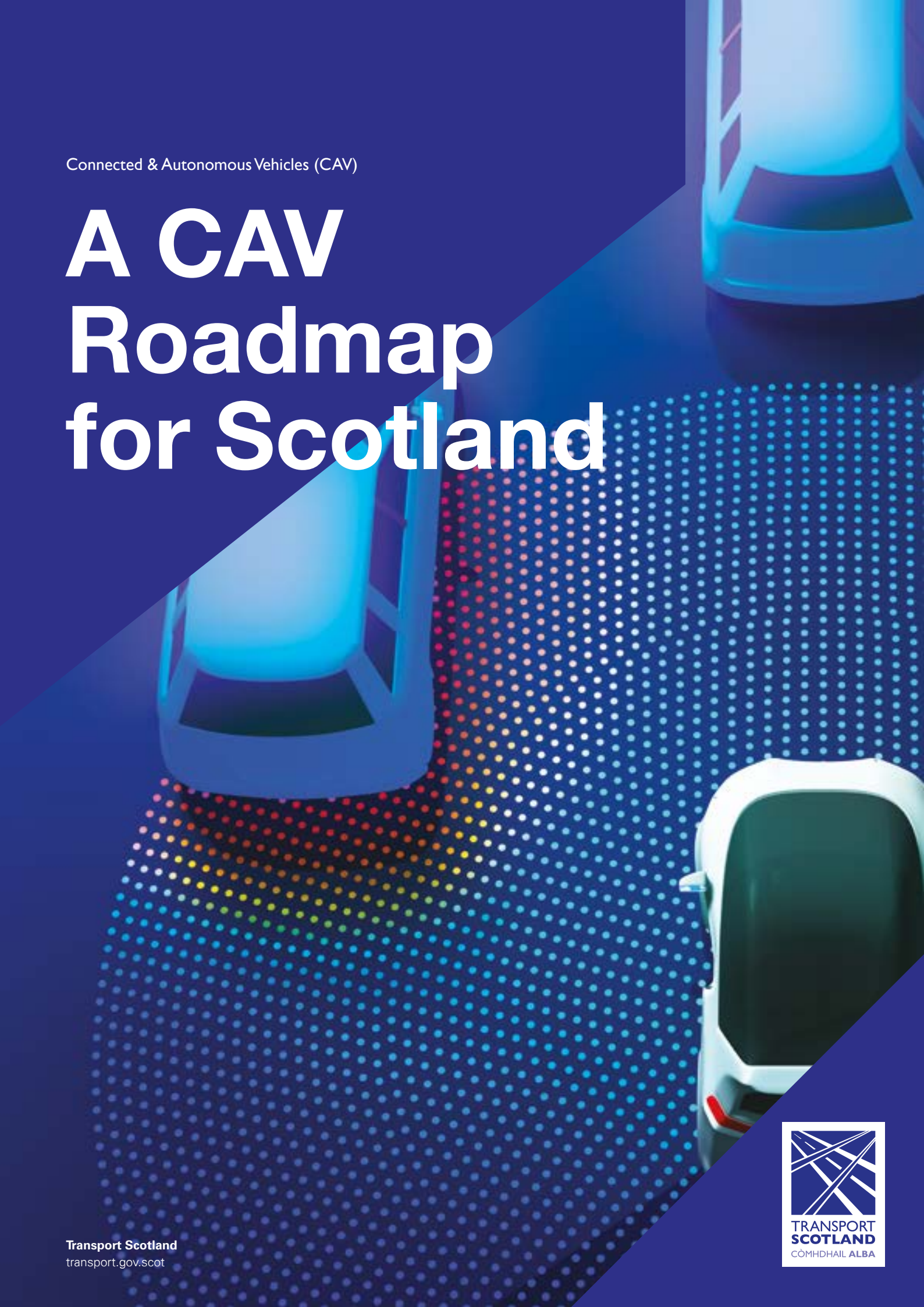
Connected & Autonomous Vehicles (CAV)

A CAV Roadmap for Scotland



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Read more online at:
www.transport.gov.scot/cav

Michael Matheson MSP

The development and deployment of Connected and Autonomous Vehicles (CAV) has the potential to bring transformative change to people's lives, not just in how we travel, but in how we work, where we live, the environment, and safety. CAV technologies also offer exciting potential for Scottish industries to be at the forefront of innovation and economic growth.

As Cabinet Secretary for Transport, Infrastructure and Connectivity I intend Scotland to be at the forefront of these technologies as they are developed, tested and implemented.

Scotland is 'open for business' to test, demonstrate and pilot autonomous vehicle trials, and to showcase what Scotland has to offer in support of the development of future intelligent mobility solutions, and this CAV Roadmap supports our Programme for Government commitment for Scotland to be at the forefront of developments in CAV, offering high quality test and demonstrator opportunities to developers and industry.

As we publish the CAV Roadmap, Scotland is already establishing its CAV credentials on the world stage with the ground-breaking and globally significant Project CAV Forth in which a consortium of partners from government, industry and academia are collaborating in the design, development and operation of a fleet of full size autonomous buses between Fife and Edinburgh, across the Forth Road Bridge.

I expect the publication of the CAV Roadmap to act as an enabler for more innovative and exciting opportunities for Scotland to be at the forefront in contributing to and developing the future of transport both in Scotland and around the world.

Michael Matheson MSP

Cabinet Secretary for Transport, Infrastructure and Connectivity

December 2019

Glossary

The following is a list of definitions for terms appearing throughout this document:

Term	Definition
Advanced Driver Assistance Systems (ADAS)	Vehicle-based intelligent systems developed to automate / adapt / enhance vehicle systems for safety and better driving.
Amsterdam Group	A group, named after the venue of the first meeting in 2012, was originally set up to assess and make recommendations in respect of who invests in Cooperative Intelligent Transport Systems first: the automotive industry or the infrastructure owners and operators. It has subsequently gone on to define key services to be delivered and how these are expected to mature. The group includes representatives from the Car-to-Car Communication Consortium, POLIS (a network of European cities and regions working together to deploy innovative solutions for a more sustainable mobility), Conference of European Directors of Roads (CEDR) and ASECAP (Association Europeene des Concessionaires d'Autoroutes et d'Ouvrages a Peage), each of which acts an umbrella organisation for a larger number of members. The role of the Amsterdam Group is to: provide a forum for networking and communication between individual members of the group; exchange experience between projects and stakeholders; communicate with EC and other bodies (e.g. ETSI / CEN); propose functional specifications and input for standards development; and identify and seek solutions to address barriers for deployment.
Autonomous / Automated Vehicles (AV)	'Autonomous (or Automated) Vehicles' are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to monitor constantly the roadway while operating in self-driving mode.
Connected Vehicles (CV)	'Connected vehicles' are vehicles that use any of a number of different communication technologies to communicate with the driver, other vehicles on the road, roadside infrastructure, and to other systems and services via the Cloud.
Intelligent Mobility	Encompassing everything from autonomous vehicles to seamless journey systems and multi-modal modelling software, Intelligent Mobility uses emerging technologies to enable the smarter, greener and more efficient movement of people and goods around the world.
Intelligent Transport Systems (ITS)	ITS is the deployment, operation, on-going maintenance and renewal of roadside infrastructure such as cable networks, CCTV and traffic detectors, gantry signals, VMS and information travellers via web services, smartphone apps, news feeds, social media and radio broadcasts.
ITS-G5	Local, beacon based, technologies that transmit data between vehicles and infrastructure using special frequencies and protocols designed for transport.
Internet of Things (IoT)	The inter-networking of physical devices, vehicles, buildings and other items – embedded with electronics, software, sensors, actuators and network connectivity that enable these objects to collect and exchange data.
Light Detection and Ranging (LIDAR)	An instrument which detects the position and/or motion of objects and which operates similarly to a radar, but which uses laser radiation rather than microwaves.
Living Lab	A user-centered, open-innovation ecosystem, often in a specific geographical context (e.g. city, region).
Mobility as a Service (MaaS)	Various forms of transport services integrated through digital mobility service platform(s), accessible by users on demand. MaaS has the potential to change the way people travel from A to B by providing more comprehensive travel planning and retail options, addressing the 'missing mile' issue.
Original Equipment Manufacturer (OEM)	Nominal parlance for Tier 1 Automotive manufacturers which integrate products, components and services to deliver a finished vehicle to the market.

Abbreviations

The following is a list of abbreviations and associated definitions for terms appearing throughout this document:

Abbreviation	Definition
ADAS	Advanced Driver Assistance Systems
ADS	Advanced Driver Systems
AI	Artificial Intelligence
AQMA	Air Quality Management Area
AVs	Autonomous Vehicles
CAV(s)	Connected and Autonomous Vehicle(s)
CCAV	Centre for Connected and Autonomous Vehicles (UK)
C-ITS	Co-operative Intelligent Transport Systems
DfT	Department for Transport
DSR	Demand-side response
EU	European Union
EVs	Electric Vehicles
GDP	Gross Domestic Product
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engines
I2I	Infrastructure to Infrastructure
I2V	Infrastructure to Vehicle
IoT	Internet of Things
ITS	Intelligent Transport Systems
LEZ	Low Emission Zone
LIDAR	Light Detection and Ranging
MaaS	Mobility as a Service
MILL	Mobility Integration Living Lab
NTS	National Transport Strategy
OEM	Original Equipment Manufacturer
R&D	Research and Development
SCDI	Scottish Council for Development and Industry
SME	Small and Medium sized enterprise
STEM	Science, Technology, Engineering, Mathematics
TSNCC	Traffic Scotland National Control Centre
UNESCO	The United Nations Educational, Scientific and Cultural Organisation
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
VMS	Variable message sign
VRU	Vulnerable Road User

Scotland is open for business to continue the testing, trialling and refining of Connected and Autonomous Vehicle technologies.

01 | Introduction

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1 Introduction

> The Scottish Government is committed to developing an integrated, sustainable, accessible and environmentally friendly transport system."

1.1 OUR MISSION

The Scottish Government is committed to developing an integrated, sustainable, accessible and environmentally friendly transport system. The development and use of Connected and Autonomous Vehicles (CAV) and associated infrastructure can deliver significant, wide-ranging benefits for the people of Scotland. Through improvements in safety and efficiency, it has the potential to bring transformative change to peoples' lives, not just in how we travel but in how we work, where we live and for the environment.

We are extremely well positioned to build on our existing industrial and academic assets and capabilities whilst simultaneously developing new skills and capabilities. We are committed to ensuring that we are able to deliver the numerous benefits that CAV technology could bring to the population of Scotland.

Scotland is very much open for business and this is an ideal environment and window of opportunity for automotive manufacturers, academic institutions, regulatory authorities and business leaders to continue the testing, trialling and refining of CAV technologies here.

The adoption of CAV technologies is expected to deliver both substantial safety benefits and economic growth attributable to productivity gains and the reduced cost of transport. Opportunities exist not only in how we use CAV technologies, but also in how we contribute to their development. Scotland has a rich heritage in innovation and we are fast becoming a leading player in digital engineering, with strong capabilities in gaming and simulation, battery technology and the use of advanced intelligence in image processing and quantum computing; all of which are key enablers of development of CAV technologies.

When combined with the uniqueness of our road network, challenges in delivering rural mobility and the recognised capabilities of our Higher Education Institutions, Scotland is a highly attractive environment in which to explore the further development of CAV technologies. We are well-positioned to build on our existing assets and capabilities whilst developing the new skills required to support CAVs.

As responsibility for the legal frameworks governing a number of emerging technologies remain a reserved matter, the Scottish Government will work with the UK Government to position Scotland as a global leader in the safe and responsible testing of automated vehicles. Facilitating fully self-driving vehicles on our roads by 2021 will help deliver the economic benefits of the Industrial Strategy in Scotland.

The initiatives proposed within this CAV Roadmap for Scotland will help us harness the opportunities and address the challenges. The time is now to unlock what CAV can do for Scotland, and what Scotland can do for CAV. Scotland is open for business. We are driven to be at the forefront of this exciting industry and committed to ensuring that all of Scotland benefits from the development and deployment of CAVs.

1.2 PURPOSE OF THIS DOCUMENT

This CAV Roadmap for Scotland explores the opportunities associated with the adoption of CAV technologies on Scotland's roads and the challenges in their deployment. It sets out the relationship between CAV technologies and the Scottish Government's transport and economic ambitions. It also explores where and how CAV technologies could be utilised, where and how we can benefit from contributing to their development and what interventions and initiatives might be required for us to unlock these opportunities.

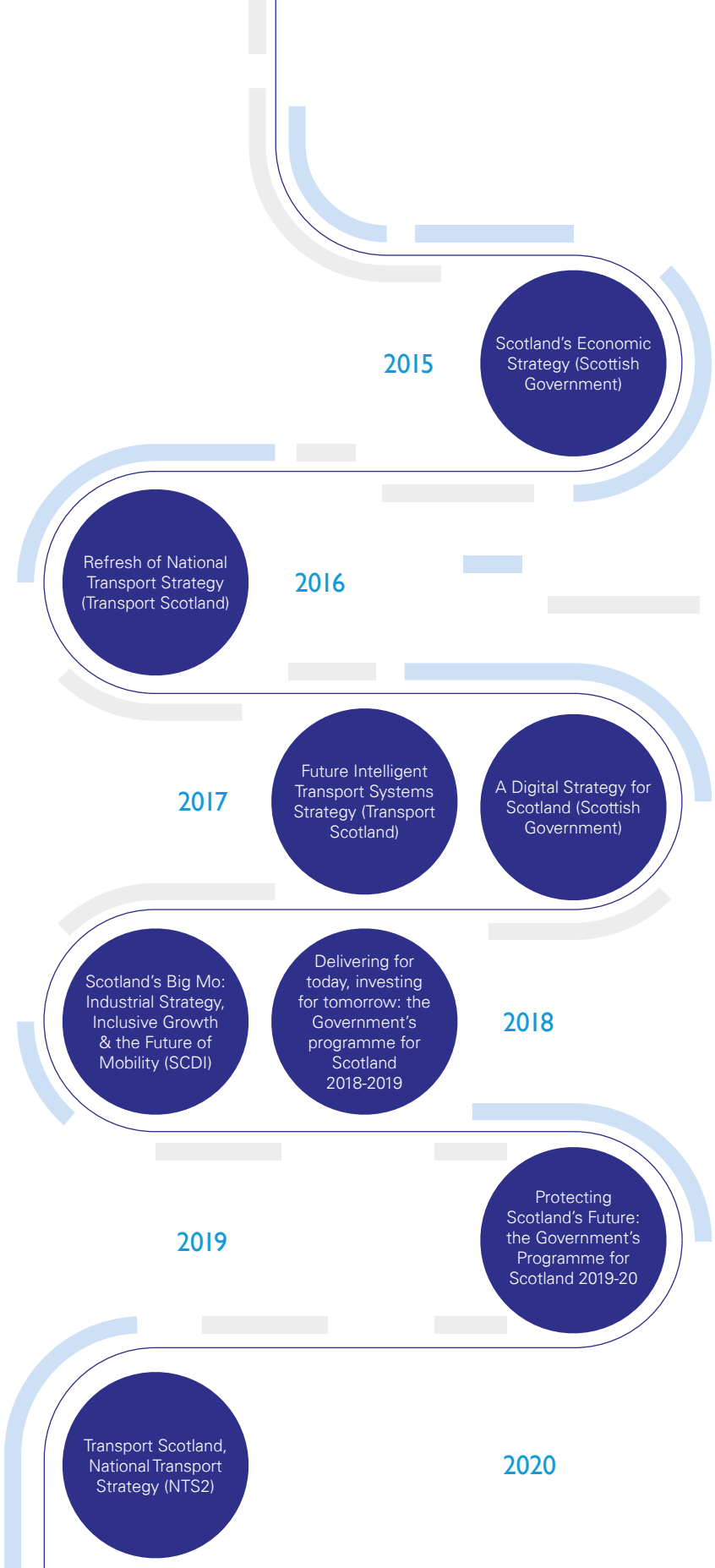


Figure 1-1:

Scottish Government publications relevant to the CAV Roadmap

1.3 OUR JOURNEY SO FAR

Connected vehicles are here – according to a recent report by The Society of Motor Manufacturers & Traders (SMMT), more than 95% of the vehicles on the road in the UK will be connected vehicles by 2025[1].

We have still to explore the potential opportunities associated with vehicle connectivity though and there remains uncertainty with respect to when autonomous vehicle technologies will be sufficiently mature and cost effective to be adopted in mainstream road transport.

Recognising this, Scotland's vision for CAV development and deployment is an integral part of wider ambitions for government, transport authorities and public infrastructure. CAV sits at the heart of the integrated transport solutions we are developing for the people of Scotland. Key priorities highlighted in the Programme for Government and supporting strategies include: improving safety, investing in sustainable infrastructure, fostering a culture of innovation, promoting inclusive and fair growth, and improving public transport integration.

The deployment and use of CAV technology in Scotland could help achieve these key priorities. Specific commitments outlined across these various documents include: hosting CAV summits to capitalise on the opportunities presented by CAV technologies; identifying and supporting trials where possible to provide a living test bed for the emerging technology; and, continued investment in transport to ensure all parts of Scotland are well connected.

This CAV Roadmap for Scotland has been developed to articulate and illustrate our continuing journey towards the adoption of CAV technologies on Scotland's roads. We welcome support and contribution from industry, public sector and road users alike to help us to achieve this successfully.

1.4 THE UNITED KINGDOM CONNECTED AND AUTONOMOUS VEHICLE TRAJECTORY

A number of the key aspects of the legal framework for autonomous vehicles are reserved matters. The UK Government has set a target of having self-driving cars on roads by 2021 and is supporting initiatives to enable the advanced trials of autonomous vehicles on the road network. This includes the issuing of a new Code of Practice for automated vehicle trialing in February 2019 which states that vehicles will be allowed to test on public roads using a remote driver, providing that the remote driver is ready to intervene at any moment, and strengthens the requirement for engagement with key stakeholders.

The figure 1-2 illustrates the key bodies which the Scottish Government will engage in respect of the development, testing and deployment of CAVs.

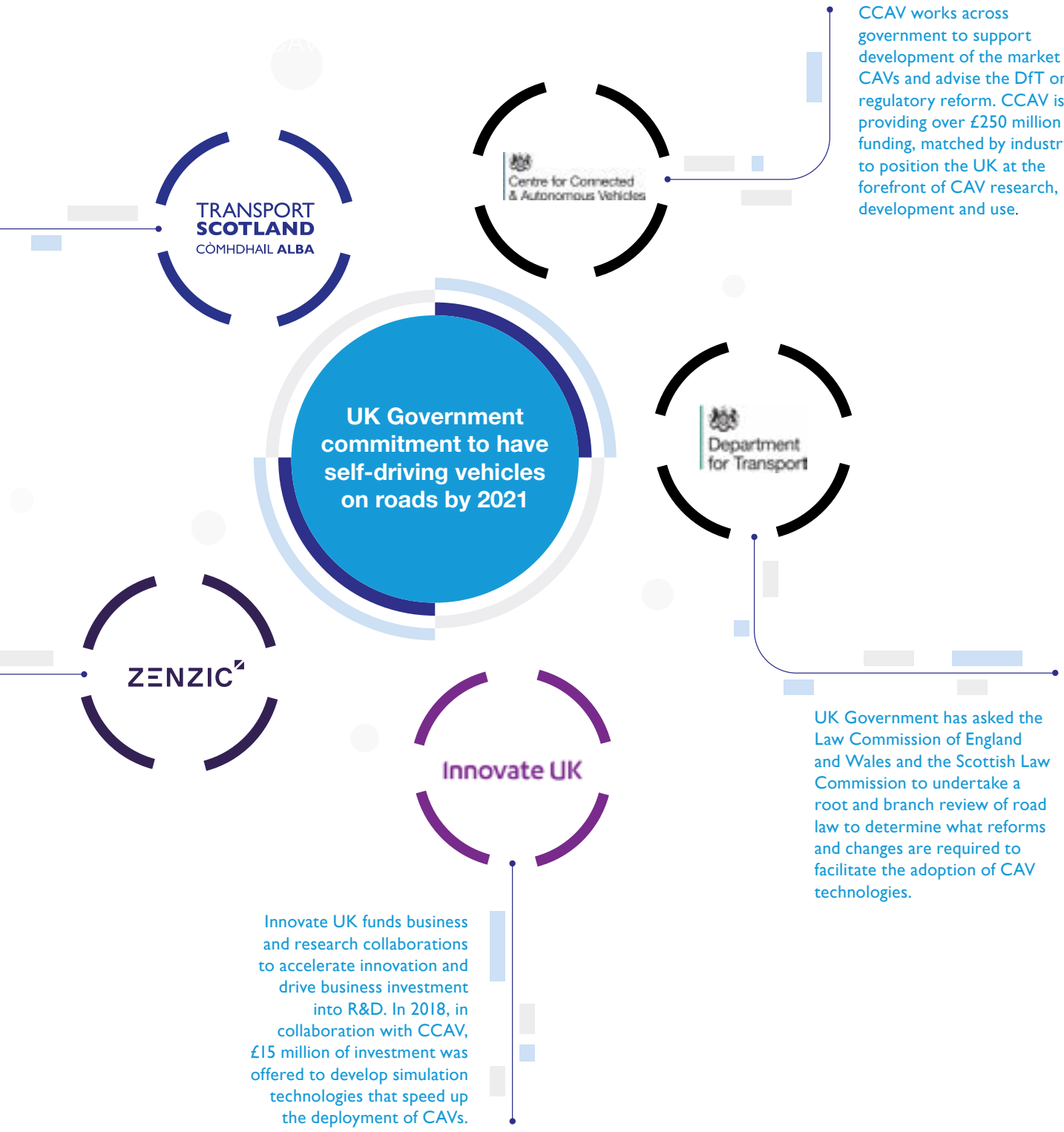
Project CAV Forth will trial the first autonomous full-sized bus fleet in passenger service after receiving £4.35 million part-funding from the Centre for Connected and Autonomous Vehicles (CCAV), delivered in partnership with Innovate UK. CAV Scotland, a Transport Scotland conference and event, brings together global experts in CAVs with live demos to assess latest developments and discuss future trials and research. Transport Scotland will work closely the DfT, other road authorities and European counterparts to determine regulations for adoption of CAV technologies on the Scottish road network.

Zenzic (formely MERIDIAN) is a government-backed and industry-led brand for the development of CAV technology in the UK. In 2018, CCAV with Zenzic and Innovate UK announced £30 million available for projects that help make the UK the most effective CAV development ecosystem in the world.

Figure 1-2:

Key stakeholders in the development, testing and deployment of CAVs

1 https://www.smmt.co.uk/reports/connected-and-autonomous-vehicles-the-global-race-to-market/



CCAV works across government to support development of the market for CAVs and advise the DfT on regulatory reform. CCAV is providing over £250 million in funding, matched by industry, to position the UK at the forefront of CAV research, development and use.

UK Government has asked the Law Commission of England and Wales and the Scottish Law Commission to undertake a root and branch review of road law to determine what reforms and changes are required to facilitate the adoption of CAV technologies.

Innovate UK funds business and research collaborations to accelerate innovation and drive business investment into R&D. In 2018, in collaboration with CCAV, £15 million of investment was offered to develop simulation technologies that speed up the deployment of CAVs.

The figure below provides an overview of the different levels of driving automation and indicates the levels at which a driver may be required to intervene and take control as compared to the levels where the vehicle could be fully autonomous.

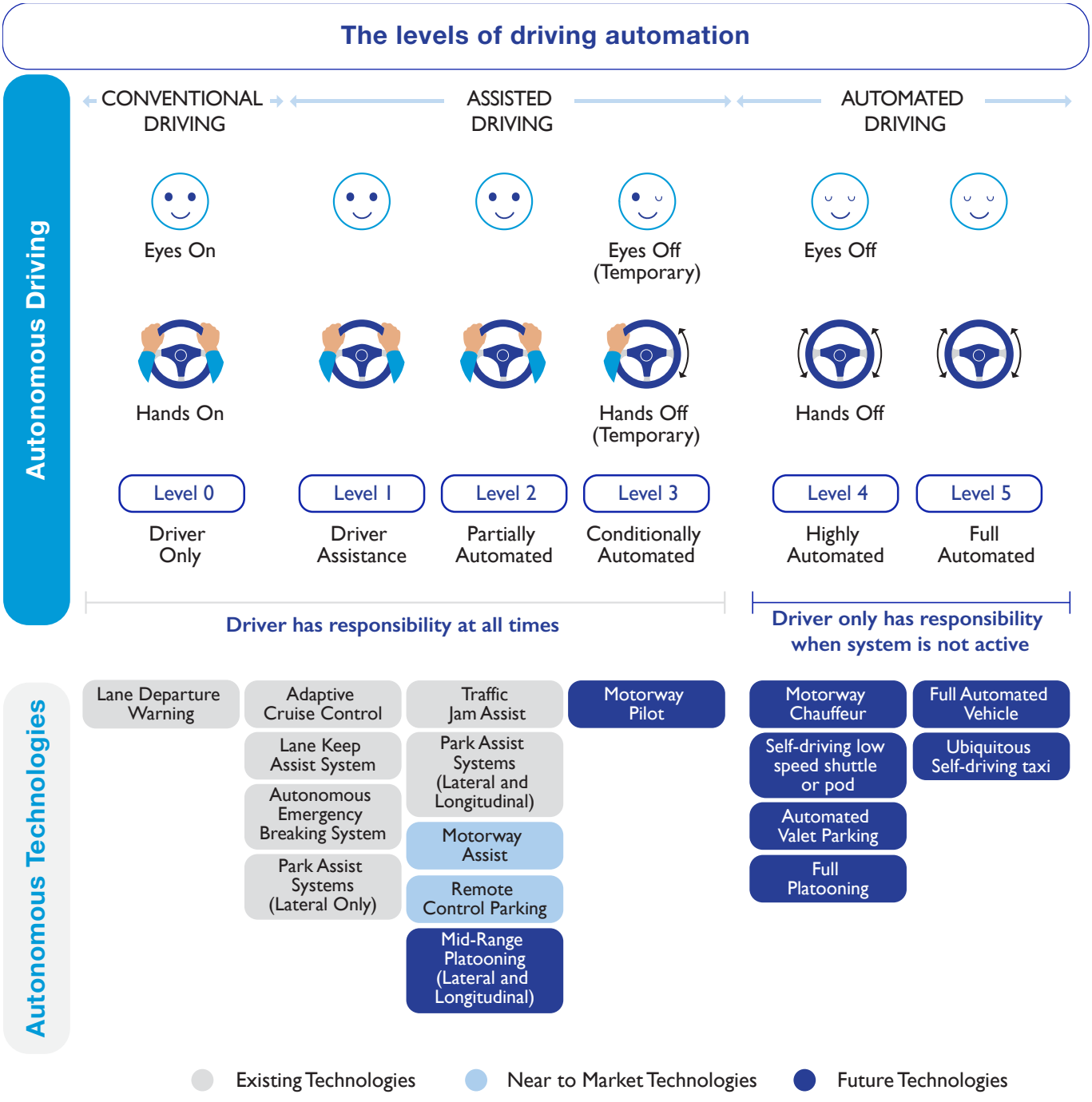


Figure 1-3:

SAE Levels of Driving Automation

This graphic is adapted from the Society of Automotive Engineers 13016 Standard and UK Centre for Connected and Autonomous Vehicles

Did you know?

Autonomous / Automated Vehicles (AV)

'Autonomous (or Automated) Vehicles' are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to monitor constantly the roadway while operating in self-driving mode.

Connected Vehicles (CV)

'Connected vehicles' are vehicles that use any of a number of different communication technologies to communicate with the driver, other vehicles on the road, roadside infrastructure, and to other systems and services via the Cloud.

For AVs to operate in a successful manner the automated driving system, which includes all the hardware and software, must be capable of undertaking the real time operational and tactile tasks required to operate a vehicle in on-road traffic (dynamic driving task) within the specific conditions under which the driving automation system is designed to function.

The role of Cooperative Intelligent Transport Systems

Cooperative Intelligent Transport Systems (C-ITS) is the generic term used to refer to the use of wireless communications between vehicles (V2V), between vehicles and infrastructure (V2I), infrastructure-to-infrastructure (I2I) and / or vehicles to other users (V2X).

Although it is possible that autonomous vehicles could be self-reliant on their driving systems, it is also possible that there will be significant reliance on C-ITS in both the trialing and the eventual deployment and adoption of both connected and autonomous vehicles.

There are ongoing worldwide developments related to C-ITS which include state and local transportation agencies, vehicle and device makers, and the public testing and evaluation of technology that will enable cars, buses, trucks, trains, roads and other infrastructure, together with other devices to communicate.

C-ITS has the potential to greatly increase the quality and reliability of information being shared through the system, enabling the sharing of information between vehicles, roadside equipment, traffic control centres and nomadic devices via a standardised communication architecture. The aim of which is to provide road users with better road safety, traffic efficiency, comfort and more efficient mobility with an increased potential for improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems.

Day 1 and 1.5 Services

The European Commission, in its C-ITS strategy, identifies a number of Day 1 services or use cases. These are services that should run seamlessly and be interoperable across the EU according to the European Commission (2017).

Day 1 services are so called as they are expected to be deployed in the short term because of their expected societal benefits and their technological maturity. A list of Day 1.5 services has also been agreed which are expected to be the next step in the C-ITS deployment due to a lower level of technological maturity.

Day 1 services fall into the categories in figure 1-4.

Day 1.5 services fall into six broad categories:

- Parking (off & on street and park & ride information);
- Smart Routing (fuelling / charging, traffic information, zone control for urban areas);
- Freight (loading zone management);
- Vulnerable Road User (VRU) protection for pedestrians and cyclists;
- Collision (cooperative collision risk warning, motorcycle approaching indication); and
- Wrong way driving.

Regardless of the UK leaving the EU, Transport Scotland supports the aims of the C-ITS Strategy and interoperability across borders and transport modes.

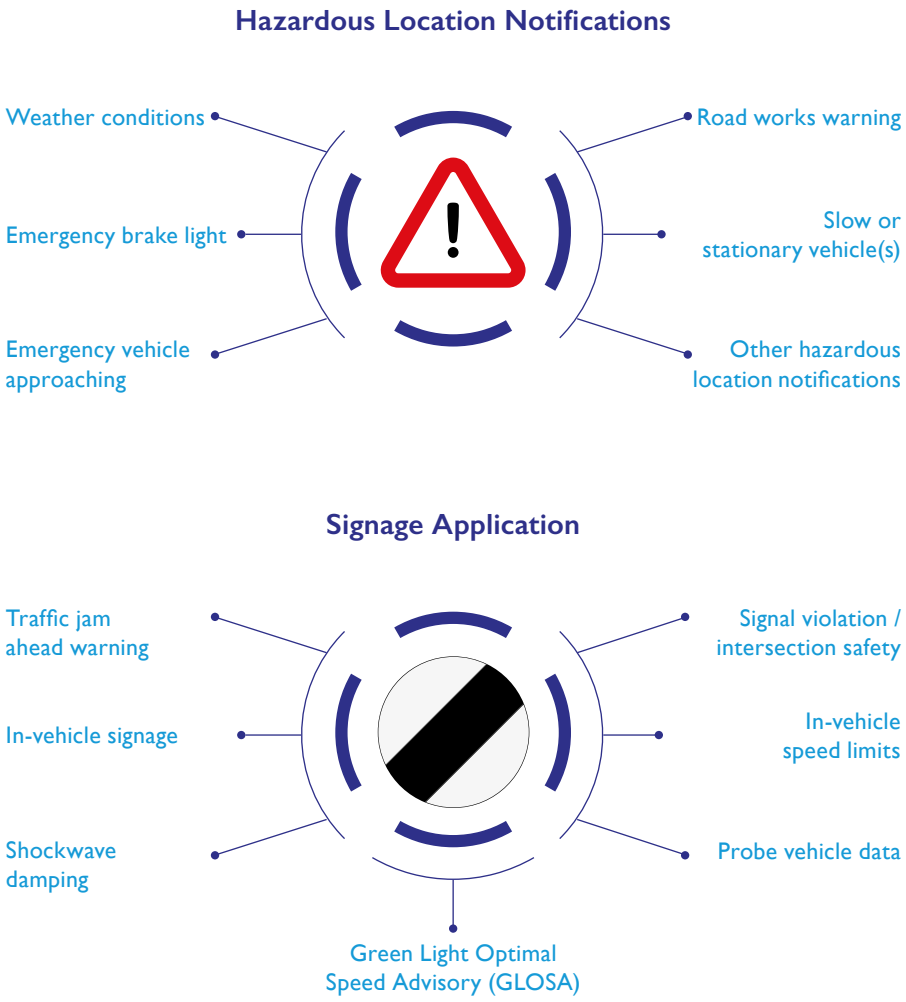


Figure 1-4:

Day 1 services and applications as an example of categorisation of 'service' and 'application'

Transport Scotland's role

The deployment of C-ITS has many areas to be developed, including legal, organisational, administrative, governance aspects, technical and standardisation features. What Transport Scotland, as the trunk road authority, may need to do to support Day 1 and Day 1.5 services and applications will be defined through ongoing standardisation works and through both national and cross-national pilot studies and testing. It is therefore critical that Transport Scotland and its counterparts are at the forefront of engagement in development and testing of CAV solutions, and participates in forums and groups, such as the Amsterdam Group, to ensure coherence with the rest of the world.

1.5 CONNECTED AND AUTONOMOUS VEHICLE TECHNOLOGIES IN THE INTELLIGENT MOBILITY ECOSYSTEM

Intelligent Mobility uses emerging technologies to enable the safer, smarter, greener and more efficient movement of people and goods and encompasses everything from autonomous vehicles to seamless journey systems and multi-modal modelling software.

It is estimated that Intelligent Mobility will be worth around £1.4 trillion globally in 2030, with CAV technologies representing £760 billion of this market and the UK is well positioned to take advantage of these opportunities[2]. In order to achieve this our ambitions for, and initiatives with respect to, CAV technologies will need to be aligned with wider Intelligent Mobility capabilities. This will need to include, but not be limited to, the electrification of transport and the movement towards seamless, personalised, multi-modal journey planning, reservations, payment and connectivity that is commonly referred to as Mobility as a Service (MaaS).

> "Positioning Scotland as a centre of global significance in future mobility technologies will require new and concerted effort to broaden out our innovation capabilities."

Positioning Scotland as a centre of global significance in future mobility technologies will require new and concerted effort to broaden our innovation capabilities, funding sources, skills and facilities, alongside targeted work to help support the development and emergence of new industries and capabilities. Transport Scotland will work in partnership with Scotland's agencies and stakeholders to create the physical and intellectual infrastructure needed to harness these opportunities, and to manage the transition to new technologies in a way that benefits Scotland's whole economy and workforce.

In aligning our ambitions across the Intelligent Mobility ecosystem our aim is to recognise benefits earlier and with greater economic efficiency. The Scottish Government has already committed to investing up to £2 million over three years from 2018 to support the testing of MaaS in Scotland and has an opportunity to co-develop technologies to create incremental value above and beyond development in isolation.

2 https://ts.catapult.org.uk/intelligent-mobility/introduction/

1.6 STAKEHOLDER CONSULTATIONS ON CONNECTED AND AUTONOMOUS VEHICLES IN SCOTLAND

The contents of this CAV Roadmap for Scotland have been informed by extensive stakeholder engagement. This has captured the views of organisations spanning industry, industry forums and trade bodies, transport and mobility forums, academia and research and public sector partners on the opportunities and challenges for Scotland.

The key themes arising from consultations with these organisations are summarised here:

Figure 1-5:

Stakeholder consultation themes

CLARITY OF INVESTMENT

Clarity is needed on the level and sources of investment and funding required to enable the development and adoption of CAV technologies in Scotland.

This is especially pertinent in key areas such as infrastructure where work is needed to explore the respective roles of the public and private sector in funding / financing and delivering connectivity.

ACCESSIBILITY AND INCLUSIVITY

CAV technologies could play a major role in improving accessibility and inclusivity within Scotland. Autonomous driving technologies could allow populations in Scotland (particularly in rural areas) to access products and services much more conveniently and efficiently.

There will be a challenge however in ensuring that certain groups are not socially marginalised, particularly those who may be on a low income. CAV service models and their associated benefits need to be available to all.

EDUCATING SCOTLAND

Further work is required to inform Scottish businesses, organisations and the general population on the benefits of CAV technologies, both in respect of safety and benefits.

This will help encourage consumer acceptance and potentially accelerate adoption of CAV technologies.

DATA

There is a significant opportunity to capitalise on the abundance of data which could be created from the development and deployment of CAVs. This data could help inform planning and decision-making, particularly for road authorities in Scotland. Work is required to identify, develop and deliver the solutions and capabilities that will be needed to collect, collate, process, analyse and act on the various data sets that could be generated.

Associated risks in respect of data ethics and cyber security will also need to be addressed, providing assurance to road users about their safety and privacy when using CAV technologies.

The availability (or lack) of data to model demand for CAV in rural communities must also be evaluated. Insufficient data will constrain the ability to forecast not only who the beneficiaries will be but how often they will use a CAV and for what purposes.

COLLABORATION

The scale of transformation associated with adoption of CAV technologies will require regular and extensive collaboration between numerous public and private sector organisations in Scotland, and the establishment of forums to facilitate this.

Scotland should continue engagement with European and wider global counterparts. CAV technology developments in other countries could provide important lessons with practical applications to Scotland's road network.

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The introduction and adoption of CAV technologies are likely to result in significant, positive impacts for our economy and society.

02 | CAV for Scotland

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2
CAV for Scotland

2.1 ALIGNMENT WITH THE NATIONAL TRANSPORT STRATEGY

The adoption of CAV technologies will help deliver the key priorities of the National Transport Strategy (NTS). The successor NTS was published in draft for consultation in July 2019, setting out our vision for the next 20 years and was developed in collaboration with over 60 partner organisations around Scotland. It articulates four priorities: Promotes equality; Takes climate action; Helps our economy prosper; and Improves our health and wellbeing. The strategy redefines investment priorities, putting sustainable and public transport at the heart of decision-making and CAV must support this.

Promotes equality:

We must ensure that these CAV innovations support the Strategy's priorities and that they do not exacerbate existing challenges such as inequality. Transport must play its part in building a fairer society, including reducing child poverty.

CAVs could improve accessibility for those with mobility issues, widening access to jobs and services.

Takes climate action:

The global climate emergency and the role of transport in helping to deliver net-zero emissions by 2045 is a key imperative. CAV, and other zero emission technologies, will need to be brought together to support mutual outcomes. In practice, this will mean bringing together our understanding of, and policies on, modal shift, transport planning and zero emission technologies. This will ensure that CAV is not viewed in isolation but as part of a wider whole-system approach to delivering net-zero.

Helps our economy prosper:

CAVs have the potential to promote inclusive growth by creating opportunities through a fair and inclusive jobs market. The development of CAV has the potential to stimulate innovation in the digital and manufacturing sectors, supporting job creation across Scotland. The strategy highlights that we will use beneficial innovation to improve our transport system and that there is the potential for Scotland to become a market leader in the development and early adoption of such transport innovations.

Improves our health and wellbeing:

Over the last few decades our increasing reliance on cars has contributed to Scotland becoming less active as a nation and our roads becoming more congested. The Strategy sets out a sustainable travel hierarchy promoting walking, wheeling, cycling, public transport and shared transport options in preference to single occupancy private car use. CAV technologies must support this move to sustainable and active transport which can also support our health and wellbeing.

Scotland's Road Safety Framework to 2020 sets out how Transport Scotland intends to achieve a 40% reduction in road casualties by 2020. Although this target is imminent and unlikely to benefit from CAVs, their development could help assist meeting future targets by removing the risk of driver error.

Published in 2015, the 'Clean Air for Scotland Strategy' sets out how the Scottish Government proposes to achieve reductions in air pollution. Following this, in September 2017, the Scottish Government's 'Programme for Government', committed to the introduction of Low Emission Zones (LEZs) into Scotland's four biggest cities (Glasgow, Edinburgh, Aberdeen and Dundee) by 2020 and into all other Air Quality Management Areas (AQMAs) by 2023 where the introduction of the National Low Emissions Framework appraisal advocates such mitigation. Although the targets set out are shorter term, CAVs could play a pivotal role in enabling the Scottish Government to achieve the goals of reducing emissions and improving air quality over the longer term.

2.2 BENEFITS OF CONNECTED AND AUTONOMOUS VEHICLES IN SCOTLAND

The introduction and adoption of CAVs is likely to result in significant, positive impacts for our economy and society.

Environmental

Air pollution in Scotland has reduced over recent years, however air quality remains an issue at a number of hotspots in Scotland's towns and cities, predominantly due to road transport. Poor air quality has a negative impact on all of our health, but we know that the very young, the elderly and those with pre-existing health conditions are particularly vulnerable. We recognise that we must build on achievements to date and continue to take action to improve air quality. CAV technologies have the potential to deliver environmental benefits to Scotland. Connected vehicle capabilities could deliver environmental benefits in reducing harsh acceleration and breaking patterns and the potential reduction in queueing and congestion resulting in smoother flow of traffic.

Productivity

In an autonomous vehicle context, removing the need to drive and be engaged opens up significant opportunities associated with the use of time, with some travelers potentially engaging in leisure activities whilst others engage in work activities. CAV capabilities have the potential to reduce queuing and / or congestion which would improve journey times and reliability of transport services, whilst automated vehicle technologies eliminate time spent driving. This could have a direct impact on public sector agencies in Scotland such as the NHS with nurses, for example, completing patient paperwork whilst travelling to their patients for routine home visits, thus saving time and increasing efficiency.

Inclusivity and access to goods and services

The potential improvement in social inclusion due to the adoption of CAV technologies is not limited to the elderly and those with mobility issues, it could also provide significant benefits in rural areas. Research has found that residential and business consumers in the Highlands and Islands are often asked to pay at least 30% more to have goods delivered than consumers elsewhere in Great Britain[3]. e-Commerce growth across the UK is cited as causing a 12% increase in parcel volumes between 2016 and 2017[4]. If CAVs are integrated successfully into freight and logistics networks, they could be used to reduce the costs of delivery significantly, particularly for those in more rural areas of Scotland.

Education and skills

The benefits of connectivity and accessibility of automated vehicles could bring extraordinary changes to the education sector, resulting in greater and fairer access to opportunities. Those currently unable to drive could be given the opportunity to travel and thus access a greater number of educational opportunities. Indeed, research suggests that automated vehicles could help over one million more people in the UK pursue a university degree[5].

Higher education is a key determinate of earning potential. Automated vehicles have the potential to broaden access for segments of the population with poor connectivity and/or accessibility constraints in respect of accessing education and training. Increasing the overall level of education in the workforce could also support the growth of skilled industries and services.

3 https://www.gov.scot/news/fairer-deliveries-for-all/
4 https://www.gov.scot/news/fairer-deliveries-for-all/
5 https://www.smmt.co.uk/reports/cavs-revolutionising-mobility-in-society/

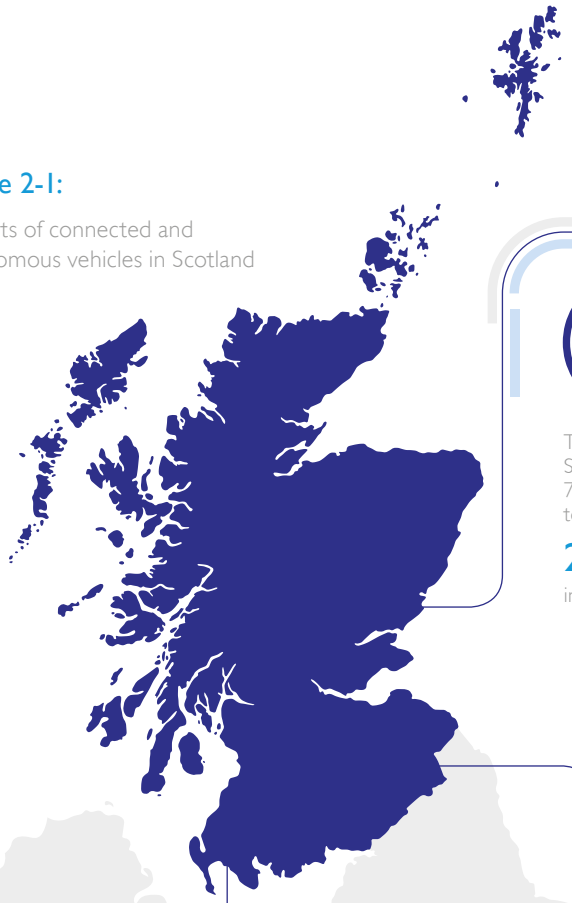
Employment and Job Creation

CAV technologies have the potential to create jobs in a range of Scottish industries, from data science to manufacturing. This could have wide ranging social benefits associated with reducing unemployment. Rather than resulting in job losses the opportunity exists to repurpose existing roles and create new roles in the delivery of CAV services.

The development of CAV technology in Scotland could have specific job creation opportunities in the digital and data sectors, building on Scotland's strong foundation in artificial intelligence (AI) and digital development through the gaming industry. There may also be the opportunity for job creation through growth in existing manufacturing industries such as bus and coach manufacturing and the enabling technologies industries (e.g. sensors and photonics), which is currently worth an estimated £2.6 billion a year to the Scottish economy[6].

Figure 2-1:

Benefits of connected and autonomous vehicles in Scotland



The proportion of Scotland's population over 75 years old is anticipated to increase by

27%

in the next 10 years[10]

Consumers in the Highlands and Islands are paying at least

30%

more for delivery than elsewhere in Great Britain[7]

Work done by AXA suggest that CAV technologies could result in a

£33.6 billion

saving to the UK freight industry over the next ten years[9]

6 https://censis.org.uk/2016/02/16/mirage-project/
7 https://www.gov.scot/news/fairer-deliveries-for-all/
9 The Future of Driverless Haulage, AXA
10 https://www.nrscotland.gov.uk/news/2017/scotlands-population-is-projected-to-increase-and-to-age

Vehicle collisions caused

146

deaths in Scotland in 2017. Driver error, which accounts for a large proportion of collisions, will be significantly reduced / eliminated by CAV technologies[8]

INITIATIVE 1

Transport Scotland will seek opportunities to influence, engage with and support initiatives to establish CAV trials that address specific Scottish contextual needs and development opportunities such as Islands, Rural Routes and the Freight, Food and Drink sectors.

SMMT has estimated that Automated Vehicles could help over

1 million

more people in the UK pursue a university degree[11]

8 https://www.transport.gov.scot/publication/reported-road-casualties-scotland-2017/
11 https://www.smmt.co.uk/reports/cavs-revolutionising-mobility-in-society/

Cross industry growth

The adoption of CAV capabilities is expected to benefit a number of existing industries through productivity gains. Examples could include the use of autonomous vehicles in forestry[12], addressing labour shortages, safety issues and the need for sustained high productivity and low wood costs and in enabling manufacturing of pharmaceuticals in the life sciences sector.

Tourism

Scottish tourism is worth more than £11 billion per annum to Scotland, representing circa 4.5% of the Scottish economy[13]. CAVs could augment the existing tourism industry with new types of sightseeing tours, and by providing improved (more frequent, affordable and accessible) links between tourist destinations such as distilleries, resorts and islands. A competitive edge could be established for Scottish tourism but it will take time to realise the benefits of this.

Safety

While Scotland has one of the lowest number of road casualties globally, 146 people were killed in a vehicle collision in 2017[14]. The approximate economic cost per collision was £2.1 million[15], added to the emotional impact on families of those involved and the response services.

Existing vehicle features such as adaptive cruise control, lane monitoring systems, remote parking capabilities and brake assist, will be augmented through connectivity and automation to deliver even greater vehicle safety capabilities, thus improving road safety. The number of collisions causing road fatalities could be significantly reduced by CAV technologies, with estimates that by 2030, CAV technologies could save over 2,500 lives and prevent more than 25,000 serious collisions in the UK[16].

Congestion and land use

Without the correct regulatory and fiscal incentive framework in place, CAVs could result in increased road use and an increase in single occupancy journeys. The role for, and success of, CAVs will be determined by the wider policies that are established to reduce congestion, promote modal shift and in turn encourage bolder and more imaginative planning and urban design. If these benefits can be realised then, under the right conditions, CAVs could help to reduce congestion by increasing average vehicle occupancy, meaning more people travel in fewer cars. Connected vehicle technology may also enable vehicles to travel faster and closer together, and to reduce congestion by reducing or eliminating accidents, with the potential to reduce journey time delays by over 40% per a recent study by the Department for Transport (DfT)[17].

There could be a reduced need for parking in city centres as CAVs could drive themselves away after picking up or dropping off. There is a unique window of opportunity for local authorities and major developers to realise the environmental and land value benefits of this, helping authorities to re-imagine places and facilitate inclusive street design.

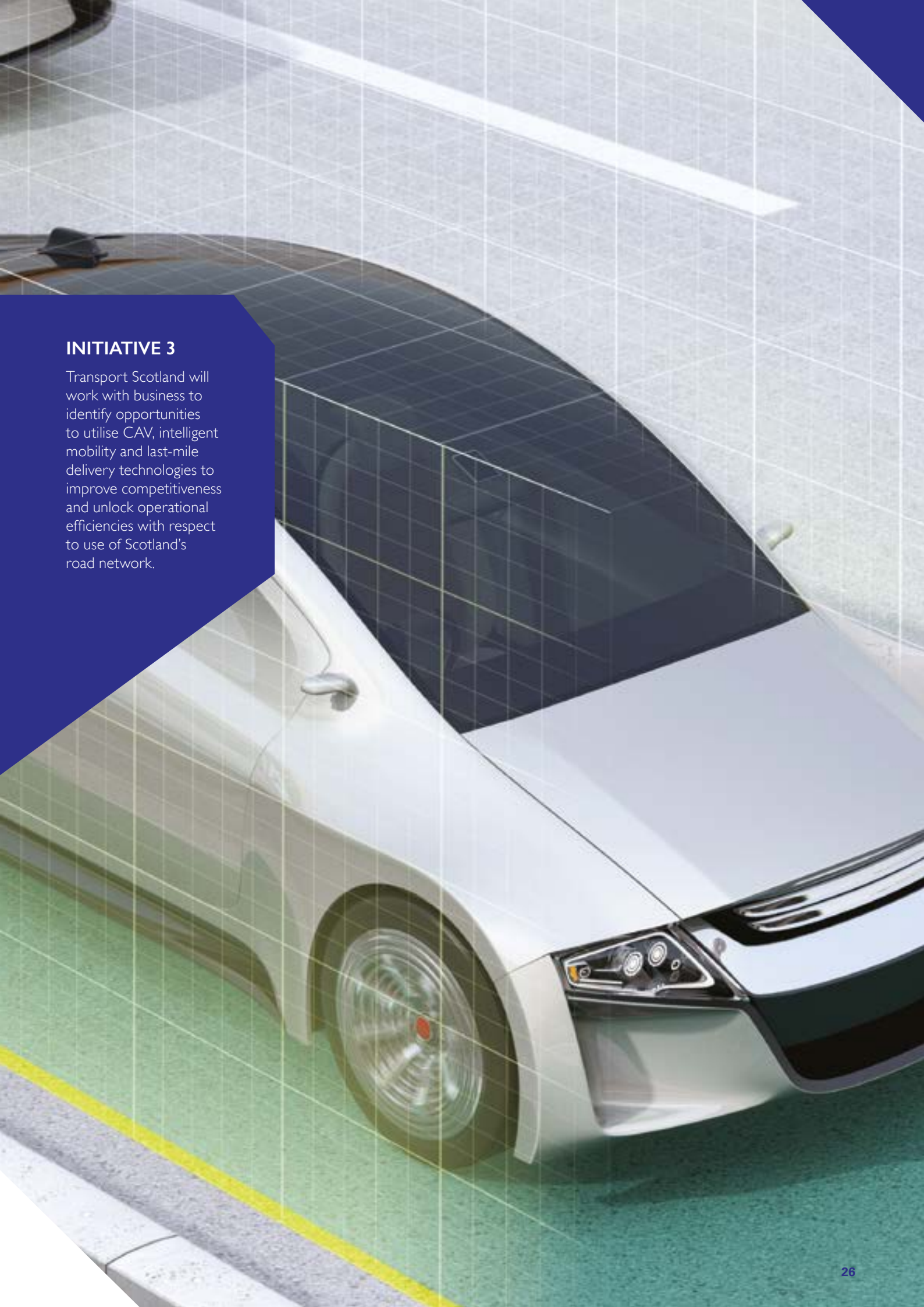
Asset condition reporting and road maintenance improvements

Connectivity in and to vehicles with sensing capabilities provides opportunities for real-time provision of data associated with road surface and asset condition to road maintainers. Leveraging this capability may help deliver efficiencies by bringing enhanced information to support the regular safety regimes and road maintenance inspections already being carried out.

INITIATIVE 2

Transport Scotland will look for opportunities to work with partners to provide information on the safety benefits of Advanced Driver Assistance Systems, and other Connectivity features that are available now, and ensure that CAVs sit at the centre of efforts to achieve the 2030 Road Safety targets.

12 https://www.sca.com/en/top-news-startpage/2018-12/investment-in-autonomous-forestry-machines/
13 https://www.gov.scot/publications/tourism-scotland-economic-contribution-sector/pages/5/
14 https://www.transport.gov.scot/publication/reported-road-casualties-scotland-2017/
15 https://www.transport.gov.scot/publication/reported-road-casualties-scotland-2017/
16 Connected and Autonomous Vehicles – The UK Economic Opportunity (KPMG & SMMT)
17 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/530091/impacts-of-connected-and-autonomous-vehicles-on-traffic-flow-summary-report.pdf



INITIATIVE 3

Transport Scotland will work with business to identify opportunities to utilise CAV, intelligent mobility and last-mile delivery technologies to improve competitiveness and unlock operational efficiencies with respect to use of Scotland's road network.

2.3 CHALLENGES OF CONNECTED AND AUTONOMOUS VEHICLE DEPLOYMENT IN SCOTLAND

Integration with the public transport network

A number of the benefits of CAV technologies are dependent on them being deployed as part of a wider Intelligent Mobility ecosystem. This type of deployment could help to reduce congestion and lead to more affordable and accessible transport services.

If CAVs are predominantly personally owned and / or used on a limited, single occupancy basis then a number of studies point to a risk of increasing congestion. With the price per mile of using an autonomous vehicle forecast to be 40% to 60% less than that of a taxi, and more equivalent with mass public transport[18], a potential mode shift from public transport to private travel modes could become a key market failure i.e. by increasing congestion, decreasing active mobility and jeopardising the sustainability of public transport services).

INITIATIVE 4

Transport Scotland intends to build on the highly successful CAV Scotland conference and demonstrator summits held in 2018 and 2019, with further events and publicity in order to showcase developments and future ambitions. This will aim to energise domestic and international companies, sharing leading practice, and encouraging educational choices.

Overcoming initial safety barriers

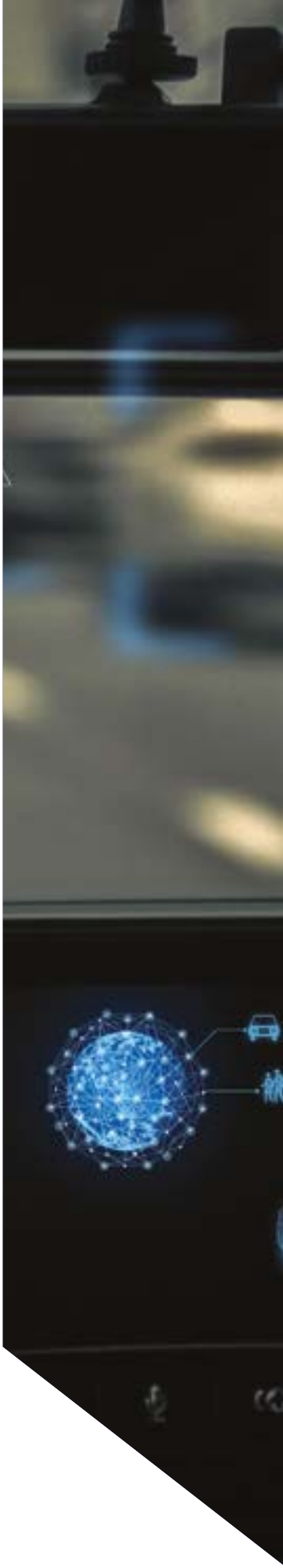
The initial mixed fleet stage will require complex interactions between autonomous vehicles, human-driven vehicles, pedestrians and other road users. The technology could face challenges in navigating unfamiliar and difficult situations which would typically require the need to exercise some form of human judgement. Human drivers may also need to adjust as autonomous vehicles could have different driving behaviours than would be expected of a human driver.

There is a risk in the overconfidence in, and over-reliance on, technology. This could lead to other road users taking more risky decisions and actions, expecting autonomous vehicles to be able to adapt appropriately. Road users purposely interfering with CAVs is a further risk and safety point for consideration; this has already been seen in a number of incidents across the world.

Consumer acceptance / uptake

Ultimately, the Scottish public must feel comfortable with CAVs. If there is not broad consumer acceptance and willingness to use the technology then it will be difficult to develop a commercially sustainable market, even if the technology and infrastructure is ready. Any initial general acceptance for CAVs amongst the public could change if, for example, there were any major incidents involving CAVs. These would be widely reported in the press and have a negative impact on consumer acceptance. It is essential that we monitor the general populations' attitudes towards CAVs as the technology becomes available for testing / use to the general public.

To mitigate unintended congestion consequences highlighted above, education is required around the utilisation of CAV as a public transport service rather than as a like for like alternative for private car.



18 Autonomous Vehicle Implementation Predictions, Implications for Transport Planning – Victoria Transport Policy Institute

12:05

Infrastructure requirements

Infrastructure is likely to play a significant role in enabling or limiting the deployment of CAVs. It is expected that enhancements in the road network will accelerate the ability to successfully adopt autonomous vehicles. Given the uncertainty of the capabilities of the initial technology, it is expected that autonomous vehicles will require well maintained roads. If the safety related, accessibility and road space capacity benefits of connected cars are to be delivered then 5G communication networks and advanced traffic management systems, including ITS, will all need to be well-developed. This will require significant input from both the public and the private sectors.

Managing extensive sets of data and information

CAV technologies will produce significant amounts of data and information which could be used by transport authorities for network operations, proactive maintenance and asset management and to inform planning and decision-making. Much of this data will be dispersed and there will be a challenge in bringing it all together in one place. Developing integrated data platforms could enable the amalgamation of data produced from CAV technologies, MaaS and other relevant solutions. There is, however, a key dependency on the availability of suitable and sufficiently extensive communications infrastructure, potentially delivered through 5G or ITS-G5 solutions.

Sustainability and energy requirements

The majority of autonomous vehicles are expected to be ULEV. The Scottish Government's commitment to phase out the need for new petrol and diesel cars and vans by 2032, as well as the general direction of the market, are likely to help ensure this is the case in Scotland.

This will need to be catered for in both sufficiency of energy generation and energy distribution, with specific focus being placed on hardening local electricity distribution networks. The implications of this for the energy networks will require partnership working and analysis is already under way to ensure that costs and any disruption in the shift to ULEVs is minimised whilst at the same time opportunities, such as grid balancing, are maximised.

Law Commission review outputs

Although trialling any level of automated vehicle technology is permitted on UK roads, (if carried out in line with UK law and Approved Codes of Practice), key legal questions still need to be resolved. UK Government has asked the Law Commission of England and Wales and the Scottish Law Commission to undertake a far-reaching review of the UK's legal framework for automated vehicles.

The review is tackling some of the fundamental questions regarding CAVs operating on public roads and is expected to be the cornerstone of their adoption in the UK. The review may however present additional legal barriers to CAV operability.

The Scottish Law Commission is involved to capture any concerns and also understand the implications for Scots law. It will be important to monitor the progress of the review through the publication of papers at key milestones during the timeline.

INITIATIVE 5

There is a need to collectively explore opportunities for investment in CAV Infrastructure with partners including the Centre for Connected and Autonomous Vehicles, Innovate UK, Scottish Enterprise, the Connected Places Catapult and the Scottish National Investment Bank.

INITIATIVE 6

We will engage with others to understand what Transport Scotland has to do to ensure future ready ITS Infrastructure for CAVs is being specified in future road investments and in the Control Room of the future.

INITIATIVE 7

Transport Scotland will encourage the capture and modelling of data during infrastructure and transport schemes and maintenance projects to be made available to companies developing simulation and testing tools for CAV software and solutions.

Scotland possesses a unique ecosystem and is well-positioned to support the rapid development of CAV technologies.

03 | Scotland for CAV

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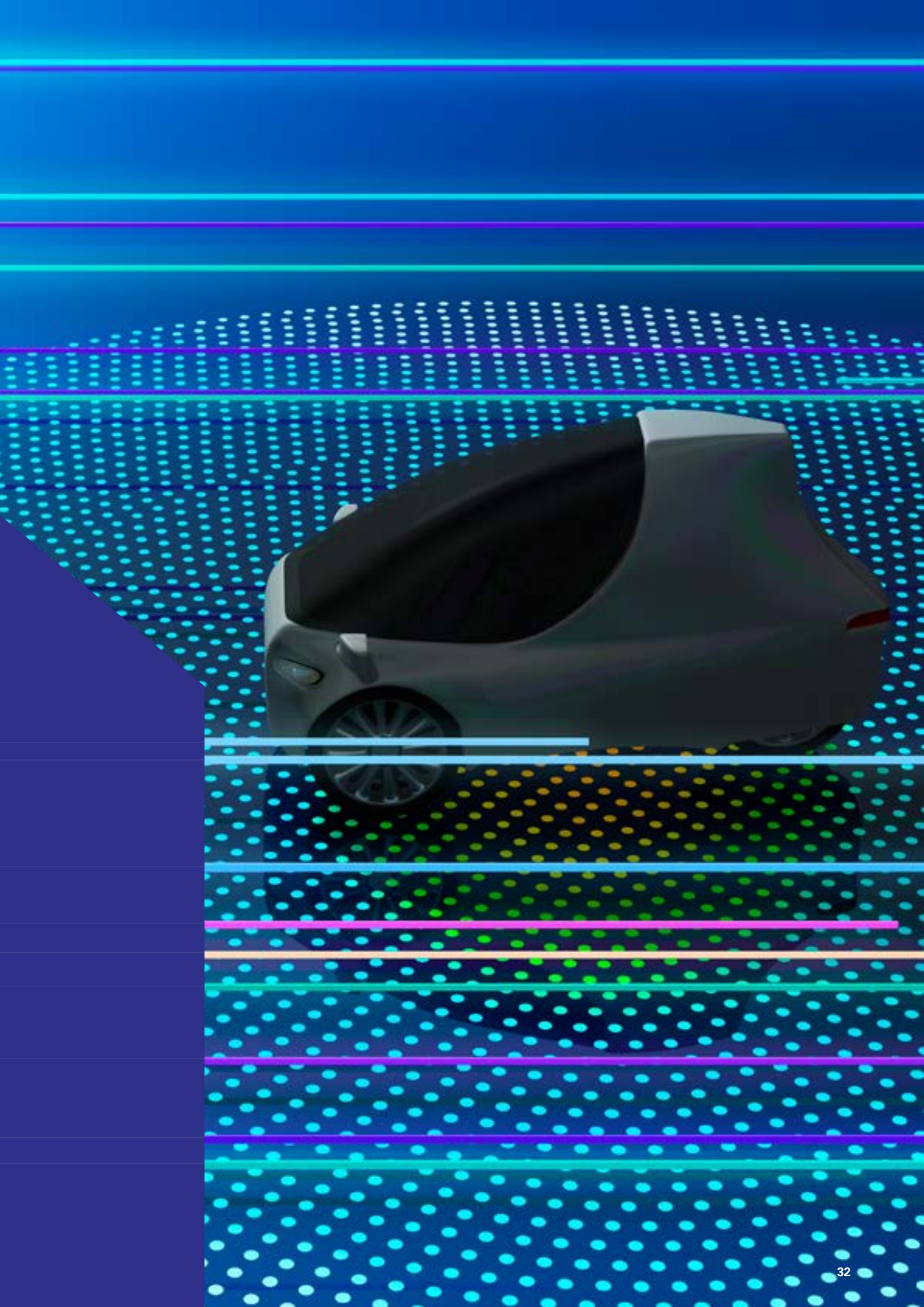
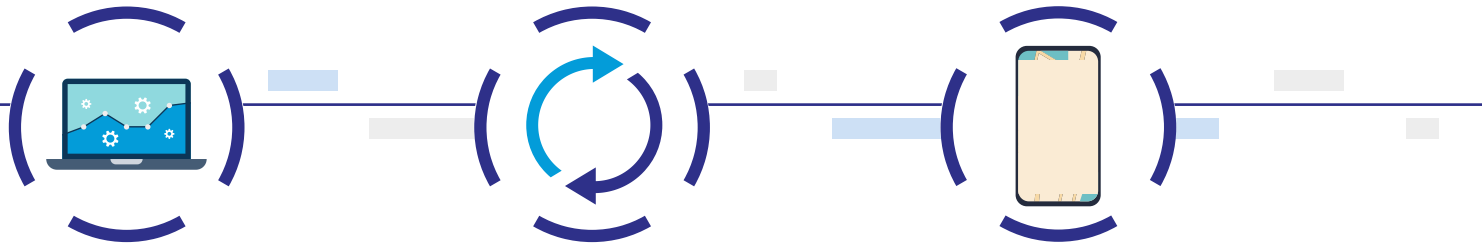


3
Scotland for CAV

3.1 A UNIQUE ECOSYSTEM

Scotland possesses a unique ecosystem, one which brings together extensive knowledge, experience, skills and capabilities from specialised industries, leading academic institutions and effective government authorities. All of this can be leveraged to support rapid development of CAV technologies and solutions. Some of the key components of this ecosystem are outlined below:

SCOTLAND'S CAV ECOSYSTEM



Data and digital

The efficient use and provision of data and digital connectivity on roads will be a crucial factor in any future involving CAVs. Scotland houses a number of companies which work on providing real-time predictive analytics. This includes collating and cleansing data sets and developing data platforms to enable analysis and decision-making for local authorities.

Roads Authority

Transport Scotland plays a key role in helping to achieve Scottish Government's transport and economic ambitions. The devolved nature of Scottish Government allows us to be flexible and responsive to developing our assets and initiatives including the likes of Traffic Scotland and ITS. This enables greater interoperability between our systems and capabilities.

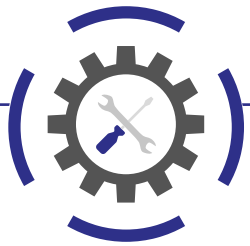
Simulation and virtual testing

Comprehensive and complete CAV testing is unlikely to be achieved by CAVs being driven exclusively on test tracks or public roads. Simulation companies based in Scotland have the necessary technology and capabilities to allow automotive parts to be tested within a virtual environment comprising different complex road scenarios.

Scotland's unique point of differentiation in the CAV industry can be the exploitation of its proven capabilities in computer gaming and AI. The global CAV market will be greatly aided by academia and industry in Scotland who can demonstrate leadership in the simulation of perception sensors and ADS decision making at the design and test stages of the product lifecycle

Figure 3-1:

Scotland's CAV ecosystem



Specialist vehicle manufacturing

Improving accessibility and enabling movement for those with mobility challenges is likely to be a key benefit of CAVs. Further, the initial deployment of CAVs could be in controlled, off-road environments such as in quarries for off-road operations. There is therefore a significant opportunity to leverage the skills and capabilities of specialist vehicle manufacturing companies based in Scotland which convert vehicles for special access as well as converting vehicles for use in off-road environments.

Sensors, Image processing and photonics

Technology companies which specialise in complex digital imaging solutions and export these solutions to global automotive OEMs; sensor fusion companies which are leaders in sensor testing systems for autonomous cars and at the forefront of the testing and measurement of ADAS sensors, including radar and LIDAR.

Academia and research

Scotland houses a number of academic and R&D institutions which are leading the way in developing technology that could be applicable to CAV – this includes universities which are globally recognised for their knowledge and skills in respect of AI, data science, machine learning and robotics; all key features of CAV technology systems.

3.2 SCOTLAND'S STRENGTHS IN FOSTERING CONNECTED AND AUTONOMOUS VEHICLE DEVELOPMENT

A unique environment for testing and adopting CAVs

Scotland is in a unique position to provide facilities to test deployment of CAVs. The breadth of Scotland's landscape, climate, topography and demographics provides an ideal testing ground to assess different CAV technologies, solutions, and service models in a variety of operating environments.

The variety and geographic distribution of Scotland's road network and communities provides multiple use cases for CAV testing, including: multi-lane motorways, islands, and rural roads.

Technology companies and original equipment manufacturers (OEMs) who are trialling vehicles in real-life settings could benefit from a range of environments. Our country's roads range from the M8 motorway through to single tracks with passing places.

The combination of the climate and topography makes Scotland's trunk road network distinctly different from other regions across the UK, allowing for a greater number of use test cases.

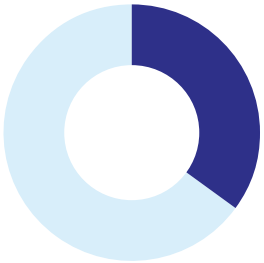
Figure 3-2:

Scotland's trunk road network

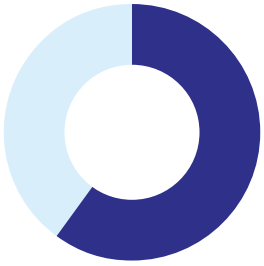
This unique environment, combined with a range of extensive academic and industrial capabilities, places Scotland in a strong position to push forward the development of CAVs, both within the UK and worldwide.

The trunk road and motorway network is 3,507 km (2,179 miles) long, including slip roads and roundabouts

It has a gross asset value of over £21 billion and represents 6% of the total Scottish road network



It carries 35% of all traffic



and 60% of heavy goods vehicles

Scottish Government estimates that there are 66 routes connecting mainland Scotland and its islands, managed by a number of public and private operators. Every year about nine million passengers and 2.8 million cars travel on these routes[19].

Known as the Road to Applecross, the route from Loch Carron to Applecross via Bealach Na Bà reaches 2,053 feet (625.7 metres) and features tight bends and single track roads with limited passing places.

19 www.audit-scotland.gov.uk/uploads/docs/report/2017/nr_171019_ferry_services.pdf

INITIATIVE 8

Transport Scotland will build on work already undertaken to assess the state of Scotland's trunk road network and understand its unique nature and features that could help develop and support the deployment of CAV technologies and services in Scotland and seek engagement with industry and other stakeholders to address the challenges.

Leading industrial capabilities

Scotland is home to leading industrial and manufacturing organisations, and transport operators.

The largest bus and coach manufacturer in the UK, and one of the world's fastest growing bus builders, is a part of the CAV Forth project team delivering the autonomous bus trial.

Scotland also houses two of the largest bus and coach service companies in the UK. One of these companies is involved in assessing opportunities to test autonomous transport services in university campuses in Scotland, having already conducted trials in the United States, whilst the other is participating in the Project CAV Forth trial and is also trialling autonomous vehicle technology scenarios in one of its larger UK depots.

Advanced ITS capabilities

Many of the benefits to be delivered by CAV technologies will be enhanced through harnessing C-ITS connectivity between vehicles and wider infrastructure. Scotland has long been at the forefront of innovation in the deployment and use of ITS. Significant investment in recent years has seen Transport Scotland build up a considerable set of tools and infrastructure assets, including the Traffic Scotland National Control Centre (TSNCC) to help monitor, control and inform traffic on the trunk road network. This provides an ideal environment for the development and piloting of both CAV technologies and wider C-ITS applications.

Transport Scotland currently provides and manages thousands of ITS assets ranging from small detector loops to large Variable Message Signs (VMS) installed on the trunk road network. The ITS infrastructure is connected to the TSNCC where various systems work together to co-ordinate responses during major incidents as well as monitoring the daily operation of Scotland's roads. The introduction of connected vehicles will allow information to be transmitted from vehicles to surrounding roadside infrastructure, and vice versa, providing details on road conditions, traffic and weather conditions, and advanced incident notifications.

Further infrastructure improvement programmes, such as the A9 and A96 dualling projects, present opportunities to install ITS infrastructure on important routes in rural areas. With improvements in connectivity and communications it could mean that vehicles almost anywhere on the trunk road network could be monitored, adding to the attractiveness of Scotland as a testing and proving ground.

Freight and platooning

The M74 / M6 corridor between Glasgow and Manchester has been identified as the most valuable route for autonomous lorries in the UK[20]. Opportunities exist to utilise both platooning technologies, i.e. to enable a convoy of lorries to travel closely together at high speeds with the first vehicle being driven and the remainder following in convoy using C-ITS and autonomous vehicle technologies, and non-platooning automated driving capabilities on this route. The characteristics of this route, such as its long distance and relatively low congestion levels, make it an ideal location in which to conduct trials on Scottish roads and provide the potential for financial benefit for operators utilising these technologies[21].

Successful collaboration between Government and Industry

Scotland is proud of continuously supporting and encouraging innovation through forums which bring together companies working on various components of CAV technologies. This includes Technology Scotland and ScotlandIS.

Technology Scotland is the representative body for the enabling technology sector in Scotland and provides an independent voice for those engaged in areas such as photonics, electronics, advanced materials, nanotechnology and advanced manufacturing.

ScotlandIS is the representative trade body for Scotland's vibrant digital economy and actively promotes the industry to the Scottish and UK governments, media and the investment community.

Such forums work to represent industry interests to governments and thus have a continuing role in shaping and influencing policy at both Scottish and UK government levels. The openness of these allows for new companies to voice their opinions on future developments, take forward policy issues to government and drive forward initiatives to help grow their businesses. These mature forums are well placed to support and provide visibility of companies engaged in developing CAV technologies and solutions.

20 http://www2.inrix.com/av-freight-study-2018
21 http://www2.inrix.com/av-freight-study-2018

Case Study

Project CAV Forth Autonomous Bus Trial

Project 'CAV Forth' will provide a globally significant demonstration of UK autonomous bus capability along a 14-mile route across the Forth from Fife to Edinburgh, using the dedicated Public Transport Corridor across the Forth Road Bridge. It was successful in a bid to the fourth round of the Connected and Autonomous Vehicles Intelligent Mobility Fund and will trial a fleet of full size single-decker buses operating autonomously.

Estimated to cost around £6.1 million, Project CAV Forth is part-funded by the Centre for Connected and Autonomous Vehicles (CCAV), delivered in partnership with Innovate UK. It is part of the UK Government's £100 million Intelligent Mobility Fund, supporting the Future of Mobility Grand Challenge.

Support for Project CAV Forth demonstrates the Scottish Government's belief that a modern transport system is fundamental to sustainable and inclusive economic growth and has the potential to deliver significant economic and societal benefits.

It will enhance Scotland's reputation for innovation and scientific excellence, demonstrating that Scotland is 'Open for Business' for CAV technologies and business. It will provide a valuable new transport connection for communities, commuters and tourists, integrating with retail, education, leisure, bus, passenger rail and tram.

Project CAV Forth will demonstrate how CAV technologies can boost inward investment in the transport and innovation sectors, helping to deliver new jobs in the technology and automotive sectors and supply chains, and demonstrate the potential benefits to safety, congestion, efficiency and the environment

The 30 month project began in 2019 and will include a 12 month service of a fleet of full-size Alexander Dennis 42-seat Enviro200 single deck buses, travelling on public roads, carrying fare-paying passengers at speeds of up to 50 mph. The Enviro200 will be fitted with Sensor Fusion AI and deliver high speed autonomous vehicle operation, initially at Level 4 autonomy.

In order to provide a successful trial of CAV public transport at scale, Project CAV Forth includes a number of specific challenges and requirements such as:

- A significant increase in Safety Case
- Sensor packaging to allow operation in all weather conditions
- Redundancy in key system elements
- AV and bus systems hardened to increase cyber security
- Human-Machine Interface (HMI) to allow driver to resume control if required
- Upgrades to ITS and roads infrastructure to support autonomous operation

The Project CAV Forth partners are –

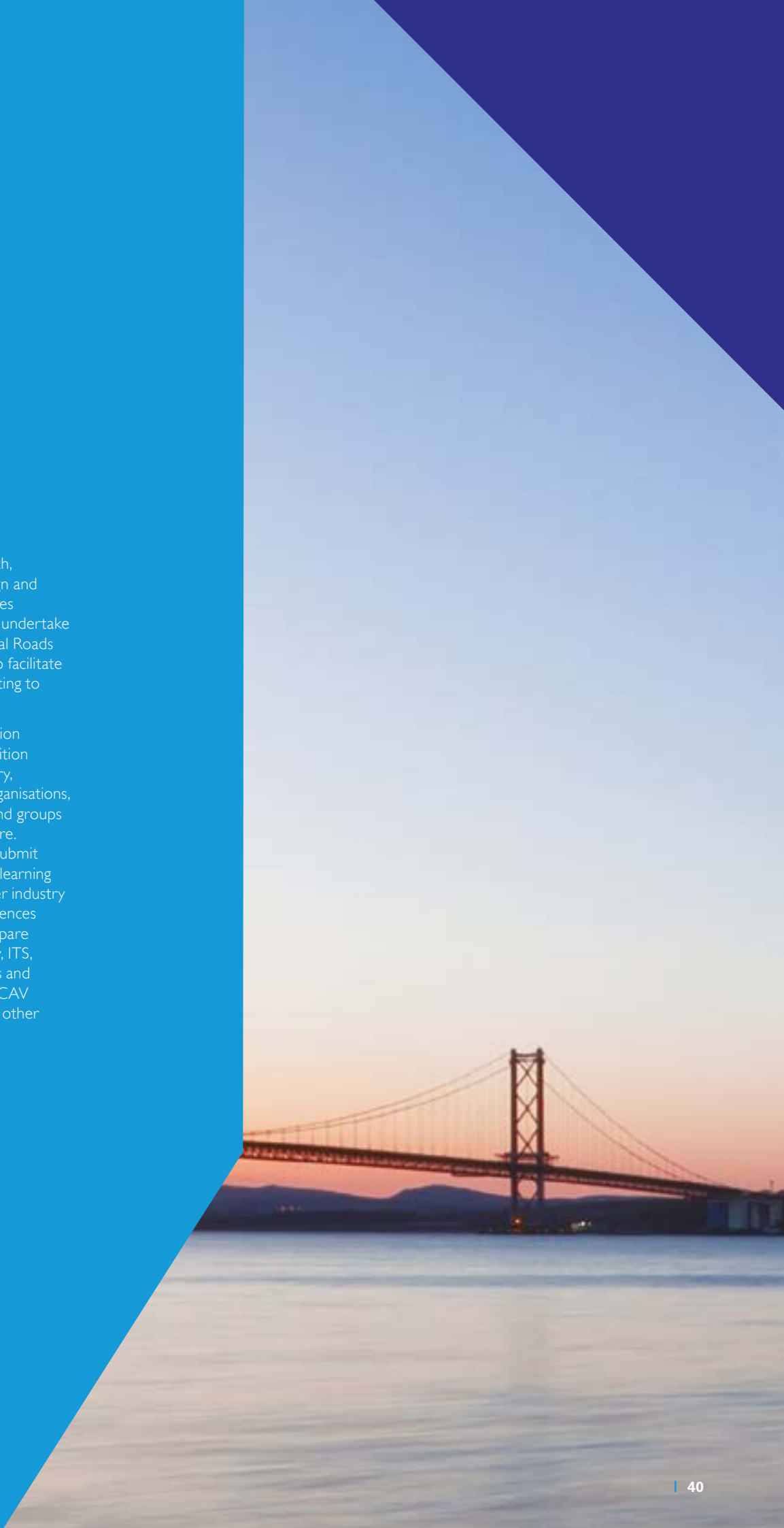
- Fusion Processing Ltd - Lead Partner (Autonomous Vehicle Technology)
- Alexander Dennis Ltd (UK's largest Bus Manufacturer)
- Stagecoach Group plc (Bus Service Operator)
- Transport Scotland (Trunk Roads Authority)
- Edinburgh Napier University (Consumer Viewpoint Measurement and Analysis)
- Bristol Robotics Laboratory, UWE (Safety Case Development)

The route, between Fife and Edinburgh, is mostly on motorways and will require the autonomous bus to safely merge and change lanes on motorways in live traffic, negotiate three traffic signal controlled roundabouts, a signal controlled crossing, five grade separated junctions, sections of single carriageway local roads and stop at bus stops both en-route and at the termini.

As Roads Authority for much of the route, Transport Scotland has control of most of the road network infrastructure on Project CAV Forth. From the Traffic Scotland National Control Centre at South Queensferry, adjacent to the Forth Road Bridge, Transport Scotland will have complete CCTV camera coverage along the route, enabling monitoring in live time and providing incident management response if required.

As a partner in Project CAV Forth, Transport Scotland will also design and implement infrastructure measures required to support the scheme, undertake liaison and relationships with Local Roads Authorities and use its facilities to facilitate education and dissemination relating to Project CAV Forth.

It is expected that the dissemination activities will include public exhibition displays, engagement with industry, professional bodies and other organisations, and hosting visiting delegations and groups at the Contact & Education Centre. Transport Scotland also aims to submit technical papers relating to CAV learning from Project CAV Forth for wider industry review and at appropriate conferences in the UK and internationally, prepare articles for publication in industry, ITS, transportation and other journals and otherwise share our learning on CAV infrastructure requirements with other Roads Authorities.



Legal reform

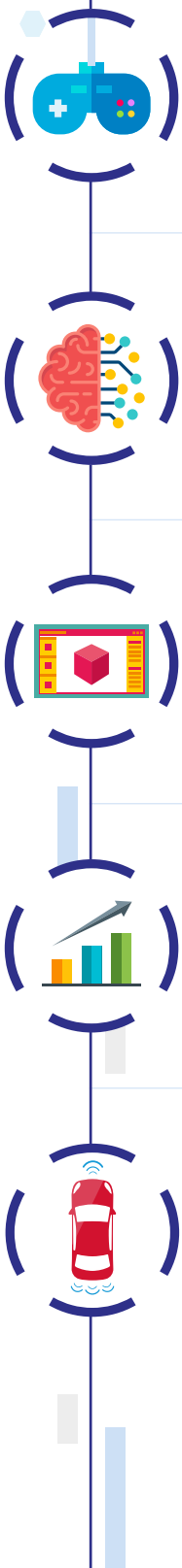
We are aware of the far-reaching implications of CAV technology and are actively considering the impact this will have on all manner of organisations and networks.

The completion of the Law Commissions' review of the UK's legal framework for automated vehicles will mean that Scotland and the rest of the UK will be one of the first regions in the world to have identified and be making progression towards fundamental reform of its roads regulations and laws, putting it in a position to both expedite adoption of CAV technologies and also to export advise.

Technology, data and innovation

A core ambition of the Scottish Government is to place Scotland at the forefront of innovation by leveraging existing expertise in data and digital and we have a strong foundation and skills base from which to position ourselves as a leader in developing the technologies, tools and solutions for a CAV future.

We also have thriving government programmes and are making significant investments in developing our capabilities.



an extensive and skilled gaming industry (91 companies work in the games sector in Scotland, adding a contribution of nearly £172 million to the UK's Gross Domestic Product (GDP)[22]) – providing skills of significant value to companies developing simulations for autonomous vehicle testing;

code-based companies who specialise in AI and machine learning, supporting the development of Smart Cities and beyond;

technology companies which specialise in complex digital imaging solutions and export these solutions to global automotive OEMs;

predictive analytics companies which provide real-time solutions; and,

sensor fusion companies at the forefront of the testing and measurement of Advanced Driver Assistance System (ADAS) sensors, including radar and LIDAR.

22 https://www.heraldscotland.com/business_hq/15912624.scotlands-video-games-industry-on-the-rise-with-huge-upsurge-in-job-numbers/

Figure 3-3:

Technology, tools and solutions for a CAV future

Academic and research capabilities

Scotland houses a number of academic institutions which are leading the way in the research and development of technology that could be applicable to CAV. Academic institutions including Edinburgh Napier University, the University of Glasgow, the University of Strathclyde and the University of Edinburgh are globally recognised for their knowledge and skills in respect of AI, data science, machine learning and robotics; all key features of CAV technology systems.

Our accomplished academic community provides substantial opportunities for those wanting to further their research and development efforts in respect of CAV technologies. Our research and development facilities combined with government-backed skills initiatives provide companies with access to a pool of new and growing skillsets and capabilities. Scotland therefore offers a ready-made platform for those wishing to trial and test digital solutions to some of the most challenging transport problems faced today, such as improving accessibility and reducing congestion.

In collaboration with our enterprise partners and others, Transport Scotland is also setting in place a new framework to support innovation in future mobility technologies. Our emphasis is on creating the right mix of networks and collaboration, funding, facilities and skills so that we increase the scale and ambition of innovation in mobility and harnessing as-yet untapped expertise in related sectors.

“Scotland houses a number of academic institutions which are leading the way in the research and development of technology that could be applicable to CAV.”

This work will focus on:

- Stimulating research and development and the new supply chains through the provision of clearly identified facilities and infrastructure;
- Increasing funding secured by Scottish companies and research institutions from third party sources, including at a UK and international level and from public and private sources;
- Developing strong international partnerships in mobility;
- Accelerating the development of innovative products and services through the sharing of expertise and experience with international partners;
- Identifying where regulatory change may be required to enable the adoption of new mobility technologies, and where action is needed in advance of those technologies emerging to ensure their safe and effective adoption.

Initiatives such as the Michelin-Scotland Alliance, and associated Innovation Parc, aim to harness Scotland’s world class research and innovation expertise. They will support the expansion of Scotland’s sustainable mobility research capabilities, manufacturing base and supply chains, and can play a key role in supporting our ambitions for economic growth and an intelligent, efficient, clean and fair mobility ecosystem.

Consumer acceptance

Numerous studies around the world have suggested that consumer confidence in CAVs is low, and in some cases, declining. This is perhaps one of the most critical areas to address, with user-experience ultimately being essential for adoption. If emergent CAV technologies are to be accepted by Scottish residents, engaging with the population to gauge appetite and starting to build confidence will be a major step in the right direction.

Scotland has an excellent base to start from in this respect. Platforms such as the popular Traffic Scotland website which collects and distributes real-time traffic information, are used extremely frequently by the Scottish population. This demonstrates a sound awareness and willingness amongst the Scottish population, to engage with (emergent) technology platforms, which will be increasingly important on the road to ensuring the successful adoption of CAVs.

Electric vehicle capability

Scotland already benefits from one of Europe's most comprehensive EV charging networks and one of the world's boldest commitments to the supporting the transition to electric vehicles, as articulated through our work to remove the need for new petrol and diesel cars and vans by 2032.

Scotland's recent commitment to a net zero carbon emissions target as part of our response to the climate emergency is a further signal of the importance of the low carbon sector to Scotland and our economy.

Transport Scotland is working closely with Scotland's energy network companies to develop new tools and systems to coordinate EV charging investments to both meet predicted pace of EV uptake, and to unleash the huge potential for innovation at the interface of mobility, the energy system and the digital revolution.

Case Study

Connected Vehicle

Infrastructure to Vehicle communications trial

Transport Scotland recently undertook a trial of V2I roadside beacons, capable of transmitting messages into an app displayed on a smartphone mounted in the vehicle. The successful trial involved sending directional static journey time information when passing the point on the network where the equipment was installed. This trial offered a proof of concept of a rapidly deployable connected vehicle solution, offering variable message passing from Traffic Scotland's existing systems, directly into vehicles.

Connected In-Vehicle Information System

Transport Scotland is working with a supply chain partner on a connected vehicle trial to demonstrate a proof of concept for a connected in-vehicle information system. This involves trialling the transmission of in-vehicle signage known as a Virtual VMS which includes delivering road rules and traffic data directly to a driver display interface. This enables richer messages to be shared with customers than on roadside signage and, in the longer term, the potential for roadside signage to be removed.

Case Study

Third Party Data

Third Party Analytics

Transport Scotland uses third party data and analytics tools to enable more effective monitoring and management of the performance of the Trunk Road Network. These cloud-based systems are capable of providing network insights not previously available to Transport Scotland, derived from multiple third party data sources.

These analytics tools are used in three main areas by Transport Scotland:

1) Operating – Traffic Scotland uses the real-time data to monitor live journey times and network conditions from the Transport Scotland National Control Centre.

2) Planning – used by the strategic transport planning team to assess proposed road schemes, and evaluate the before and after benefits of deployed schemes.

3) Informing – used for answering numerous information queries received from a wide range of interested parties on the performance of Scotland's strategic road networks.

Connected vehicle data, especially real-time location and trajectory information, provides a highly valuable augmentation to the existing data sets, enabling Transport Scotland to better understand demand for, and the condition of the network.

Autonomous Vehicle Road Rules Platform

Transport Scotland is engaged with a supply chain partner working to develop the first platform that enables road authorities to record and validate traffic rules and regulations, in a format which can be processed by autonomous vehicles operating on public roads.

In time the platform will also leverage information from CAVs to report infrastructure improvement needs through communication channels between CAVs and transport authority networks.

3.3 SCOTLAND'S CHALLENGES IN MAINTAINING AND GROWING ITS CAPABILITIES

Skills availability

Maintaining and growing Scotland's existing digital capabilities will require engagement throughout the Scottish education sector with a focus placed on Science, Technology, Engineering and Mathematics (STEM) subjects.

Alongside the wider disruption taking place across mobility, such as ULEVs and MaaS, the deployment of CAVs has the potential to support the growth of a variety of new skills and opportunities.

Access to markets

60% of Scotland's exports are to the rest of the UK[23], with 18% to the EU and 22% to the rest of the world. Development and nurturing of world-leading autonomous vehicle technology capabilities (from photonics to simulations) requires access to the OEM market, which is seeing a significant decline in the UK with recent announcements by four leading manufacturers that they are re-locating their facilities. There is a need to establish clear routes to market and advertise Scottish capabilities globally.

Transport Scotland has a number of initiatives underway to help gather evidence on ULEV and other emerging technologies relevant to CAV. A short-term industry advisory group to advise ministers on actions to grow Scotland's automotive sector and supply chains is being considered and there are opportunities to include CAV in this.

INITIATIVE 9

Transport Scotland will engage with education partners to encourage an awareness of CAV in STEM, with specific reference to Scotland's contributory industries to the market place, and ensure it is captured within their considerations for future curriculum.

INITIATIVE 10

Working with partners, such as Scottish Enterprise and the Scottish National Investment Bank, Transport Scotland will investigate and support the targeting of international markets for Scottish companies developing CAV technologies which have global exportation potential.

INITIATIVE 11

Working with partners in Scottish Government Digital and Digital Scotland Transport Scotland will investigate opportunities for proactive investment in CAV infrastructure and services to deliver targeted outcomes.

23 https://www2.gov.scot/Topics/Statistics/Browse/Economy/Exports/ESSPublication

Collaboration and scale

Forums such as CENSIS (a Scotland based Centre of Excellence for sensing and imaging systems and Internet of Things (IoT) technologies) and CodeClan (a Scottish industry-led and award winning digital skills academy, helping to bridge the digital skills gap in Scotland's growing technology industry) are being established to bring together Scottish enterprises. These are not dedicated to the CAV market and a gap exists with respect to a forum to bring together Scottish companies developing CAV-supportive technologies and solutions, enabling collaboration and scaling to provide compelling solutions to the market.

Trials and pilots

To be credible in the global market Scottish businesses and research institutions need to have refined their capabilities and products locally. Live trials and pilots provide opportunities to do so. Examples such as the CAV Forth pilot and Dundee Mobility Integrated Living Lab ('MILL') project are indicative of the types of opportunities that can benefit Scottish businesses. Opportunities for further initiatives could be explored across Scotland. This could also have the benefit of improving consumer acceptance by demonstrating CAV technologies in operation.

"To be credible in the global market Scottish businesses and research institutions need to have refined their capabilities and products locally. Live trials and pilots provide opportunities to do so."

INITIATIVE 12

As part of the existing work on maximising the benefits from the UK Industrial Strategy for Scotland, Transport Scotland and the Scottish Government will work with BEIS, DfT, CCAV and Innovate UK to influence further investment through Industrial Strategy Funding related to the Future of Mobility Grand Challenge.

INITIATIVE 13

Working with our project partners, Transport Scotland will deliver the Project CAV Forth Autonomous Bus Pilot as a key component of the 2018-19 Programme for Government's commitment on "Future of Transport – Intelligent Mobility", supporting the research, development, demonstration, and deployment of CAVs, and exploring with others how Scotland can best capitalise on the opportunities and benefits of this technology.

The deployment of CAVs will bring transformative changes in the way people travel, work and live.

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Conclusion and Summary

4.1 SCOTLAND IS OPEN FOR BUSINESS

The deployment of CAVs in Scotland will bring transformative changes in the way people travel, work and live, and could lead to significant economic benefits. We are extremely well-positioned to build on our existing industrial and academic assets and capabilities whilst simultaneously developing new skills and capabilities. We are committed to ensuring that we are able to deliver the numerous benefits CAV technology could bring to the population of Scotland by proactively identifying and addressing challenges head-on with the support of industry, academia and our national and local government partners.

CAV is a key enabler of delivering the Programme for Government

The adoption of CAV technologies offers significant potential to help deliver a number of commitments set out in the Programme for Government. In doing so, CAV technologies will help drive inclusive, environmentally sustainable growth throughout Scotland, within a safe, enhanced and integrated transport system. We recognise that there are a number of challenges to overcome, ranging from consumer acceptance, affordability, infrastructure configuration, condition and availability, and law and regulation. We are committed to addressing these challenges and unlocking the significant benefits for the country.

Scotland is integral to the future of CAVs

Scotland possesses world-leading digital strengths and capabilities which will be integral in overcoming the barriers to the successful deployment of CAVs, and can offer unique environments in which to test both vehicles and their respective service models. There is a consensus that it is not possible to test all real-world scenarios before allowing vehicles to test on live roads.

Transport Scotland is well placed to facilitate testing on live road environments. As roads authority for Scotland's trunk road network we control and operate over 3,500km of roads in Scotland, connecting our major cities, towns, airports and ports.

The Scottish strategic road network is hugely diverse, from the 10-lane M8 through and around Glasgow and Scotland's first 'smart motorway' corridor along the M90 Queensferry Crossing corridor, to a network of all-purpose dual and single carriageway trunk roads, some of which are in remote rural areas where the trunk road is often the only road.

The diversity of Scotland's strategic road network offers opportunities for testing and trialling connected and autonomous vehicles and the technologies that will enable them. Transport Scotland will look to work with developers, suppliers and industry to identify those parts of our network where live road trials and pilots can be supported in a safe and meaningful way.

Scotland's strengths in simulation and virtual reality which provides excellent opportunities to ensure that the challenges of testing connected and autonomous vehicles can be met through virtual testing and image processing of vehicle components and systems in complex road test scenarios.

Scotland's research institutions, universities, and technology, photonics and data industries will continue to develop progressively more capable and cost effective sensor, image processing and AI solutions for adoption by OEMs. Vehicle manufacturers like Alexander Dennis are going to continue to develop their product ranges to provide CAV ready vehicles across the world.

The Scottish Government is committed to supporting these industries and helping them grow by addressing skills, market access, and research and development challenges.

We are in a prime position to capitalise on the benefits associated with CAV. Scotland already possesses many of the new and unique skill sets required to develop, exploit and deploy CAV technologies successfully. Developing the Scottish workforce will help to cement Scotland's position as a global leader of industry and academia, particularly in sectors such as data and digital.

Creating an efficient and accessible CAV supply chain will be crucial. The Scottish Government acknowledges many benefits of connectivity and automation but is also aware of the need to prepare for the changes the technology could bring.

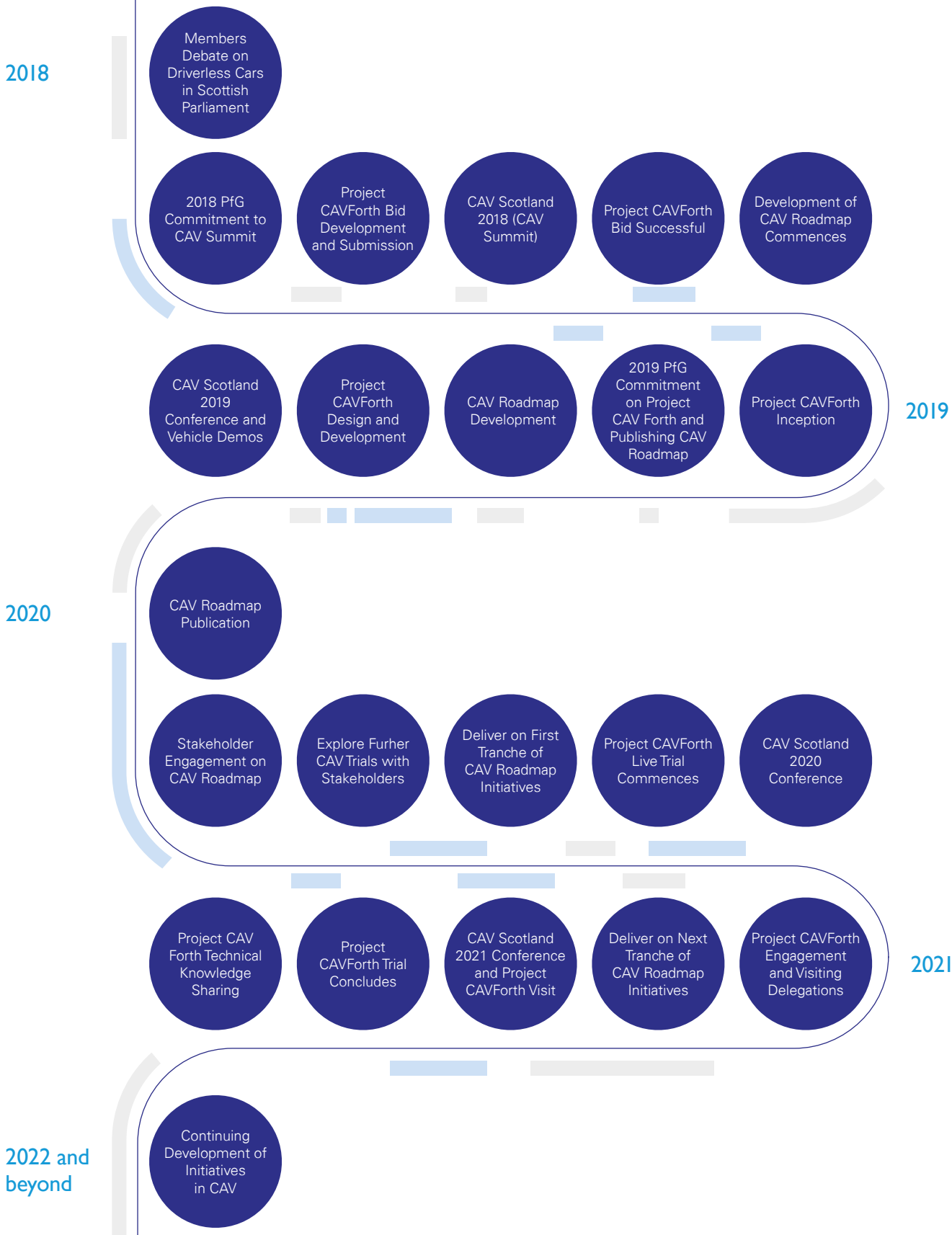
Scotland is open for businesses and warmly welcomes collaboration, investment and involvement from across industry, academia and public sector partners to help us realise our vision for economic growth and securing a prominent position in the future of the CAV market.

In the period since the Members' Debate on driverless cars in the Scottish Parliament on 15 March 2018, Transport Scotland has been actively engaged on developing this CAV Roadmap and a number of associated initiatives.

These include establishing the CAV Scotland conference and demonstrator summit, which is now a highly regarded annual event on the conference calendar, and working with our partners on the development and delivery of Project CAVForth.

Figure 4-1:

Milestones to delivery of CAV ambitions



During the course of Project CAV Forth we look forward to host visitors from across the CAV Sector at out Contact and Education Centre overlooking the Forth Road Bridge to raise awareness of the project, update on progress, and disseminate our learning from the point of view both of a project partner and a roads authority.

We will continue current activities with our wider supply chain, partners and stakeholders in bringing forward innovative schemes in connected vehicle solutions and new infrastructure design, and look for opportunities to enhance our use of data analytics, and improve our ITS systems and equipment to facilitate the trialling and deployment of CAV technologies on Scottish roads.

Looking further ahead, Transport Scotland will continue to engage with existing stakeholders, partners, and our supply chain, and to seek new relationships and opportunities to work with other to help us to deliver on the initiatives set out in this CAV Roadmap and enhance our capabilities in support of our CAV ambitions.

The CAV Roadmap sets out how Scotland is well placed to play an increasingly important role in the development of future mobility initiatives, including in connected and autonomous vehicle technologies, pilots and trials, to offer exciting potential for Scottish industries to be at the forefront of innovation and economic growth.

Delivering the initiatives of the CAV roadmap and the aims and objectives of our Future ITS Strategy, will confirm that Scotland is indeed 'open for business' in CAV developments and further establish our credentials and reputation for innovation on the world stage.

Our commitment

The initiatives we have set out in this CAV Roadmap for Scotland are aligned to the UK Government's ambition of having autonomous vehicles on UK roads by 2021. Our roadmap will therefore be updated as required in order to keep up with the latest CAV developments and opportunities. We have already begun efforts to deliver some of the commitments outlined in this roadmap and we will continue to build on this to ensure the Scottish Government's ambitions for CAV in Scotland are fully realised.

Appendix

Initiatives Portfolio

The initiatives below and as cited throughout the document have been developed with consideration of their alignment to Scottish Government's strategic objectives in relation to the National Transport Strategy, Programme for Government and the ITS Strategy.

Term	Definition
1	Transport Scotland will seek opportunities to influence, engage with and support initiatives to establish CAV trials that address specific Scottish contextual needs and development opportunities such as Islands, Rural Routes and the Freight, Food and Drink sectors.
2	Transport Scotland will look for opportunities to work with partners to provide information on the safety benefits of Advanced Driver Assistance Systems, and other Connectivity features that are available now, and ensure that CAVs sit at the centre of efforts to achieve the 2030 Road Safety targets.
3	Transport Scotland will identify opportunities to leverage CAV technologies to improve competitiveness and operational efficiencies and link to Intelligent Mobility, and the external enablers required to deliver on opportunities, mobility solutions and technologies, including last mile delivery, ULEV and digital innovation.
4	Transport Scotland intends to build on the highly successful CAV Scotland conference and demonstrator summits held in 2018 and 2019, with further events and publicity in order to showcase developments and future ambitions. This will aim to energise domestic and international companies, sharing leading practice, and encouraging educational choices.
5	There is a need to collectively explore opportunities for investment in CAV Infrastructure with partners including the Centre for Connected and Autonomous Vehicles, Innovate UK, Scottish Enterprise, the Connected Places Catapult and the Scottish National Investment Bank.
6	We will engage with others to understand what Transport Scotland has to do to ensure future ready ITS Infrastructure for CAVs is being specified in future road investments and in the Control Room of the future.
7	Transport Scotland will encourage the capture and modelling of data during infrastructure and transport schemes and maintenance projects to be made available to companies developing simulation and testing tools for CAV software and solutions.
8	Transport Scotland will build on work already undertaken to assess the state of Scotland's Strategic Road Network and understand its unique nature and features that could help develop and support the deployment of CAV technologies and services in Scotland and seek engagement with industry and other stakeholders to address the challenges.
9	Transport Scotland will engage with education partners to encourage an awareness of CAV in STEM, with specific reference to Scotland's contributory industries to the market place, and ensure it is captured within their considerations for future curriculum.
10	Working with partners, such as Scottish Enterprise and the Scottish National Investment Bank, Transport Scotland will investigate and support the targeting of international markets for Scottish companies developing CAV technologies which have global exportation potential.
11	Working with partners in Scottish Government Digital and Digital Scotland Transport Scotland will investigate opportunities for proactive investment in CAV infrastructure and services to deliver targeted outcomes.
12	As part of the existing work on maximising the benefits from the UK Industrial Strategy for Scotland, Transport Scotland and the Scottish Government will work with BEIS, DfT, CCAV and Innovate UK to influence further investment through Industrial Strategy Funding related to the Future of Mobility Grand Challenge.
13	Working with our project partners, Transport Scotland will deliver the Project CAV Forth Autonomous Bus Pilot as a key component of the 2018-19 Programme for Government's commitment on "Future of Transport – Intelligent Mobility", supporting the research, development, demonstration, and deployment of CAVs, and exploring with others how Scotland can best capitalise on the opportunities and benefits of this technology.

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