Enabling connected and autonomous vehicles:

The smart investment for UK infrastructure

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Executive Summary

We are in the middle of a connectivity **revolution**

Connected and autonomous vehicles (CAV) have the potential to fundamentally change the way we live, work and drive.

Last year, UK drivers wasted an average of 31 hours in rush-hour traffic, costing the average motorist £1,168. Traffic congestion is also a significant contributor to the UK's air quality problems, attributed to an estimated 40,000 premature deaths every year.

CAV, a subset of intelligent mobility, promise to relieve congestion through the use of emerging technology and data, bringing estimated annual benefits to the UK in the region of £51Bn by 2030. While much of the focus has been on autonomous, or 'self-driving', vehicles, there are connected vehicle technologies very near to market which have proven benefits in improving traffic flow, improving safety and reducing harmful emissions from vehicles.

The UK's readiness for CAV is let down by its digital and physical infrastructure. We must invest in smart infrastructure to enable these technologies, which may include additional mobile network infrastructure, the latest roadside technology, cyber-secure intelligent transport systems or, more likely, a combination of all the above. The global market for CAV is estimated to be worth £907Bn by 2035. The UK is currently in a good position to build on existing investments made through the Centre for Connected and Autonomous Vehicles (CCAV) and realise these benefits earlier. However, strong competition from across the globe means that time is short if we are to make the most of this opportunity.

This report looks at the significant progress to date as well as the opportunities ahead for the UK from the CAV market, putting forward five recommendations to build on existing capability and progress:

1. Commission the deployment of an agreed set of Collaborative Intelligent Transport System (C-ITS) services across a wider area of the UK road network

2. Encourage/incentivise combined and local authorities to upgrade their traffic management systems

3. Invest in the development of transport-related cyber security expertise in the UK through future funding competitions

4. Investigate potential changes to urban design and public transport to incentivise shared ownership models

5. Investigate links between connected vehicles and the incentivisation of alternative fuels.

With the right investment strategies, holistic approach, policy environment and continued levels of collaboration, the UK can continue to be at the forefront of connected and autonomous vehicles.

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UK drivers wasted an average of 31 hours in rush-hour traffic last year. Not only does this increase the stress of travelling from A to B, but it also costs the average motorist £1,168[1] extra per year. Our congested transport network is a big contributor to the UK's air quality problems, which are linked to an estimated 40,000 premature deaths in the UK each year[2].

Intelligent mobility (IM) is a concept that aims to connect various transport modes through technology and data with surrounding environments. It "uses emerging technologies to enable the smarter, greener and more efficient movement of people and goods around the world"[3]. This incorporates everything from autonomous vehicles to seamless journey systems and multi-modal modelling software.

One subset of intelligent mobility is connected and autonomous vehicles (CAV), which are seen as a huge opportunity for the UK to help address some of our key transport challenges. The benefits of CAV, such as enabling more efficient journeys and reducing the costs of freight transport, are estimated to be worth £51Bn/year by 2030, after taking into account a cost of £11bn/year to install and maintain more intelligent infrastructure[4].

There is currently a lot of hype around the autonomous aspect of CAV, also known as 'self-driving cars'. The recent UK Autodrive[5] trials of autonomous vehicles in Milton Keynes and Coventry show how this research is being taken seriously. However, while partially-automated vehicles are already on the roads, fully automated vehicles which can drive on all roads across the UK road network may still be some years away.

Figure 1: Connected and Autonomous Vehicle Market Data – data from multiple sources

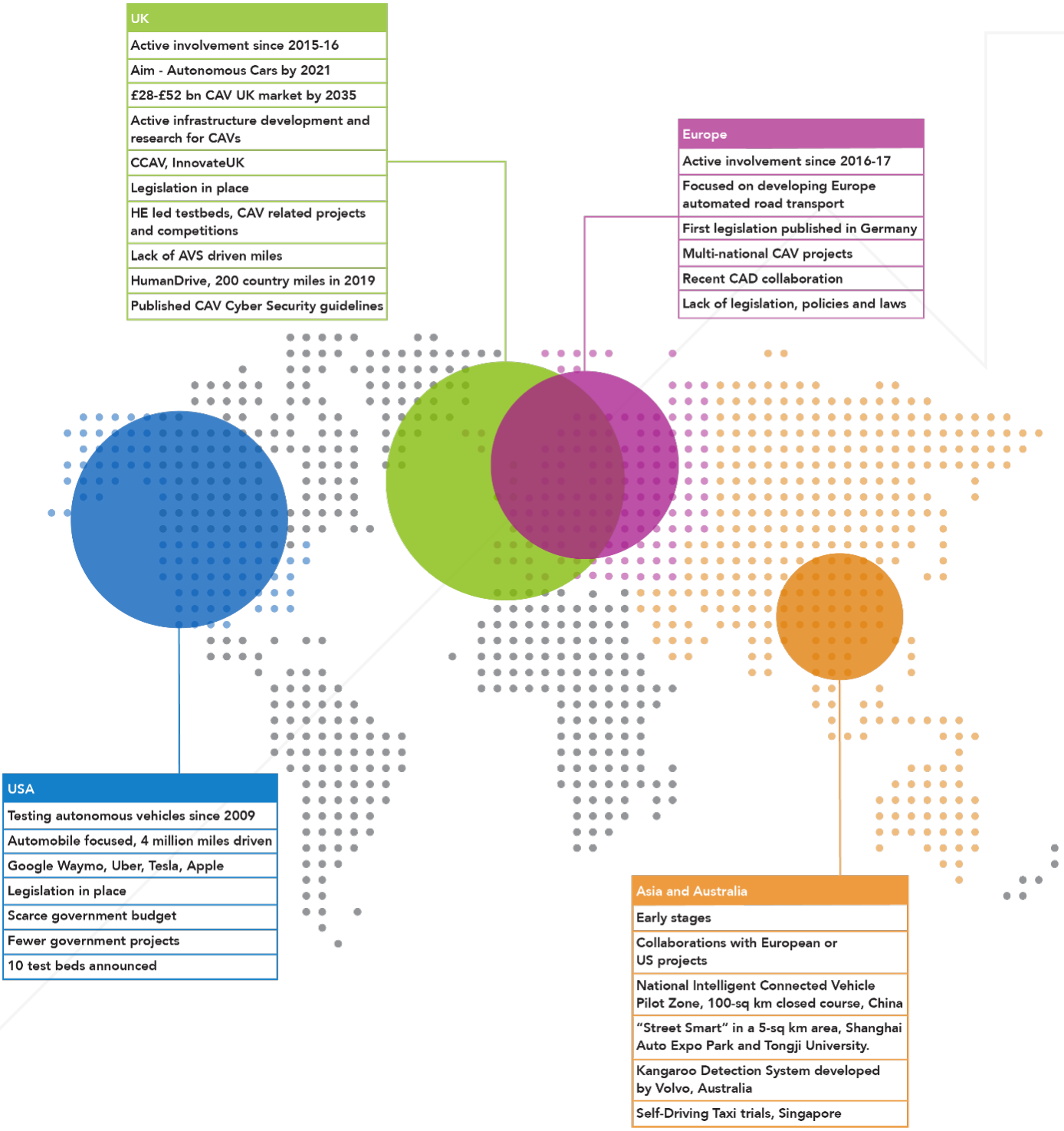


Figure 2: A sample of Connected and Autonomous Vehicle testing initiatives across the world.

There are, however, connected vehicle services which could be delivered today to start bringing benefits to the public. In the very near future, connected vehicles will be able to receive messages directly from the surrounding infrastructure and other nearby vehicles. Your car will tell you whether to speed up or slow down as you approach the next set of traffic lights to avoid having to stop. It will know when you are approaching incidents or roadworks and will warn you or suggest a diversion, and it will gather data from other connected vehicles on the road to keep you safe while driving. These are all services included in an agreed list of 'day 1 services', as defined by the Amsterdam Group and the European Cooperative Intelligent Transport System (C-ITS) Platform[6].

These services have been shown to improve congestion and traffic flow, resulting in fewer delays to journeys, reduced fuel consumption and therefore reduced emissions. They also improve safety through better provision of information such as lane closures to drivers, and the targeted sharing of data between vehicles.

There is a strong business case to invest in enabling C-ITS services across the UK. To support the further development of CAV and ensure the UK's security, investment in transport-related cyber security capability is also of vital importance. In addition, there are further benefits to be discovered through shared ownership models and linking up connected vehicle technologies with the incentivisation and optimisation of alternative fuels, which are only starting to be fully understood and would benefit from further investigation.

Tackling congestion with technology

One of the main causes of congestion on UK roads is drivers hitting the brakes or suddenly changing lanes, causing a chain reaction. This has been found to have more of an impact on traffic than collisions[7]. Congestion in urban areas may also be exacerbated by problematic street layouts and designs.

Intelligent mobility solutions seek to reduce the negative effects our transport systems have on our surroundings, whilst simultaneously improving the experience and safety of road travel. Examples include a move towards services such as Uber and Citymapper, which use communication with the traveller and real-time traffic data updates to offer the idea of 'mobility as a service'. These services boost the use of public transport, as it becomes much easier to navigate and a more efficient mode of travel. This in turn helps to reduce car ownership, especially in highly congested, highly polluted cities where there is a great need for this[8].

Vehicle manufacturers such as Nissan have developed intelligent driving, intelligent power and intelligent integration to tackle the problems with congestion, carbon emissions and communication between vehicles, people and infrastructure[9]. According to the Society of Motor Manufacturers and Traders (SMMT), "already more than half of new cars sold are available with at least one semi-autonomous driving feature and the vast majority have some form of connected technology"[10].

The current largest barriers to IM and CAV development are connectivity capability and the UK's digital infrastructure. Issues such as poor mobile internet coverage is leading some automotive manufacturers to look to other countries to roll out new connected technologies[11]. Increasing international competition makes this a global race to become a leader in what promises to be a global market worth £907Bn by 2035[12].

With the development of autonomous vehicles there is an opportunity for new shared ownership models to evolve. If private vehicle ownership remains the norm, the benefit of autonomous vehicles on congestion may be limited. Shared ownership combined with autonomy using technological solutions opens up new business models which could reduce the number of vehicles on the road, with concepts such as robo-taxis. Across China, Europe, and the United States, the shared-mobility market was nearly $54 billion in 2016 and is expected to experience impressive annual growth rates in the future[13].

To enable these opportunities, authorities must consider multi-model systems, city planning and the role of public transport within a CAV-enabled world. Options such as making certain areas 'autonomous only' could increase the use of these vehicles, but if not linked to public transport systems or combined with ridesharing initiatives could increase traffic and congestion rather than decrease it.

Cooperative Intelligent Transport Systems (C-ITS):

What are they and why are we interested?

For the UK to remain competitive in the international CAV market, there is a need to invest and improve our digital infrastructure. One way of doing this is to enable Cooperative Intelligent Transport Systems (C-ITS) across the UK, to realise the expected benefits.

C-ITS focus on the communications between technologies providing intelligence on the transport network, including vehicles, roadside units, infrastructure such as traffic lights or road signs or a wider network. Increased communication between these devices has the potential to significantly improve road safety by helping the driver to take the right decision and adapt to the traffic situation[14], as well as reducing the causes of congestion and improving driver comfort.

The C-ITS 'Day 1' and 'Day 1.5' services listed in Table 1 have been identified based on their potential to answer major societal needs. The total benefits of deploying thee services across the Trans-European Transport Network (Ten-T), of which the UK is a part, has been estimated to reach €15Bn per year by 2030[15]. The expected benefits are dominated by reduced travel times (2 billion hours, or 3% of total time spent on the road), reduced accident rates and reduced fuel consumption.

In England, the average person spends 216 hours in a car each year[17]. Over 14% of that time (31 hours) is currently spent in rush hour traffic[18]. By smoothing traffic flows and reducing accident rates, C-ITS services have the potential to allow commuters and travellers to reclaim that lost time.

Even more importantly, the safety related services such as hazardous location warning, in-vehicle speed limits and intersection safety are expected to bring an additional 7% reduction in fatalities, as well as serious and minor injuries. In terms of sustainability and air quality, fuel consumption and CO_2 emissions are expected to drop by 1.2% by 2030, with smaller reductions in other harmful emissions such as NOx, CO, VOC and PM[19].

Table 1: C-ITS day 1 and day 1.5 services. Data from[16]

Day 1 Services	Day 1.5 Services
Emergency electronic brake light	Off street parking information
Emergency vehicle approaching	On street parking information and management
Slow or stationary vehicle(s)	Park & Ride information
Traffic jam ahead warning	Information on AFV fuelling & charging stations
Hazardous location notification	Traffic information and smart routing
Road works warning	Zone access control for urban areas
Weather conditions	Loading zone management
In-vehicle signage	Vulnerable road user protection (pedestrians and cyclists)
In-vehicle speed limits	Cooperative collision risk warning
Probe vehicle data	Motorcycle approaching indication
Shockwave damping	Wrong way driving
GLOSA / Time To Green (TTG)	
Signal violation / Intersection safety	
Traffic signal priority request by designated vehicles	

Investing in C-ITS, CAV and intelligent mobility

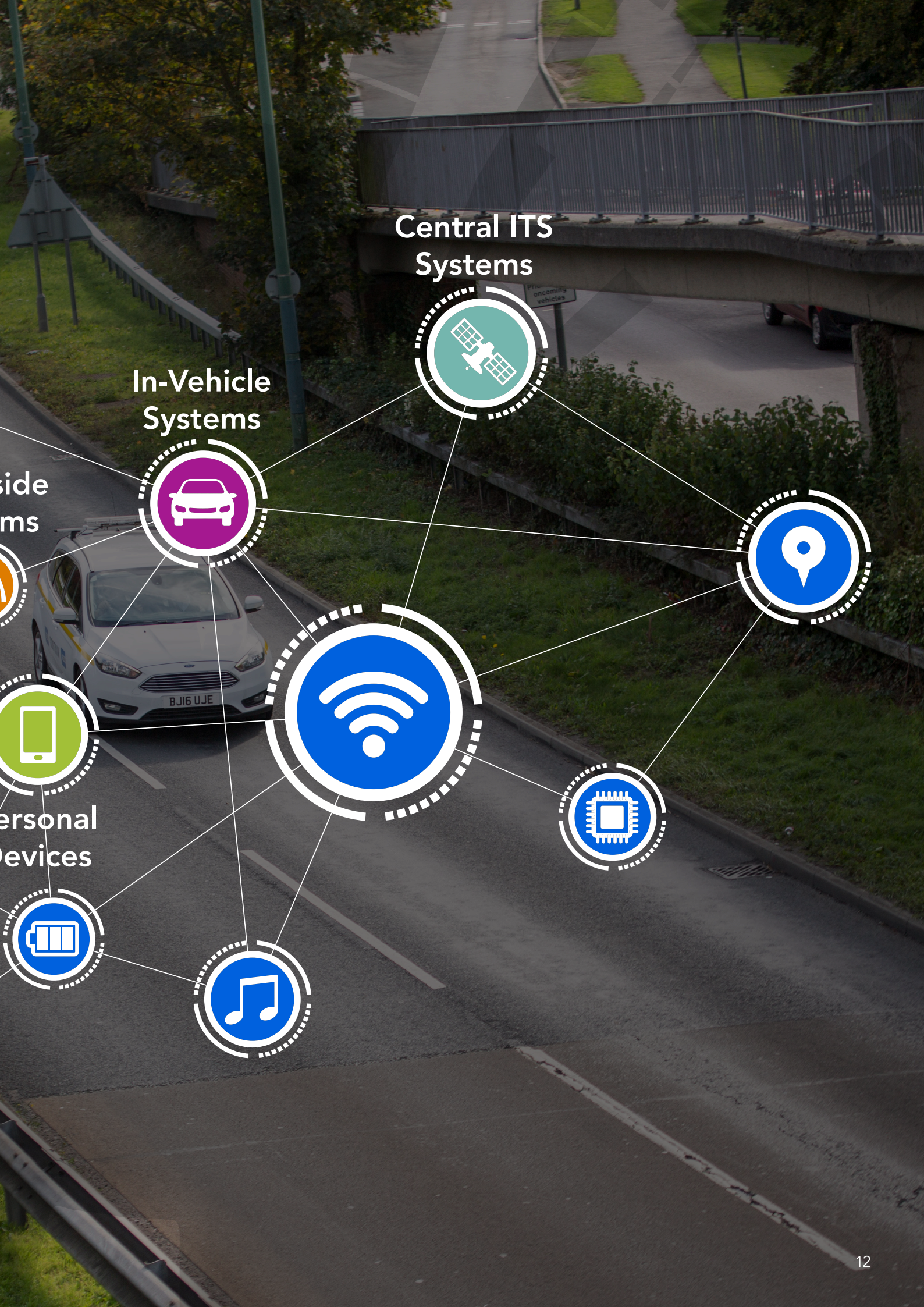
The C-ITS services, and the connectivity required to enable them, underpin future developments in autonomous vehicles and intelligent mobility services. The UK market for CAV (vehicles) is estimated to be worth £28Bn in 2035, and the market for CAV technologies (installed in vehicles) a further £2.7Bn[20]. However, this does not take into account wider economic impacts of the use of CAV technologies or creation of new and novel business models.

As we have experienced with the likes of services such as Uber and Deliveroo, with connectivity and technology comes disruptive business models, with all the associated opportunities for economic growth. An example is MaaS Global[21], who are bringing together car hire, bus, tram, bikes, trains and taxi services into a single monthly subscription model via their Whim app. This sort of service would not be possible without connectivity and adoption of technology.

Enabling the C-ITS services requires different systems to communicate:

- Central systems to manage C-ITS services for a city or section of the transport network
- Roadside systems such as beacons which enable vehicle-to-infrastructure communication
- In-Vehicle systems which enable both vehicle-to-vehicle and vehicle-to-infrastructure communication
- Personal devices including mobile phones, tables or sat-navs.

Figure 3: Components of a Cooperative Intelligent Transport System


Central ITS Systems
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Some of the identified services, such as 'emergency vehicle approaching', require vehicle-to-vehicle connectivity. Others such as 'road works warning' and 'GLOSA / time to green' require vehicle-to-infrastructure or vehicle-to-network connections.

Global vehicle manufacturers such as Volkswagen[22] and General Motors[23] have already invested in the in-vehicle systems required to enable their 2019 vehicles to take advantage of these services.

Here in the UK, the Government has invested £120m in research and development for CAV through match-funded investments with industry[24]. Costain is a key partner in the Midlands Future Mobility testbed, which will be the UK's largest real-world testbed across the West Midlands and will deploy the enabling infrastructure to accelerate CAV development[25]. This testbed is ideally located to build upon the strong automotive manufacturing capability based in the region, and involves the West Midlands Combined Authority and Warwick Manufacturing Group working alongside industry partners.

Highways England, the Department for Transport, Kent County Council and Transport for London are all involved in the A2M2 Connected Corridor project to test the interoperability of specially-equipped vehicles interacting with roadside infrastructure, and to promote the UK as market leader in CAV and C-ITS technology. Costain are leading the delivery of this project, which is part of InterCor, an EU project that aims to test services that are interoperable across borders, connecting the UK to the Netherlands, France and Belgium[26].

The Journeys of tomorrow start today

Midlands Future Mobility will be developing new tehnologies quickly, connecting passengers and goods with vehicles in new ways.

Together, we are developing a unique environment that will enable the testing of new automotive and communications technologies

50-mile network of roads

Continuous connectivity

diverse road environments

Smart monitoring

Figure 4: Midlands Future Mobility – CAV Testbed

These investments help transport authorities and industry partners to understand the challenges involved in implementing these services and increase collaboration between the UK and other countries. This is particularly important in making sure the technologies still work when users travel across country borders.

A key question that remains is where future investments are best spent to enable these C-ITS services as quickly as possible across the UK road network. Decisions need to be made on the extent of roadside systems to be deployed – or whether these are required at all – and how best to upgrade existing central systems to communicate directly with a new generation of smarter, connected vehicles. The vehicle manufacturers have had C-ITS in their sights for some time, UK infrastructure and the systems which sit behind it now need to be made ready for the connected revolution.

Investing in the live deployment of the day 1 and day 1.5 C-ITS services across an area of the UK road network would force an answer to some of these questions, and act as a proving ground to monitor and measure the expected benefits as connected vehicles become more widely used. This would naturally become an area to try new services and models as they are developed by enterprising and disruptive businesses.

Across the UK, we have a diverse range of systems covering local authority areas, some of which are now coordinated by a combined authority with devolved budgets and controls. Achieving maximum benefits from CAV is to an extent dependent on the involvement of these authorities in upgrading their systems to be 'CAV-ready'. This means enabling two-way communication with roadside infrastructure, vehicles and networks, which will allow proactive management of the transport network. Some authorities are already at the forefront of developments and have been proactive in this area, others may require support. Anything the government can do to incentivise and encourage these developments would ultimately help to achieve the expected benefits.

Meridian[27] have been set up by the UK government to help bring the many stakeholders together to assist in answering some of the complex questions remaining, and to facilitate and support the acceleration of the UK's CAV sector. Many uncertainties remain including standards, approach to cyber security, whether vehicles need 'digital passports' and to what extent the UK should look to develop a 'digital twin' of the transport network. What is clear is that investing in the smart infrastructure required to enable these services is key to the UK's future success in intelligent mobility.

The cyber-security challenge

The increased connectivity introduced to transportation through CAV results in increased risk of cyber-attack, if the systems (central, vehicle, roadside and personal) are not thoroughly protected and constantly updated. The uptake and acceptance of CAV, and therefore the realisation of benefits, will be very dependent on their safety and security being thoroughly demonstrated to the public.

According to the Joint Committee on the National Security Strategy, the gap between demand and supply of cyber-security skills for Critical National Infrastructure (CNI), which includes transportation, water supply and electricity generation amongst others, is now verging on a crisis[28].

For connected vehicles, the use of Public Key Infrastructure (PKI) certificates to verify the authenticity of the newly connected devices to the transport network is the current best practice approach. However, these standards are still being developed, new approaches may be needed to take into account scalability issues and rapidly changing communications technology.

The UK Government announced a spend of £1.9Bn from 2016-2021 to mitigate cyber risks and develop capabilities. However, as highlighted in the Flourish Insurance and Legal report on the successful implementation of CAV: "Given the cost to businesses of dealing with cyber attacks or breaches, the potential cost to Government of not investing in this area could potentially be significantly greater in terms of lost investment, jobs, productivity and tax receipts."[29] Further developing cyber security capabilities will also have considerable economic benefits, given the importance to a vast array of new technologies which will improve future productivity and standards of service across the UK[30].

To incentivise the development of cyber-security capability by the private sector, the government could consider focussing future funding opportunities on this area, specifically relating to the unique challenges brought by the introduction of CAV to UK roads.

Connectivity and alternative fuels

The vehicles of the future are set to move away from petrol and diesel to make use of alternative fuels. While electric vehicles (EV) have been around for decades, there has been a slow uptake in the UK due to a lack of infrastructure and challenges with range anxiety. By comparison, in Norway EV have made up 45% of new car sales in 2018 (or 60% when including plug-in hybrids)[31], compared to sub 3% in the UK (8% including hybrids)[32]. Norway achieved this by starting the drive for EV infrastructure in 2007 while the technology was still developing. There are parallels to be drawn here with the currently developing CAV market where the UK has the opportunity to lead.

There are also potential synergies to be made between enabling CAVs and incentivising alternative fuel vehicles. Connected vehicles generate data, and many of these vehicles will use alternative fuels. Decisions on how to tackle blockers such as range anxiety and lack of charging / refuelling infrastructure can be informed by the ever-increasing fleet of connected, low carbon vehicles. Frustrations by users of these vehicles could be quickly communicated and acted upon by the authorities with whom the data is shared. This may be particularly important when considering how the highest polluters such as heavy goods vehicles could be converted to alternative fuels. With 30% of total nitrogen oxide (NOx) emissions and 20% of total PM emissions attributed to transport[33], this is a challenge worthy of further investigation.

Enabling connected and autonomous vehicles - recommendations

In their 2018 Autonomous Vehicles Readiness Index, KPMG placed the UK at number five in the world, behind Sweden, the US, Singapore and the Netherlands, who ranked top. In infrastructure, the UK ranked 10th, due to "one of the lowest scores for 4G coverage, along with significant improvements which may be required to the road network"[34]. The report does, however, highlight that the UK has positioned itself as an attractive proving ground for autonomous vehicle technology in Europe through recent government investments in this area (Midlands Future Mobility being one of these).

To improve the UK's readiness for CAV, and to build on this useful niche, this report suggests 5 areas where the UK government should focus investment:

1. Commission the deployment of an agreed set of C-ITS services across a wider area of the UK road network

This would help to quantify and clarify the benefits of these, produce answers to some of the outstanding technical questions and promote the uptake of connected vehicles in the UK. To enable these services may also require upgrading 4G coverage across the road network, which would underpin future autonomous vehicle and mobility services. A hybrid solution of cellular and roadside unit-based services is a likely option to ensure coverage across areas which are a mix of urban, inter-urban and rural roads.

2. Encourage or incentivise combined and local authorities to upgrade their traffic management systems

To enable the C-ITS services and realise the benefits, the central traffic / transport management systems used by local authorities must be able to communicate with infrastructure and vehicles. Making these systems 'CAV-ready' will not only encourage the uptake of connected vehicles but will also promote disruptive urban mobility business models, such as shared mobility services and multi-model transport connections.

The longer-term aim should be to enable these systems to communicate seamlessly to ensure that those using the transport network consistently receive a high-quality service.

3. Invest in the development of transport-related cyber security expertise in the UK

Increased connectivity results in increased risk of cyber-attack, if the systems (central, vehicle, roadside and personal) are not thoroughly protected and constantly updated. This requires a significant level of expertise, which will only grow as these technologies become more widely adopted. The UK Government announced a spend of £1.9Bn from 2016-2021 to mitigate cyber risks and develop capabilities. This is across all aspects of cyber security, and there are many inherent uncertainties associated with CAV which may require a more targeted approach. This expertise could be grown

through future funding competitions to incentivise businesses to build capability in this area.

4. Investigate potential changes to urban design and public transport to incentivise shared ownership models.

While enabling C-ITS services would be a great leap forward, there are potentially even larger benefits to be gained by considering changes to urban design and public transport. This is particularly true where this would incentivise new ownership models and result in fewer vehicles on the road. The answers will be very dependent on local environments, geographies and demographics. Questions to be asked include:

a. How can we change/enhance current road and public transport layout to steer people towards shared ownership over private ownership, whilst still maintaining public transport use and increasing walking and cycling?

b. What behaviours are desirable to drive the target benefits in congestion and air quality? A balance may be needed between investments into better public transport routes, new shared CAV hubs, incentivisation models for urban mobility schemes and enhanced rural connectivity.

5. Investigate potential links between connected vehicles and the incentivisation of alternative fuels

Given the fundamental shift away from petrol and diesel vehicles to alternative fuels, how can data sharing with connected vehicles inform plans for new charging/refuelling infrastructure? If, as seems likely, electric vehicles play a large part in any new mix, how can we reduce the uncertainty for additional loading on the energy network using these connected technologies? Funding specific studies into these areas could bring much wider benefits by joining up thinking across the transportation and energy sectors in the UK.

Summary

The UK has clear challenges with congestion on our transport networks. Connected and autonomous vehicles (CAV) are expected to help relieve congestion using emerging technology and data, bringing estimated annual benefits in the region of £51Bn by 2030. However, while partially-automated vehicles are already on the roads, fully automated vehicles which can drive on all roads across the UK road network may still be some way away.

The Cooperative Intelligent Transport System (C-ITS) day 1 and day 1.5 services can be delivered today to start bringing benefits to the public. These focus on the communications between technologies providing intelligence on the transport network and are expected to bring benefits worth €15Bn per year by 2030 across Europe. Combining these benefits with an anticipated UK market for CAV and CAV technologies of £30.7Bn by 2035, there is a very strong case for the UK to position itself as a leader in CAV technology through investing in smart infrastructure, building on the investments made to date in CAV research and development.

To build on existing developments and keep the UK at the forefront of this industry, the following suggestions are put forward:

1. Commission the deployment of an agreed set of C-ITS services across a wider area of the UK road network

2. Encourage/incentivise combined and local authorities to upgrade their traffic management systems

3. Invest in the development of transport-related cyber security expertise in the UK through future funding competitions

4. Investigate potential changes to urban design and public transport to incentivise shared ownership models

5. Investigate potential links between connected vehicles and the incentivisation of alternative fuels.

Costain and connected and autonomous vehicles

"We believe connected and autonomous vehicles are an important part of the future of transportation. Costain are at the forefront of developments to enable CAV technology and services in the UK."

Costain is dedicated to improving people's lives through smart infrastructure solutions.

Our connected and autonomous vehicles programme is focused on the delivery of four key services:

1. Deliver and maintain vehicle to infrastructure (V2X) communication systems for national and local transport authorities

2. Advise national and local transport authorities on how to realise the benefits of CAV

3. Collect and analyse CAV data with strategic partners to improve the safety and security of the transport network

4. Provide cyber-security assurance for new technology connecting to transport networks.

We are delivering these services on the UK's largest real-world testbed, one of the UK's first pilot connected vehicle corridors and the UK's first HGV platooning trial, amongst others.

This expertise is backed up by over 150 years of experience in the delivery of national infrastructure projects across the transportation, energy and water sectors. We have been improving peoples' lives since 1865. We deliver services across consultancy, complex project delivery, technology integration and implementation and asset optimisation.

For most of the last two centuries, the solution to infrastructure reaching capacity or becoming life expired was to build more of it: more roads, more railway lines, more water treatment works.

In recent decades it has become clear that we can't always build our way out of our most complex challenges. What society demands from us now is to get more efficiency out of our existing assets. To be smarter. Here at Costain our clients are asking us to provide more intelligent infrastructure solutions that will enable them to be smarter and more efficient.

They want to understand exactly how their existing assets are operating, how those assets can be used more efficiently, and how they can maximise capacity. The best way to achieve this is by integrating engineering and programme management skills with digital technology capabilities. This is certainly the case when it comes to solving congested roads and smart traffic management which is the focus for this report. Technology is available now and being trialled which in the near future can make a real difference to our lives.

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