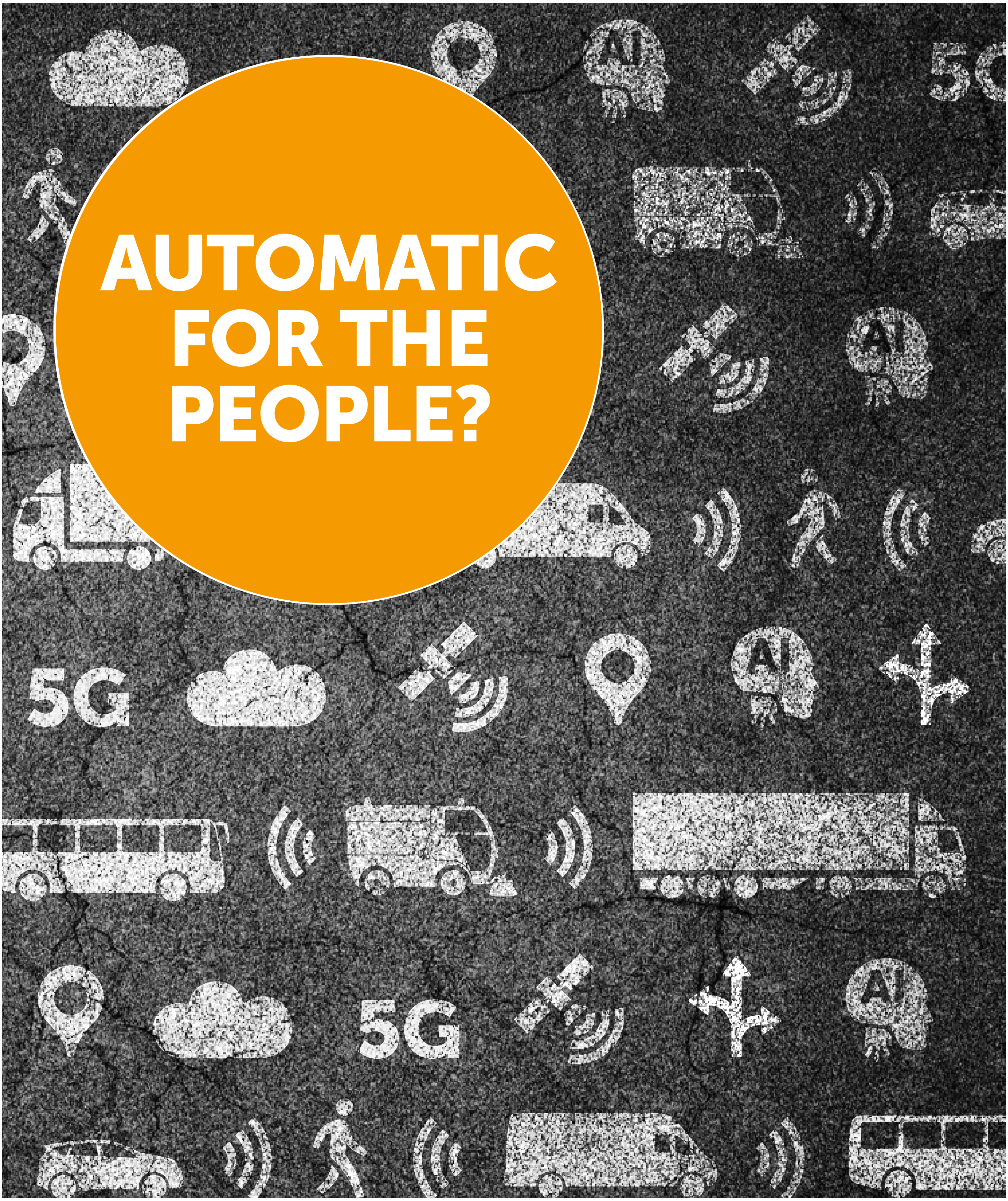
AUTOMATIC FOR THE PEOPLE?



ISSUES AND OPTIONS FOR TRANSPORT AUTHORITIES ON CONNECTED AND AUTONOMOUS VEHICLES

URBAN TRANSPORT GROUP

The Urban Transport Group
represents the seven strategic transport bodies which between them serve more than twenty million people in Greater Manchester (Transport for Greater Manchester), Liverpool City Region (Merseytravel), London (Transport for London), Sheffield City Region (South Yorkshire Passenger Transport Executive), Tyne and Wear (Nexus), West Midlands (Transport for West Midlands) and West Yorkshire (West Yorkshire Combined Authority). The Urban Transport Group is also a wider professional network with associate members in Strathclyde, Bristol and the West of England, Tees Valley, Nottingham and Northern Ireland.

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INTRODUCTION

Connected and autonomous vehicles (CAVs) can be considered a 'Marmite' issue. People tend to either instinctively love or hate the idea of fully autonomous vehicles with little middle ground. Reports on the subject are often equally polarised, taking either an evangelical or a doom-laden tone as they imagine the utopia or dystopia they will eventually unleash. Some imagination is required in either case given that nobody can say for certain exactly how CAVs will evolve, at what pace and with what consequences.

Envisaging a future with CAVs involves making a number of assumptions about how people will respond to them; at what level of autonomy and connectivity they will predominantly operate and in what circumstances; what the applications might be for different modes of transport; and how soon (if ever) they will come to dominate the transport mix. These assumptions have implications for transport policy, networks and infrastructure but also for a wide range of other policy areas, from public health to urban planning.

This helps to explain why CAVs have also been described as a 'wicked problem'[1]. A wicked problem is one that is difficult (or impossible) to solve because of incomplete, contradictory and changing requirements. It involves many stakeholders with differing views, a large potential economic impact, no determinable stopping point and complex interdependencies. Wicked problems are not 'bad' but are extremely challenging for policy makers.

The CAV industry also increasingly recognises the challenges that mass deployment of the technology presents, requiring *'government approval, public trust, brand marketing, the ability to manufacture at scale and the technical knowhow to manage a fleet.'*[2]

Whilst this report cannot give definitive answers as to what the future trajectory for the development of CAVs will be, it does aim to provide an objective framework for city regions to think about CAVs, their implications for wider priorities and the approaches they might therefore take. In doing so, this report seeks to do three things that set it apart from the many other reports there are on CAVs.

Firstly, it specifically looks at CAVs from the perspective of city region transport authorities in the context of their wider objectives and responsibilities, rather than considering CAVs in isolation from wider public policy considerations.

Secondly, it does not solely focus on the implications of an as yet hypothetical end state where the vast majority of vehicles are fully autonomous. Instead, it recognises that vehicles are increasingly connected and have begun to operate with features which have a degree of autonomy. We have therefore already embarked on a CAVs trajectory.

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Regardless of whether this trajectory ends in a future where all vehicles are fully autonomous, there are implications in the here and now for transport authorities. This report takes the view that CAVs are, and will continue to be, a moving target with live implications at every twist and turn rather than a single leap to a pre-determined end state on which all thinking and policy making should focus on accommodating.

Thirdly, whilst many other reports on CAVs focus exclusively on how cars might become fully autonomous, this report looks at a wider range of vehicles including buses and public service vehicles. It also looks at the implications of CAV technologies for the roads these vehicles will be travelling on.

The report begins by providing clarification on what we mean by CAVs before assessing what stage the technology is at and where it sits in terms of UK government policy and priorities.

The report then analyses the four key areas often highlighted as representing the main potential contribution of CAVs (safety, economic, social and environmental benefits) before examining six challenges of particular relevance to transport authorities.

Consideration is then given to the options open to transport authorities in terms of how they might approach the emergence of CAVs. It features a number of international examples highlighting a range of approaches from laissez faire to acting as a guiding hand.

Finally the report suggests what transport authorities can do now to respond effectively to the development of CAVs and what actions national government should take to enable them to do so.

INTRODUCING CONNECTED AND AUTONOMOUS VEHICLES

Defining Connected and Autonomous Vehicles

For the purposes of this report, we define connected and autonomous vehicles as:

- those which use an external network connection to communicate in some way – either to the driver, other vehicles, roadside infrastructure or the cloud, or to any combination (or all) of these **and**
- are automated in some way – that is, they can perform some or all functions without driver input.

Vehicles can have varying degrees of connectivity and automation.

In respect of automation, the most widely used model is that developed by SAE which describes six levels of vehicle automation[3]:

Level 0	No Automation	Eyes on	Hands on
Level 1	Driver Assistance	Eyes on	Hands on
Level 2	Partial Automation	Eyes on	Hands on
Level 3	Conditional Automation	Eyes off (temporary)	Hands off (temporary)
Level 4	High Automation	Eyes off	Hands off
Level 5	Full Automation	Eyes off	Hands off

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The human driver performs all aspects of all driving tasks, even when these are enhanced by warning or intervention systems.

The driver assistance features can carry out either the steering or acceleration/deceleration.

The driver assistance features can carry out both steering and acceleration/deceleration.

The driving automation features can perform all driving tasks but a human 'fallback-ready user' is expected to respond appropriately to 'a request to intervene'. The fallback-ready user must be receptive to a handover request or to an evident system failure, but is not expected to monitor the driving environment.

The driving automation features can perform all the driving tasks within their 'operational design domain' (for example, motorways only). There is no expectation that the human user will respond to a request to intervene. If the limits of the system are exceeded, the system will put the vehicle into a 'minimal risk condition', such as a safe stop.

This is identical to Level 4 except that the driving automation features are not limited by an operational design domain. Instead they are capable of performing all driving functions in all situations that a human driver could.

Connected and autonomous technology has potential applications for a wide range of vehicle types – from cars to buses and from road sweepers to HGVs.

What stage is CAV technology at?

Connectivity features have been built into road vehicles for some time. This could be a connection to a phone, Bluetooth, GPS, sat nav or the internet, via an internal SIM, allowing the vehicle to remain online at all times[4]. It is estimated that there are over three million vehicles in the UK with internet connectivity[5]. Most are single vehicles connected to an information cloud. Current connectivity features include smartphone integration, roadside assistance, parking apps, remote diagnostics and voice commands[6].

The next level of connected vehicles are still in their infancy but would eventually be able to communicate with one another, with road infrastructure and even across national borders[7] with the goal of improving safety and efficiency. Developments in AI and machine learning could see connected vehicles learning from their collective experiences.

Some autonomous features are common in the vehicles of today, including automatic starters, gearboxes and wipers; emergency braking; cruise control; lane assist; and park assist.

It is interesting to note that, outside of the road environment, automation/driverless operation is relatively common on metro networks around the world. UITP reports[8] that globally 25 cities run automated metro lines, with the first dating from 1981. The trains require no driver in the front cabin or staff assigned to a specific train.

Vehicles with more autonomous features are, however, beginning to appear on our streets as part of real-world trials of the technology. The recently completed 'DRIVEN' project, for example, tested automated vehicles on the streets of Oxford on a daily basis[9] as well as demonstrating autonomous fleet driving in London's *'complex urban environment'*[10]. Meanwhile, robot food[11] and package[12] delivery pods are successfully navigating the streets of Milton Keynes (albeit monitored by human operators who can step in if required).

Whilst there are many more trials and demonstrations planned and underway, we are still a long way away from regularly seeing Level 3-Level 5 autonomous vehicles on our streets. Developers of self-driving cars, for example, have suffered setbacks as they attempt to refine the technology, some with tragic consequences for car occupants and other road users alike.

Furthermore, trials and demonstrations are an entirely different prospect to large-scale deployment. James Farley, Ford's President of New Businesses, Technology and Strategy has commented that the development of self-driving systems is necessary, but not enough to build a business on. He talks about the continuing *'uncertainty around the manufacturability of the sensing systems, the regulatory environment [and] the scaling of the customer facing business.'*[13]

Mindful of the complexities posed by urban environments, CAV developers are increasingly embracing *'operational design domains'*[14] and geo-fencing. This involves focusing on more predictable, constrained tasks and environments that the vehicles can handle now, or soon (for example, running on segregated portions of the highway, on set routes between two points or in defined spaces like airports or university campuses).

CAV testing on campus – Salford

Transport for Greater Manchester is working in partnership with the University of Salford to test a 15-seater Level 4 autonomous vehicle in a real-world environment around the private roads of the University campus.

Current vehicle registration requirements (such as the need for the driver to have a clear view and for a steering wheel) mean it cannot yet be used on public roads. Eventually, the project plans to link the vehicles in to the wider public transport network, connecting people to rail, bus and tram hubs as well as to the University's second campus at Media City.

Even in the constrained environment of the University campus, a number of practical challenges have emerged. The team has discovered that the vehicle's Lidar system (which acts as 'eyes') cannot function in horizontal rain or in snow, both of which cause the vehicle to stop. Low hanging branches also stop the vehicle as it is unable to determine what the obstruction is made of and how likely it is to cause damage. A bird landing on a rooftop antennae also impeded the vehicle's progress. These small examples highlight the huge challenges CAVs will face when operating in a complex streetscape.

The Level 4 autonomous vehicle on campus. Credit: Rebecca Fuller

The Government Office for Science predicts that *'Automation could plausibly challenge the transport system status quo from the 2030s onwards, for trains and buses but also, potentially for private car-based transport'*[15].

Buses, trams and trains are thought of as natural candidates for early automation given they typically follow predictable routes and can use infrastructure (like bus lanes) designed to minimise encounters with conventional traffic.

Europe's first full-sized autonomous bus fleet – Fife/Edinburgh

Europe's first full-sized autonomous passenger bus fleet trial is set to launch this year, serving up to 10,000 passengers per week between Fife and Edinburgh across the Forth Road Bridge, plus on-road and hard shoulder running[16]. Since 2018 the bridge has been designated as a Public Transport Corridor, with access to motor vehicles (other than buses and taxis) restricted[17].

Ferrytoll Park and Ride in Fife and Edinburgh Park train and tram interchange sit at either end of the route[18], offering connections through to the wider transport network.

Each bus will be able to carry up to 42 people and, whilst it will operate at Level 4 automation, a driver will remain on board in line with regulations. Autonomous systems developed for the trial are anticipated to provide spin-offs that can help conventional buses, for example, sensors that can recognise and alert the driver to pedestrians and cyclists, automated emergency braking and replacement of external mirrors with advanced vision systems[19].

The trial, named Project CAVForth, is a partnership between Stagecoach Group, Alexander Dennis, Fusion Processing, Bristol Robotics Laboratory, Napier University and Transport Scotland. The project has received £4.35m from Innovate UK[20].

An example of an autonomous bus being tested as part of the project
Credit: Buttons0603 CC BY-SA 4.0 https://creativecommons.org/licenses/by-sa/4.0/deed.en

World's first autonomous tram – Potsdam, Germany[21 22]

The world's first autonomous tram – Combino, developed by Siemens – launched on the streets of the German city of Potsdam in 2018, operating amongst real traffic and people. Accompanied by a human ready to step in if needed, the tram reacts to trackside signals and is able to detect and respond to hazards, automatically taking action to avoid them by slowing down or braking.

Siemens has sold some of the technology used for the tram in its 'Tram Assistant' package of software and sensor hardware. Designed to prevent collisions, the system can be retrofitted to any Siemens-built tram.

With the Association of German Transport Companies, Siemens is working to draft a safety and legal framework for the use of autonomous light rail vehicles as German (and European) law does not currently provide for it.

The Combino in action. Credit: Siemens

Connected and Autonomous Vehicles in context

CAVs are seen as forming part of a wider transition to a 'smart mobility future'. One useful frame for this is the CASE model[23], which refers to the future of mobility as:

Connected
Autonomous
Shared
Electric

In order to contribute to a future where streets are not clogged with traffic and choked by pollution, it will be important to ensure that CAVs develop in a way that encourages shared mobility (e.g. pool cars, public transport, consolidation of freight deliveries) and that minimises emissions.

To maximise environmental, social, health and economic benefits, any smart mobility future must also get the basics right, ensuring walking, cycling and public transport are prioritised. Regardless of technological developments, these modes will always be the most efficient in transporting large numbers of people from A to B.

A study from UC Davis found that autonomous vehicles operating without electrification and without a sharing model would lead to a 20% increase in vehicle miles and growing carbon emissions[24]. Whereas electric autonomous vehicles, combined with increased ride sharing, public transport use, walking and cycling could reduce car travel by 50% by 2050 and dramatically reduce carbon emissions when accompanied by a decarbonised electricity supply[25].

UK PRIORITIES AND POLICY POSITION ON CONNECTED AND AUTONOMOUS VEHICLES

The 'Future of Mobility' is one of the 'grand challenges' at the heart of the UK Government's Industrial Strategy[26] and further elaborated in 2019's *'Future of Mobility: Urban Strategy.'* The Industrial Strategy pledges to ensure *'we continue to have one of the most open environments in the world for transport innovation and new services.'*[27] This focus is paying dividends with the UK ranked second only to Singapore in terms of its policy and regulation preparations around CAVs in 2019[28].

In the Industrial Strategy, the Government states that it wants to see fully self-driving cars on UK roads by 2021. It also sees the UK as well placed to lead on the relevant areas of research and development to position itself as a frontrunner in the global CAVs market.

A dedicated Centre for Connected and Autonomous Vehicles (CCAV), established in 2015, supports this work. CCAV is a joint endeavour between Department for Business, Energy and Industrial Strategy and Department for Transport policy teams. The Government is now taking forward the early priorities it has identified to support its ambitions around CAVs. Much of the activity is focused around ensuring that the UK is a *'world leader in the safe testing and roll-out of self-driving vehicles'*[29] and that the country is at the forefront of innovation.

Safe testing and roll-out of Connected and Autonomous Vehicles

The Government has stated that *'People's safety will be our number one priority in our approach to emerging mobility innovation'*[30]. As such, the desire to position the UK as the obvious choice for the testing of CAVs is underpinned by a consistent focus on ensuring the safety of transport users and wider communities.

In 2015, CCAV published the Government's Code of Practice for trialling automated vehicles. Updated in 2019[31], the code clarifies that trialling any level of automated vehicle technology is possible on any UK road if carried out in line with UK law.

No permits or surety bonds need to be obtained, but to comply with the law, the trialling organisation needs to ensure it has:

- A driver or operator, in or out of the vehicle, who is ready, able, and willing to resume control of the vehicle;
- A roadworthy vehicle; and
- Appropriate insurance in place.

The 'roadworthy' element means that even Level 4 and Level 5 CAVs need to share the features of conventional vehicles if they are running on public roads. The Driver and Vehicle Licensing Agency is currently unable to register a vehicle that does not have a steering wheel or wing mirrors, both of which are deemed necessary for roadworthiness. Vehicles would also need to meet crash testing requirements. 'Pod' type vehicles (such as that used in the Salford case study on page 9) or other novel designs are therefore not currently legal on public roads in the UK and can only be used on private land (like a university campus). In the US however, a novel vehicle design has recently been granted permission to run on public roads without a driver in control.

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The R2 van loaded with a shopping delivery. Credit: Nuro

Nuro R2 delivery van – Houston, Texas[32]

In February 2020, the USA's National Highway Traffic Safety Administration granted exemptions to robotics company Nuro's autonomous R2 van to allow it to run on public roads.

The small, electric, lozenge shaped van has a flexible interior accessed via hatches that open when a code is punched in. It is described by the manufacturer as being able to handle errands of all kinds – from delivering dinner to dry cleaning. It is not designed to accommodate an occupant.

The exemptions mean that Nuro can use cameras and sensors instead of mirrors, round the edges to save space, use an opaque panel instead of a windscreen and construct the vehicle from softer materials.

The Transport Secretary said that rules calling for a rearview mirror and a windscreen 'no longer make sense' in the case of the R2. The exemption also means that the vehicle does not have to be under the control of a driver at all times.

Nuro has been allowed to build 5,000 of the vehicles but must provide updates to the government every three months with technical information, including about any crashes. The R2 will be delivering groceries and takeaways in Houston from February 2020.

The Code of Practice also notes that trialling organisations *'should speak with the road and enforcement authorities, develop engagement plans, and have data recorders fitted.'* It is interesting that the word 'should' rather than 'must' is used, meaning that transport authorities could in theory find CAVs being trialled in their area without prior consultation. However, this would be unlikely provided all involved follow the good practice that the Code sets out beyond the three basic legal requirements.

To this end, the Code provides guidance on how best to conduct autonomous vehicle trials to[33]:

- Support and promote safety as well as build public confidence.
- Support cooperation between trialling organisations and those responsible for traffic management, infrastructure, law enforcement and other stakeholders to support maximum road safety.
- Encourage sharing of information to help uphold and develop the highest standards of safety in the UK and internationally.

Safety considerations are woven throughout the document which is intended to be of use not just to would-be trialling organisations but also to transport authorities, highway authorities, emergency services, licensing authorities and others looking to engage with them.

Building on the foundations set by the Code, the Government has since announced it is developing a new safety regime for CAVs called CAV PASS[34].

The system will first focus on enabling advanced trials and eventually help assure the safety and security of CAVs for their mainstream sale and use.

Alongside the Code of Practice and planned safety assurance regime, the Government has also launched a regulatory review to *'establish a flexible regulatory framework to encourage new models of transport and new business models'*[35]. Legal and regulatory options specifically for CAVs are also being explored by the Law Commission at the request of CCAV[36].

A world-leader in innovation

CCAV has so far provided over £250 million in funding, matched by industry, *'to position the UK at the forefront of CAV research, development and use.'*[37] Over 70 projects involving more than 200 partners have been funded so far[38].

There are many opportunities for transport authorities to become involved with these projects. Indeed, transport authorities have been partners in more than 20 CCAV funded projects so far, according to the latest available summary[39].

The table shown on pages 15-16 briefly summarises all the projects listed by CCAV as having transport authority partners[40]. It provides an indication of the wide variety of work that transport authorities have been involved in and how, together with industry and academia, they have been able to place themselves at the cutting edge of CAV innovation.

Project	Transport authority involved in partnership	Description	Funding Round	Project Timeline
GATEway	Royal Borough of Greenwich	Demonstrating the use of CAVs for last mile mobility with key focus on interaction with people.	Four Cities Trials	2015-2018
UK Autodrive	Coventry City Council, Milton Keynes Council	Urban demonstrations on public roads and footpaths in Coventry and Milton Keynes.	Four Cities Trials	2016-2018
Venturer	Bristol City Council, South Gloucestershire Council	Investigating barriers to adoption of CAVs.	Four Cities Trials	2015-2018
Flourish	Bristol City Council, South Gloucestershire Council	Developing products and services that maximise the benefits of CAVs for users and transport authorities.	Connected and Autonomous Vehicles 1	2016-2019
MOVE_UK	Royal Borough of Greenwich	Focusing on connected systems validation and big data analysis.	Connected and Autonomous Vehicles 1	2016-2019
UK CITE	Coventry City Council, West Midlands Combined Authority	Creating an advanced environment for CAVs in real life conditions on 40 miles of roads.	Connected and Autonomous Vehicles 1	2016-2018
ATLAS	Royal Borough of Greenwich	Studying what is needed for safe, reliable, resilient autonomous navigation.	Connected and Autonomous Vehicles 1	Not stated.
ACCRA	Leeds City Council	Exploring the potential of CAVs for cleaner air.	Connected and Autonomous Vehicles 2	2017-2018
Capri	South Gloucestershire Council	Delivering a complete pod on-demand mobility service.	Connected and Autonomous Vehicles 2	2017-2020
DRIVEN	Oxfordshire County Council	Deploying fully autonomous vehicles in urban areas and on motorways culminating in multiple end-to-end journeys between London and Oxford.	Connected and Autonomous Vehicles 2	2017-2019
Synergy	Transport for Greater Manchester, Stockport Metropolitan Borough Council, Manchester City Council	Trialling multi-vehicle platoons at Manchester Airport and an in-vehicle virtual concierge service.	Connected and Autonomous Vehicles 2	2017-2020
robopilot	South Gloucestershire Council	Developing and demonstrating autonomous driving for a truck, including real world testing on public roads and at UPS depots.	Connected and Autonomous Vehicles 2	2018-2020
SWARM	Milton Keynes Council	Developing a machine-based vehicle supervision system, applied to a fleet of autonomous pods.	Connected and Autonomous Vehicles 2	Not stated.
AutopleX	Transport for West Midlands, West Midlands Combined Authority	Enhancing the vision and perception capabilities of CAVs.	Connected and Autonomous Vehicles 3	Not stated.
MultiCAV	Oxfordshire County Council, South Oxfordshire District Council, Vale of White Horse District Council	30 month trial of passenger-carrying autonomous vehicles within a business park and on public roads, providing links to public transport.	Connected and Autonomous Vehicles 3	2018-2020

Project	Transport authority involved in partnership	Description	Funding Round	Project Timeline
LAMBDA-V	Birmingham City Council	Exploring the potential to process massive datasets to model a generic human driver profile and extend that to algorithms for CAV rules.	Connected and Autonomous Vehicles 3	2018-2019
MaaS:CAV	Oxfordshire County Council	Integrating CAVs into a Mobility as a Service platform.	Connected and Autonomous Vehicles 3	Not stated.
ParkAV	City of Westminster, Coventry City Council	Exploring how automated valet parking might work.	Connected and Autonomous Vehicles 3	Not stated.
dRISK	Transport for London	Building a comprehensive knowledge graph of all CAV risk scenarios from which test cases will be fed into simulators to test the vehicle control system.	Connected and Autonomous Vehicles: Simulation and Modelling	2019-2020
OMNICAV	Oxfordshire County Council	Building a testing environment delivering representative coverage of UK roads.	Connected and Autonomous Vehicles: Simulation and Modelling	2018-2020

Project Synergy[41] – Greater Manchester

Transport for Greater Manchester and Stockport and Manchester councils are part of a consortium involving industry, academic and public authority partners to deliver a CAV trial called Project Synergy.

The scheme is testing two types of CAVs to serve Manchester Airport. Three autonomous pods will carry passengers between airport car parks and passenger terminals whilst autonomous electric cars in platoon formation will travel between Stockport rail station and the airport.

Since the CCAV summary of projects was published, the 'Connected and Autonomous Vehicles 4' competition has been held, focusing on piloting CAV passenger services. The competition saw government backing given to three public CAV trials[42]:

- The CAVForth autonomous bus service project (see case study on p.10 and 19).
- Project Apollo which will test autonomous taxi services in Greenwich (building on the DRIVEN project, see table above).
- ServCity which will develop a London-based mobility service using six autonomous Land Rover Discovery vehicles (building on the UK Autodrive project, see table above).

Some £100 million of CCAV's funding has also been channelled through Zenzic for the development of CAV testing and development capabilities in the UK[43]. This investment has been matched by industry.

Zenzic brings together government, industry and academia to shape what it describes as a 'connected and self-driving ecosystem' and establish the UK as a world leader for the innovation and development of CAV technology. The projects funded through the Innovate UK and CCAV competitions form the heart of 'Testbed UK' a network of facilities, all within a three hour drive of one another, *'with the capability to take ideas from concept to development both virtually and physically'*[44]. The six core Testbed UK facilities are as follows[45]:

Facility	Location	Focus
CAVWAY	Leicestershire	Road junctions – allows junctions of many different configurations to be simulated.
HORIBA MIRA – Coventry University CAV Testbed	Warwickshire	Controllability – able to safely assess the limits of controllability in a fully connected and configurable environment.
Midlands Future Mobility	Coventry	Offers a diverse, monitored, 'real-world' road network of over 100km. Explores complex and unpredictable situations that cannot be assessed through simulation alone.
ConVEx	Coventry	Open platform for the commercial exchange of data to enhance and accelerate development of new mobility products and services.
Millbrook-Culham Urban Testbed	Bedfordshire	Controlled and semi-controlled CAV testing covering 90km of roads. Access to a 2,000 person adult population on a secure site to capture human aspects of real world operation for CAVs.
Smart Mobility Living Lab: London	London	Uses public and private roads in Greenwich and the Olympic Park to safely develop and validate new transport technologies.

Transport authorities are also involved in Testbed UK. Transport for London is part of the consortium behind the Smart Mobility Living Lab whilst Transport for West Midlands is part of the Midlands Future Mobility and ConVEx consortiums.

Funding to support CAV innovation has also been made available via other parts of the Government. For example, the National Infrastructure Commission, together with Highways England and Innovate UK, launched a prize for ideas on how to deliver a world-class road network in the UK, ready for CAVs[46]. The joint winners of the prize were City Science and Leeds City Council (see box below).

Winners of the Roads for the Future Prize[47] – Exeter and Leeds

In 2018, following 81 entries from across the country, the winners of the National Infrastructure Commission Roads for the Future Prize were announced. The joint winners were City Science, based in Exeter, and Leeds City Council.

The City Science entry examines how sections of roads in urban areas could initially be dedicated to driverless vehicles as a key step in kick-starting their take-up and safe integration into the existing transport network.

The Leeds City Council entry looks at how data generated from digitally connected cars could be used to improve traffic light sequencing, allowing highway authorities to better manage traffic on their roads and reduce tailbacks.

The Government is also investing millions in developing and deploying 5G wireless technology and infrastructure[48], including on our roads, to support (among other things) the introduction of CAVs and people's productivity whilst travelling in them.

EXPLORING THE CASE FOR CONNECTED AND AUTONOMOUS VEHICLES

CAVs have the potential to deliver a broad range of economic, environmental, social and safety benefits. However, the likelihood of these benefits being achieved is unpredictable and highly dependent on factors like the level and spread of automation among vehicles on the roads; the modal mix; the take-up of shared models of ownership and use; and how the majority of vehicles are powered.

As the Government Office for Science note, the time frames for the maturation of CAVs and other new technologies are *'unclear and their impacts highly uncertain'*[49]. The House of Lords Science and Technology Select Committee inquiry into CAVs reached a similar conclusion, stating that there is *'little hard evidence to substantiate the potential benefits and disadvantages of CAVs because most of them are at a prototype or testing phase. Furthermore, as with any new technology or advancements, there may be unforeseen benefits or disadvantages that have not yet presented themselves.'*[50]

With these limitations in mind, this section explores the strength of the case for CAVs in four key areas often highlighted in the debate around the benefits of CAV technology – safety, economic, social and environmental.

Safety

Perhaps the most frequently cited anticipated benefit (and simultaneously, key concern) around CAVs is safety.

Semi-autonomous driving systems in 'traditional' vehicles are already improving safety. In London, for example[51], features such as automated emergency braking and Intelligent Speed Assistance (which helps the driver keep to the speed limit) form part of Transport for London's Bus Safety Standard, launched in 2018[52].

Separately from automation, the connectivity of vehicles is also being used to achieve safety benefits. Since March 2018, all new cars sold in the EU are fitted with the eCall system. The system automatically contacts the emergency services if a car's airbags deploy. It uses GPS to tell the emergency services the time the airbags were deployed, the location, direction of travel, type of car and type of fuel used. A microphone allows the driver to speak directly to the call handlers[53]. Systems like this can reduce emergency service response times by up to 60% in built-up areas[54], helping to prevent injuries from worsening.

Information about hazards, changing road conditions and issues with infrastructure can be communicated directly to connected vehicles, and (in future) speeds could be automatically adjusted, helping to improve safety in the management of incidents[55]. Connected vehicles could even learn from one another and adjust their behaviour as AI and machine learning technology develops.

The assumption is that once the majority (or ideally all) of vehicles achieve Level 4-Level 5 automation, human error – estimated to be the cause of some 86% of accidents in the UK – will be eliminated[56].

4

CAV bus trial aimed at making cities safer[57] – Fife/Edinburgh

The previously mentioned CAVForth autonomous bus fleet project in Scotland is developing buses specifically designed to make them safer in city environments.

A number of key innovations are included with the aim of reducing the risk of crashes:

- **Pedestrian detection:** recognises anyone crossing in front of the bus and automatically inhibits the engine. This could, for example, stop the bus pulling away whilst the driver is distracted looking for a gap in the traffic.
- **Intelligent speed assist:** automatically limits the speed of the bus to the speed limit on any stretch of road.
- **New wing mirror technology:** replaces wing mirrors with an HD camera feed combined with radar to identify cyclists in the vehicles' blind spots. Audio and visual alerts are used and images fed to the driver. Removal of wing mirrors also eliminates the risk of clipping road users and aids streamlining (and therefore fuel economy).

Safety design features can be taken further still for vehicles which are designed only to carry goods.

Nuro R2 delivery van – Houston, Texas[58]

The Nuro R2 delivery van described on p.13 is designed only to carry goods, with no space for human occupants. With no driver or passengers to protect, the vehicle has been designed to *'keep what's outside even safer than what's inside'*.

It is lighter and slower than a passenger car and the rounded contours are designed to make it more likely that objects coming into contact with it glance off.

Softer materials have been used for the front and rear panels and the front acts as a crumple zone to minimise the potential for injury.

Having no occupants also means that, in the event of an unavoidable collision, the vehicle will always self-sacrifice, prioritising the safety of humans, other road users and occupied vehicles over its contents.

Conversely, and despite these positive developments, safety is also perceived as a key risk surrounding CAVs, particularly in the minds of the public.

A number of high profile crashes have shown that CAV technology is still very much in its infancy. To date, there have been six automated driving system car fatalities[59]. Five of these involved self-driving Tesla vehicles[60]. For example, in 2016 a Tesla using autopilot mode collided with a white HGV which it failed to distinguish against the sky and the Tesla driver was killed[61].

In 2018, a self-driving vehicle being tested by Uber hit and killed a pedestrian in Tempe, Arizona, when she was crossing the street[62]. Investigations later revealed that the car was unable to recognise that pedestrians do not always use approved crossing points[63]. The back-up driver was also not alerted and did not have their eyes on the road in time to intervene.

Currently, all CAVs seeking to operate on public roads in the UK require a human driver or operator (in or out of the vehicle), who must remain alert and ready to intervene if needed. Whilst this back-up is necessary as the technology is developed, tested and refined it also means that all CAVs have the potential to be affected by fallible humans.

This has led some to suggest that CAVs below Level 4 should be avoided altogether[64] because humans find it difficult to 'dip in and out' of alertness[65]. Only being required to intervene occasionally also risks deskilling drivers who – when they are required to step in – may find it difficult to respond appropriately and in good time.

The House of Lords inquiry into CAVs received evidence to suggest that *'In simulated emergencies, up to a third of drivers of AVs did not recover the situation, whereas almost all drivers of manual cars in the same situation were able to do so. In addition, research showed that drivers of automated vehicles took, on average, six times longer to respond to emergency braking of other vehicles compared to manual drivers.'*[66]

For full safety benefits to be achieved, CAVs would need to operate exclusively among other self-driving vehicles. Unless CAVs are segregated in some way they will be subject to errors from other, human drivers. It has been suggested, for example, that human drivers may pick up risky driving behaviours from CAVs, such as driving too close to other vehicles[67]. This risk of complacency also extends to other road users – pedestrians and cyclists could become used to crossing roads at any point, confident that a vehicle will stop for them, something that could be very dangerous in mixed traffic.

Economic

Estimates place the value of CAVs to the UK economy at around £50bn per year by 2025/2030[68]. A frequently cited study for the Society of Motor Manufacturers and Traders (SMMT) by KPMG places the value at £51bn by 2030[69]. Clearly, such estimates must be treated with caution and awareness of vested interests in the success of the motor industry.

According to the KPMG research, the vast majority (£40bn) of these impacts are for consumers. The figure is derived from predictions around better use of time spent in vehicles; more efficient journeys leading to greater productivity and labour market flexibility; and savings around costs of insurance, running costs and parking.

Interestingly, the only costs that the KPMG analysis subtracts from the total value are around necessary increases in infrastructure investment and road maintenance (£11bn). It is easy to see how such predictions could underestimate costs.

Looking at the estimated consumer impacts alone, there may be costs and unintended consequences related to urban sprawl and congestion as travelling longer distances becomes more pleasant and productive, or around health as people become less physically active due to more time spent in vehicles.

There are also questions as to how genuinely productive people can be whilst travelling. Around one in five adults suffer from car sickness and nausea, something which would limit their ability to work on the go, particularly as the most common reasons for feeling unwell when travelling in a car are reading (61%) and using a phone or tablet (50%)[70].

Furthermore, in terms of consumer benefits, public transport already offers people the opportunity to be productive whilst travelling and to save on the costs of insurance, running costs and parking. It also makes efficient use of available space and usually involves active travel at either end of the journey. Potentially, automation could further add to the appeal of these modes if the result was cheaper travel using dedicated infrastructure, like bus lanes, to bypass traffic congestion.

The argument for automation enabling people to make more productive use of time spent in vehicles becomes more compelling for the freight industry. Whilst someone will usually still be needed to accompany goods to their destination, time spent taking them there could be better spent. Time that would have previously been spent driving could instead be used to complete paperwork, respond to customers, order parts or book appointments, leading to productivity gains and potentially savings for customers.

A common question surrounding the economics of CAVs is their likely impact on jobs. SMMT has suggested that whilst connected vehicles would create new jobs, autonomous vehicles would lead to a shift in jobs[71].

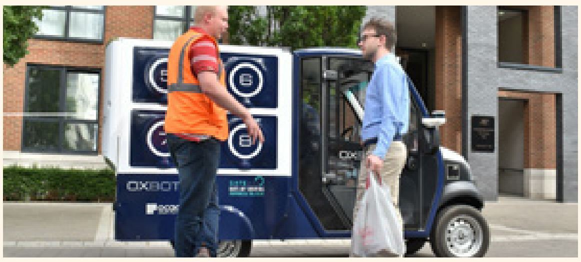
More highly automated CAVs (Level 4 upwards) could result in the loss of driving jobs which are currently a key part of the UK economy.

More than 950,000 people were employed as drivers in the road transport sector in 2016. These include HGV, van, bus, coach, taxi and PHV drivers, as well as driving instructors[72].

Numbers employed in driving expand far beyond the road transport sector alone. Research for MoneySuperMarket[73] calculates that 1,184,000 driving jobs in the UK are at a significant risk of being taken over due to automation. The research estimates that for every 10 driving positions, 8.3 face a 50% or higher chance of losing their role to machines. The jobs at highest risk were said to be food delivery drivers and customer delivery drivers (both at 98% chance of becoming automated, see case study below); rubbish truck and forklift drivers (both 93% chance); and bus, taxi, limo, van, HGV and removal van drivers (all 89% chance of automation).

Driverless deliveries – London and Milton Keynes

In 2017 as part of the GATEway Project (led by TRL and funded by the UK government), Ocado Technology (a division of UK grocery company Ocado) completed a two-week trial of autonomous grocery deliveries, using a 'CargoPod' vehicle developed by Oxbotica[74][75]. Accompanied at all times by human minders, the small electric vans were designed to carry eight crates and to be ideal for areas where larger vehicles are unsuitable. Unlike regular grocery deliveries, customers were required to go to the van to collect their shopping, rather than having it delivered to the door in person[76].



A customer collects his shopping from the van.
Credit: GATEway

Gated communities were one of the biggest obstacles that the trial encountered as the accompanying human was still needed to press buttons to open the gates[77].

Meanwhile, robot food[78] and package[79] delivery pods (resembling small boxes on wheels) by Starship are successfully navigating the streets of Milton Keynes (with human chaperones). The design of Milton Keynes favours small delivery bots. It is criss-crossed with underpasses and overpasses meaning that there is less need for the robots to negotiate traffic. Starship robots made their 50,000th delivery in the town in April 2019[80].

Delivery robots at a shopping centre in Milton Keynes.
Credit: StevePotter49 CC BY-SA 4.0
https://creativecommons.org/licenses/by-sa/4.0/deed.en

New role profiles may emerge as driving becomes 'deskilled'. The example of freight also highlights that there would be a continuing need for 'chaperones' for goods and that the nature or efficiency of the job could change with automation. A similar prediction could be made around public transport – we may no longer need drivers but, for customer peace of mind and safety, we may still need 'hosts'. Other vehicles providing a service, such as concrete mixers or rubbish trucks, will also continue to need people on board to do the skilled labour that a vehicle would not be able to do on its own.

Some argue that in order to improve the efficiency – and affordability – of services we need to shift our focus away from how we can automate drivers and instead think about *'how we can automate away tasks to make their work more efficient.'*[81] It has been suggested, for example, that drones could *'free up time for people to focus on higher-value work by automating routine tasks, such as infrastructure inspection'.*[82]

Autonomous metro lines – shifting role profiles

Metro lines around the world have been operating without drivers or specific on-board staff for many years. UITP report[83] that this has required significant changes to the qualifications of staff: *'Routine driving work disappears and staff are no longer locked inside a cabin, but deployed along the line and in contact with customers.'*

These new role profiles are still skilled positions which combine previously separate functions to create more diverse and potentially more stimulating jobs. Front-line staff require customer service skills as well as the technical knowledge to maintain and reset defective equipment or drive in case of failure.

This is in marked contrast to the role of a train driver which can often be lonely and remote from customer interactions. Where comparison is possible with conventional lines, indicators suggest greater job satisfaction and reduced absenteeism[84].

Re-deployment of staff to customer-facing roles in and around interchanges has been found to increase passenger satisfaction too, including increased feelings of safety and security[85].

Preparing bus drivers for autonomous futures[86] – Singapore

Around 100 bus drivers in Singapore are being trained to handle autonomous buses with more to follow as the technology develops. The initiative follows the signing of a Memorandum of Understanding (MOU) between the Land Transport Authority and industry stakeholders, including unions, employer representative bodies and bus operators.

The MOU is intended to demonstrate the signatories' commitment to upskill bus captains to enable them to take on new roles as autonomous technology develops. One role highlighted is that of 'safety operator', trained to take control of an autonomous bus if needed and remotely monitor its operation.

CAVs could also generate entirely new jobs. Research by KPMG[87] suggests that if the UK were to develop into a centre for excellence in CAV technology, 25,000 automotive manufacturing jobs could be created by 2030; plus 320,000 additional jobs generated by improvements in productivity and greater mobility of workers; as well as new jobs to support markets created by CAVs (for example, in digital media). If shared fleets of CAVs emerge, there will also be jobs in managing, maintaining and cleaning the vehicles.

Social

CAVs are often promoted as *'transformative and empowering for those with mobility issues.'*[88] Such claims are often endorsements of one particular kind of CAV – self-driving cars – which are seen as offering enhanced personal mobility for people who are currently unable to drive a car because of disability or older-age related issues. The Disabled Persons Transport Advisory Committee say that *'Technology has huge potential to make transport easier for disabled people and bring advantages to some people who will never otherwise get the benefits of the private car.'*[89]

In practice, CAVs are unlikely to be a mobility panacea for all. Some people will always need assistance getting in and out of vehicles and in reaching their final destination. Furthermore, there is a danger that in widening private car access (whether or not this is from a shared pool), the result will be a hollowed-out public transport network and neglected walking and cycling infrastructure, with all the health and equity challenges this implies.

On the other hand, automation and connectivity could potentially be used to improve the public transport offer and increase its appeal over more individualised vehicles, particularly in respect of affordability and availability.

CAV technology (once fully matured) could remove the need for drivers, thus potentially reducing overheads and making public transport more affordable. CAV mass transit is also likely to be electrically powered, further reducing overheads from fuel costs.

Some have predicted that, as CAV technology develops, more cities may decide to fully subsidise their bus services[90] as the financial outlay compared to the likely benefits becomes increasingly attractive (for example, reduced traffic, reduced drunk driving, increased commercial activity).

However, it is unclear to what extent an entirely unstaffed public transport vehicle would be acceptable, safe or practical. As mentioned above, it could be that some form of customer host or conductor will always be necessary, in which case staff overheads will remain and limit the extent to which fares could be lowered. That said, a recent study found that running a driverless dial-a-ride service with a steward on board could be between 26 and 41% cheaper than current equivalents[91].

If the operational costs of running public transport could be lowered by CAV technology, it may be possible to increase its availability, offering frequencies and levels of coverage that are currently not commercially viable, like early morning and late night, weekend and rural services[92].

Out-of-hours autonomous shuttle service[93] – Cambridge

Smart Cambridge, led by Cambridgeshire County Council, has been awarded £3.2 million by CCAV to develop autonomous shuttles to operate on part of the city's guided busway at times when ordinary buses do not run.

The out of hours service will run between Trumpington Park and Ride and Cambridge Station via the Cambridge Biomedical Campus site (which includes two hospitals), offering additional benefits for people working early or late shifts.

The shuttles, designed to seat 10-15 people, will be made in Coventry and are expected to appear on the busway by late Summer 2020.

Artist's impression of what the shuttle could look like. Credit: Cambridgeshire County Council, Aurrigo

UITP describes how in existing automated metro systems, operators have gained the flexibility to make better use of assets. Automation brings the promise of *'more tailored service coverage, reducing overcapacity supply at off-peak hours and enabling operators to inject trains in response to sudden surges in demand, for example in the case of big events.'*[94]

Reduced overheads also offer the opportunity to run smaller, shared CAVs providing first and last mile services, connecting people in outlying areas and suburbs to main transport hubs at a lower cost, as well as providing an attractive alternative to the private car.

Suburbs on key commuter routes could also see improved service frequencies and capacity using smaller autonomous vehicles, as envisaged by the Shared Use Mobility Center in the US:

"If there's a 12-person little vehicle coming down the street every five minutes versus a 40-person vehicle coming every 20 minutes, then you've got more capacity in that corridor and a much better experience for people."[95]

In the nearer future, continual improvements to connectivity features (with or without accompanying automation) could see more flexible and dynamic routing to reach more people whilst ensuring optimum efficiency for the network and convenience for the user.

Environmental

It is widely assumed that in order to contribute to a smart mobility future, CAVs will need to be electrically powered, ideally via a decarbonised power generation network.

Vehicles powered in this way will emit very little air pollution. Some degree of particulate matter from tyre wear will still be present, but it is anticipated that this will be reduced by the smoother driving styles CAVs employ, with less sudden acceleration and deceleration.

Estimates have suggested, for example, that the optimal eco-driving styles enabled by CAV technology (such as smoother braking and acceleration) could reduce energy consumption by between 5% and 20%[96].

A study led by the University of Michigan found that the added weight, electricity demand and aerodynamic drag of the sensors and computers used in CAVs are significant contributors to their lifetime energy use and greenhouse gas emissions. However, when savings associated with driving efficiencies were factored in, the net result was a reduction in lifetime energy use and associated greenhouse gas emissions of up to 9% compared to conventional vehicles[97].

Research by the Institute of Mechanical Engineers, Low CVP and University of Leeds predicts that *'The majority of system-wide energy efficiency gains are likely to result from high levels of connectivity and coordination between vehicles and infrastructure, not through automation per se. The greatest benefits will come from streamlining traffic flow, eco-routing, optimising network capacity and reducing congestion.'*[98]

Environmental concerns could act as a key driver in the way CAVs develop. Mott Macdonald, for example, notes that growing climate change and energy market crises could *'amplify concerns regarding innovations that promote lifestyle profligacy.'*[99] In this context, owning a car or single vehicle occupancy could become stigmatised and socially unacceptable.

KEY ISSUES FOR TRANSPORT AUTHORITIES ON CONNECTED AND AUTONOMOUS VEHICLES

This section explores some of the key issues which transport authorities need to consider when thinking through their potential options around CAVs. We focus in particular on:

- The transition to CAVs
- Viability of a sharing model
- Hollowing-out of public transport, walking and cycling
- Impact on the urban realm
- Impact on transport authority costs
- The digital deficit – data, skills and access

The transition to Connected and Autonomous Vehicles

The transition period during which vehicles with increasing levels of autonomy appear on the transport network is likely to be long and potentially indefinite. During this time, CAVs and conventionally driven vehicles may be operating alongside each other meaning that many of the benefits outlined in the previous section are unlikely to be fully achieved for some time – if ever. Indeed, some commentators believe that *'full autonomy, let alone universal shared use, is an impossibility'*[100]. Transport authorities will need to give some thought to what this transition stage could look like and how they might manage it.

Over the transition period, a mixture of self-driving and conventional vehicles could exacerbate congestion on city streets, with the Government's Actuary Department warning that *'traffic delays [can be] expected to worsen if only 25% of the vehicles are fully automated'*[101]. If operating in a mixed fleet, CAVs may be unable to adopt driving styles that maximise traffic flow and would continue to be faced with unpredictable human behaviour.

Unless CAVs are separated in some way from conventional vehicles (e.g. dedicated lanes for autonomous buses, CAV only streets, closed networks) all existing features for conventional vehicles (parking, speed bumps, road signs) would need to be maintained and potentially even added to as road users (including pedestrians and cyclists) learn how to safely share space with one another.

Viability of a sharing model

The increasing use of shared vehicles over private vehicle ownership is often placed at the centre of visions for a sustainable future involving CAVs.

5

BotRide – Irvine, California[102]

BotRide is a shared, on-demand, autonomous vehicle fleet trial operating on public roads in Irvine, California. A collaboration between Hyundai, Pony.ai and Via, the service uses advanced algorithms to enable multiple riders to share the same vehicle, booked via an app.

The app directs passengers to nearby stops for pick up and drop off, allowing for quick and efficient shared trips without lengthy detours, fixed routes or schedules. A central goal for the trial is to study consumer behaviour in an autonomous ride-sharing environment.

A customer prepares to catch his booked BotRide. Credit: Hyundai

Without the widespread use of shared fleets of vehicles (fully integrated with public transport services) it is often argued that there will be more traffic, less available road space and considerable limits to equality gains.

Research suggests that the public is yet to be sold on sharing vehicles. A survey of 730 Bristol residents[103] presented participants with four theoretical options to choose from:

1. A privately owned autonomous vehicle
2. An autonomous taxi (exclusive use)
3. An autonomous vehicle to be shared with up to 10 people (potentially strangers) travelling to similar destinations
4. An autonomous bus operating like a conventional bus

Well over half of the participants said that they would not be willing to use any of these options. Option three was the least popular (63% were unwilling to use it), followed by option two (54.5% unwilling to use). Options four (autonomous bus) and one (a privately owned autonomous vehicle) were the most popular choices, although 53% were still unwilling to use these.

The research found that participants were willing to pay a premium for more private modes (e.g. a privately owned car or sole use of a taxi) over shared or mass transit options.

The Bristol study purposely over-represented longer-established households with relatively older heads, typically aged 30 plus with experience of car ownership. It is possible that a younger cohort may be more willing to share, however, the popularity of Uber among younger people suggests that they too are content to pay a premium for privacy and a direct door-to-door service.

Similar findings emerged from a Government supported public dialogue[104] – participants recognised that sharing could achieve many of the potential benefits of CAVs, but they were reluctant to take up this model themselves. Cost savings did not persuade them otherwise, unless the savings were in the order of 25-50% compared to the cost of their current journey. Participants expressed additional concerns around personal safety in shared vehicles.

The Government has stated that exploring barriers to sharing will be a key priority for their future research into mobility[105].

Hollowing-out of public transport, walking and cycling

Without careful planning, there is a danger that the ease, convenience and comfort offered by more individualised CAV formats (particularly if they take users from door to door) could see them replace trips that would otherwise be taken on foot, by bike or on public transport. This risks leaving behind a skeleton public transport network for those with limited access to the alternatives. Ultimately, this would lead to more individual vehicles on the road, containing people who are experiencing increasingly inactive and atomised lifestyles.

There is evidence that the increasing availability and convenience of ride-hailing services like Uber and Lyft is already impacting on active travel and mass transit use. A major survey[106] of 4,000 ride-hailing service users across seven major US metropolitan areas found that, without a ride-hailing option, between 49 and 61% of trips either would not have been made, or would have been completed by public transport, bike or on foot.

Walking, cycling and public transport (whether connected and autonomous or not) will always represent the most space-efficient means of transporting large volumes of people. These modes also offer benefits for health and the environment as well as usually being more affordable than using a car or taxi. Transport authorities will need to consider how these modes remain relevant, competitive and attractive if there is a transition to more fully autonomous vehicles.

Impact on the urban realm

In an interview with the Independent newspaper, the Policy and Networks Manager of the Royal Town Planning Institute likened the arrival of CAVs to when private cars first became widely available between the 1930s and 1950s, noting that *"we just kind of adopted this new way of getting around wholesale, without thinking of the spatial implications...How did this change where we live and how we work? We aligned that around the car and down the line that led to a million different problems."*[107]

It is important that we avoid repeating the mistakes of the past. Cities which were designed around vehicles sought to move people out of the way of traffic, enabling it to travel unimpeded and at speed. Some visions of a CAV future imagine a stepping up of segregation in the urban realm. Kinder Baumgardner, President of international landscape architecture, planning and design firm SWA describes present day Hong Kong as a potential model for an autonomous future: *'If you look at Hong Kong, you have a city where pedestrians and vehicles are already separated to some extent. People use skyways, vehicles have unrestricted road space, almost the way you could imagine an autonomous city operating in the future if you scale it up'*.[108]

The example of Hong Kong is a clear case of people having to adapt their behaviour for the convenience of vehicles. An alternative future for the urban realm would see this position reversed with the streets given back to people and designed to maximise their free movement rather than unfettered vehicle access. This is likely to include lower vehicle speeds and more 'give and take' between road users.

Cycling UK imagines a future *'with AVs regulated to travel at safe speeds and subjected to access restrictions in urban areas'* meaning *'pedestrians and cyclists will enjoy much higher priority and the overall environment will be far more pleasant for them.'* [109] The eventual removal of driver error would help make road-sharing easier and safer. High take-up of shared modes would help free up road and street space.

In their *'Manifesto for City Centres in the Age of the Driverless Car'*, the consultancy Steer suggests that *'With the advent of CAVs, local authorities and policy makers will have a once-in-a-lifetime chance to re-consider how their cities' streets function as part of a movement network, offering a unique opportunity to use the 'extra space' to retrofit their cities in a more context-conscious and sustainable way.'*[110]

As the above quote suggests, it is often argued that CAVs, when fully mature and widespread, will free up space on our streets, leaving more room for other features such as wider pavements, parklets or cycle hire stations. Two factors are central to this assumption:

- Public transport, cycling and walking will be prioritised and complemented by a largely shared fleet of smaller vehicles (resulting in less traffic on the roads and more space for people).
- Fewer parking spaces will be needed as connected and autonomous cars or pods will drop off their passengers before going on to another job or returning to base.

As discussed above, public transport, cycling and walking are at risk of becoming hollowed-out in a CAV future and the viability of a shared model is by no means guaranteed.

In respect of parking, it is true to say that connected and autonomous cars will no longer need to remain at or near their destination having dropped off their passengers. It is easy to imagine the disappearance of large town and city centre car parks, freeing up space for other uses like public squares or play areas.

However, whether they are shared or privately owned, cars will need to go somewhere after they have dropped off their passengers. Returning home empty; circling the city waiting for another 'job'; or returning to a 'base' all add to congestion and contribute to a less pleasant urban realm. To maintain a healthy urban realm, authorities will need to consider regulatory measures to discourage this empty running. The need to return to a base would mean some form of parking would still be required even if this was out of town or underground. Potentially these car parks could fit more vehicles in a smaller space as CAVs would require far less room for manoeuvre than human drivers.

Whilst centrally located car parking could become unnecessary, CAVs will not necessarily free up kerb space. Both passenger and freight CAVs will continue to require space to pick-up and drop-off people and goods. Some 'standing still' space will continue to be needed on our streets.

The OECD recommend[111] that public authorities should anticipate and plan for the revenue impacts of shifting kerb use from car parking to pick-up/drop-off points. They suggest authorities consider whether they wish to price kerb usage and explore which instruments they might use (although acknowledge that these instruments have yet to be developed in many cases). They say that *'Pricing curb use can help cities retain the ability to manage traffic and transport demand by replacing parking pricing mechanisms.'*

Smart technology and connected vehicles could mean that these spaces are *'no longer static, inflexible installations. Instead curb use will resemble dynamic, highly flexible, self-solving puzzles.'*[112] Booking, allocating and controlling the use of spaces for different purposes and at different times of the day could all be done dynamically and in real time, with the infrastructure communicating with vehicles to control access.

Removing the need for a driver could make it more practical and cost effective to confine certain tasks and vehicle types to operating at particular times of the day. Automated road sweepers and gritters, for example, could run late at night or in the early hours of the morning ensuring the urban realm is in optimum condition for the day ahead.

Furthermore, if freight vehicles were able to operate without drivers, greater use could be made of night-time deliveries, helping to enhance urban realm and improve safety during the rest of the day.

Westfield AutoSweep[113]

Road sweeping is frequently safety critical, ensuring that foreign objects are removed from roadways to reduce the risk of punctures and associated collisions and delays. They also help to remove rubbish and debris, contributing to a more pleasant urban realm.

The Westfield Autosweep project seeks to automate this process with the aim of bringing about cost and time savings as well as better deployment of workers.

The project will bring together a Westfield 'POD' vehicle, a Johnston Sweeper and the Fusion Autonomy system to make the UK's first fully autonomous pure electric road sweeper. The vehicles may even be equipped with advanced sensors to enable them to automatically separate rubbish collected into different types[114].

The technology will be trialled at a number of UK airports as well as at the Trafford Centre in Manchester and MediaCity in Salford.

The AutoSweep pictured at an airport. Credit: Westfield

Impact on transport authority costs

Maintaining high quality urban realm and roads could become more costly as CAVs are introduced. CAVs may be less able to adapt to potholes[115]. They could also cause more damage to the road surface as they run consistently in the same lane positions meaning greater wear and tear in the wheel tracks[116]. CAVs use sensing technology such as Lidar as their 'eyes', requiring the street environment to be kept clear of obstructions, such as low-hanging branches, which could cause the vehicle to stop as it attempts to avoid damage.

Furthermore, according to the Government Actuary's Department, 'CAVs *would require markings, signals and signs to be maintained to a higher standard than at present to make sure instructions can be followed.*'[117] KPMG estimate that the cost of upgrading infrastructure and maintaining roads to a high standard for CAVs will rise to £11bn by 2030.

Even very subtle graffiti or stickers on road signs (that a human may not even notice), have been found to result in the cameras used in self-driving vehicles misidentifying the sign in the majority of cases[118].

All of this could present a challenge given council budgets for road maintenance are already under considerable strain. According to the Asphalt Industry Alliance, *'Highways teams in England and Wales report that the gap between the funds they received in 2017/18 and the amount they actually needed to keep the carriageway in reasonable order is approaching £556 million – a shortfall of £3.3 million for every authority'*[119].

The digital deficit – data, skills and access

CAVs will require high levels of digital connectivity in order to perform to their full potential. Smart technology could, for example, be used to programme cars to move out of the way and give priority to higher occupancy or emergency vehicles[120]. It could also be used to automatically price trips according to the number of passengers in the vehicle or environmental impact[121]. Cities could programme their streets to automatically control speeds, decide which vehicles will be given priority and when and who is allowed where.

CAVs will also be constantly recording and analysing information and data about their surroundings – from the behaviour of pedestrians to the state of road surfaces. This data could be used by local and highway authorities to generate insight on travel demand or which roads should be prioritised for maintenance or early intervention[122], invaluable for building an intelligent city.

We are, however, some way from achieving the connectivity that would enable CAVs to perform to their optimum capability. Currently less than 20% of UK roads have full 4G coverage, less than half have full 3G coverage, and 2% of roads (4,600 miles) have no 2G coverage from any network provider[123].

The House of Lords inquiry into CAVs has recommended that *'The Government must take action with Highways England to improve digital connectivity, removing 'not spots' on British roads… in order to realise the benefits of connected vehicles'*[124].

Transport authorities face a challenge in understanding how to future-proof their infrastructure to enable CAVs to communicate with each other and their surroundings, as well as to feedback in a way that is accessible and useful. This is a substantial task, particularly given there is no certainty regarding what technologies will dominate and what they will require of infrastructure.

Engineering consultancy HORIBA MIRA note a potential disconnect between what CAV manufacturers are developing and what those responsible for infrastructure are prioritising: *'Where autonomous vehicles are currently based on sensing technology such as Lidar, radar and cameras, infrastructure providers are focusing on bringing advanced communication and vehicle monitoring systems to the road network – resulting in a disjointed approach when it comes to mainstream CAV deployment.'*

They see the ultimate goal as being to combine these capabilities, *'enabling CAVs to connect and learn from other vehicles and the infrastructure to optimise mobility solutions and improve safety.'*[125] The consultancy recommends that road infrastructure authorities – including local councils – must team-up with CAV developers to share knowledge and develop trials.

The focus of road infrastructure providers on ensuring advanced communication networks are in place is, however, understandable given that one of the few certainties is that cities will need to ensure that their infrastructure is equipped to allow the generation, collection and analysis of large volumes of data. New devices are being designed that will need 5G to perform to their full potential, something that is being tested and rolled out in some UK cities[126].

5G Urban Connected Communities Project[127] [128] – West Midlands

The West Midlands is to be the UK's first multi-city 5G test bed (and the first of its kind anywhere in the world), with hubs in Birmingham, Coventry and Wolverhampton. Submitted by West Midlands Combined Authority (WMCA), connected and autonomous vehicles formed a key part of the successful bid.

5G connectivity is seen by many as an essential pre-requisite for the roll-out of CAVs given the split-second decisions vehicles will have to make, taking account of the varied and complex data provided by their surroundings[129]. WMCA is set to receive £25million in match funding from the Government to deliver the project.

WMCA will partner with Jaguar Land Rover to facilitate real world testing of driverless cars, benefiting from the use of 5G.

The test bed also plans to use 5G to support 'Connected Ambulances', enabling paramedic crews to access live streaming of patient data en-route to a scene, as well as draw on specialist advice on arrival (for example, via video conferencing).

The RAC Foundation highlights the needs of CAVs for highly accurate and precise data, recommending that *'Implementing roadside communications – for instance incorporating communication devices in street lights – may be desirable on all roads, and actually essential on urban roads for both precision and as a backup to other systems.'*[130]

Having installed increasingly sophisticated technology, the RAC Foundation warns that local authorities are likely to face significantly increased maintenance costs, arguing that this has been the case in the aviation and rail sectors[131].

Assuming greater network coverage is achieved and the necessary infrastructure is in place, cities will then need to contend with accessing and making best use of the data that is generated, something that is fraught with difficulty. To begin with, there is the question of who owns the data.

There is a risk that vehicle and infrastructure manufacturers, for example, will want to hold on to the data for their own use to generate intelligence around potential customers and their behaviour. Transport authorities would be well advised to have data-collection and data-sharing policies ready before CAVs arrive.

There is then the question of whether transport authorities will have the staff capacity and skills to handle and analyse the data and translate insights into improvements on the ground. In the view of the Local Government Association, this task represents a big challenge for councils but one which it is important for them to rise to given it *'is likely to become a key function of local highway authorities in the near future.'*[132]

Assuming data is made available and that staff have the skills to use it, there are then issues around privacy, ethics, accountability and transparency that transport authorities must be able to answer.

OPTIONS FOR TRANSPORT AUTHORITIES ON CONNECTED AND AUTONOMOUS VEHICLES

6

Cities around the world are taking various approaches to CAVs and the issues they raise that UK transport authorities can learn from.

Laissez-faire – various US states

In the USA for example, a somewhat laissez-faire approach is not unusual as states compete to provide the most attractive environment for new start-ups, technology and innovation. This can, however, be very dangerous.

Arizona took an 'all roads open to CAV testing' approach with few restrictions and little oversight. It was the site of the first fatal crash involving a self-driving vehicle and a pedestrian in the US[133]. Following the crash, Uber (who were responsible for the vehicle) were expelled from operating autonomous cars on public roads.

Other cities in the US have also ended up stepping in reactively once it becomes clear that a trial or new service is having negative impacts.

For example, San Francisco had taken a fairly relaxed approach to allowing small delivery robots to run along city pavements. However, as numbers increased, pedestrians began to complain that robots constituted an obstruction to walking. Lawmakers responded[134] by passing legislation to ensure that only nine delivery robots are allowed to operate at any one time across the entire city. Additionally, they are only allowed to operate in industrial areas or on pavements that are at least six feet wide. They must also be accompanied by a human chaperone at all times. Referring to previous experiences of disruptive technology, the author of the legislation said:

"When it comes to being proactive about the development of common sense regulations for commuter shuttles or the sharing economy, such as Airbnb or Uber, somehow we have sent the signal that it is acceptable to act now and ask for forgiveness later... That is not an example of a city that leads."[135]

Guiding hand – Singapore

Singapore is recognised as taking more of a 'guiding hand' approach to the deployment of CAVs, topping the 'policy and legislation' category in KPMG's Autonomous Vehicle Readiness Index (closely followed by the UK in second place)[136]. The city-state already has strong disincentives to private car ownership and is keen to actively shape CAVs as an opportunity to transform public transport and further reduce reliance on private cars[137].

As far back as 2014, Singapore's Ministry of Transport set up the Committee on Autonomous Road Transport for Singapore together with the public sector, academia and industry to provide thought leadership and guidance to the development of CAVs.

The country's Land Transport Authority (LTA) has a three-phase road map for deployment of the technology[138]. Phase One involves trials in testbeds and controlled environments, including within the Centre of Excellence for Testing and Research of AVs (CETRAN) which simulates real world road environments. CETRAN will certify CAVs for use on public roads and develop Singapore standards for the vehicles.

Phase Two involves limited town deployment of mass transit/shared CAVs on selected commuter services as well as deployment of truck platoons and utility vehicles (e.g. road sweepers) in some areas. The final phase will see island-wide deployment – new towns will be designed to work for CAVs and existing towns will be retrofitted.

The road map is underpinned by upgrades to infrastructure, systems, regulations and standards; action to boost public acceptability; work with industry; and efforts to equip the workforce with the right skills (e.g. retraining bus captains, see case study on p.23). In terms of regulations and standards, one particularly notable action has been the amendment of Singapore's Road Traffic Act to empower the Transport Minister to regulate the use of CAVs[139]. It allows changes to rules to be made quickly to adapt in response to developments in CAV technology. Importantly, a sunset clause is included at the end of five years, at which point, regulation will cease to have an effect unless it is incorporated into relevant Acts or the sunset clause is extended. This enables the Singapore government to balance controls and flexibility.

Partner – Helsinki

Like Singapore, Helsinki in Finland also aims to use CAV technology to enhance public transport and sustainable mobility[140], but in this case the regional transport authority (HSL) takes the role of partner rather than leader. The entire road network is described as open for experimentation and the traffic safety authority take a permissive approach[141]. HSL sees its job as to help integrate CAVs into the public transport system as well as identify suitable routes and areas for pilots. It also works to define the reasonable role and added value of automated vehicles in the public transport system, keeping its overarching goal of enhancing the mass transit network in mind.

In the examples above, the approach taken is very much influenced by the context and culture of each city, state and country, and may not directly apply to the UK. However, whether transport authorities take a 'hands off' approach as in many US states (with the option to intervene if negative outcomes occur), act as a guiding hand and thought leader as in Singapore or something in-between the two (as in Helsinki), there is no doubt that they have a central role in preparing for, and managing, the emergence of CAVs. Leaving the planning and implementation entirely to the market would lead to uncertain and potentially negative impacts in our cities, depending on the priorities, motivation and resources of the private sector players who are involved. The quote below from Elon Musk, co-founder and CEO at Tesla, a leading developer of self-driving cars, helps to illustrate the danger of private sector priorities and world views being at odds with goals for sustainable city development:

'I think public transport is painful... Why do you want to get on something with a lot of other people, that doesn't leave where you want it to leave, doesn't start where you want it to start, doesn't end where you want it to end? And it doesn't go all the time... And there's like a bunch of random strangers... And that's why people like individualised transport, that goes where you want, when you want.'[142]

Guided by the wrong hands, there is a risk that CAVs will be implemented in a way that leads to chaotic, uncoordinated networks; increased congestion; declining active travel and public transport use; greater use of scarce energy supplies; inequality of access to transport; and increasing vehicle miles travelled.

Setting the ground rules

It is the task of transport authorities, in partnership with central government – and ideally with vehicle manufacturers and would-be transport service providers – to steer the introduction of CAVs in a direction that maximises the benefits to people, safety, the environment and the economy at local level. This input is also necessary to ensure that the development of CAVs is informed by infrastructure requirements and constraints in the real world[143] and that consumer benefits are balanced with protecting the wider public interest in the context of unique local circumstances and wider civic aspirations.

UITP recommends that *'Now is the time to start preparing the right regulatory framework for AVs to ensure they will serve cities' policy objectives'*[144].

By setting out what is acceptable and what outcomes they want to see, transport authorities also give confidence to investors who will gain a good idea of what they will need to do in order to be welcomed into a city. In doing so, cities can remain 'open for business' and attractive to innovators whilst at the same time ensuring that CAV developers understand the rules they must play by.

Given that there are so many uncertainties around exactly how CAVs will evolve and when, increasing numbers of cities are choosing to begin with a 'principles' based approach which they can use as a barometer to measure not just CAVs, but any new transport service or technology.

The Department for Transport's 'Future of Mobility: Urban Strategy' takes just such an approach, setting out nine principles that will guide its response.

The Government's nine Principles for the Future of Mobility[145]

In facilitating innovation in urban mobility for freight, passengers and services, the Government state that its approach will be underpinned as far as possible by the following Principles:

- New modes of transport and new mobility services must be safe and secure by design.
- The benefits of innovation in mobility must be available to all parts of the UK and all segments of society.
- Walking, cycling and active travel must remain the best options for short urban journeys.
- Mass transit must remain fundamental to an efficient transport system.
- New mobility services must lead the transition to zero emissions.
- Mobility innovation must help to reduce congestion through more efficient use of limited road space, for example through sharing rides, increasing occupancy or consolidating freight.
- The marketplace for mobility must be open to stimulate innovation and give the best deal to consumers.
- New mobility services must be designed to operate as part of an integrated transport system combining public, private and multiple modes for transport users.
- Data from new mobility services must be shared where appropriate to improve choice and the operation of the transport system.

Transport for London (TfL) has also taken a principles-based approach which applies to all new transport services and technologies, as set out in the Mayor's Transport Strategy (see box on p.38).

Policy 23 – London[146]

Part of the London Mayor's Transport Strategy – Policy 23 – provides the guiding principles for London's approach to new transport services and technologies, including CAVs. The principles are as follows:

a) **Supporting mode shift away from car travel:** new transport services should not encourage more car journeys, especially where there are good walking, cycling or public transport options.

b) **Complementing the public transport system:** new services should help more people who would otherwise complete their journey by car to access the public transport network, while not reducing walking and cycling to and from stops and stations. They should also provide a means of travel in areas where public transport connectivity is currently poor.

c) **Opening travel to all:** new services should be accessible to all and should not contribute to the creation of social, economic or digital divides in which some people would have better travel options than others.

d) **Cleaning London's air and reducing carbon emissions:** new services should achieve the very best emissions standards to reduce emissions of carbon dioxide, nitrogen oxides and particulate matter in London, and enable faster switching to cleaner technologies.

e) **Creating a safe, attractive environment on our streets:** new services and technology should help create a safer, quieter and more pleasant environment on London's streets, where it is more attractive to walk or cycle, and should not lead to existing active trips being made by non-active modes. There must always be an emphasis on the safety of passengers, people walking and cycling, and other road users. Where this involves introducing technology directly into the street, it should be done in a co-ordinated way that enhances the overall character of the street, reduces clutter, and does not prevent future potential re-allocation of space for walking, cycling and public transport.

f) **Using space efficiently:** new services must make efficient use of road and kerb space, be appropriate for the area of London in which they operate and support opportunities to re-allocate space for walking, cycling and public transport.

g) **Sharing data and knowledge:** where possible, data and knowledge should be shared with TfL and the Greater London Authority to enable improved monitoring, operating and planning of the transport network.

London has also set out its position on CAVs in a statement[147] and developed specific guidance setting out its expectations of organisations seeking to trial CAVs in London[148]. Intended to sit alongside the Mayor's Transport Strategy, TfL's CAV Statement and CCAV's Code of Practice, the guidance sets out:

- London's collaborative approach.
- How to establish contact (emphasising that this should be done at the earliest opportunity).
- What prospective trialling organisations will need to tell TfL and affected London boroughs.
- Standards to be met and permissions to be sought.

- Responsibilities around transparency and communications with local communities.
- Expectations around data and knowledge sharing.
- It is hoped that, together, this suite of documents will be used as a platform for building positive relationships with industry. Furthermore, they could all serve as useful templates for other transport authorities to adapt as they develop their own positions and guidance on CAVs.

Powers and regulations

Having set the principles and ground rules that are right for their people and places, transport authorities can look at what they can do with existing powers and regulations to ensure CAVs serve the needs of cities. For example, they could explore how licensing could be used to limit numbers of vehicles – as is already done for taxis – or consider measures such as road user charging to discourage private cars from entering cities or to deter empty running.

However, the availability of many useful levers is highly dependent on action at national level. The Government is currently conducting a review to explore regulation around new transport modes (including CAVs) looking at whether existing laws are fit for purpose and what might need to change[149].

The Law Commission is also looking specifically at what regulations might be needed to govern what it refers to as Highly Automated Road Passenger Services (HARPS)[150] having also explored issues around safety assurance and legal liability for CAVs.

UTG is commissioning specific research on what an appropriate legal and regulatory framework for smart futures on transport might look like in relation to the key challenges transport authorities face. This will be the subject of a separate report.

Getting the basics in place

Transport authorities, with support from national government, can also work on getting the basics in place which will support the sustainable introduction of CAVs but also serve them well regardless of when (or if) CAVs take off. These include, but are not limited to, investment in:

- **Alternatives to individualised, motorised modes** that instead move large volumes of people efficiently and in a way that brings benefits to safety, health and the environment – walking, cycling and public transport. Work to ensure these modes offer an experience that surpasses what car-based travel offers now and in the future. Design places that put people first, not vehicles. Make walking and cycling routes safe and attractive. Make public transport vehicles high quality spaces within which to spend time and be productive. Make these modes the obvious choice so that they have a competitive edge as new mobility formats emerge.

- **Electrification and charging infrastructure** for the full range of vehicles from e-cargo bikes to buses, trains to vans.

- **Safer roads** – as the House of Lords inquiry advised, *'CAVs are not the only way to reduce road casualties.'*[151] Traffic calming measures, lower speed limits, improved crossing facilities and vehicle design features such as improved vision standards for HGVs all help to improve safety outcomes for vulnerable road users, saving lives and for relatively low costs[152].

- **5G connectivity** to make the most of smart vehicles and the 'internet of things'.

- **Skills** – work on developing the skills of the current and future workforce in order to be able to make the most of the increasing volumes of data coming our way and use it to build more intelligent transport networks.

CONCLUSIONS AND RECOMMENDATIONS

This report has shown that our largest urban areas in particular are already embracing the potential benefits CAVs and other new transport technologies could bring for their communities and are playing an active role in developing trials to ensure that their operation is grounded in the real-world and all its complexities – from horizontal rain to budgetary constraints.

The report has sought to build on this work and to provide a framework for transport authorities to think about the wider and long term implications that CAVs have for urban transport (as well as wider public policy goals) and the role that transport authorities could play on CAVs.

It has shown that although we are already on a CAVs trajectory there are considerable uncertainties about how fast and how far it will go. It is also possible that CAV technology may find its most advanced and rapid application for some types of vehicles but not for others. These uncertainties are compounded because each stage of the CAVs journey could evolve under different business models, or wider transport scenarios, bringing with it the potential for a differing mix of challenges and benefits.

However, even with this degree of uncertainty and complexity there are a number of conclusions that can be drawn.

Wider public policy goals for urban areas, around creating inclusive economies which are environmentally sustainable, already inform the strategies and policies of transport authorities. This report suggests that whatever approach transport authorities take to CAVs, it should be embedded in a **principles-based model** against which they can gauge and guide the evolving contribution of CAVs to those wider public policy goals.

A number of authorities, as well as the UK government, have developed sets of principles that suit the ambitions, context and priorities of the areas they serve. If this approach is followed it will help to steer CAVs policy in a way that maximises the wider benefits to people and places.

Much of the debate around CAVs has focussed on the vehicles with relatively little attention given to the roads they will run on. To operate effectively and safely CAVs will require a far better maintained **highway network** than we currently have, bringing significant cost implications. It is time we stopped talking almost exclusively about the vehicles and started talking more about the standard of road infrastructure that CAVs will need and how this will be funded.

A particular type of CAV – the car – also dominates the CAVs discussion when, in fact, public service vehicles running on segregated infrastructure, campus mobility and utility vehicles could be more logical and beneficial early applications for the technology, as well as offer scope for greater transport authority involvement. It is important that the considerable resources being invested into long term aspirations for Level 5 cars do not obscure the potential for delivering more attainable gains for **other types of vehicles** (particularly those with public service functions).

Much of the literature on CAVs is also preoccupied with how to respond to an end state (whether that is a utopian dream or a Bladerunner-style nightmare) where all vehicles are Level 5. However, the reality is that we have already begun an uneven and unpredictable journey which may or may not end in universal Level 5 vehicles.

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More policy attention should be given to how best national and sub-national government can respond to the messier, here and now reality of **continual and uneven transition.**

It is unlikely that transport authorities will wish to take responsibility for overall regulation of the safety of CAVs or their technical development. However, given the major implications for transport networks, urban transport authorities need **regulatory tools** to control shared CAVs in the same way that they already have such tools in relation to conventional buses and taxis. The extent to which they want to use these tools should be at the discretion of each transport authority (as is the case for conventional buses and taxis) but without such powers there are risks of temporary swamping of provision to gain market dominance, the undermining of mass transit and other disbenefits which may go against the public interest.

At the same time, transport authorities need more effective **'sandbox' powers** which they can use to trial new CAV applications where they wish to do so.

In short, the wider principles around devolution of decision making over local transport should extend to CAVs as they do to vehicles which are not autonomous. Having spent recent decades making progress towards the devolution of decision making we should avoid the danger that technology becomes the means by which urban transport policy making is re-centralised whilst its provision is deregulated.

CAVs are one element in wider transformative mobility futures which transport authorities face. This transformative change also includes the rapid growth in app-driven Private Hire Vehicle services; e-scooters and powered personal mobility devices; dockless bikes; and the explosion in data.

For transport authorities, responding to these waves of change sits alongside all their existing transport roles and responsibilities as well as other significant challenges, like playing their part in tackling the climate emergency. Yet at the same time, transport authority **resource funding** has been significantly reduced in recent years.

This leaves transport authorities for even some of the UK's largest urban areas with few or no specialist staff working on transformative technological issues like CAVs. At a time when vast amounts of state and private funding are being pumped into the CAVs sector, a vanishingly small fraction of that amount is being spent on equipping urban areas with the long term capacity they need to respond to the opportunities this could bring. It is time to address this significant imbalance to ensure that CAVs have the supporting infrastructure and policies they will need to function in a way that works for people, places and UK PLC as a whole.

More widely, if the Government's commitment to accelerating the take up and development of CAVs is to be realised then transport authorities need **a seat at the top table** on how this is to unfold. National policy makers, transport authorities and CAV developers alike agree that widespread roll out of CAVs presents huge challenges – from getting the legal framework right to predicting consumer responses and from developing viable business models to future proofing our roads. These 'wicked problems' cannot be solved alone.

Continuing dialogue which explores and respects the priorities of the different stakeholders will be essential. Both 'heaven' and 'hell' scenarios for a CAV future are possible. Given their responsibility to place the public interest first, it is vitally important that local government has a seat at the table to help sway the balance towards the more heavenly possibilities.

In support of these findings this report makes the following recommendations to Government.

Recommendation 1: Support transport authorities to make connections with national policy makers and CAV developers

National government has an important role to play in convening stakeholders to promote dialogue, involvement and exchange of expertise. Local government must be supported to be part of this conversation given that how CAVs develop will have direct consequences for their places and communities, impacting on local priorities and aspirations for good or ill.

Recommendation 2: Maintain a balanced research programme into the impacts of CAVs

As CAVs develop, it will be important to conduct balanced research to assess their economic, social, environmental, safety and health impacts. Such research is vital to inform planning and decision making at local and national level.

Recommendation 3: National government to provide guidance to transport authorities on how to manage a lengthy – potentially indefinite – transition to CAV technologies

Such guidance can never be definitive and must take the form of an evolving resource as future scenarios become clearer. However, it should give transport authorities an overview of the issues they will need to consider and the contingencies they may need to put in place as CAVs develop.

Recommendation 4: Ensure transport authorities have the long-term funding certainty they need to plan for, and respond to CAVs

To plan effectively for CAVs and other future transport developments, transport authorities need longer term funding certainty to have the space and security to think strategically and to recruit and retain the skills they will need. This would, for example, allow the formulation of long-term, phased plans to ensure new transport developments – like CAVs – form part of a wider vision for how we want our places to look and feel and what we want them to achieve. It would also allow for the upskilling of the workforce to get the best out of the opportunities CAVs could bring around data.

Recommendation 5: More research and funding to be focused on the highways CAVs will run on

The highway maintenance and infrastructure requirements of CAVs are important – and potentially very costly – considerations for transport authorities with limited budgets even to catch-up with the current road maintenance backlog. Government at national and local level, together with industry and academia must work to understand the implications CAVs will have for our roads.

Recommendation 6: Develop a legal and regulatory framework for CAVs which gives transport authorities the powers they need both to innovate and to balance the consumer interest with the wider local public interest

With regulatory reviews currently being conducted by Government and the Law Commission exploring the legal framework that should apply to CAVs, we need a system which continues to allow for local discretion and decision making over local transport, including the ability to regulate autonomous shared vehicles in the same way as shared conventional vehicles (taxis and buses).

Transport authorities also need anticipatory or 'sandbox' regulations which give them the flexibility and security to identify, build and test smart technology, including CAVs. Crucially, regulations should give transport authorities the powers they need to act if a new mobility service or product is causing harm to the public good.

Overall this report shows that if we are to get the best from emerging CAVs technologies then we need to take a broader view of the vehicles that might benefit, and the highways infrastructure they run on, than is currently the case. We also need to move away from a fixation with idealised, and as yet, hypothetical end states of full autonomy. Instead we need to focus more on the here and now reality of an uneven and uncertain series of transitions which in turn need to be placed within the context of how they benefit both people and the wider public policy goals that cities have for inclusive and sustainable economies. Transport authorities need to be involved and properly resourced and empowered on CAVs if their benefits are to be fully realised.

Finally, despite all of the many important and unanswered questions that will continue to surround CAVs for many years to come, one thing is certain: we cannot wait in the hope that CAVs will save us.

Much can be achieved with the tools we have now and investing in these will stand us in good stead when – and if – more autonomous CAVs become a mainstream feature of our transport network. This includes prioritising public transport, walking and cycling to ensure they can hold their own against individual, motorised modes; boosting our charging infrastructure to support electrification of vehicle fleets; working to make our roads safer; extending 5G connectivity to make the most of smart vehicles; and ensuring we have the skills to understand and apply the insights they could bring. Focusing on these tasks now – as well as implementing the recommendations outlined above – will help ensure that as CAV technologies develop, we will be ready to get the best out of them for our places and people.

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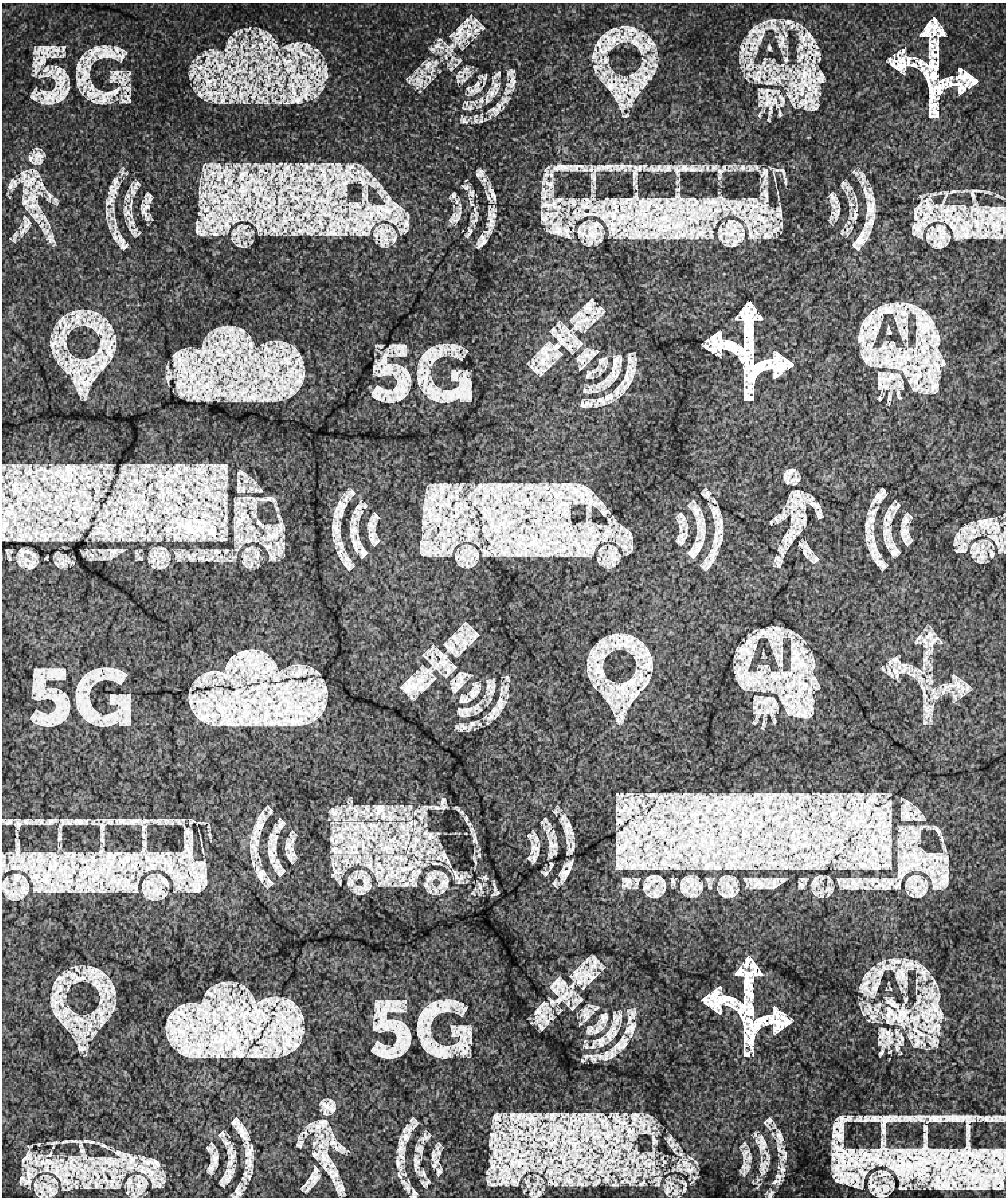

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