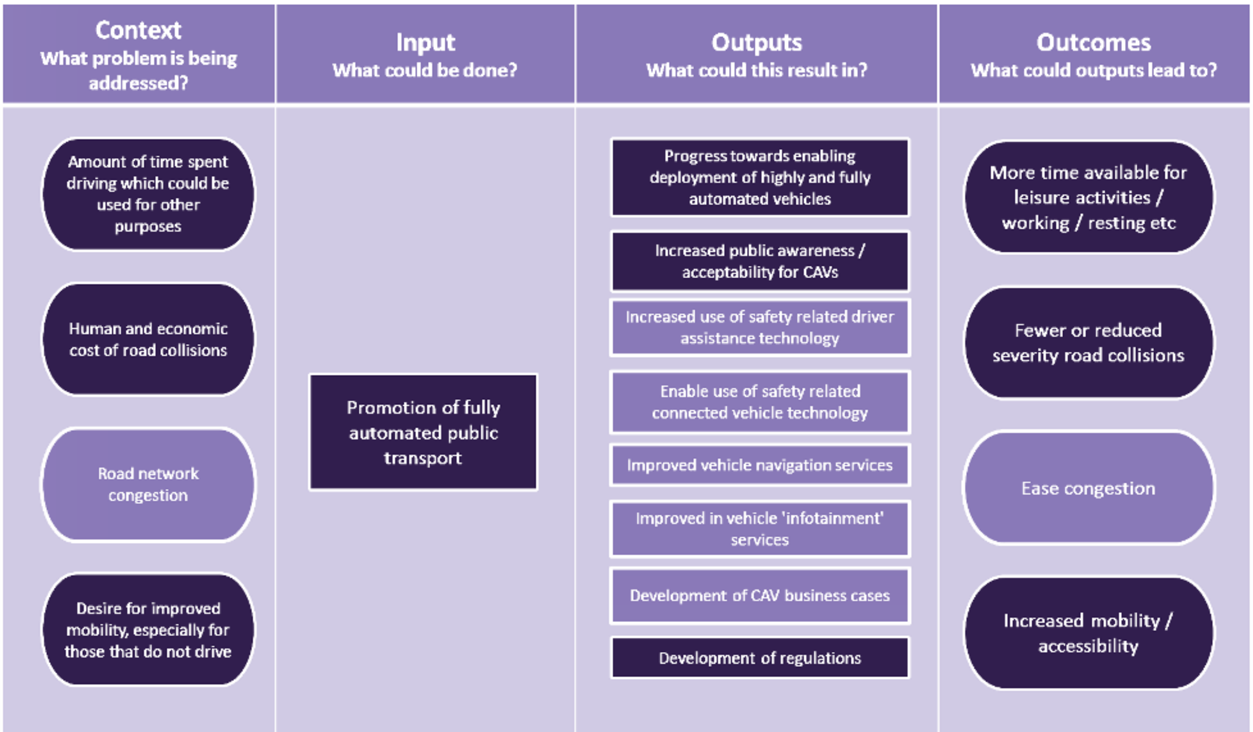


FIGURE 1-2: Context, Outputs and Outcomes relating to Specific Input

Promotion of fully automated public transport could contribute to the deployment of fully AVs, increased public awareness and acceptability and the development of regulations, which in turn could lead to more time available that was previously used for driving, fewer or reduced severity collisions and increased mobility. It may also lead to reduced congestion, but this depends largely on the local context and the nature of modal shift, so the link is perhaps less clear.

It is useful to keep in mind the context, outputs and outcomes relating to individual inputs. This could enable the outcomes that are most desirable to be targeted. More generally, the outcomes listed above may lead to economic, social and environmental benefits.

[1] DfT, Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies, Feb 2015
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401565/pathway-driverless-cars-main.pdf

2. METHODOLOGY

2.1 Stakeholder Consultation Methodology

A significant part of this project was to gain insights from a sample of the stakeholders involved in advancing the connected and AV agenda. Guidelines for the design of qualitative research were consulted and it was decided that the study would seek to undertake in-depth interviews with 25 experts in the area of CAVs.

TSC staff invited a wide range of potential participants, in total, nearly 100 invites were sent. Invitees were sent a presentation which outlined the background to the study. The presentation posed the main question as:

> "What actions could be taken by the public sector to accelerate and realise the benefits of connected and AVs"

The assumptions behind the key question were clarified as follows:

- Focussed short term (0-5 years) measures to accelerate CAVs.
- Assumed the key audience will be DfT and highway authorities.
- Focus on UK, but will consider learnings and emerging standards from overseas.
- The UK Government is interested in safety, environment, congestion and accessibility, as well as economic and industrial benefits.

Interviews were undertaken by telephone or in person. The final split of interviewees by category is as follows:

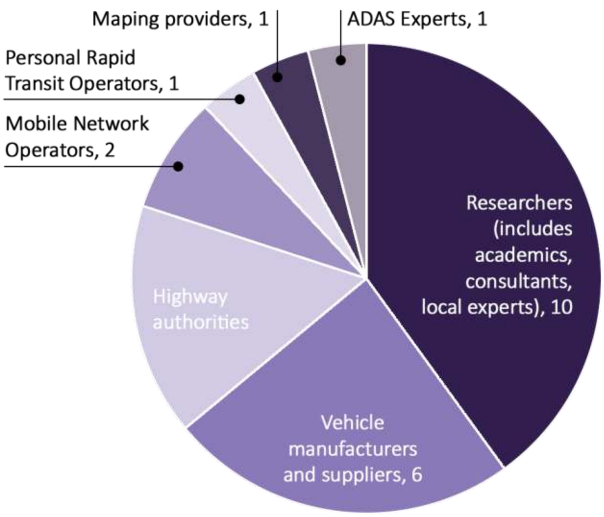


FIGURE 2-1: Stakeholder interviewees, split by category

To ensure the study was not too UK-centric, many participants were based internationally. The final split of participants, based upon where they are currently based, was as follows:

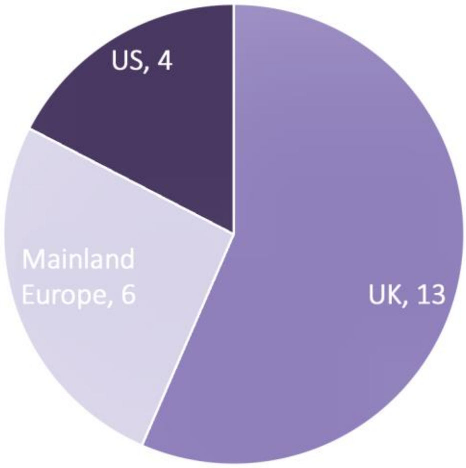


FIGURE 2-2: Stakeholder interviewees, split by category

Interviewees were asked a list of standard questions, which included:

- From your own specific business / area, what are the top 3 key developments happening now?
- What are top 3 barriers to implementing CAV environments?
- What is your organisation aiming to achieve through CAVs?
- How do you see vehicle manufacturers / telecoms providers / local & national Government / infrastructure providers working together and what could each do to accelerate deployment?
- What would be your message to the DfT?
- What questions do you have about CAVs?

A large range of non-standard questions were also asked, which followed from the responses to the above. The results are discussed in the next section of this report. It was agreed that interviewees would remain anonymous in the interests of encouraging frank and honest comments and insights.

2.2 Literature Review Methodology

The literature review that was undertaken was focused on answering the same fundamental question that was posed by the Stakeholder Consultation:

> "What actions could be taken by the public sector to accelerate and realise the benefits of connected and AVs"

Over 100 documents, including academic papers, industry reports, white papers and presentations were analysed, to help form the main recommendations that were directed towards the public sector. Sources of information included conference papers, such as those presented at the Intelligent Transport Systems (ITS) World Congress. The results are discussed within the next section of this report.

3. RESULTS

3.1 What are the Key Developments happening now?

During interviews, stakeholders were asked what they felt were the particularly exciting developments happening now with regard to either connected or AVs. The answers are summarised on Figure 3-1.

Answers were varied. In the area of connected vehicles, they included the benefits of black box style telematics solutions for the insurance industry, the recognition of connected vehicles as a strategic opportunity for mobile network operators, to general and specific advancements in connected vehicle technology.

In the area of AVs, stakeholders referred to the progress of Google in developing the technology, the cost of components decreasing and the inclusion of Advanced Driver Assistance Systems (ADAS) as standard features on many new vehicles.

More generally, stakeholders were enthusiastic that Governments around the world are now engaged in both CAVs and it is on the agenda of all stakeholders, which was not the case a few years ago. There was also a recognition that the UK has an opportunity to grasp.

3.2 What are the barriers?

Stakeholders were then asked what the barriers are to CAVs. Figure 3-2 summarises the responses. On the connected vehicle side, barriers include data issues, such as who should own it, how it is made available and organised, how it is kept secure and private. There were business case issues, regulatory and organisational issues, local authority issues, concerns regarding bandwidth and coverage of the current cellular network and cyber security.

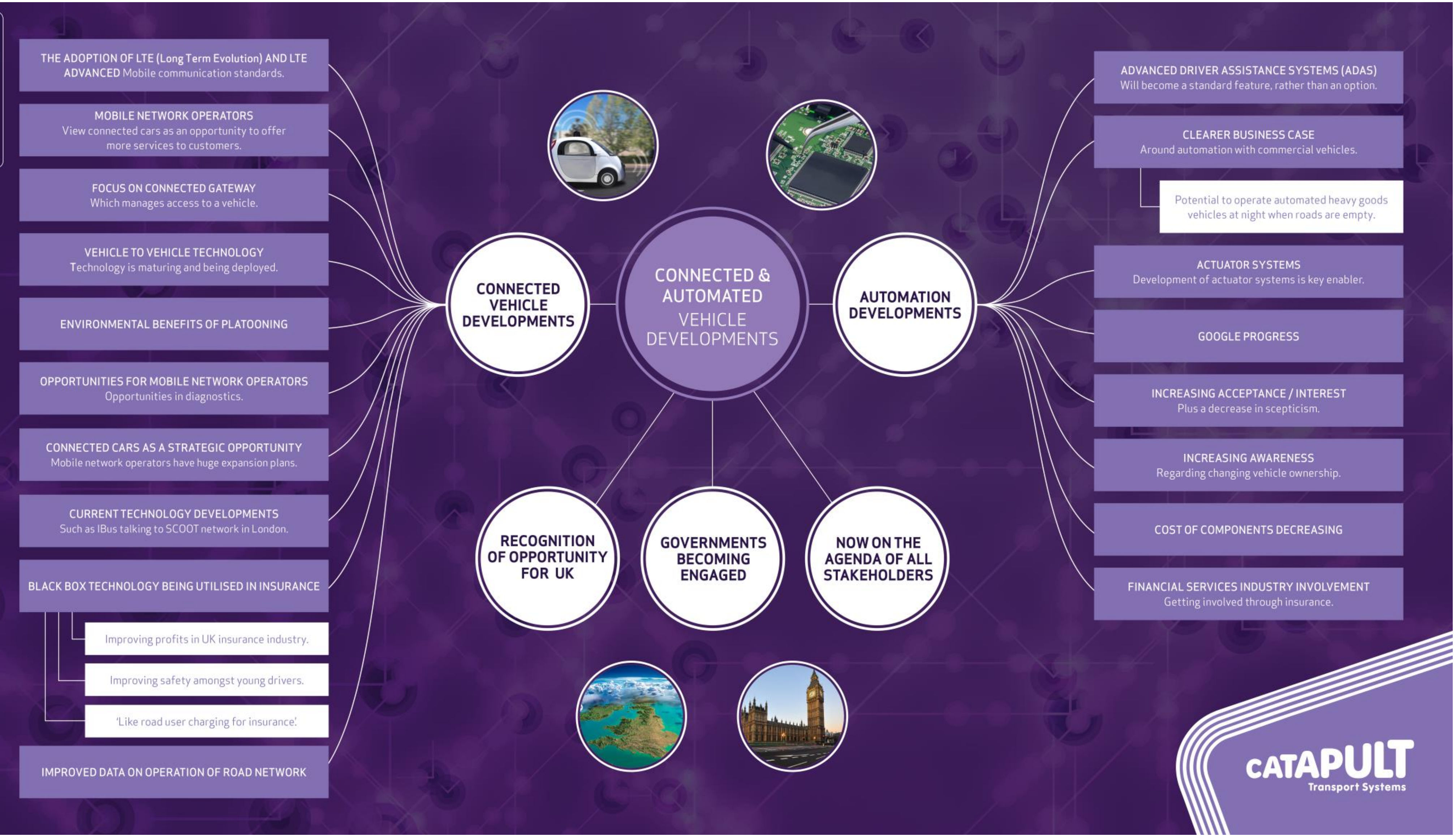
On the automation side, barriers included technical issues, such as the performance of vehicles in inclement weather, complexity around the mix of vehicles and the need for AVs to have a safe place to stop should the technology fail. Liability was often cited as a concern, and the legality of highly or fully AVs. The limited metrics for determining the safety of AVs was expressed by a number of stakeholders. Business case issues included the cost of mapping and technology, and a feeling amongst some that car makers have been reluctant to invest heavily in developing the technology. User acceptance barriers were also discussed, including concerns regarding existing ADAS.

3.3 Recommendations

The long list of recommendations was compiled from a combination of stakeholder interviews and from literature review of over 100 documents. They include a variety of potential interventions, some high level and quite general and some more specific. It was found that inputs could be organised into three areas:

- Figure 3-3: Near term automation technology opportunities – refers to inputs related to technology which is in use already or very close to market, such as ADAS.
- Figure 3-4: Highly / fully AVs opportunities.
- Figure 3-5: Cooperative ITS (C-ITS) opportunities – refers to connectivity applications.

To help readers navigate this document, many of the recommendations outlined within Figures 3-3 to 3-5 have reference number which refers to the paragraph reference within section 4 that contained further information.



THE ADOPTION OF LTE (Long Term Evolution) AND LTE ADVANCED Mobile communication standards.
MOBILE NETWORK OPERATORS
View connected cars as an opportunity to offer more services to customers.
FOCUS ON CONNECTED GATEWAY
Which manages access to a vehicle.
VEHICLE TO VEHICLE TECHNOLOGY
Technology is maturing and being deployed.
ENVIRONMENTAL BENEFITS OF PLATOONING
OPPORTUNITIES FOR MOBILE NETWORK OPERATORS
Opportunities in diagnostics.
CONNECTED CARS AS A STRATEGIC OPPORTUNITY
Mobile network operators have huge expansion plans.
CURRENT TECHNOLOGY DEVELOPMENTS
Such as IBus talking to SCOOT network in London.
BLACK BOX TECHNOLOGY BEING UTILISED IN INSURANCE
Improving profits in UK insurance industry.
Improving safety amongst young drivers.
'Like road user charging for insurance'.
IMPROVED DATA ON OPERATION OF ROAD NETWORK
CONNECTED VEHICLE DEVELOPMENTS
CONNECTED & AUTOMATED VEHICLE DEVELOPMENTS
AUTOMATION DEVELOPMENTS
RECOGNITION OF OPPORTUNITY FOR UK
GOVERNMENTS BECOMING ENGAGED
NOW ON THE AGENDA OF ALL STAKEHOLDERS
ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS)
Will become a standard feature, rather than an option.
CLEARER BUSINESS CASE
Around automation with commercial vehicles.
Potential to operate automated heavy goods vehicles at night when roads are empty.
ACTUATOR SYSTEMS
Development of actuator systems is key enabler.
GOOGLE PROGRESS
INCREASING ACCEPTANCE / INTEREST
Plus a decrease in scepticism.
INCREASING AWARENESS
Regarding changing vehicle ownership.
COST OF COMPONENTS DECREASING
FINANCIAL SERVICES INDUSTRY INVOLVEMENT
Getting involved through insurance.
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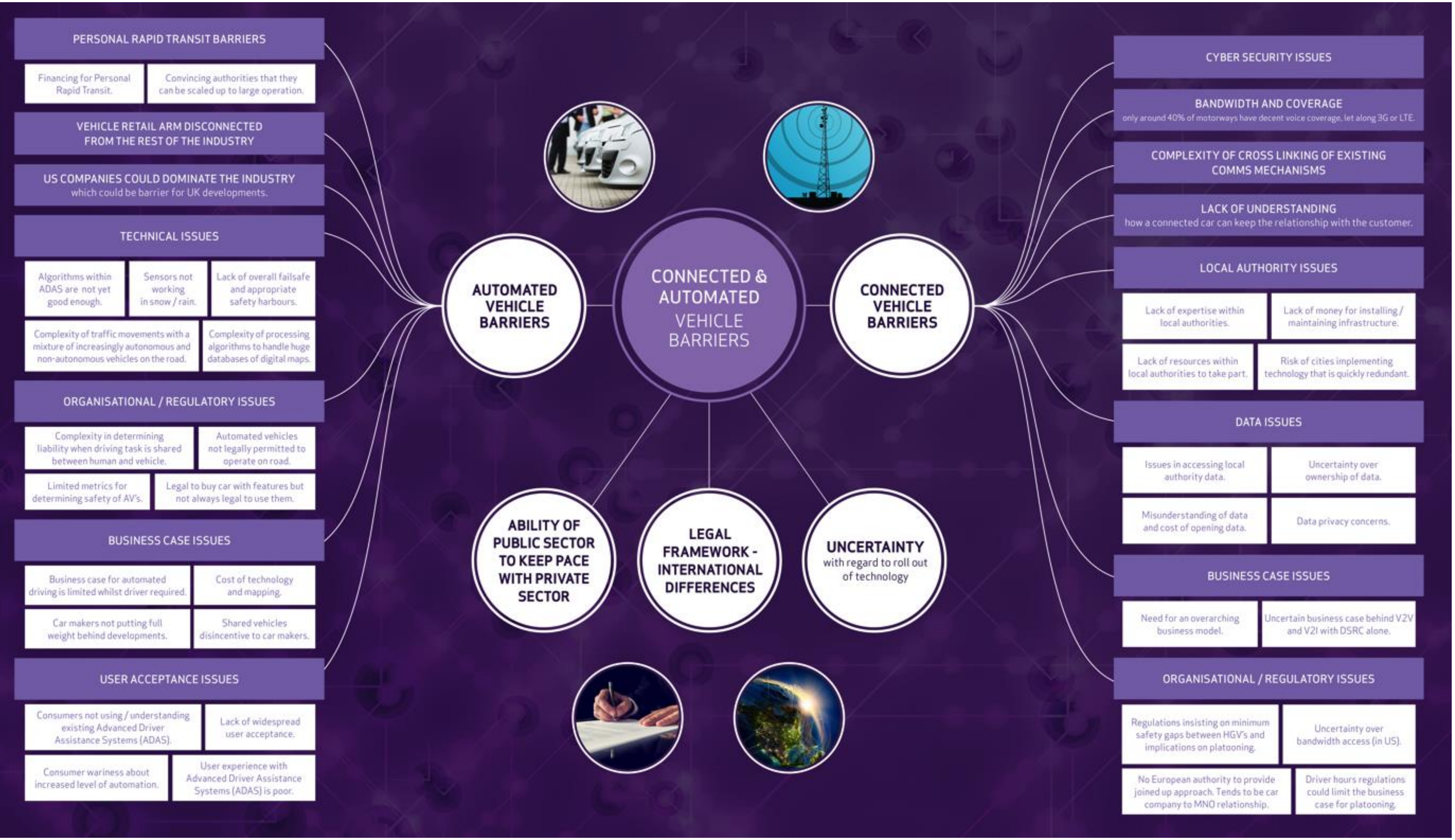
FIGURE 3.1

FIGURE 3.2



CONNECTED & AUTOMATED VEHICLE BARRIERS
AUTOMATED VEHICLE BARRIERS
CONNECTED VEHICLE BARRIERS
ABILITY OF PUBLIC SECTOR TO KEEP PACE WITH PRIVATE SECTOR
LEGAL FRAMEWORK - INTERNATIONAL DIFFERENCES
UNCERTAINTY with regard to roll out of technology
PERSONAL RAPID TRANSIT BARRIERS
Financing for Personal Rapid Transit.
Convincing authorities that they can be scaled up to large operation.
VEHICLE RETAIL ARM DISCONNECTED FROM THE REST OF THE INDUSTRY
US COMPANIES COULD DOMINATE THE INDUSTRY
which could be barrier for UK developments.
TECHNICAL ISSUES
Algorithms within ADAS are not yet good enough.
Sensors not working in snow / rain.
Lack of overall failsafe and appropriate safety harbours.
Complexity of traffic movements with a mixture of increasingly autonomous and non-autonomous vehicles on the road.
Complexity of processing algorithms to handle huge databases of digital maps.
ORGANISATIONAL / REGULATORY ISSUES
Complexity in determining liability when driving task is shared between human and vehicle.
Automated vehicles not legally permitted to operate on road.
Limited metrics for determining safety of AV's.
Legal to buy car with features but not always legal to use them.
BUSINESS CASE ISSUES
Business case for automated driving is limited whilst driver required.
Cost of technology and mapping.
Car makers not putting full weight behind developments.
Shared vehicles disincentive to car makers.
USER ACCEPTANCE ISSUES
Consumers not using / understanding existing Advanced Driver Assistance Systems (ADAS).
Lack of widespread user acceptance.
Consumer wariness about increased level of automation.
User experience with Advanced Driver Assistance Systems (ADAS) is poor.
CYBER SECURITY ISSUES
BANDWIDTH AND COVERAGE
only around 40% of motorways have decent voice coverage, let along 3G or LTE.
COMPLEXITY OF CROSS LINKING OF EXISTING COMMS MECHANISMS
LACK OF UNDERSTANDING
how a connected car can keep the relationship with the customer.
LOCAL AUTHORITY ISSUES
Lack of expertise within local authorities.
Lack of money for installing / maintaining infrastructure.
Lack of resources within local authorities to take part.
Risk of cities implementing technology that is quickly redundant.
DATA ISSUES
Issues in accessing local authority data.
Uncertainty over ownership of data.
Misunderstanding of data and cost of opening data.
Data privacy concerns.
BUSINESS CASE ISSUES
Need for an overarching business model.
Uncertain business case behind V2V and V2I with DSRC alone.
ORGANISATIONAL / REGULATORY ISSUES
Regulations insisting on minimum safety gaps between HGV's and implications on platooning.
Uncertainty over bandwidth access (in US).
No European authority to provide joined up approach. Tends to be car company to MNO relationship.
Driver hours regulations could limit the business case for platooning.

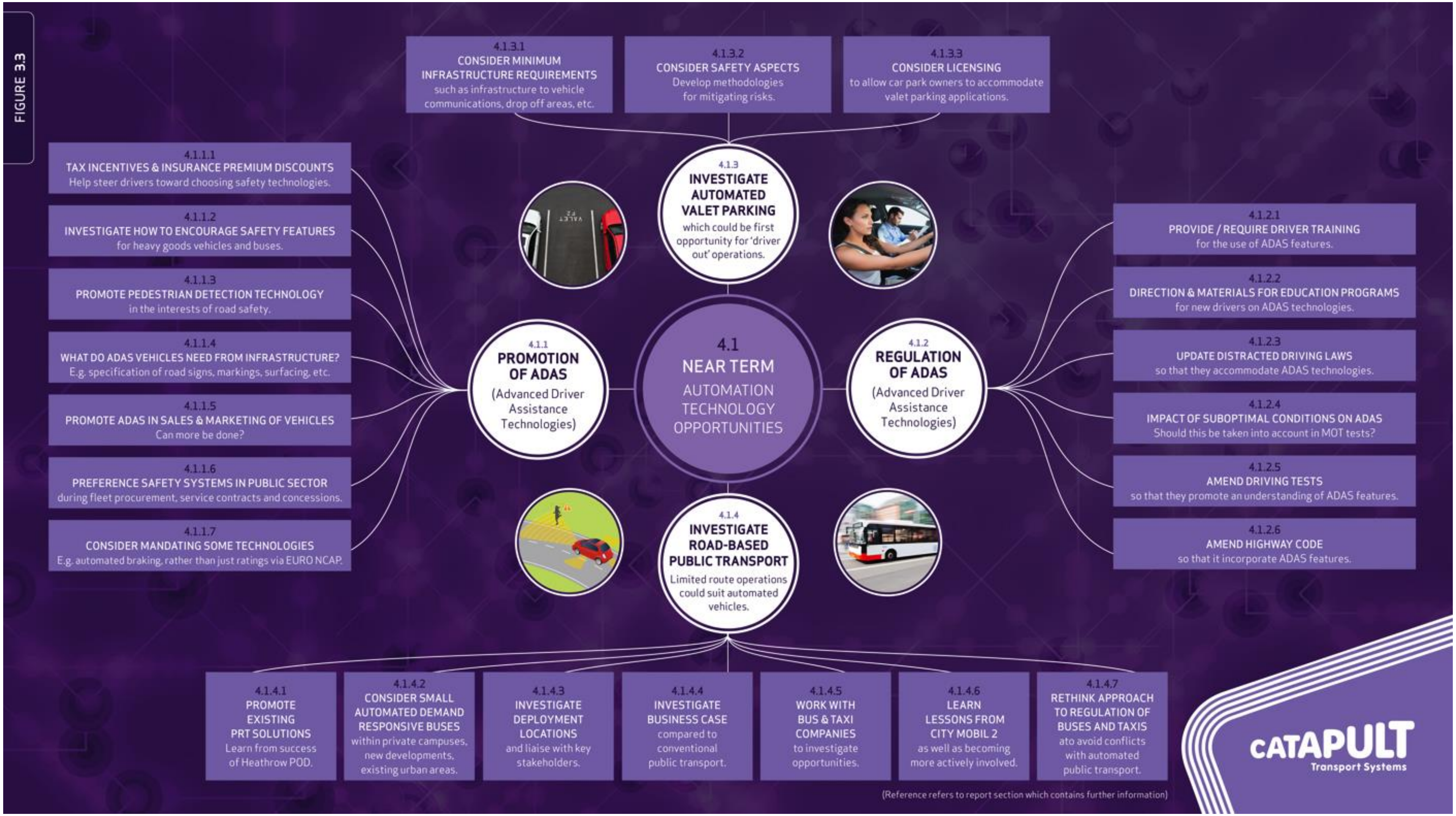


FIGURE 3.3
4.1
NEAR TERM
AUTOMATION TECHNOLOGY OPPORTUNITIES
4.1.1
PROMOTION OF ADAS
(Advanced Driver Assistance Technologies)
4.1.1.1
TAX INCENTIVES & INSURANCE PREMIUM DISCOUNTS
Help steer drivers toward choosing safety technologies.
4.1.1.2
INVESTIGATE HOW TO ENCOURAGE SAFETY FEATURES
for heavy goods vehicles and buses.
4.1.1.3
PROMOTE PEDESTRIAN DETECTION TECHNOLOGY
in the interests of road safety.
4.1.1.4
WHAT DO ADAS VEHICLES NEED FROM INFRASTRUCTURE?
E.g. specification of road signs, markings, surfacing, etc.
4.1.1.5
PROMOTE ADAS IN SALES & MARKETING OF VEHICLES
Can more be done?
4.1.1.6
PREFERENCE SAFETY SYSTEMS IN PUBLIC SECTOR
during fleet procurement, service contracts and concessions.
4.1.1.7
CONSIDER MANDATING SOME TECHNOLOGIES
E.g. automated braking, rather than just ratings via EURO NCAP.
4.1.2
REGULATION OF ADAS
(Advanced Driver Assistance Technologies)
4.1.2.1
PROVIDE / REQUIRE DRIVER TRAINING
for the use of ADAS features.
4.1.2.2
DIRECTION & MATERIALS FOR EDUCATION PROGRAMS
for new drivers on ADAS technologies.
4.1.2.3
UPDATE DISTRACTED DRIVING LAWS
so that they accommodate ADAS technologies.
4.1.2.4
IMPACT OF SUBOPTIMAL CONDITIONS ON ADAS
Should this be taken into account in MOT tests?
4.1.2.5
AMEND DRIVING TESTS
so that they promote an understanding of ADAS features.
4.1.2.6
AMEND HIGHWAY CODE
so that it incorporate ADAS features.
4.1.3
INVESTIGATE AUTOMATED VALET PARKING
which could be first opportunity for 'driver out' operations.
4.1.3.1
CONSIDER MINIMUM INFRASTRUCTURE REQUIREMENTS
such as infrastructure to vehicle communications, drop off areas, etc.
4.1.3.2
CONSIDER SAFETY ASPECTS
Develop methodologies for mitigating risks.
4.1.3.3
CONSIDER LICENSING
to allow car park owners to accommodate valet parking applications.
4.1.4
INVESTIGATE ROAD-BASED PUBLIC TRANSPORT
Limited route operations could suit automated vehicles.
4.1.4.1
PROMOTE EXISTING PRT SOLUTIONS
Learn from success of Heathrow POD.
4.1.4.2
CONSIDER SMALL AUTOMATED DEMAND RESPONSIVE BUSES
within private campuses, new developments, existing urban areas.
4.1.4.3
INVESTIGATE DEPLOYMENT LOCATIONS
and liaise with key stakeholders.
4.1.4.4
INVESTIGATE BUSINESS CASE
compared to conventional public transport.
4.1.4.5
WORK WITH BUS & TAXI COMPANIES
to investigate opportunities.
4.1.4.6
LEARN LESSONS FROM CITY MOBIL 2
as well as becoming more actively involved.
4.1.4.7
RETHINK APPROACH TO REGULATION OF BUSES AND TAXIS
ato avoid conflicts with automated public transport.
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(Reference refers to report section which contains further information)

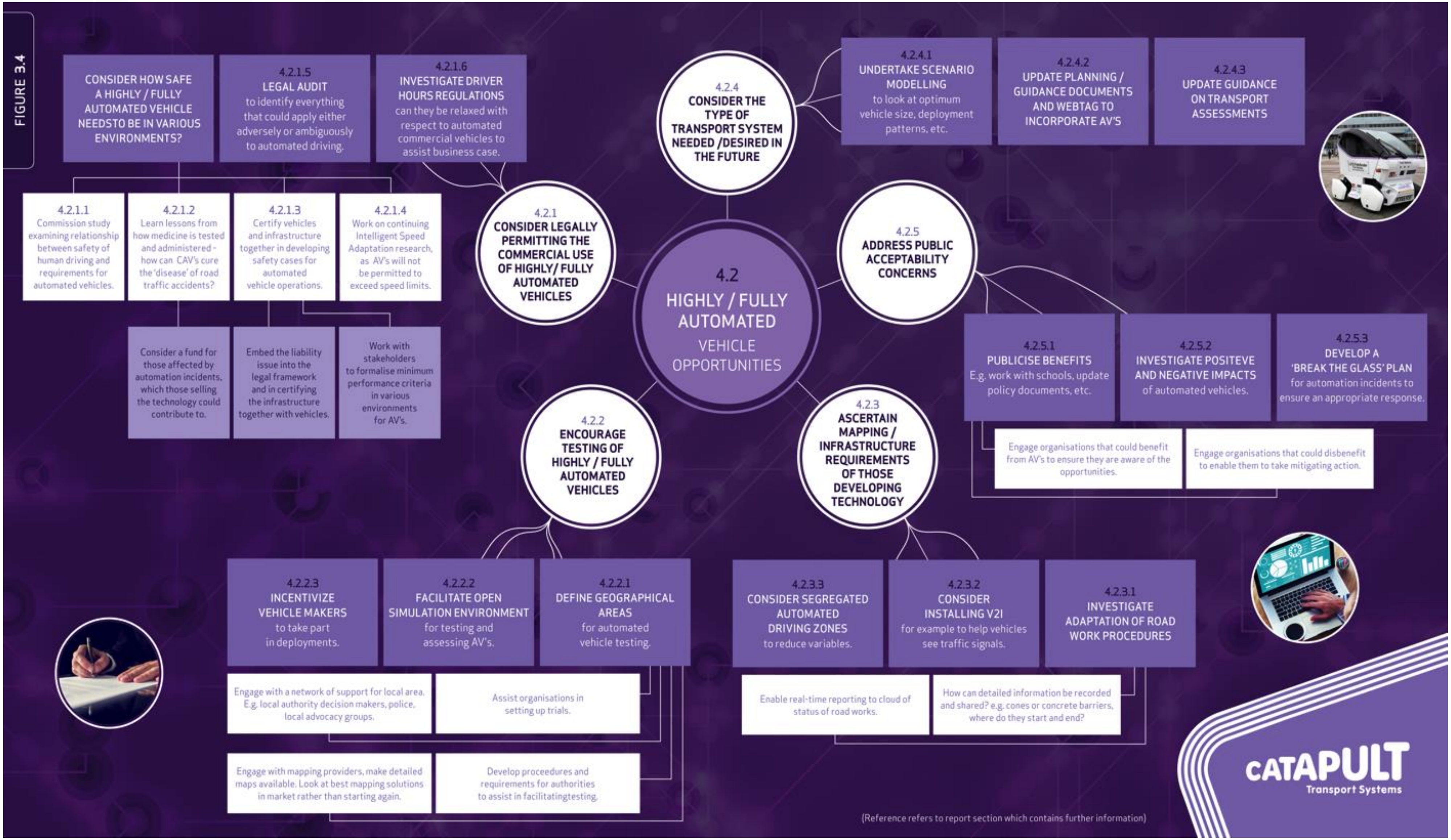
FIGURE 3.4
4.2
HIGHLY / FULLY AUTOMATED VEHICLE OPPORTUNITIES
4.2.1
CONSIDER LEGALLY PERMITTING THE COMMERCIAL USE OF HIGHLY/ FULLY AUTOMATED VEHICLES
CONSIDER HOW SAFE A HIGHLY / FULLY AUTOMATED VEHICLE NEEDSTO BE IN VARIOUS ENVIRONMENTS?
4.2.1.5
LEGAL AUDIT
to identify everything that could apply either adversely or ambiguously to automated driving.
4.2.1.6
INVESTIGATE DRIVER HOURS REGULATIONS
can they be relaxed with respect to automated commercial vehicles to assist business case.
4.2.1.1
Commission study examining relationship between safety of human driving and requirements for automated vehicles.
4.2.1.2
Learn lessons from how medicine is tested and administered - how can CAV's cure the 'disease' of road traffic accidents?
4.2.1.3
Certify vehicles and infrastructure together in developing safety cases for automated vehicle operations.
4.2.1.4
Work on continuing Intelligent Speed Adaptation research, as AV's will not be permitted to exceed speed limits.
Consider a fund for those affected by automation incidents, which those selling the technology could contribute to.
Embed the liability issue into the legal framework and in certifying the infrastructure together with vehicles.
Work with stakeholders to formalise minimum performance criteria in various environments for AV's.
4.2.4
CONSIDER THE TYPE OF TRANSPORT SYSTEM NEEDED /DESIRED IN THE FUTURE
4.2.4.1
UNDERTAKE SCENARIO MODELLING
to look at optimum vehicle size, deployment patterns, etc.
4.2.4.2
UPDATE PLANNING / GUIDANCE DOCUMENTS AND WEBTAG TO INCORPORATE AV'S
4.2.4.3
UPDATE GUIDANCE ON TRANSPORT ASSESSMENTS
4.2.5
ADDRESS PUBLIC ACCEPTABILITY CONCERNS
4.2.5.1
PUBLICISE BENEFITS
E.g. work with schools, update policy documents, etc.
4.2.5.2
INVESTIGATE POSITEVE AND NEGATIVE IMPACTS
of automated vehicles.
4.2.5.3
DEVELOP A 'BREAK THE GLASS' PLAN
for automation incidents to ensure an appropriate response.
Engage organisations that could benefit from AV's to ensure they are aware of the opportunities.
Engage organisations that could disbenefit to enable them to take mitigating action.
4.2.2
ENCOURAGE TESTING OF HIGHLY / FULLY AUTOMATED VEHICLES
4.2.2.3
INCENTIVIZE VEHICLE MAKERS
to take part in deployments.
4.2.2.2
FACILITATE OPEN SIMULATION ENVIRONMENT
for testing and assessing AV's.
4.2.2.1
DEFINE GEOGRAPHICAL AREAS
for automated vehicle testing.
Engage with a network of support for local area. E.g. local authority decision makers, police, local advocacy groups.
Assist organisations in setting up trials.
Engage with mapping providers, make detailed maps available. Look at best mapping solutions in market rather than starting again.
Develop proceedures and requirements for authorities to assist in facilitatingtesting.
4.2.3
ASCERTAIN MAPPING / INFRASTRUCTURE REQUIREMENTS OF THOSE DEVELOPING TECHNOLOGY
4.2.3.3
CONSIDER SEGREGATED AUTOMATED DRIVING ZONES
to reduce variables.
4.2.3.2
CONSIDER INSTALLING V2I
for example to help vehicles see traffic signals.
4.2.3.1
INVESTIGATE ADAPTATION OF ROAD WORK PROCEDURES
Enable real-time reporting to cloud of status of road works.
How can detailed information be recorded and shared? e.g. cones or concrete barriers, where do they start and end?
(Reference refers to report section which contains further information)
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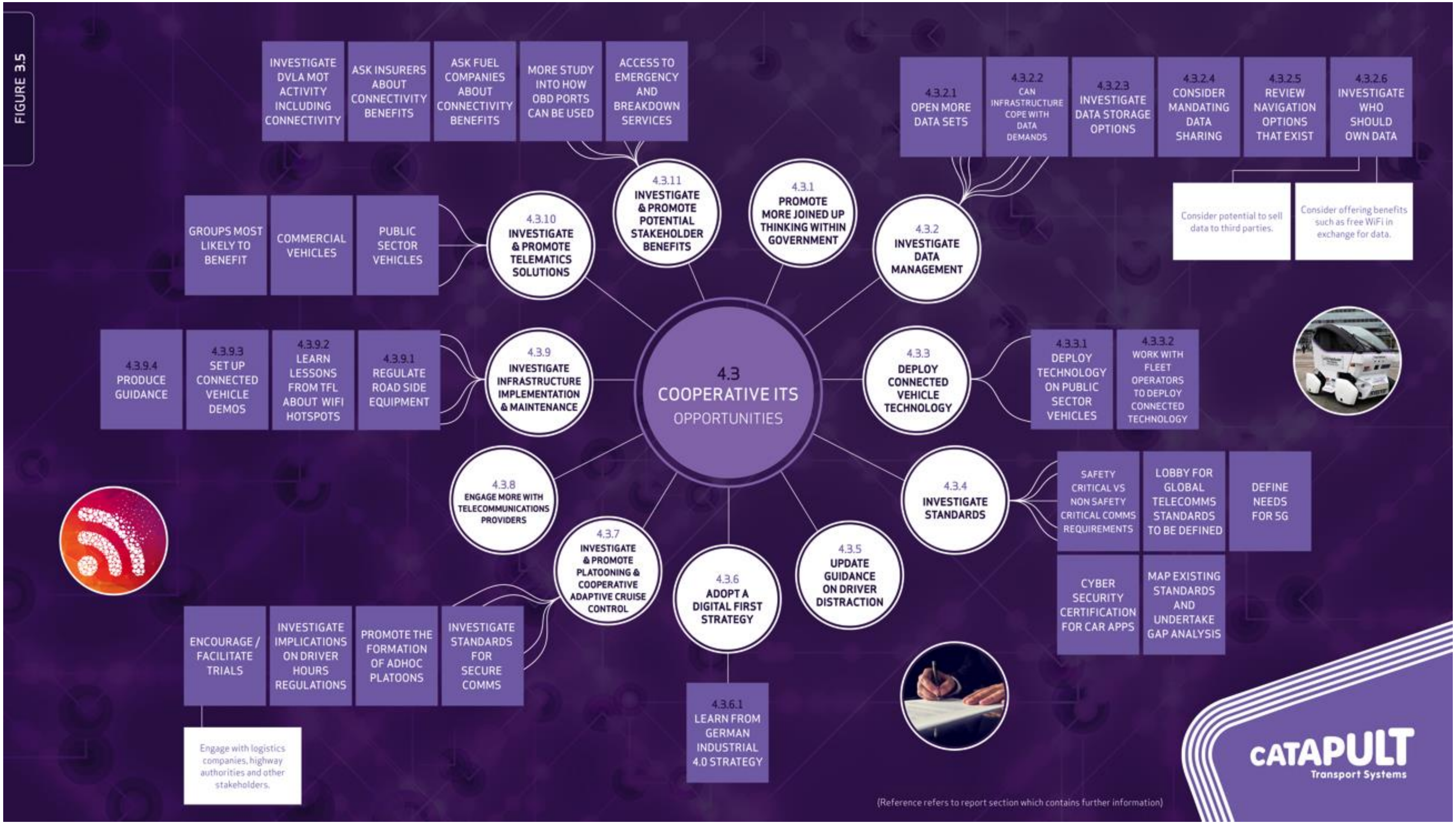
FIGURE 3.5
4.3
COOPERATIVE ITS
OPPORTUNITIES
4.3.1
PROMOTE MORE JOINED UP THINKING WITHIN GOVERNMENT
4.3.2
INVESTIGATE DATA MANAGEMENT
4.3.2.1
OPEN MORE DATA SETS
4.3.2.2
CAN INFRASTRUCTURE COPE WITH DATA DEMANDS
4.3.2.3
INVESTIGATE DATA STORAGE OPTIONS
4.3.2.4
CONSIDER MANDATING DATA SHARING
4.3.2.5
REVIEW NAVIGATION OPTIONS THAT EXIST
4.3.2.6
INVESTIGATE WHO SHOULD OWN DATA
Consider potential to sell data to third parties.
Consider offering benefits such as free WiFi in exchange for data.
4.3.3
DEPLOY CONNECTED VEHICLE TECHNOLOGY
4.3.3.1
DEPLOY TECHNOLOGY ON PUBLIC SECTOR VEHICLES
4.3.3.2
WORK WITH FLEET OPERATORS TO DEPLOY CONNECTED TECHNOLOGY
4.3.4
INVESTIGATE STANDARDS
SAFETY CRITICAL VS NON SAFETY CRITICAL COMMS REQUIREMENTS
LOBBY FOR GLOBAL TELECOMMS STANDARDS TO BE DEFINED
DEFINE NEEDS FOR 5G
CYBER SECURITY CERTIFICATION FOR CAR APPS
MAP EXISTING STANDARDS AND UNDERTAKE GAP ANALYSIS
4.3.5
UPDATE GUIDANCE ON DRIVER DISTRACTION
4.3.6
ADOPT A DIGITAL FIRST STRATEGY
4.3.6.1
LEARN FROM GERMAN INDUSTRIAL 4.0 STRATEGY
4.3.7
INVESTIGATE & PROMOTE PLATOONING & COOPERATIVE ADAPTIVE CRUISE CONTROL
ENCOURAGE / FACILITATE TRIALS
INVESTIGATE IMPLICATIONS ON DRIVER HOURS REGULATIONS
PROMOTE THE FORMATION OF ADHOC PLATOONS
INVESTIGATE STANDARDS FOR SECURE COMMS
Engage with logistics companies, highway authorities and other stakeholders.
4.3.8
ENGAGE MORE WITH TELECOMMUNICATIONS PROVIDERS
4.3.9
INVESTIGATE INFRASTRUCTURE IMPLEMENTATION & MAINTENANCE
4.3.9.1
REGULATE ROAD SIDE EQUIPMENT
4.3.9.2
LEARN LESSONS FROM TFL ABOUT WIFI HOTSPOTS
4.3.9.3
SET UP CONNECTED VEHICLE DEMOS
4.3.9.4
PRODUCE GUIDANCE
4.3.10
INVESTIGATE & PROMOTE TELEMATICS SOLUTIONS
GROUPS MOST LIKELY TO BENEFIT
COMMERCIAL VEHICLES
PUBLIC SECTOR VEHICLES
4.3.11
INVESTIGATE & PROMOTE POTENTIAL STAKEHOLDER BENEFITS
INVESTIGATE DVLA MOT ACTIVITY INCLUDING CONNECTIVITY
ASK INSURERS ABOUT CONNECTIVITY BENEFITS
ASK FUEL COMPANIES ABOUT CONNECTIVITY BENEFITS
MORE STUDY INTO HOW OBD PORTS CAN BE USED
ACCESS TO EMERGENCY AND BREAKDOWN SERVICES
(Reference refers to report section which contains further information)
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4. ANALYSIS

4.1 Near Term Automation Technology Opportunities

This mind map shown in Figure 3-3 3 illustrates a number of measures which take advantage of technology which is either in use already or is close to market. The following section sets out further detail the contents of the mind map.

4.1.1 Promotion of ADAS

Two strands relate specifically to ADAS. There are measures that can assist with promotion of ADAS and measures that could help to regulate the use of ADAS (see section 4.1.2 for Regulation of ADAS). The promotion of ADAS is seen as an opportunity to improve the safety of the highway network.

A report undertaken by Boston Consulting Group[2] provides a useful overview of different types of ADAS feature, split into the three categories of Aid, Warn and Assist, as well as outlining some 'partially autonomous' features:

	ADAS FEATURES			PARTIALLY AUTONOMOUS
	Aid	Warn	Assist	
Definition	Aid features improve visibility for the driver by providing additional display or illumination	Warn features alert the driver of potential danger through sensory cues: auditory, visual or haptic	Assist features engage steering, acceleration, and/or brake systems if necessary	Automated features allow vehicle to be driven/ stopped without driver intervention in certain scenarios
Feature (Year)	Night vision (2000) Rear camera (2002) Adaptive front lights (2006) Surround view systems (2007)	Forward collision warning (2000) Park assist (2002) Lane departure warning (2005) Blind spot detection/rear cross traffic (2006) Driver monitoring (2006)	Forward collision assist (2008) Self-park (2006) Lane keep assist (2014) Pedestrian avoidance (2014) Intelligent speed adaptation (~2018)	Single lane highway autopilot (2016) Autonomous valet parking (2017) Traffic jam autopilot (2017) Highway autopilot with lane changing (2018) Urban autopilot (2022)
Technology	Mono cameras Infrared (night vision) Laser lights	Mono and stereo cameras Radar (short) Steering inertia Ultrasonic	Mono and stereo cameras Radar (short and long) LIDAR Ultrasonic	Mono and stereo cameras Radar (short and long) LIDAR GPS/mapping Ultrasonic
Control	Lower level of system integration; supplier ownership		Driver begins to share control OEM integration High level of system integration	

FIGURE: 4-1: ADAS Categories of Features (sourced from Boston Consulting Group)

[2] Boston Consulting Group, A Roadmap to Safer Driving through ADAS, 2015

http://www.mema.org/Document-Vault/PDFs/2015/MEMA-BCG-ADAS-Report.pdf

> "if every vehicle on the road were equipped with ADAS technologies, these systems would sharply reduce the toll that vehicle accidents take on society"

The report also includes a useful timeline of safety related technologies, which outlines when features have been introduced historically as well as predicting the introduction of future safety technology:

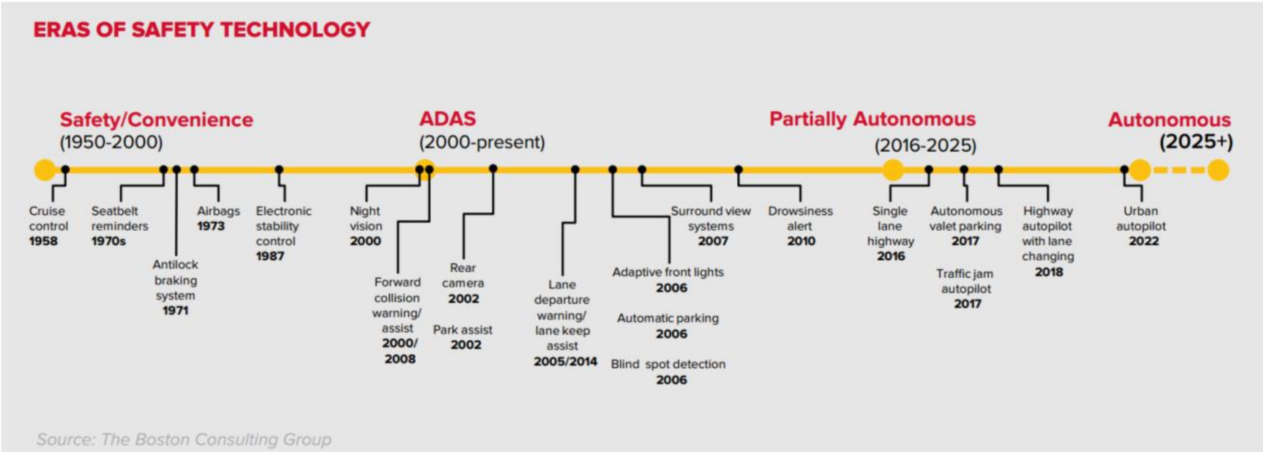


FIGURE 4-2: Eras of Safety Technology (sourced from Boston Consulting Group)

4.1.1.1 Provide tax incentives & insurance premium discounts to help steer drivers towards choosing safety technology

This recommendation was from the Boston Consulting Group report; within which it is stated:

> "Legislators can directly and positively influence consumer behaviour with laws that offer tax deductions or rebates to consumers for purchasing ADAS features and set industrywide accident reduction targets across a five- or 10-year timeline"

In the UK car vehicle tax rates are already based on engine size, fuel type and CO2 emissions, and therefore are aimed at reducing emissions and helping the environment. This could be one such mechanism for encouraging safety

4.1.1.2 Investigate how to encourage safety features for heavy goods vehicles and buses

Encouraging safety features in heavy goods vehicles was suggested by a stakeholder that works for a highways authority. There is a lot of work going on in this area already, but a study could investigate if more could be done. For example, under Transport for London's Safer Lorry Scheme, heavy goods vehicles without basic safety equipment such as side guards and certain types of mirrors are prohibited from entering London. Further incentives and / or requirements could encourage blind spot detection, pedestrian detection and other features on large commercial vehicles technology. Another is through insurance premium discounts, and it is understood that insurance companies are already taking Autonomous Emergency Braking (AEB) technology into consideration when setting premiums. The authorities could assist the insurance industry in determining the potential safety benefits of other ADAS features.

4.1.1.3 Promote pededstrian detection technology in the interests of road safety

TSC staff were provided with a demonstration of pedestrian detection technology using an ADAS equipped vehicle and a dummy to represent a child. The driver accelerated towards the dummy to a speed of perhaps 15mph, and the vehicle made a beeping sound and then automatically braked and stopped less than a metre short of the child, all without the driver touching the brake pedal. When seen in use the potential benefits are quite clear.

The recommendation was made by the ADAS expert that we spoke to. The mechanism for promotion of the technology would need investigation, and could include some of the other measures discussed in this section.

4.1.1.4 Investigate what ADAS features need in terms of infrastructure

This was another recommendation from the ADAS expert, who is exposed on a day to day basis with the latest ADAS on a wide variety of vehicles, and drives them in a wide range of environments. Within the interview, it was stated:

> "Highways England are thinking about how infrastructure can be better adapted for ADAS equipped cars. The infrastructure providers need to work closely with the vehicle manufacturer. The positioning of road signs can be critical as to whether the car can see them. White lines, tarmac etc. – the way roads are manufactured with a groove in the centre where the white lines are. Sometimes the camber of the road and the ditches can pull the car to the centre and the steering cannot overcome this without applying too much torque. We need to remember we also need local roads to be good enough, not just trunk roads"

Following investigation into this area, it could be appropriate to revise highway design documentation such as the 'Design Manual for Roads and Bridges (DMRB)' and 'Manual for Streets'. It could also be worth investigating the economic case for make adaptions to existing highways to assist ADAS enabled vehicles.

4.1.1.5 Promote ADAS in the sales and marketing of vehicles

This recommendation is not necessarily for the authorities, but it was stated that it should be easier to search for vehicles with particular ADAS features. When visiting popular car buying websites it is possible to search for cars by age, fuel consumption, CO2 emissions etc., but for not those with AEB, for example. It was also discussed that the retail arm of the car industry seems disconnected from the technology side, and staff within car show rooms need a better understanding of the latest technology in order to educate the public

4.1.1.6 Preference safety systems in public sector fleet procurement, service contracts and concessions

This was recommended by one stakeholder who represented a highways authority, and is also referenced within a presentation by Bryant Walker Smith, a US based legal expert who specializes on the law of self-driving vehicles[3]. With reference to the US, Bryant Walker Smith states:

> "States, countries and municipalities in the United States own nearly 1.5 million cars, 500,000 buses and another 1.5 million trucks. If the turnover rate for these fleets is ten percent, then these governments purchaswe some 350,000 vehicles annually – five times more each year than Tesla has sold in its entire existence. Because of contracts and concessions, the number of vehicles closely associated with government services is likely even greater"

The numbers would be lower for the UK given the smaller population, but the proportion of public sector vehicles within the overall fleet may be comparable. Therefore, encouraging the latest technology within the fleet may have a larger impact than might be expected.

4.1.1.7 Consider mandating some technologies rather than just ratings via Euro NCAP

The European New Car Assessment Programme (Euro NCAP) is an independent consumer information programme that aims to encourage manufacturers to exceed the minimum safety related performance criteria for vehicles. Vehicles are tested and a star rating is awarded. The ratings are available to view online for any vehicle model that has been tested, and are also displayed in the car showroom. Euro NCAP looks at vehicles sold within the European market. One of the categories under which vehicles are now tested is named 'Safety Assist'. The five subcategories include:

- Electronic Stability Control
- Seatbelt Reminders
- Speed Assistance
- AEB Interurban
- Lane Support

[3] Bryant Walker Smith, A US Legal Perspective on Automated Driving, https://www.adaptive-ip.eu/files/adaptive/content/downloads/Deliverables%20%26%20papers/AdaptIVe_Legal%20Aspects%20WS_PR_Bryant%20Walker%20Smith_USC.pdf

In addition, under the ‘Pedestrian Protection’ category there is a sub-category for ‘AEB Pedestrian’ which refers to the technology discussed under 4.1.1.3.

Whilst the promotion of the best performing ADAS technologies is encouraging, one stakeholder who works for a vehicle Original Equipment Manufacturer (OEM) supplier suggested that these technologies could be mandated rather than just given ratings, in the same way that seatbelts and other safety features were mandated in the past. On this issue, according to a recent article the Chief Executive Officer (CEO) of Thatcham, Peter Shaw, reportedly[4] said:

> “We’re heavily engaged with the [DfT] and over the past 18 months we have been talking to and lobbying ministers and the opposition and what we’ve got is words of support from the likes of [parliamentary under-secretary of state for the DfT] Andrew Jones and [minister of state for the DfT] has been to Thatcham to engage with us. “However, they have fallen short of promising any changes in legislation that would support the introduction of mandatory auto braking systems. They are supportive, they believe the technology works and they want to see it adopted by manufacturers actively marketing and fitting it, but they don’t want to mandate it. “This is part of a broader strategy in the government, which is not to legislate and instead be a soft touch government. I don’t think we can expect the mandating of auto braking in the next three years. It requires [global technical regulation] so usually when systems like this are mandated it’s done at a European level”

4.1.2 Regulation of ADAS features

4.1.2.1 Provide / require driver training for the use of ADAS features

ThIs intervention seeks to address the concern that drivers are:

- Unaware of the ADAS features available on the vehicle that they are using.
- Unaware of how to use a particular ADAS feature.
- Unaware of exactly how the ADAS feature works, and what its limitations are.

The above points raise highway safety concerns. It is a missed opportunity if drivers are not using technology that could enable them to drive more safely. It is a highway safety risk if drivers are using features incorrectly, or over-estimating the ability of those features. The importance of this was highlighted by the ADAS expert we spoke to, who added that it’s not just the public, but also car sales staff that don’t fully understand ADAS features, and so would struggle to inform the general public about their use. It was stated:

[4] Callum Brodie, “Government unwilling to mandate AEB systems in new cars”, 15th Jan 2016,

http://postlive.dev.incisive.pro.pugpig.com/2016/01/15/government-unwilling-to-mandate-aeb-systems-in-new-cars/

> "We have people at AA Driving Schools for people to learn how to use this technology properly, but the manufacturers have to encourage it. It's different to other technology like a radio or Bluetooth or hand free phone, which people are more familiar with, but trusting a car to brake or steer for you goes against everything you learn. Until you've understood it and sampled it it's hard to understand it, and its limitations. Knowing how Adaptive Cruise Control (ACC) works, when it is safe and unsafe to use it takes experience. If ACC is set at 60mph but is approaching a 40mph bend, unless there is something in front the car will attempt to take the bend at 60mph. Dealers and sales people don't understand this; so how can they explain this to the general public?"

The mechanism for delivery of training would require investigation.

4.1.2 Regulation of ADAS features

Related to 4.1.2.1 above, education material relating to ADAS could be made available online. One website, called MyCarDoesWhat.org, seeks to address this issue. It was developed in the U.S. by the University of Iowa and the National Safety Council to educate the public on how to best interact with these safety features. The videos on the website highlight the limitations or the technology as well explaining how to use them, which was something the ADAS expert that we spoke to highlighted as of particular importance.

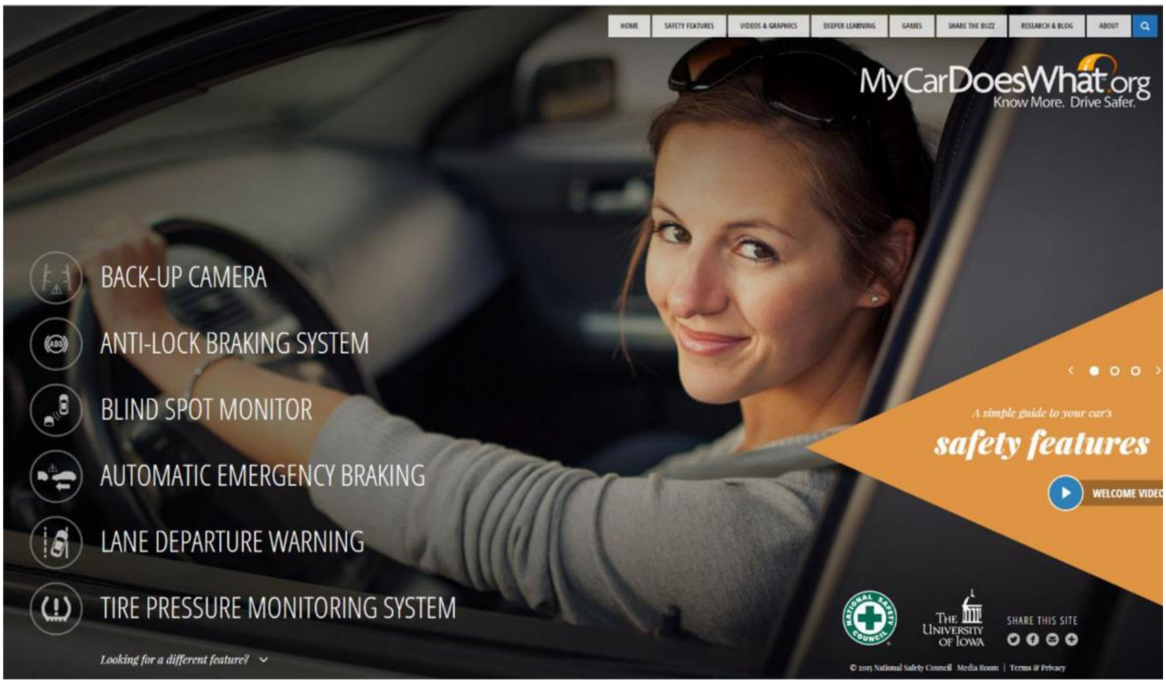


FIGURE 4-3: MyCarDoesWhat.org – created by University of Iowa to educate the public on ADAS features

The intervention could include provision of a version of this website for a UK audience and promoted by the UK authorities. This could be supplemented by educational online videos supplied by the car industry with information specific to individual vehicle models.

4.1.2.3 Update distracted driving laws to that they accommodate ADAS

This recommendation was taken from 'Autonomous Vehicle Technology: A Guide for Policy Makers'[5], within which it was stated:

> "Stakeholder interviews identified a wide variety of potential issues concerning communications for AVs. For example, the creation of a communications platform in AVs that can be used for driver assistance and safety reasons may also be used for voice communications, navigation assistance, and infotainment. More than one stakeholder suggested there could be conflicts with states' distracted driving laws and regulations, especially concerning navigation systems. Distracted driving laws vary widely from state to state, and could pose a challenge for development of a standard communications platform for AVs. State lawmakers should begin to consider updating distracted driving laws to accommodate AV technologies."

There is a close relationship between distractions due to ADAS and distractions due to vehicle connectivity applications and navigation applications, therefore it is possible that one study could look into the area of driver distraction in relation to all emerging vehicle technology. UK law states that "it is illegal to ride a motorcycle or drive using hand-held phones or similar devices". It goes on to state that "You can use hands-free phones, 'sat navs' and 2-way radios when you're driving or riding. But if the police think you're distracted and not in control of your vehicle you could still get stopped and penalised".

If the vehicle has relived the driver from the driving task (at least temporarily), the driver might be tempted to use a telephone and could argue that they were not driving the vehicle at that particular time. Clarification on this issue might be beneficial both for the public and the police.

4.1.2.4 Investigate the impact of sub-optimal conditions on ADAS

This recommendation was from an ADAS expert who regularly uses, tests and provides training on their use:

> "Much of the testing of ADAS features is when the tyres are new, the brakes are new, on a dry track under controlled conditions. What happens when the brakes are worn, tyres are worn, tyre pressures are uneven, in the rain etc.?"

[5] RAND, Autonomous Vehicle Technology: A Guide for Policy Makers, 2014
http://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-1/RAND_RR443-1.pdf

4.1.2.5 Amend the Driving Test to promote and understanding of ADAS

Clearly it is not practical for all driving instructors and examiners to use ADAS equipped vehicles, but the Driving Theory Test perhaps should include a section on ADAS, and could start to make new drivers aware that they may be sharing the road with AVs in coming years.

4.1.2.6 Amend the Highway Code to discuss ADAS

Rule 120 of the Highway Code discusses Anti-Lock Brakes (ABS) and there are many references to seat belts, but little reference to new safety related technology. The following is stated as a Government action within DfT's Pathway to Driverless Cars documents (Annex D, #18):[6]

> "Determine whether a section on AVs should be developed and included in the Highway Code, to help guide how road users should interact with these vehicles"

The above action may be more focussed on higher levels of vehicle automation, but it is worth considering whether references to ADAS should be included, and could also discuss the possibility that road users could be sharing the road with AVs in coming years.

[6] DfT, The Pathway to Driverless Cars: detailed review of regulations for automated vehicle technologies, February 2015 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401565/pathway-driverless-cars-main.pdf

4.1.3 Investigate Autonomous Valet Parking

The DfT expressed interest in the issues surrounding Autonomous Valet Parking (AVP), which is seen as one of the early opportunities for a vehicle to operate in fully automated mode without a driver present in the vehicle. AVP involves a vehicle being driven to the entrance of a car park, the driver exiting the vehicle and the vehicle driving itself to a car parking space in autonomous mode with no vehicle occupants. A number of systems in development appear to be close to market readiness, which is why this has been included as a near term automation technology opportunity. Systems are already coming to market which enable remote control parking, whereby the driver can command or control the vehicle into a parking space using a remote control device. This could be useful for parking a vehicle in a tight space or garage where door opening would be difficult once parked. Examples of this include the 2016 Mercedes E-Class Remote Parking Pilot[7] and the Remote Control Parking feature available on the BMW 2016 7-Series[8].

BMW's 'Remote Valet Parking Assistant' is an example of AVP. A modified version of the BMW i3 was demonstrated searching for and manoeuvring into a car parking space with no driver or occupants at the Consumer Electronics Show in January 2015. Daimler, Bosch and car2go are also working on a similar system which enables automated manoeuvring in 'appropriately equipped' parking garages. However, as recommended by one stakeholder, it is important to think about the practicalities. Some questions that need answering in relation to this technology include:

4.1.3.1 Consider Minimum Infrastructure Requirements of AVP

The car park operators would need to establish how the dropping off and collecting of vehicles would be managed without leading to congestion or hazardous situations around the car park entrance and exit points? Would special pick up and drop off areas need to be created? This issue is very specific to each car park, the existing vehicle flow patterns and anticipated AV usage at different times of the day. The minimum requirement for infrastructure to vehicle communications equipment would need to be investigated. For example, would vehicles need to be told where empty spaces are before they enter the car park or would they be able to drive around searching for them in the same way that human drivers do. Clearly the former option would be preferable, but the latter would be more scalable and require less infrastructure investment. The latter option also avoids the requirement for every vehicle using the car park to be connected. If a fully AV broke down or experienced an issue that lead to it becoming an obstruction, car park operators would need a method for removing such vehicles that allows for absence of the vehicle owner. It may be worth considering whether car park operators might need to be able to remotely control vehicles, for example to direct them to a particular location, without the owner being present. There are potentially significant benefits in the adoption of AVP, not just in terms of convenience for vehicle owners, but also in terms of car parking capacity. It may be possible, for example, to allocate areas of a car park for AVs only to park, and they would not need the typical width of 2.4m for a car parking space, which is partly to allow users to open car doors for vehicle access. An average car is 1.8m wide, it may be possible to reduce the width of spaces to, say, 2.0m, which would equate to a 20% increase in spaces. Longer term, cars could arrange themselves so that they block in cars that are not needed for certain periods for further efficiency gains. The BMW demonstration does not use any special supporting infrastructure, but Daimler is taking the connected approach for its AVP. The company is working on the AutoPlaz project, with partners at the FZI automotive lab and will see the car negotiate a tight spiral ramp and find a parking place. Sensors will be deployed in the car park and there will be a connection to the cloud to access data. Volkswagen (VW) is researching automated parking and uses a different approach. The feature, which VW calls 'Trained Parking' stores a set route such as from driveway to garage. It is unclear how this could be scaled to a car park as it is unable to find a space, instead it would take you to the pre-programmed space. It is conceivable though, that this method could be used as part of the valet parking scenario for the main route that the car would have to take.

[7] 2016 Mercedes E-Class Remote Parking Pilot https://www.youtube.com/watch?v=KCHeswihtsI

[8] BMW Demonstrates 2016 7-Series' Remote Control Parking http://www.carscoops.com/2015/06/bmw-demonstrates-2016-7- series-remote.html

4.1.3.2 Consider Safety Aspects of AVP

Car parks are currently used by pedestrians as well as vehicles, so either vehicles would need to operate safely in fully automated mode in a pedestrian environment, or car parks could be chosen where pedestrians can be restricted (at least initially). Particular hazards include the risk of children running out from between parked vehicles. The standard of safety to which the AV would need to perform would need to be established and verified. The maximum speed of fully AVs in a car park environment would need to be agreed. The type of functional safety analysis being undertaken for the LUTZ Pathfinder project in Milton Keynes, and other projects involving vehicles moving amongst pedestrians, would be of particular relevance.

4.1.3.3 Consider Licensing of AVP

It may be appropriate for a car park operator to obtain some kind of license or permit to offer their car park for use by fully AVs. This license could address some of the issues above.

4.1.4 Investigate road based public transport

Road based public transport may be amongst the most attractive first applications of driverless transportation as vehicles follow fixed routes, and the infrastructure can be extensively mapped and adapted along those routes to aid the vehicles, and removing the driver could significantly reduce the operating cost, whilst significantly improving the efficiency and service level of the system. This section discusses possibilities relevant to this concept.

4.1.4.1 Promote existing PRT solutions

Fully automated public transport solutions have been with us for some time. In the UK, the Heathrow POD entered full service on 7th May 2011 and continually transports passengers between Heathrow Terminal 5 and the business car park.

FIGURE 4-4: The Heathrow POD Route (source: Heathrow POD presentation)

As described by the operators, the POD is an environmentally sustainable, low energy, low noise and zero emission system. Other examples of public transport systems which involve automated road-based vehicles include

An automated people mover connecting the Rotterdam metro station Kralingse Zoom with the Rivium business park in the neighbouring new town of Capelle aan den Ijssel, which has been in operation since 1999 and is operated by 2getthere. Over 2,500 people use the system daily.[9]

The Masdar Personalised Rapid Transit (PRT) system opened to the general public on November 28, 2010, with 13 pod/cars transporting passengers along an 800m route. The system was an initial trial of a system which was originally planned to be much larger with 80 stations and thousands of vehicles, but financial constraints limited the project to just the trial system close to the Masdar Institute of Science and Technology.[10]

Existing PRT solutions have a proven safety, environmental and passenger service record, and may be appropriate for further applications particularly where a fully segregated solution is possible or desirable. The Heathrow POD, at least in a private campus setting, offers evidence of a favourable business case and this could be taken into consideration by local authorities and developers. According to the POD operators, in terms of infrastructure cost it compares favourably with other public transport options such as light rail.

4.1.4.2 Consider small automated demand-responsive buses

In the past, the above type of personal or group rapid transit solutions have been reliant on dedicated infrastructure. Such infrastructure has clear benefits for public transport vehicles in terms of journey time reliability, but can be costly both financially and environmentally. The sensing capability, processing power and intelligence of Automated Control Systems (ACSs) in the vehicles is enabling them to mix with either general traffic or with pedestrians, and as such, it may be beneficial to investigate fully automated public transport solutions that are not reliant on dedicated infrastructure, and as such could be rolled out far more widely.

The following quote from Luca Guala of the Italian consulting firm Mobility Thinktank summarises this idea[11]:

> "Why minibuses and not taxis? Firstly, because it is much simpler to teach a robot to follow a fixed route, rather than teach it to go anywhere the passengers want to go. Such a system is already operational in Rotterdam and it works well, but it has one drawback: the tracks are segregated and they represent an ugly severance in the urban tissue. But if the vehicles are allowed to run with cars cyclists and pedestrians, a public transport route can be "adapted" with unobtrusive measures to accept driverless vehicles, and the people sharing the road will quickly learn to live with them. The main problem here was not technical, as legal."

[9] 2getthere website detailing Rivium GRT http://www.2getthere.eu/projects/rivium-grt/

[10] 2getthere website detailing Masdar PRT http://www.2getthere.eu/projects/masdar-prt/

[11]Human Transit website, "Luca Guala: driverless buses will be more transformative than driverless taxis" http://www.humantransit.org/2014/11/luca-guala-driverless-buses-will-be-more-transformative-than-driverless-

Typically, traditional bus services for medium sized towns and cities are focussed around a town centre. It might be possible to catch a bus from a residential area to the town centre. This might involve waiting ten minutes or so at the stop, and the route to the town centre may not be direct and can be quite circuitous. If you wish to go to a destination other than the town centre that is not along the route, then you need to change services at the town centre, which adds significantly to the journey time and inconvenience. Consider that one particular route was replaced with small AVs. The route could be mapped in great detail, and special arrangements could be put into place to manage road works and obstructions. Communications equipment could be installed along the corridor. It is possible that due to decreased operating cost from the absence of a driver it becomes economically viable to service the route with a number of smaller AVs. It might then be possible to operate a service more akin to a personal rapid transit network and offer a more demand responsive service. For example, buses could be waiting for passengers, rather than the other way around. The passenger could input their destination, and the vehicle could bypass certain stops and take a more direct route. Buses could serve sparsely populated areas only when needed, rather than on a set timetable. This model could then evolve and grow. Public transport services would no longer be limited to their existing routes, but could route along other public transport corridors (or any street that was adequately mapped and certified). The network could then evolve to offer a town wide public transport solution, which combines the efficiency and low passenger cost of the bus operating model with the flexibility and service level of the taxi operating model. With the above in mind, there are several potential options to promote fully automated public transport solutions:

4.1.4.3 Investigate deployment locations and liaise with key stakeholders

Stakeholders might include private campus operators, local authorities, developers, vehicle manufacturers and those developing ACSs. Such environments might include:

- Private campuses – advantageous as controls can be put into place to control access.
- New developments – the public transport system can be designed from scratch and there is an absence of a legacy system. Funding could be provided via ‘Section 106’ development contributions.
- Busways – could be amongst the least challenging environments technically, and it’s conceivable that trials could be undertaken outside of the hours when the infrastructure is being used by the conventional bus operator. Offering a demand responsive night time service could make more use of the busway asset.

4.1.4.4 Investigate business case compared to conventional public transport

Investigate how automated public transport compares to traditional solutions in terms of quality of service, environmental impacts, cost etc.

4.1.4.5 Work with bus and taxi companies to investigate opportunities

Clearly if the deployment and usage of AVs does accelerate then they will become a threat to the existing way in which bus companies and taxi operators operate. However, as these companies are experts in fleet management and already have facilities to support vehicle fleet operations, they could be ideal partners to involve in new trials and deployments.

4.1.4.6 Learn lessons from City Mobil 2

City Mobil 2 is a multi-stakeholder project co-funded by the EU, under which automated road transport systems in various locations across Europe. The newsletters[12] provide useful information on the latest deployment activities. It is essential that lessons are learnt from City Mobil 2, many of which were conveyed during a stakeholder interview who was involved. The more successful City Mobil 2 demonstrations were those in which there was a strong local commitment to support the project, and those that failed were those where it was more difficult to find the support of local people

[12] City Mobil 2 Newsletters, http://www.citymobil2.eu/en/Downloads/Newsletters-other-dissemination-material/

The importance of having the infrastructure certification, local government, public transport operator and communication provider working in harmony was emphasised. It was also suggested that rather than think about adapting infrastructure, initially fully AVs should be deployed in the existing infrastructure, and the right locations should

4.1.4.7 Rethink approach to the regulation of buses and taxis

This recommendation was taken from a report by the International Transport Forum[13]. Within this document, it is stated:

> "As of late 2014, almost all regulatory action regarding automated cars and other on-road vehicles has focused on the conditions in which on-road testing and operation of these vehicles takes place, including vehicle and driver licensing (see annex). This is of course an essential element in the progression towards the commercial deployment of increasingly automated and ultimately selfdriving vehicles. Crucially, however, driver and vehicle licensing are not the only regulatory elements that will be challenged by the deployment of highly AVs. As noted earlier, the urban mobility pathway leading to the deployment of on-demand AV services is a plausible development in many urban areas. In these cases, automated on-demand mobility systems will provide services similar to those provided by taxis and public transport, two highly regulated industries. Authorities will have to adapt - and possibly rethink - their approaches to regulating these activities in order to avoid conflicts. Failure to do so might even prevent the deployment of the urban mobility pathway for autonomous vehicles which would stifle innovative uses for this technology and potentially lead to welfare losses."

[13] International Transport Forum, Automated and Autonomous Driving - Regulation under uncertainty, 2015 http://www.internationaltransportforum.org/Pub/pdf/15CPB_AutonomousDriving.pdf

4.2 HIGHLY / FULLY AV OPPORTUNITIES

This mind map shown in Figure 3-4 illustrates a number of measures which will seek to accelerate the deployment of highly and fully AVs. The following section sets out further detail in respect to the contents of the mind map.

4.2.1 Consider legally permitting the commercial use of highly / fully AV

There were a number of references within the stakeholder consultation exercise and within literature to the need to legally permit the commercial use of highly and fully AVs. A recent announcement by the United States Department of Transportation (DoT) confirmed promotion of fully AVs, which was supported with a $4 billion proposal in President Obama's fiscal 2017 budget to develop connected and autonomous vehicle technology[14]:

> "DoT and National Highway Traffic Safety Administration (NHTSA) will develop the new tools necessary for this new era of vehicle safety and mobility, and will seek new authorities when they are necessary to ensure that fully autonomous vehicles, including those designed without a human driver in mind, are deployable in large numbers when demonstrated to provide an equivalent or higher level of safety than is now available."

But this cannot happen until the vehicles have been certified as safe for use on a particular piece of infrastructure. A fundamental question is how safe AVs need to be. Further to the above quote, the NHTSA press release also confirmed that:

> "Within six months, NHTSA will work with industry and other stakeholders to develop guidance on the safe deployment and operation of autonomous vehicles, providing a common understanding of the performance characteristics necessary for fully autonomous vehicles and the testing and analysis methods needed to assess them."

A legal expert that was consulted is quoted as follows:

> "Many commentators and manufacturers suggest that the lack of legal answers to issues raised by autonomous vehicles is holding back their development and integration into society. However, the law and regulation to facilitate AVs could be written fairly easily once an understanding is reached that if the driver is not in control, the system must be. The very definition of an autonomous vehicle is that the system, not the driver, is in control. So if you've accepted that the vehicle is in control at all times (including when something goes wrong) the law needs to decide (i) how the vehicle should react when something goes wrong and (ii) in taking such action, what level of performance it needs to have. There doesn't appear to have been much work to develop what those regulations needs to look like."

The following recommendations seek to address this issue.

[14] NHTSA press release, 14th January 2016, http://www.nhtsa.gov/About+NHTSA/Press+Releases/dot-initiatives-acceleratingvehicle-safety-innovations-01142016

4.2.1.1 Commission study examining the relationship between the safety of human driving and requirements for AVs

There are at least two purposes to this initiative. The first is to provide the ability to set a baseline against which AVs can be expected to perform. It is often expressed that an AV should be at least as safe as a humanly operated vehicle, but do we have a firm handle on how safe human driving is? As stated by one researcher based in the US:

> "I've done a simple calculation based on US traffic safety statistics to show that we have 3 million hours of driving for every fatal crash and 65,000 hours of driving for every injury crash, so to be equally as safe we need to meet those levels, and for the UK the numbers would be significantly higher because your traffic safety statistics are better than ours. But then the question is what process do you follow to verify that the automated system will be able to go 3 million hours without a fatality? You cannot afford a 3-million-hour test programme. For statistical purposes you would probably need to go ten times that to demonstrate the 3-million-hour mean time between fatal events. There's no verified simulation you can run to verify that process, there's no analytical method you can follow to analyse the software to say yes it's not going to encounter any critical bugs in 3 million hours of operation. So that inability to verify the system is closely coupled with the problem of how do you design the system to get to that higher level of safety."

Another researcher pointed out:

> "Luck plays a big role in driving, sometimes we make a small mistake and if another car was one metre to the left or right then there would have been a big accident, but it wasn't. So most of the time when we make errors as humans it doesn't appear in any statistics. For a self-driving car, every minor mistake is analysed."

The second purpose to this initiative is to build public acceptability. It is often forgotten that driving is one of the most hazardous activities in day to day lives. Based on 2014 averages, today, and every day, there will be 533 reported casualties on the UK road network which will include five deaths and 62 seriously injured people, and UK roads are statistically amongst the safest in the world. It is widely accepted that accidents involving AVs are inevitable as the vehicles become widespread, but collisions involving an AV, especially those that involve human casualties, will be widely reported. It may be beneficial to have detailed evidence on the relative safety of the alternative to automated driving to enable an impartial and considered response. To investigate human driving behaviour, the findings of previous studies and ongoing studies into this area could be analysed. One example of a currently underway study is European naturalistic Driving and Riding for Infrastructure and Vehicle safety and Environment"[15] (UDRIVE), which is the first large scale European naturalistic driving (meaning that the behaviour of road users is observed unobtrusively in a natural setting) study on cars, trucks and powered-two wheelers. As an interesting footnote to this subject, a useful analysis has been published by Bryant Walker Smith of Stanford School of Law into the subject of 'Human Error as a Cause of Vehicle Crashes'.[16]

[15] UDRIVE website: http://www.udrive.eu/index.php/about-udrive

[16] Bryant Walker Smith, Human Error as a Cause of Vehicle Crashes, December 2013 http://cyberlaw.stanford.edu/blog/2013/12/human-error-cause-vehicle-crashes

4.2.1.2 Learn lessons from how medicine is tested and administered

This recommendation was made by both a legal expert in the UK, and an academic researcher in the US. The researcher is quoted as follows:

> "The food and drug administration in the US has a methodical process that when medication comes to the market they are tested in multiple hospitals and they test side effects and that decides if they are going to grant approval. That doesn't mean that there is not going to be side effects, but it means that the benefits are deemed to outweigh the disadvantages. We need to adopt a similar way of thinking."

Whilst the legal expert in the UK was quoted as follows:

> "A normal approach would be to start from the bottom up and suggest that autonomous vehicles need to be intrinsically safe to start with irrespective of what those vehicles are replacing. However, if you come from the top down and look at autonomous vehicles as a replacement for an existing imperfect (human error prone) form of transport then you start to see the safety benefits and improvements in terms of reducing death and injury. This is the same approach as finding cures for deaths in medical environments, as long as you can explain the approach in a way that does not receive an adverse public reaction then that is the best way to approach the standards."

4.2.1.3 Certify vehicles and infrastructure together in developing safety cases

This recommendation came from a researcher who is actively involved in the City Mobil 2 studies:

> "Automation will only be safe if done with infrastructure evolvement and therefore certification is key. You cannot certify an AV unless you also have the infrastructure with it, so the two are certified together. You can make the certification of infrastructure as general as possible so it covers a large percentage of the overall infrastructure. Still you need to think of an automated function which is embedded in infrastructure."

When pressed to elaborate further, the response was as follows:

"I normally use the video from Nissan (https://www.youtube.com/watch?v=NUh6KM0sTl4) which is exactly what should not be done. When you teach a computer to behave wrongly as a human would do which is over speeding in a situation in which you should slow down because there are parked cars and there is a flaw in your visibility so you never know whether there will be a pedestrian who at the last possible minute will jump in front of your car. The pedestrian (or dummy in the video) jumps in front of the car, the car detects the pedestrian and detects that there is a free space to the side to make an evasive manoeuvre. This is the worst possible behaviour you can teach to an automated car. It will kill hundreds of thousands of people. Firstly, you are given the false pretence that you can speed up in an environment in which you can't. If you want high speed driving, then you have to remove parked cars. If you allow parked cars, then you have to slow down. Secondly you are providing the driver who holds the steering wheel a false sense of security because he will think he can look around, do other things because he will think that the car will take care of this itself, which is not true. Thirdly you will have to teach the car to make choices. If you have pedestrians jumping out from both sides you will have to teach the car to choose which one to kill. This is not acceptable. You cannot teach a machine to choose which human to kill. So we must not allow the deployment of this type of technology and we have the possibility of shaping the legal framework so that these types of choices don't need to be made. The maximum speed to be set for the vehicle has to comply with the complexity of the environment that the vehicle is in. If the vehicle detects parked cars there is no evasive manoeuvre to do, you have to slow down to pedestrian speed. If this causes a problem of congestion, then you need to remove parked cars from the street. This is the overall global thinking that needs to be done when rethinking overall mobility that the innovation of automation will bring."

4.2.1.4 Continue Intelligent Speed Adaptation Research

The DfT has categorically stated within the Pathway to Driverless Cars[17] document that AVs would be prohibited from exceeding speed limits:

"Some developers of AVs have also argued that the vehicles should be allowed to adopt similar driving characteristics to human drivers, including exceeding speed limits and displaying certain 'assertive' characteristics. The Department is clear that exceeding speed limits would not be acceptable. AVs will be expected to obey all current rules of the road."

There has long been discussion about limiting the speed of manually driven vehicles, which is known as Intelligent Speed Adaption (ISA). A research paper by the University of Leeds ITS team suggests that there is more research needed into this area.

[17] DfT, The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies, February 2015 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401565/pathway-driverless-cars-main.pdf

“ISA implementation, which was originally perceived as a radical measure promoted by a fringe of safety researchers in now considered virtually inevitable even by the car manufacturing industry. However, the research is by no means complete and there are a considerable number of important aspects and issues that remain unexplored. For example, there has been relatively little systematic real-world research exploring the impact of different levels of ISA intervention, ranging from advisory to non-over ridable systems. There is little information to date on long-term behavioural adaptation to ISA and even less on long-term adaptation by non-ISA drivers to the presence of ISA vehicles. The implications of different Human Machine Interfaces (HMIs) such as the haptic throttle design used in Sweden and the “dead throttle” approach adopted in the Netherlands and the UK have not been explored. In terms of implementation strategies, the full potential benefits of ISA have hardly been touched on: issues that remain to be explored include how best to implement dynamic ISA and what are the implications of the ability, offered by ISA, to provide traffic calming at very low cost. There are also major problems on the system architecture side, which will need to be solved if a Pan-European capability is to be offered. And finally, and by no means least, the question of how ISA and non-ISA vehicles can operate side by side has not been addressed.”

This last point could be of particular relevance. With a greater roll out of AVs that will always adhere to the speed limit, it’s possible that human drivers become frustrated and be more likely to attempt risky over taking manoeuvres. In addition, automated drivers may be more cautious then human vehicles, and may even stop unexpectedly when detecting something it perceives to be a threat, but actually is not.

4.2.1.5 Undertake Legal Audit

This recommendation was made by Bryant Walker Smith[18], within which he stated:

“A legal audit should identify and analyse every statute and regulation that could apply either adversely or ambiguously to automated driving.”

4.2.1.6 Investigate whether driver hours regulations could be relaxed with respect to automated commercial vehicles

Automation offers the opportunity for driver hours’ regulations to be investigated. These are the rules which determine how many hours a driver can legally drive or do other work related to the vehicle or its load to avoid driver fatigue. Currently in Great Britain a driver must not drive for more than 10 hours per day, and cannot be ‘on duty’ for more than 11 hours per day.

On long journeys, two drivers may take turns to drive, in which case the non-driver is considered to be on duty rather than driving. It may be worth considering whether a driver who is permitted can be relieved of the driving task by automation could be considered on duty rather than driving. This would change the business case for the automation of commercial vehicles. This legislation could also be examined with respect to platooning, as discussed as part of

[18] Bryant Walker Smith, A US Legal Perspective on Automated Driving, https://www.adaptiveip.eu/files/adaptive/content/downloads/Deliverables%20%26%20papers/AdaptIVe_Legal%20Aspects%20WS_PR_Bryant%20Wal ker%20Smith_USC.pdf

4.2.2 Encourage testing of highly / fully AVs

Within the consultation exercise, a vehicle manufacturer developing automated systems for heavy goods vehicles indicated that it should be easier to undertake testing. Infrastructure issues such as a lack of detailed mapping data and quality of road markings were cited as barriers to AVs. The City of Chicago is taking steps preparing itself to be a testing ground for automated driving by identifying "innovation zones". Brenna Berman, Chief Information Officer (CIO) at Chicago's Department of Innovation and Technology reportedly said:

> "When you're dealing with the built environment, there are city processes that can slow you down," she said. "Anything from permitting to installation to even identifying the best neighbourhood for the technology you're looking at. What we want to do with those innovation zones is kind of pre-approve and prep certain neighbourhoods across the city to pilot a technology."[19]

This relates to one of the recommendations made by Sir Mark Walport and Professor Dame Nancy Rothwell from the Council for Science and Technology in their letter to the Prime Minister, dated 23rd July 2015 [20]:

> "The government should work with business to create the world's first 'real world lab': an area in a busy UK town where autonomous and connected vehicles and their networks can be used and tried."

4.2.2.1 Define Georgraphic Areas for AV Testing

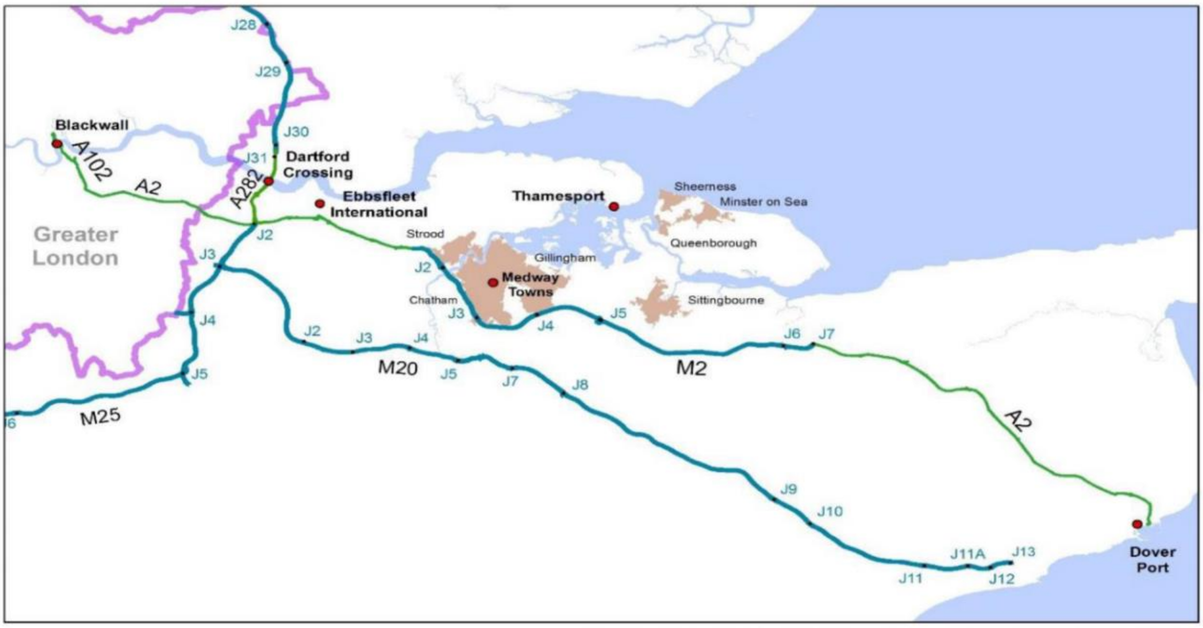
It is suggested that specific geographic zones are defined for automated driving and arrangements to make testing and deployment of AVs within the zone as straightforward as possible. Such arrangements might include:

- Describing how the quality of markings and signage will be ensured within the zone.
- Ensuring that high quality digital maps of the zone are available.
- Describe how debris and foreigh objects would be kept to a minimum. This might include minimizing the risk of animals entering the highway.
- Describe how special arrangement for roadworks could be put into plae. Any changes to the road network of this type would need to involve updates to the detailed maps.
- Safe harbor areas for high speed routes so that vehicles can stop safely should they need to.
- Investigate installation of Vehicle to Everything (V2X) equipment within the zone.
- Establishing arrangements with the local highways authority and local police.

[19] ChicagoInno website, 9th Jan 2015 http://chicagoinno.streetwise.co/2015/09/01/chicago-is-identifying-innovation-zones-to-testdriverless-cars-in-mayors-new-beta-city-initiative/

[20] Council for Science and Technology, Letter to Prime Minister, 23rd July 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/459521/cst-15-1-driverless-vehicles.pdf

The TSC were informed by DfT that two areas of particular interest include automated motorway driving and automated valet parking, so these two environments are obvious candidates for such zones, as well as the 'busy UK town' as suggested by Sir Mark Walport. In terms of automated motorway driving, the A2 / M2 has already been chosen as a "connected corridor" to enable high quality communications along the A2 / M2 from Dover to the Blackwall Tunnel. The intention is that by providing the infrastructure, automotive manufacturers, traffic managers and app developers could pilot and develop new products.



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Department for Transport gisu1415j140

FIGURE: 4-5: A2 / M2 Connected Corridor (Source DfT)

One reason that the A2 / M2 corridor was chosen is because it connects one of the UK's busiest container ports at Thamesport with the Cross-Channel port at Dover. Within the consultation exercise, the movement of freight was highlighted as one of the early potential applications for AVs as there is a clear business case for reducing fuel costs through initiatives such as platooning, and in the longer term Driver Hours Regulations could be revisited in light of the increasing automation of vehicles and the reduced workload of the driver. It may be beneficial to trial not just the connectivity aspects of the corridor, but also the potential for vehicle automation along the corridor. There are references in literature to the greatest benefits resulting from 'connected automation', as summarised by Figure 4-6, taken from a presentation by Frans op de Beek representing the Amsterdam Group. The the A2 / M2 corridor could offer one of a number of test environments for AVs.

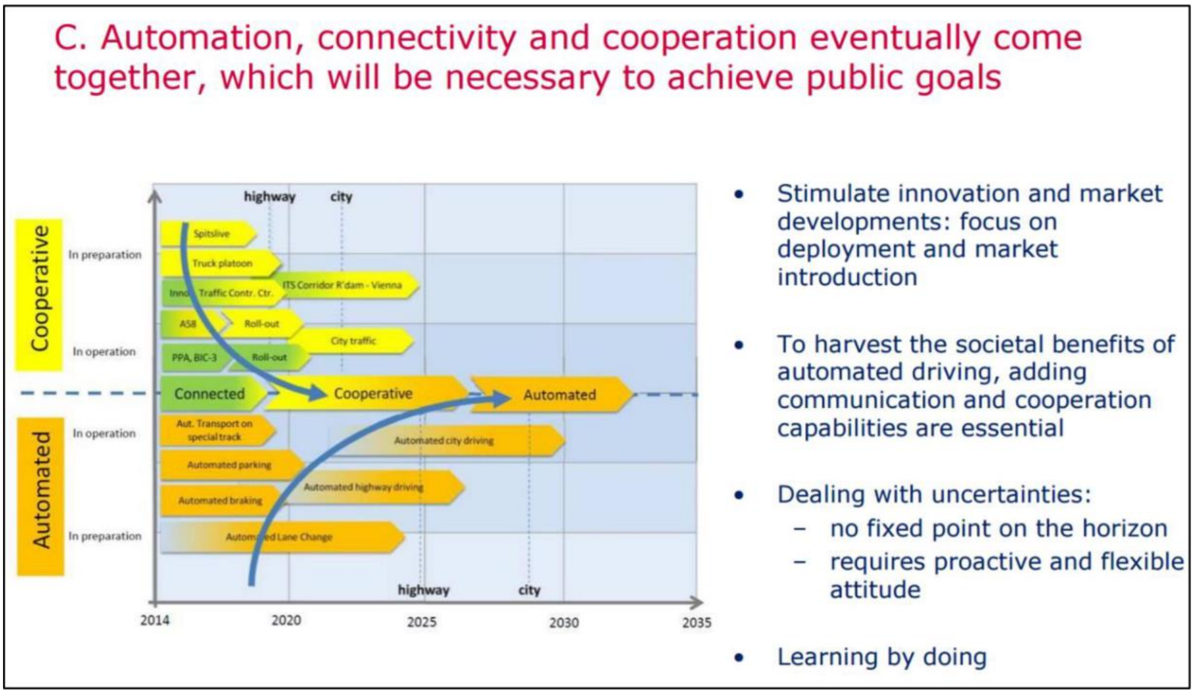

FIGURE: 4-6: Slide from "Cooperation in the field of Automated and connected driving", Frans op de Beek, Amsterdam Group[21]

As discussed as part earlier in this section, car parks could be identified for the trialling of automated valet parking systems, and arrangements with the car park operators could be agreed in advance and the installation of V2X infrastructure could be explored at an early stage. This is an area that the Greenwich "Gateway" driverless car project will be looking at, so close cooperation with the progress of this project will be required. A range of road types could be offered to researchers for testing purposes. Some examples, along with potential challenges for AVs, are outlined as follows:

- Motorways. Often cited as one of the less complex environments due to prohibition of vulnerable road users, absence of complicated junction types, high standard of carriageway maintenance, clear markings and generally predictable behaviour of other vehicles. They often provide a hard shoulder, which could act as a safe harbour area for AVs, although stationary vehicles on the hard shoulder are still at risk from vehicles that deviate from the nearside lane. Could include Motorway junctions and slip roads.
- Motorway service stations. Includes acceleration and deceleration lanes and low speed car parking areas. Often car park designs can be complex in terms of one-way systems, non-standardised signage and markings. High numbers of pedestrians, which can be obscured by parked vehicles.
- Two / three lane dual carriageway subject to national speed limit. Similar to motorways but can include roundabouts, signalised and priority controlled junctions. Often do not offer hard shoulder, so an AV may not be able to stop safely. Road markings may not be as comprehensive as for motorways. Possibility of pedestrians crossing carriageway or cyclists using carriageway.
- Two / three lane dual carriageway subject to 40 / 50 mph speed limit. As above, but potentially less risky due to lower speed, but may feature a higher number of pedestrians, cyclists, crossing points and junctions.

[21] https://amsterdamgroup.mett.nl/Downloads/downloads_getfilem.aspx?id=506556

- Two-way single carriageway roads subject to national speed limit. One of the most dangerous types of road due to the potential for high speed impacts between vehicles travelling in opposite directions. Used by pedestrians and cyclists. Rarely offers the ability to stop safely on the carriageway. Can include all types of junction. Can be rural in nature, and animals can be obscured by hedgerows to the roadside. Road markings, signage and surface quality can be highly variable and sightlines and road signage can become compromised by foliage.
- Urban roads subject to 30mph or lower. Stopping on the carriageway is less risky due to lower vehicle speeds. Potentially much higher numbers of pedestrians, cyclists, crossing points and junctions. Junctions can include poorly marked mini-roundabouts, for example, and zebra crossing where an AV would be expected to give-way to pedestrians, which may present challenges. Vehicle to Infrastructure (V2I) connectivity could be beneficial, particularly at signalised junctions and crossings.
- Pedestrian areas. Lower speeds reduce the potential for high speed collisions and offers the opportunity of true 'door-to-door transport'. Unpredictability of pedestrians can present challenges. Pedestrian network was not designed for vehicle use, and the pavement is not constructed to vehicle standards. Progress of a vehicle will be highly dependent on pedestrian density. Vehicles will often still need to cross carriageways to complete a journey.
- Car parks. Low speed environment. Often car park designs can be complex in terms of one-way systems, non-standardised signage and markings. High numbers of pedestrians, which can be obscured by parked vehicles. V2I connectivity could be investigated in advance of trials. Road type is one variable when it comes to testing and operating AVs. Other variables are nicely summarised by a diagram from a report by the International Transport Forum[22]:

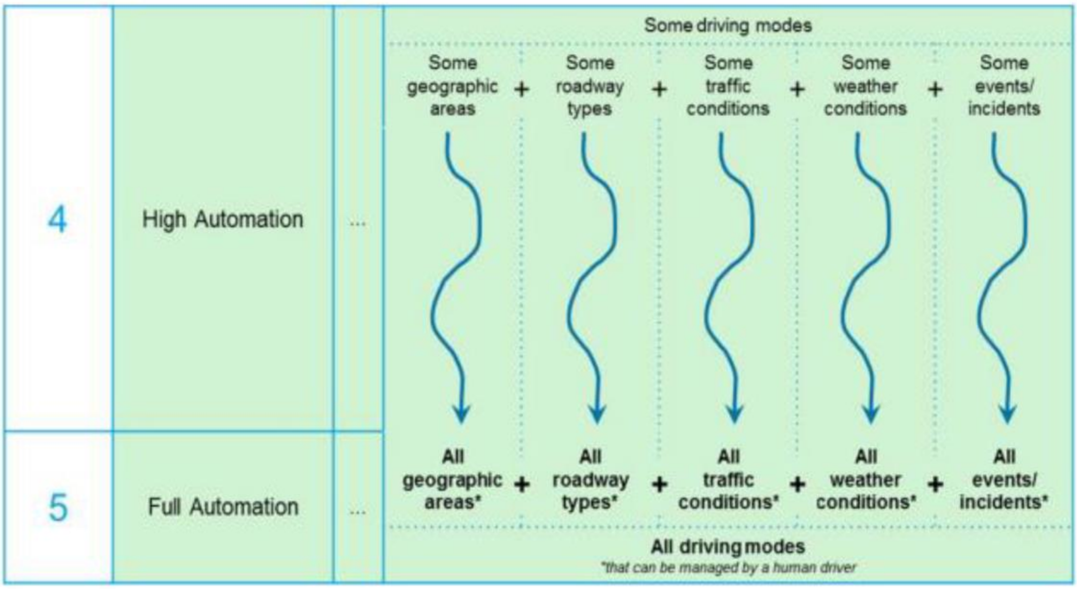

FIGURE: 4-7: Transitio from high to full driving automation across different contexts (source: International Transport Forum)

[22] http://www.internationaltransportforum.org/Pub/pdf/15CPB_AutonomousDriving.pdf

4.2.2.2 Facilitate open simulation environment for testing and assessing AVs

With reference to testing, and to the question of how safe highly and fully AVs need to be, it may be essential to not just test in real world environment but also within virtual environments. This initiative corresponds to a stakeholder comment from a researcher who specialises in IT innovations:

> "[An open simulation environment] could make an independent assessment of the capabilities of selfdriving cars much easier. The idea would be that one would set up a project and define a simulation system where car manufacturers would plug in the software system and plug in the sensors then the simulation would send them the data that a LIDAR receives and the data a camera would see and we could observe how the car operates. If such a simulation was available and open, it would be much easier to put in roads, traffic situations that companies and developers could use to train their cars and at the same time you could establish a standard that is capable of testing the quality of the cars which would also help us to make a clear case to the public that we don't just rely on the companies themselves but we have evidence that the cars can do what they say they can. This would also bring stakeholders together. Everybody who builds self-driving cars run simulations, but they are not necessarily simulations of the whole car with all sensor information coming in, but are often on the level of specific functions within the car. Only in 2014 did Google announce that they are capable of simulating the entire car with full sensor data for a couple of thousand miles of US roads with very realistic simulations. I don't think this is something you'd find in auto companies."

With reference to testing, and to the question of how safe highly and fully AVs need to be, it may be essential to not just test in real world environment but also within virtual environments. This initiative corresponds to a stakeholder comment from a researcher who specialises in IT innovations:

As reported by the Guardian[23], and numerous other sources, in August 2014:

"Google has built a "Matrix-style" digital simulation of the entire Californian road system in which it is testing its self-driving cars – and is lobbying the state's regulators to certify them based on virtual rather than real driving. The extensive simulation exists entirely inside computers at the company's Mountain View location, and the cars have so far virtually "driven" more than 4 million miles inside it, facing challenges just like those in the real world, such as lane-weaving motorists, wobbly cyclists and unpredictable pedestrians." "California's regulations stipulate autonomous vehicles must be tested under "controlled conditions" that mimic real-world driving as closely as possible. Usually, that has meant a private test track or temporarily closed public road. But Ron Medford, Google's safety director for the self-driving car programme, has been arguing that the computer simulation should be accepted instead. In a letter in early 2014 to California state officials, which the Guardian has obtained under freedom of information legislation, Medford wrote: "Computer simulations are actually more valuable, as they allow manufacturers to test their software under far more conditions and stresses than could possibly be achieved on a test track." He added: "Google wants to ensure that [the regulation] is interpreted to allow manufacturers to satisfy this requirement through computer-generated simulations.""

The article goes on to state:

""In a few hours, we can test thousands upon thousands of scenarios which in terms of driving all over again might take decades." A key improvement from the digital simulator is helping the computer running the car figure out situations that human drivers typically navigate with social signals, like lane changes, merges and four-way stops. "It's not just about the physics of avoiding a crash," says [Google spokeswomen Katelin] Jabbari. "It's also about the emotional expectation of passengers and other drivers.""

A first step could be to consult with the industry on the whether such a system would be of use, to investigate technical specifications that would enable various ACSs developed by different organisations to interface with the simulator platform (which may or may not be technically feasible) and discuss potential industry collaborations to formulate into a programme of works. It could be that developing such a simulator as a unique asset could benefit the UK, and the UK road network could be installed into the simulator to enable developers to test their systems virtually on UK roads.

[23] The Guardian, "Google lobbies to test self-driving cars in Matrix-style virtual world", August 2014 http://www.theguardian.com/technology/2014/aug/21/google-test-self-driving-cars-virtual-world-matrix

4.2.2.3 Incentivise vehicle makers to take part in deployments

A US researcher that we consulted with suggested that vehicle makers have more to lose than to gain from taking part in deployments, and therefore financial incentives and making sure that liability is managed is key.

4.2.2.4 Acertain mapping / infrastructure requirements of those developing technology

This relates to 4.1.1.4 which discusses infrastructure requirements for ADAS features, and could include the following activities.

4.2.3.1 Investigate adaptation of road works procedures

Ideally, AVs would need real-time, detailed information regarding road works, and other variances in the transport system. For road works on a motorway, for example, they would need to know whether they are formed of cones or concrete barriers. They would need to know exactly where they start and end. They would need to know the exact times that they are implemented and removed. Procedures would need to be adapted to ensure all of the various third parties that undertake such road construction activities record and submit the information in an accurate and standardised manner, and this would be particularly challenging. This initiative results from a number of stakeholder comments relating to barriers to AVs, and also from a report from the RAND Corporation[24], which stated:

> "Transportation agencies could further maintain and provide online, real-time, detailed records of construction and other variations in the transportation system…Such efforts would aid both AVs and human drivers who could use such up-to-date information for real-time route planning."

4.2.3.2 Consider installing infrastructure to vehicle (I2V) equipment

A stakeholder for a Tier 1 supplier, who is working at the cutting edge of AV technology, commented:

> "Certain things are very difficult to interpret with a high degree of reliability, one of which is traffic lights. For example, if the traffic light is occluded by a truck, and if the truck has a light in exactly the same position as the occlusion occurs, so high up with some green or red spot then the vision algorithms gets confused because the software is expecting a light but may interpret the light on the truck as the traffic light. I think if automated driving is implemented you need V2X on traffic lights."

As discussed in relation to AVP, I2V could also help vehicles to locate car parking spaces and generally could help vehicles to 'see' what is outside of visual range. There is much discussion regarding whether connectivity is a requirement for automation, but there seems to be a growing consensus that the greatest benefits are achievable with a combination of connectivity and automation.

[24] RAND, Autonomous Vehicle Technology: A Guide for Policymakers, 2014 http://www.rand.org/pubs/research_reports/RR443-1.html

4.2.3.3 Consider implementation of segregated automated driving zone to reduce variables

This issue seems to divide opinion amongst experts, but some advocate that segregation of AVs would aid deployment, at least in the early years. The complexity of traffic movements within mixed user environments was cited as one barrier to automation, so reducing this variable seems logical if it is possible. It may also assist with public acceptance as the public would know clearly where they are likely to interact with an AV. Others suggest that such a solution will never be scalable, and for AV technology to have a significant impact on travel behaviour the intelligence within the vehicle needs to be able to cope with mixed traffic environments. It may be worth considering more permanently allocating infrastructure to the use of AVs, such as reallocating disused rail lines as AV roads. There have been suggestions that a planned orbital tunnel around London could be used exclusively but AVs [25]. Such assumptions could dramatically change the design criteria for such infrastructure, and impact on the required visibility, lane widths, signage, markings, signals etc.

4.2.4 Consider the type of transport system needed / desired in the future

It is important to think carefully about the type of transport system needed in the future, and we use this thinking to shape policy decisions. For example, we need to limit the environmental impact of transport, whilst at the same time provide travellers with options that limit journey time, guarantee journey time reliability and provide with a high degree of safety and security. We want to ensure transport is accessible to all. We might want to ensure journeys are as pleasant as possible and stress is minimised. We might want to provide the means to engage in work and leisure activities whilst travelling. ‘Traveller Needs’ was the subject of a large study undertaken by the TSC, and the results should be carefully considered when planning for highly and fully AVs [26].

4.2.4.1 Undertake scenario modelling to look at optimum vehicle size, deployment patterns

Modelling could have an important role to play in helping to decide how best to implement AVs, particularly in terms of public transport provision. Interesting studies have already been completed, such as Urban Mobility System Upgrade[27], which looked at the changes that might result from the large-scale uptake of a shared and self-driving fleet of vehicles in the City of Lisbon. The study explored two different self-driving vehicle concepts, for which they used the terms “TaxiBot” and “AutoVot”. TaxiBots are selfdriving cars that can be shared simultaneously by several passengers. AutoVots pick-up and drop-off single passengers sequentially. The report looked at impacts on car fleet size, volume of travel and parking requirements over two different time scales: a 24-hour average and for peak hours only.

What they found is that TaxiBots, combined with high-capacity public transport, could remove 9 out of every 10 cars in a mid-sized European city. Even in the scenario that least reduces the number of cars (AutoVots without high-capacity public transport), nearly eight out of ten cars could be removed.

In terms of impacts on congestion, a TaxiBot system in combination with high-capacity public transport uses 65% fewer vehicles during peak hours.

[25] ITS International, Report proposed autonomous transport system for London, 14th July 2014 http://www.itsinternational.com/categories/utc/news/report-proposes-autonomous-transport-system-for-london/

[26] Transport Systems Catapult, Traveller Needs and UK Capability Study, October 2015 https://ts.catapult.org.uk/traveller-needs-and-uk-capability-study 27 International Transport Forum / CPB, Urban Mobility System Upgrade, How share self-driving cars could change city traffic, May 2015 http://www.internationaltransportforum.org/Pub/pdf/15CPB_Self-drivingcars.pdf

[27] International Transport Forum / CPB, Urban Mobility System Upgrade, How share self-driving cars could change city traffic, May 2015 http://www.internationaltransportforum.org/Pub/pdf/15CPB_Self-drivingcars.pdf

An AutoVots system without public transport would still remove 23% of the cars used today at peak hours. However, overall vehicle-kilometres travelled during peak periods would increase in comparison to today. For the TaxiBot with high-capacity public transport scenario, this increase is relatively low (9%). For the AutoVot car sharing without high capacity public transport scenario, the increase is significant (103%). While the former remains manageable, the latter would not be. This is strong evidence to indicate that where congestion is an issue, travellers should be encouraged to travel within the same vehicle as others. A study could look at the most appropriate vehicle size, in terms of the number of passengers that can be accommodated. In all cases examined, self-driving fleets completely removed the need for on-street parking. This is a significant amount of space, equivalent to 210 football fields or nearly 20% of the kerb-to-kerb street space in our model city. Additionally, up to 80% of off-street parking could be removed, generating new opportunities for alternative uses of this valuable space. It should be considered within long term land use planning that there may be less demand for car parking in the future, although it is not easy to predict exactly when, and the scale of reduced demand as it is dependent on the unpredictable deployment of AVs.

4.2.4.2 Consider updates to design and planning documentation

In light of the above, and as recommended by one stakeholder who works in the transport planning industry, it could be beneficial to start considering updates to documents such as:

- DMRB volume 9 is titled 'Network - Traffic Control and Communications', so could start to include references to V2X connectivity. Also consider whether standards need to be or could be amended in light of ADAS features on vehicles, and increasing levels of automation.
- Manual for Streets. This document could start to consider not just connectivity at a more local level and review geometric design criteria in light of the requirements of ADAS enabled vehicles and increasing levels of automation. It could start to explore providing pathways for fully AVs, such as the City Mobil 2 style shuttles, delivery robots, and Low-carbon Urban Transport Zone (LUTZ) Pathfinder style pods.
- Local planning documents. A number of studies and experts are predicting that a shift to shared vehicle ownership models and AVs that could drop off passengers and continue to another destination could lead to significantly less parking required within towns and cities. Long term plans could take this into account, and start to consider the value of the land currently used for parking and what other uses might be appropriate.

4.2.4.3 Update Guidance on Transport Assessments

Transport modellers are required to model future year scenarios as part of Transport Assessments for new developments, which can look 10 or 15 years into the future. These type of assessments could start to take into account scenarios that include AVs. Transport Assessment could also begin to investigate alternative public transport models that include smaller, demand responsive automated buses, as discussed under recommendation 4.1.4.2.

4.2.4.3 Address Public Acceptability Concerns

There is evidence that public attitudes towards vehicle automation technology are changing and the public are more willing to entertain the concept of driverless road vehicles than previously. However, what often gets lost in the reporting of such technology are the considerable potential benefits, not just in terms of safety but also in terms of accessibility and providing mobility options for those that cannot drive or choose not to drive. Ensuring public acceptability is considered by a legal expert that was consulted as crucial if fully AVs are to be legally permitted:

> "Because so much depends on the public accepting that these vehicles will not be perfect in every single environment and situation, a key development is to ensure that the public are educated regarding the acceptable risks that autonomous vehicles pose. As a general concept, you can only implement legislation and regulations when it will be generally publically acceptable to do so. It is extremely rare that a law is brought in when there is not at least an undertone of public acceptance. Law is there to regulate public behaviour in accordance with rules and regulations that the public views to be appropriate. A key development for facilitating autonomous vehicles is therefore gradually building public trust, confidence and acceptance that these vehicles will exist and will operate in public environments and that they will, occasionally and far less frequently than human controlled vehicles, be involved in accidents."

4.2.5.1 Publicise benefits

One suggestion from a stakeholder is to work with the Department for Education to encourage the subject to be studied in schools. The suggestion was that if school children become excited about the idea, they would communicate this to their parents. A further suggestion was to investigate policy documents across Government and ensure that, where appropriate, they take account of the potentially changing mobility environment over the coming decades.

4.2.5.2 Commission study into positive and negative impacts of AVs

Numerous studies have been undertaken, such as Studies could be undertaken to attempt to fully understand the potential benefits and impacts on all aspects of the UK economy.

4.2.5.3 Develop a 'Break the Glass' plan for automation incidents

A recommendation taken from Bryant Walker Smith[28] is to develop a 'Break the Glass plan' for automation incidents:

> "Who will respond publicly to a crash, and how? What relationships will be essential to effective coordination? What evidence and information will need to be preserved, and how? Especially if officials have publicly embraced the potential of these technologies, how will they address any fear or outrage that results from a high profile crash, regardless of where it occurs? A government that addresses these issues proactively and ultimately positively signals its credibility as a potential technological partner."

[28] Bryant Walker Smith, A US Legal Perspective on Automated Driving, https://www.adaptiveip.eu/files/adaptive/content/downloads/Deliverables%20%26%20papers/AdaptIVe_Legal%20Aspects%20WS_PR_Bryant%20Wal ker%20Smith_USC.pdf

4.3 Cooperative ITS Opportunities

Taking the European Road Transport Telematics Implementation (ERTICO) definition[29], Co-operative ITS is a subset of overall ITS that communicates and shares information between ITS Stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort. ITS Stations can be units installed in vehicles, at the road side, in traffic control/management centres, in service centres, or in hand-helds. The ERTICO document also sets out potential applications and use cased of CITS:

Basic Set of Applications definitionApplications Class	Application	Use case
Active road safety	Driving assistance - Co-operative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance - Road Hazard Warning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle - accident
		Stationary vehicle - vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data - Hazardous location
		Decentralized floating car data - Precipitations
		Decentralized floating car data - Road adhesion
		Decentralized floating car data - Visibility
		Decentralized floating car data - Wind
Cooperative traffic efficiency	Speed management	Regulatory / contextual speed limits notification
		Traffic light optimal speed advisory
	Co-operative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Co-operative local services	Location based services	Point of Interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software / data provisioning and update
		Vehicle and RSU data calibration.

Table 2 ETSI Basic Set of Applications (BSA), Source: ETSI TR 102 638 V1.1.1 (2009-06) 18

FIGURE: 4-1: ETSI Basic Set of Applications (BSA), Source: ERTICO report

This mind map shown in Figure 3-5 illustrates a number of measures which will seek to accelerate the deployment C-ITS. The following section sets out further detail in respect to some of the contents of the mind map. A general recommendation with regards to connectivity came from a representative of the telecommunications industry:

[29] As detailed within "Guide about technologies for future C-ITS service scenarios", ERTICO ITS Europe, March 2015, http://www.telematicsvalley.org/assets/Guide-about-technologies-for-future-C-ITS-services-v1-0.pdf

> "10 years ago the emphasis from the DfT was very much about road safety and we've done a fantastic job of reducing accidents on the road from distracted driving and so on. But for the next 10 years they need to be thinking much more about how can data analytics improve the five things: safety, environmental, congestion, accessibility and economic/industrial benefit. I don't think we've done enough on those five looking forward to the future."

4.3.1 Promote more joined up thinking within Government / Adopt a Digital First Strategy

These two recommendations were made by a telecommunications industry stakeholder:

> "I would like to see as an outcome the DfT adopt a Digital First strategy where they accept that data and data analytics is the new oil and that starts to put in place projects and programmes that will lead towards every vehicle being connected by a given date. We think that things holding this up are not just within the DfT but the way in which the DfT works with the Department for Business Innovation and Skills (BIS). It tends to be car manufacturing is more in BIS, whereas roads are more in transport, so there needs to be a more joined up approach between the DfT and BIS. Clearly because connectivity and telecoms sits within the Department for Culture, Media and Sport (DCMS) the three departments should work together more closely. A specific example: the Automotive Council sits in BIS, it doesn't typically talk to the Information Economy Council which sits partly in BIS and partly in DCMS. In order to deliver the Digital First vision, in which data is the new oil, of every vehicle being connected there will need to be a joined up approach."

4.3.1.1 Learn from the German Industrial 4.0 Strategy

Industry 4.0, or the fourth industrial revolution, is a term first used at the Hannover Fair in October 2012 to describe a high-tech strategy of the German government which promotes the computerisation of manufacturing. It is of relevance to automated and connected vehicles as automation and connectivity are at the heart of the strategy.

4.3.2 Investigate data management

In today's digital world, those who can access and analyse data have significant advantages, and the power of data is huge. As described above, data is the new oil. Therefore, investigating the management of data in relation to connected vehicles is of key importance.

4.3.2.1 Open more datasets

With reference to the previously mentioned report by ERTICO on the Communication Technologies for future C-ITS Scenarios:

> "The challenge and the opportunity for ITS is to realise scenarios where the effective sharing of information achieves benefits for a broad and diverse stakeholder community justifying the efforts and costs. It should be ensured that data generated anywhere in the traffic system is made useful to as many travellers and stakeholders as possible using all available communication channels already from the start of deployment, in order to maximise the value of the investments and accelerate the deployment and uptake of the services."

4.3.2.2 Can infrastructure cope with data demands?

If, as outlined above, all vehicles are to be connected, investigations would be needed into whether the UK has the capacity and bandwidth to collect and send the vast amounts of data, for example from 22 million vehicles.

4.3.2.3 Investigate storage options

There are big questions surrounding where data is to be stored, and how to keep it secure. If real-time critical decisions are being made based on the data, security will be paramount.

4.3.2.4 Consider mandating data sharing

This initiative relates to particular recommendations from literature, as well as observations from stakeholders, an example of which is included in a report by ERTICO[30].

> "The challenge and the opportunity for ITS is to realise scenarios where the effective sharing of information achieves benefits for a broad and diverse stakeholder community justifying the efforts and costs. It should be ensured that data generated anywhere in the traffic system is made useful to as many travellers and stakeholders as possible using all available communication channels already from the start of deployment, in order to maximise the value of the investments and accelerate the deployment and uptake of the services."

KPMG, in conjunction with the Society of Motor Manufacturers and Traders (SMMT) produced a report which stated the following on this subject[31]:

> "Current data protection laws again are substantially sufficient to deal with personal locational data collected by vehicles and consumers already have some experience of 'opting in' to data sharing on their smartphones. However, to unlock the societal benefits of data sharing it may be that some limited level of mandatory data sharing is desirable such as that being achieved through the EU's ecall initiative expected to be implemented in 2018."

It is understood from stakeholders that working on behalf of highways authorities that data from connected vehicles could be extremely valuable in assisting with the operation and maintenance of the road network, as summarised by the following comments, which were made by two separate stakeholders representing highway authorities:

[30]ERTICO, Communication Technologies for future C-ITS service scenarios, March 2015
http://ertico.assetbankserver.com/assetbankertico/action/viewAsset;jsessionid=DC67CC4D9F7AC1803664F2F65A3D6553?id=13199&index=38&total=144&collection=ITS%20 Deployment&categoryId=38&categoryTypeId=1&filterId=0&sortAttributeId=1&sortDescending=false&movedBr=null

[31] KPMG, Connected and Autonomous Vehicles – The UK Economic Opportunity, March 2015
http://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UKEconomic-Opportu...1.pdf

> "There is potential for significant improvement in the richness of the data that we've got about how the network is operating, so if you've got information to and from vehicles on the network in real time you can manage the network more efficiently."
>
> "We're interested in getting information to drivers to try to influence their mode choice and route choice and by having connected vehicles can see the benefit in having far more granular data on the road network. The more connected cars you have, the more improvement to the richness of the data, which is a major benefit."

4.3.2.5 Review Navigation Options that Exist

This suggestion came from a stakeholder from the telecommunications industry:

> "It's time to review some of the navigation options that exist in relation to vehicles not just for accuracy but because the data that comes from it will depend on the accuracy and having some common themes. The Satellite Applications Catapult could be commissioned to do a review of the navigation systems that exist to talk about levels of accuracy and talk about any improvements in terms of understanding to the vehicle owner and the third party recipient of data."

4.3.2.6 Investigate who should own the data

Related to storage and access to data is the whole question of ownership of data. Some stakeholders suggested that data should be owned by those that generated it. There could be mechanisms under which data could be sold. The public could be offered benefits in exchange for data, which is essentially how retail loyalty schemes operate. By clarifying who owns what data, generating business models to support connected and AVs will become much easier.

4.3.3 Deploy connected vehicle technology on public sector vehicles and encourage amongst fleet operators

A number of local authority stakeholders that we spoke to were enthusiastic about the potential benefits of connected vehicles in terms of the richness of data about the status of the transport network. It may be possible for connected vehicles to provide a wealth of information in real time about traffic conditions on the network, as well as on the status of the infrastructure such as pavement condition, pot holes, signage and markings, etc. An example of one application is the 'Pothole Alert' research being undertaken by Jaguar Land Rover (JLR) and Coventry City Council.[32]

[32] JLR Media Centre, "Jaguar Land Rover Announces Technology Research Project To Detect, Predict And Share Data On Potholes", 10th June 2015 http://newsroom.jaguarlandrover.com/en-in/jlr-corp/news/2015/06/jlr_pothole_alert_research_100615/?locus=1

FIGURE: 4-8: Pothole Alert Research, source: Jaguar Land Rover

Private sector vehicles could be used to trial these type of connected vehicle applications, and could also aid the chicken and egg problem surrounding vehicle to vehicle applications, as outlined by the US DoT in their report[33]:

"The cooperative nature of the connected vehicle environment generally precludes traditional topdown central planning of connected vehicle application deployments. For example, V2I safety applications using Dedicated short-range communications (DSRC) will not provide benefit until both vehicles and infrastructure have been enabled with DSRC communications. As such, it becomes difficult to justify the benefits of infrastructure deployment until a certain number of vehicles with V2I capabilities have been deployed—a condition which is outside the control of the agency deploying the infrastructure. On the other hand, the vehicles will not necessarily be equipped with V2I safety applications until the infrastructure is deployed—a condition which is outside the control of the vehicle and aftermarket manufacturers. Solutions to this deployment challenge could come from taking advantage of opportunities where public agencies control the vehicles as well as the infrastructure—for example, in transit fleets, or among their own maintenance vehicle fleets. The DoT Operations and Maintenance scenario advances this opportunity with specific connected vehicle applications. Agencies might also initiate connected vehicle application deployment partnerships with private fleets—commercial vehicle operators or rental car fleets."

[33] USDOT, National Connected Vehicle Field Infrastructure Footprint Analysis, 27th Dec 2013 http://stsmo.transportation.org/Documents/Task%206a%20AASHTO_CV_Footprint_Deployment_Scenarios_v2.pdf

The SCOOP@F project is a C-ITS project being undertaken at five pilot sites in France by a consortium which includes the French Ministry of Transport. Within this project it is planned to retrofit highway patrol vehicles with on-board units.[34]

- A number of actions could be undertaken as part of this initiative, such as:
- Compile an itinerary of existing public sector vehicle fleets and levels of connectivity.
- Consult with various organisations on the principle of fitting additional equipment into the fleet. Such organisations might include emergency services, local authorities, Highways England etc.
- Investigate what data would be of most use to local authorities and Highways England, and in what format.
- Look in detail at potential technology solutions that can provide that data, including any changes required to back-end systems to make use of it.
- Investigate business case for installing equipment.
- Initiate a field trial of chosen technology.

It could be possible to partner with or incentivise non-private sector vehicle fleet operators, such as bus companies, vehicle hire companies, etc., to install equipment on their vehicles.

4.3.4 Investigate Standards

Standards are of key importance in the automotive and telecommunications industry. But what is a standard? Put simply, a standard is an agreed way of doing something - the distilled wisdom of people with expertise in their subject matter area and who collectively know the needs of the various stakeholders. Another of the recommendations made by Sir Mark Walport and Professor Dame Nancy Rothwell from the Council for Science and Technology in their letter to the Prime Minister, dated 23rd July 2015[35]:

> "Recommendation 2: The government should identify areas where it can usefully develop standards for key parts of the operating systems for autonomous and connected vehicles. It should work with business, the British Standards Institution and international partners to develop relevant standards and to promote their international adoption. Where appropriate, standards may include related UKowned intellectual property."

[34] Project SCOOP presentation, Guy Fremont – SANEF, September 2015 http://www.codecs-project.eu/fileadmin/user_upload/pdfs/Workshop_C-ITS_Deployment/Fremont_Scoop%40F.pdf

[35] Council for Science and Technology, Letter to the Prime Minister, 23rd July 2015 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/459521/cst-15-1-driverless-vehicles.pdf

A representative from Transport for London (TfL) stated:

> "…out of 100% of what is needed to see technology uptake, maybe 20% could be influenced by what the public sector does. The rest is what the private sector does, but what is in the 20%? What are the minimum standards of predictability, interoperability and reliability that we need to ensure and how does this compare to international standards so that we can get on with work that only the public sector can do and the likes of Ford and Siemens and Apple can get on with the exciting technology development and bring it to market."

Amongst the suggestions raised by stakeholders:

- Different communications standards are required for safety critical applications compared to nonsafety critical applications.
- Existing standards need to be mapped and a gap analysis undertaken to identify those that require development.
- There is a desire within industry for global standards to be defined, as car manufacturers and telecommunications providers would not necessarily appreciate different standards for the UK compared to internationally.
- There was a suggestion that DfT need to help to define requirements for 5G, other than low latency.
- Commission a study into on-board Wi-Fi. One telecommunications expert explained that the best solution for connectivity will probably be a combination of cellular and Wi-Fi.

Standards around car apps need investigation to ensure that they are not a security threat to the other vehicle systems. The following comment related to car app stores:

> "There should be a study of car apps stores. I think car apps stores could be both dangerous and an opportunity. An example of danger is somebody putting apps in a car app store which causes a cybersecurity nightmare - an accident or theft even. The apps that could benefit society are those that have a certification process that have investigated things like cyber security, data theft, so we know where the data is going to go when an app is downloaded from a car app store. At present there are two types of car app store that exists. The ones that are proprietary, for example BMW, so if you have a BMW car then the only world you are in is BMW. That seems wrong as if you want to take the app from one car to another you can't. The web based app stores are more open. Examples include Mojio (https://www.moj.io/). We need to know which car app stores are out there and which ones are fit for purpose for UK roads. I don't want heavy handed regulation but I think it makes sense to have a study of the car app stores and their safety orientated processes."

4.3.5 Update guidance on driver distraction

It was suggested that driver distraction laws could be examined in relation to ADAS features (reference 4.1.2.3), but equally they could be looked at in relation to connectivity applications which divert the driver's attention from the driving task. As stated by the Royal Society for the Prevention of Accidents (RoSPA):

> "A substantial body of research shows that using a hand-held or hands-free mobile phone while driving is a significant distraction, and substantially increases the risk of the driver crashing. Drivers who use a mobile phone, whether hand-held or hands-free:
>
> - are much less aware of what's happening on the road around them
> - fail to see road signs
> - fail to maintain proper lane position and steady speed
> - are more likely to 'tailgate' the vehicle in front
> - react more slowly, take longer to brake and longer to stop
> - are more likely to enter unsafe gaps in traffic
> - feel more stressed and frustrated.
>
> They are also four times more likely to crash, injuring or killing themselves and other people. Using a hands-free phone while driving does not significantly reduce the risks because the problems are caused mainly by the mental distraction and divided attention of taking part in a phone conversation at the same time as driving."

With an increasing amount of technology at driver's fingertips, it may be beneficial in the interests of road safety to review the law and guidelines relating to driver distraction. This might include a review of car app stores, for example, and how apps designed for use whilst driving are certified as safe. In the U.S., the NHTSA has published guidelines on this topic.[36] These are non-binding, voluntary guidelines to promote safety by discouraging the introduction of excessively distracting devices in vehicles.

4.3.6 Adopt a Digital First Strategy

Refer to 4.3.1 for further information.

[36] NHTSA, Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices http://www.distraction.gov/downloads/pdfs/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronicdevices.pdf

4.3.7 Investigate and Promote Platooning / C-ACC

Platooning involves two or more vehicles travelling very close to each other and linked electronically so that the driver of the lead vehicle has both longitudinal and latitudinal control of following vehicles. This enables drivers of subsequent vehicles to be relieved of the driving task whilst the vehicle is under the control of the driver of the lead vehicle. It is usually considered for heavy goods vehicles, although passenger vehicles could also form or join platoons.

Platooning saves fuel because the close proximity of the vehicles reduces drag, and there have been numerous studies demonstrating considerable fuel savings. Platooning could also lead to smoother traffic flow, with less vehicles braking and accelerating independently of each other.

Platooning also offers the opportunity for driver hours' regulations to be investigated. These are the rules which determine how many hours a driver can legally drive or do other work related to the vehicle or its load to avoid driver fatigue. Currently in Great Britain a driver must not drive for more than 10 hours per day, and cannot be 'on duty' for more than 11 hours per day.

On long journeys, two drivers may take turns to drive, in which case the non-driver is considered to be on duty rather than driving. It may be worth considering whether a driver in a platoon could be considered on duty rather than driving. This legislation needs to be examined in any event due to automation technology; a change to the driver hours' rules could be warranted when lorries begin to drive autonomously without the need for the driver to monitor the vehicle and environment (reference 4.2.1.6).

A similar but more simple alternative to platooning is called Cooperative ACC (C-ACC), in which the driver of the lead vehicle assumes control the of the speed of following vehicles, but drivers in the following vehicles still need to steer to retain latitudinal control.

C-ACC offers reduced benefit because the headway between vehicles needs to be significantly higher to allow the driver of a following vehicle sufficient visibility to be able to steer. Platooning, compared to CACC is more complex to implement, but offers greater potential benefits. Although the potential benefits of platooning are clear, there are a number of barriers:

- Generally speaking, the logistics industry is operating on small profit margins and don't have much funding available to invest in research, even though the long term benefits could be significant. Therefore, the public sector would need to invest in the development of the technology. The economic benefits of doing so would need to be investigated, but it is thought that it would be a good value investment. It should be considered in light of advances in vehicle automation generally.
- Individual logistics companies do not often have two lorries going to the same place, so the opportunities for forming platoons for just one company would be limited. If an open, standardised and secure system could be developed so that platoons could be formed from any company, then there would be a far higher chance of forming platoons, and take up of the technology would be higher, but creating a standardised and secure communication link would not be straightforward.
- There is limited benefit to be an early adopter of such technology, so encouraging uptake to achieve a critical mass may require incentives. This is true of many connected vehicle applications.
- There are concerns that long platoons could create a hazard and may prevent other vehicles exiting a highway. Keeping platoons to no more than 3-4 vehicles could address this.
- Seeing some vehicles travelling in platoons may encourage other drivers to tailgate.
- Knowledge of the fuel efficiency gains achievable from platooning may encourage lorry drivers to tail gate.

However, given the potentially significant benefits to the economy and the environment, it is considered that platooning should be investigated further, and trials on UK roads should go ahead.

4.3.8 Engage more with telecommunications providers

This recommendation was made by two prominent representatives of the telecommunications industry, one of whom stated:

> "Five years ago the DfT wouldn't talk to us because they said they we're all about safety and they didn't want to encourage mobile phones in cars at all. We are beginning to see a reversal of that but what we haven't yet seen is the momentum forward. The support from DfT for the SMMT CAV Forum is a positive step. My message is how do we get momentum forwards which includes pro-innovation, pro-safety measures but with economic and industrial benefits in the process. Their policy line has to be more pro-connectivity than it has been."

4.3.9 Investigate infrastructure implementation and maintenance

4.3.9.1 Regulate road side equipment

This relates to a reference within a report from the NHTSA. On page 42 of the document, a policy need is highlighted:

> "Policy Need: Determination of Authority for NHTSA to regulate Road Side Equipment Description: NHTSA will thoroughly evaluate the need to regulate aspects of RSE operation and assess its authority for doing so."

The need to provide a single point of contact in Government to oversee aspects of road side equipment could be investigated.

4.3.9.2 Learn lessons from TfL about Wifi hotspots

A stakeholder from a Tier 1 supplier made the following comment:

> "Because of the spectrum, mobile network operators are in a monopolistic situation, so the reason the authorities were looking at trying to put public WiFi down the motorways or down the connective corridors to try and break that paradigm, which is to try and provide a high standard of connectivity and therefore provide a service through offsetting the costs of doing things, so if for example we decide to contract a mobile network operator to provide a superior coverage on a major road network you are then constrained by what they want to do. A very good business model is to talk to TfL who actually set up all the WiFi hotspots on the trains and then he essentially franchised out that service. That is the thought process of the Highways England discussion which is we put in a network and then it can be franchised out to whoever and that generates an income back into the Highways England and to other people."

4.3.9.3 Set up connected vehicle demonstrations

It was felt amongst some stakeholders that there should be more connected vehicle demonstrations in the UK, building on the demonstration currently being planned for the A2 / M2 study in Kent and the work being undertaken in Newcastle. The DfT are coordinating with organisations such as CODECS[37] (COoperative ITS DEployment Coordination Support), and ITS (UK)[38] and this should continue.

FIGURE: 4-9: C-ITS deployment activities across Europe (source: CODECS)

4.3.9.4 Produce Guidance

This recommendation came from several representatives of highway authorities. A representative from Transport for London stated:

> "There is a risk because of [the fast moving nature of technology] that cities implement technology that will be quickly redundant. We'll be frantically putting in VHS recorders when most people are streaming. How do you enable large, pressured organisations to remain fleet of foot and avoid spending vast sums of money on something which turns out to be useless? Maybe it could be detaching technology from fixed infrastructure as far as possible. It could be an issue around education - what do we even mean by an autonomous vehicle? A starter kit for senior managers in authorities would be helpful."

[37]CODECS website: http://www.codecs-project.eu/index.php?id=7 38 ITS(UK) website: http://www.its-uk.org.uk/

It could be beneficial for DfT to produce a guidance note for traffic managers which addresses some of the comments raised above. A further stakeholder working for a highway authority stated:

> "With respect to infrastructure the biggest barrier is revenue supporting the kit that you might need installed. Highway authorities don't have the revenue to support kit on the street. It's not just about installation costs but also ongoing costs, maintenance etc."

The guidance note could investigate possible opportunities to access funding for connected vehicle equipment, which might include Innovate UK calls, or European funding from sources such as Connecting Europe Facility (CEF).

4.3.10 Investigate and promote telematics solutions

We spoke to one stakeholder who worked for a mobile network operator that is heavily involved in providing telematics solutions via the insurance industry, which prompted some interesting insights.

> "A typical insurance company for every £1 they bring in they would be lucky if they pay 99p out but they are usually paying £1.10 to £1.15. It is generally so competitive especially as the markets are aggregated with Gocompare and Moneysupermarket, it's very fine lines. So the notebook they are losing money on or breaking even at best, whereas Ingenie [which uses Telematics] for every £1 they bring in they are paying out 71p. This has changed the market completely. The loss ratio is quite low. Some companies have gone in to compete with high loss ratios. But with the black box in the car you get some really good driving data. As this market has matured we've seen three subvert calls:
>
> - There is the pay when you drive which is quite punitive so you can't drive at weekends for example.
> - There is the pay as you drive such as 'Insure the box' where you get 6,000 or 8,000 miles per year. This is very clever because the average mileage per person is 9,332 per year. The average person when they go online says they do 6,000 miles per year. People think if they put lower mileage they'll get cheaper insurance but the algorithm builds in that if you say 6,000 you're going to do 9,332 so somebody with no black box will bump that policy up. Insurethebox know that if you put 6,000 miles you're realistically going to run out in September so you can buy more miles. So it's like road user charging for insurance.
> - The third is the 'pay and drive', which is 'Ingenie' so they're polling about 10 times per second so it's very clever. So if you're driving well you'd get a text message which would be green to say you're driving very well and your policy will come down even further. If you've clipped a few corners or you've been speeding or tailgating or overtaking on the inside you'll get an amber or red, and if you get two red incidents you'll get a black. They will then bring you in and put you on a corrective driving course. They try to avoid cancelling the contract because if you have insurance cancelled it's very difficult to get insurance again and its bad publicity. There is a paper that went to Government before Christmas. Of 117,000 user cases of those aged between 17 and 24 with black boxes in their car, compared with typical crash and fatality rates, they bought the number of crashes down by 40%. So people who drove with a black box were 40% less likely to be involved in a serious or fatal car accident.

Generally, 17-24 years olds are 10 times more likely to be in a serious or fatal car accident. Insurers are far more interested in serious and fatal accidents and not really interested in bent metal. Directline 2.5 years ago paid out £24 million for one accident which involved three teenagers who are now paraplegics and require 24-hour road the clock care for the rest of their lives. The number of accidents are going down but the size of the payments is going up. This is due to the medical care improving and people living longer and needing care for longer."

Therefore, among the groups most likely to benefit telematics can offer some substantial benefits in terms of changing driver behaviour, and can also help to lower premiums for good drivers and make insurance more profitable. It can also help to limit people's mileage, which may encourage drivers to switch modes and help reduce road congestion. A stakeholder for a large bus company also explained the benefits of telematics when used for professional drivers. A traffic light system was introduced onto the dashboard of buses. If the driver performed a manoeuvre which made passengers "look up from their newspaper" an amber light was displayed. If the driver performed a manoeuvre which made passengers grab onto the seat in front of them, a red light was displayed. When the system was in use, the standards of driving and fuel efficiency improved dramatically. An investigation could look into whether more could be done to promote such solutions from the public sector.

4.3.11 Investigate / promote potential benefits to stakeholders

It was suggested that the number of connected cars, where connected is defined as a car with subscription, is already significant and will increase dramatically over the next few years, and it is appropriate to consider stakeholders that could be encouraged to develop applications that make use of the connectivity. These include Driver and Vehicle Licensing Agency (DVLA) who could look at MOT activity, insurers, fuel companies, emergency services, vehicle recovery companies. With respect to On Board Diagnostic (OBD) ports, the following quote was taken:

"There should be a more open study into how the OBD ports can be used on vehicles, both old and new. This could open up a new ecosystem which would be very useful. This both a licensing question to the DfT as well as BIS question. As soon as you know what OBD ports are and which ones exist you can start to open up new markets. I don't believe in the world where every OBD port should only be seen by the car manufacturers or the franchise dealers. I believe in opening up markets in an open standard way. The knowledge of the OBD port and how it's evolving is very important. If we're going to create 'internet on wheels' we're going to need to know what access exists to the OBD ports on a range of vehicles. It could be to help the customer know what's going on, it could be an OBD port with cellular that requests maintenance, or even talks to a breakdown company. It's thinking about OBD from a services point of view rather than just plugging in for its own sake. OBD are used today by breakdown service providers for analytics, but they tend to have to be stationary in order to do so. I mean access to OBD for a range of services; some when stationary and some when on the move."

With respect to breakdown and emergency services, the following quote is relevant:

"The whole world of 999 was designed in 1937 needs an update. After 78 years isn't it time we use more data for both breakdown and emergency services. That should be a Cabinet Office responsibility rather than just DfT."

5 WHAT ARE THE PRIORITIES?

Deciding what, out of all of the interventions discussed, should be the priorities is no easy task, and there are no right or wrong answers. Many of the recommendations are not mutually exclusive and could be undertaken in parallel, and it would be prudent to pursue multiple avenues simultaneously, for which significant resources are needed. However, in order to aid decision making, TSC has worked to deduce the relative potential impact or importance of specific measures, and the potential timescales over which they could be undertaken. This section, therefore, presents what we feel are the most important priorities for the public sector to help accelerate the deployment of CAVs.

What are the Priorities?

Reference	Measure	Potential Importance / Impact	Potential timescale (years)				
			1	2	3	4	5
4.1.1	**Promotion of ADAS**						
4.1.1.1	Tax incentives & insurance premium discounts	3	■	■	■	■	
4.1.1.2	Investigate how to encourage safety features in HGV's / buses	5	■	■	■	■	■
4.1.1.3	Promote pedestrian detection technology	4	■	■	■		
4.1.1.4	Investigate what ADAS vehicles need from infrastructure	2	■				
4.1.1.5	Promote ADAS in sales and marketing of vehicles	1	■	■			
4.1.1.6	Preference safety systems in public sector during fleet procurement	5	■	■	■	■	■
4.1.1.7	Consider mandating some technologies	2	■	■	■	■	■
4.1.2	**Regulation of ADAS**						
4.1.2.1	Provide / Require driver training	2	■	■	■	■	■
4.1.2.2	Provide online guidance in the use of ADAS	5	■				
4.1.2.3	Update distracted driving laws	3	■	■	■		
4.1.2.4	Impact of suboptimal conditions on ADAS	4	■	■			
4.1.2.5	Amend driving tests	4	■				
4.1.2.6	Amend highway code	4	■				
4.1.3	**Investigate automated valet parking**						
4.1.3.1	Consider minimum infrastrcture requirements	1		■	■		
4.1.3.2	Consider safety aspects	2		■			
4.1.3.3	Consider licensing	2		■	■		
4.1.4	**Investigate Road Based Public Transport**						
4.1.4.1	Promote Existing PRT Solutions	1	■	■			
4.1.4.2	Consider Small Automated Demand Responsive Buses	4	■	■	■	■	■
4.1.4.3	Investigate Deployment Locations	3	■	■			
4.1.4.4	Investigate Business Case	3	■				
4.1.4.5	Work with Bus & Taxi Companies	2			■	■	■
4.1.4.6	Learn Lessons from City Mobil 2	2	■	■			
4.1.4.7	Rethink approach to regulation of buses and taxis	2	■	■			

TABLE 5-1: Near Term Automation Technology Priorities

Reference	Measure	Potential Importance / Impact	Potential timescale (years)				
			1	2	3	4	5
4.2.1	**Consider legally permitting the commercial use of fully automated vehicles**						
4.2.1.1	Examine relationship between safety of human driving and requirements for automated vehicles	4					
4.2.1.2	Learn lessons from how medicine is tested and administered	2					
4.2.1.3	Certify vehicles and infrastructure together in developing safety cases	4					
4.2.1.4	Work on Intelligent Speed Adaptation	1					
4.2.1.5	Legal Audit to identify everything that can apply to automated driving	4					
4.2.1.6	Investigate whether driver hours regulations could be relaxed	1					
4.2.2	**Encourage testing of highly / fully automated vehicles**						
4.2.2.1	Define geographical areas for automated vehicle testing	3					
4.2.2.2	Facilitate open simulation environment for testing and assessing AV's	5					
4.2.2.3	Incentivize vehicle makers to take part in deployments	3					
4.2.3	**Ascertain mapping / infrastructure requirements of those developing technology**						
4.2.3.1	Investigate adaptation of road work proceedures	5					
4.2.3.2	Consider installing V2I	4					
4.2.3.3	Consider implementing segregated automated driving zones	2					
4.2.4	**Consider the type of transport system needed / desired in future**						
4.2.4.1	Undertake scenario modelling	4					
4.2.4.2	Update planning / guidance document and WebTAG to incorporated AV's	2					
4.2.4.3	Update Guidance on Transport Assessments	2					
4.2.5	**Address public acceptability concerns**						
4.2.5.1	Publicise benefits	2					
4.2.5.2	Commission study into positive and negative impacts	2					
4.2.5.3	Develop a 'Break the Glass' plan for automation incidents	3					

TABLE 5-2: Highly / Fully AV Priorities

Reference	Measure	Potential Importance / Impact	Potential timescale (years)				
			1	2	3	4	5
4.3.1	**Promote more joined up thinking within Government**	4					
4.3.2	**Investigate Data Management**						
4.3.2.1	Open more data sets	4					
4.3.2.2	Investigate if infrastructure can cope with data demands	4					
4.3.2.3	Investigate data storage options	4					
4.3.2.4	Consider mandating data sharing	3					
4.3.2.5	Review navigation options that exist	2					
4.3.2.6	Investigate who should own data	4					
4.3.3	**Deploy connected vehicle technology on public sector vehicles, and encourage amongst fleet operators**	3					
4.3.4	**Investigate standards**	5					
4.3.5	**Update guidance on driver distraction**	3					
4.3.6	**Adopt a digital first strategy**	4					
4.3.7	**Investigate and promote platooning / C-ACC**	4					
4.3.8	**Engage more with telecommunications providers**	5					
4.3.9	**Investigate infrastructure implementation and maintenance**						
4.3.9.1	Regulate road side equipment	2					
4.3.9.2	Learn lessons from TfL regarding WiFi hotspots	1					
4.3.9.3	Set up connected vehicle demonstrators	5					
4.3.9.4	Produce guidance for highway authorities	4					
4.3.10	**Investigate & promote telematics solutions**	4					
4.3.11	**Investigate & promote potential benefits to stakeholders**	3					

TABLE 5-3: Cooperative ITS Priorities

5.1.1 Near term automation priorities

Therefore, based on this work, the priorities for near term automation include:

- Investigate if more can be done to promote safety features in HGV's and buses;
- Preference safety systems in public sector fleet procurement;
- Provide direction and materials for education on ADAS features, which could include a website;
- Promote pedestrian detection technology;
- Look into the impact of sub-optimal conditions on ADAS performance;
- Update driving theory tests and the highway code to reference ADAS;
- Consider small automated demand-responsive buses as a new mode of transport, and look into the business case and deployment locations

5.1.2 Highly / fully AV priorities

Priorities to accelerate the deployment of highly / fully AVs include:

- Examine the relationship between safety of human driving and requirements for AVs (which could help legally permit fully AVs);
- Consider infrastructure alongside vehicles in safety analysis;
- Undertake a legal audit to identify everything that can apply to automated driving;
- Facilitate an open simulation environment for testing and assessing AV's;
- Investigate infrastructure requirements of those developing the technology;
- Investigate adaptation of road work procedures, to make real-time detailed information available to AV's;
- Consider installing V2I equipment where it aids AV's, for example in helping AV's to communicate with traffic signals and at road works;
- Undertake scenario modelling to look at the potential impacts of AV's on the transport network.

5.1.3 Cooperative ITS Opportunities

Priorities to accelerate C-ITS include:

- Investigate data management, including opening more datasets, consider the ability of infrastructure to cope with data demands and ownership of data;
- Investigate standards;
- Adopt a 'Digital First' Strategy;
- Investigate and promote platooning / C-ACC;
- Produce guidance for highways authoriites;
- Promote telematics solutions.

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