Ministry of **Transport**
TE MANATŪ WAKA

Autonomous Vehicles

Background paper two

International Developments

The Ministry of Transport has started a work programme looking at the challenges and opportunities Autonomous Vehicles (AVs) present to the transport system in New Zealand. This paper outlines the approach being taken by several countries to shape the deployment of AVs on public roads and the development pathways and the progress of leading companies operating in those countries.

Introduction

New Zealand is a taker of technology. On the one hand, this allows us to observe and evaluate the success of other jurisdictions' approaches to the deployment of autonomous vehicles (AVs) before committing to a course of action ourselves. On the other hand, it means we need to deliberately and consciously follow international developments so we are prepared for the arrival of new vehicle technologies on our roads.

This paper aims to build wider understanding of the approaches other countries are taking to support the deployment of AVs. We have selected nine countries leading AV deployment worldwide, and several companies developing the technology within these countries. This is not a comprehensive stocktake of all global AV activity, but covers New Zealand's vehicle import markets and highlights some of the most prominent players in the AV development space.

As the development of AVs moves so quickly, this paper has limited the discussion to developments up to and including 1 March 2021.

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Australia

Approach to AV Deployment

Australia's goal is a regulatory framework that supports 'the safe commercial deployment and operation of automated vehicles at all levels of automation in Australia'. Driving this is the safety, productivity and environmental benefits that AVs are expected to deliver.

Australia has a significant programme of work underway to review and reform existing legislative frameworks through its National Transport Commission (NTC). Across its automated vehicle program, the NTC has aimed to ensure that reforms are outcomes based, with safety as the key outcome, allowing industry to determine how best to achieve those outcomes; that reforms are neutral as to the technologies, applications and business-models that industry develop; and that reforms are nationally consistent and internationally aligned. The NTC, in conjunction with the Commonwealth Government, state and territory governments and Austroads, is reviewing Australia's overall readiness for the commercial deployment of automated vehicles. The focus of the review is on trials, regulation, infrastructure and public attitudes, the review will report to the Infrastructure and Transport Council by May 2021.

Australia has already made a series of key decisions on AVs. Of note, Australia will incorporate a self-certification approach for automated driving systems (ADS) into existing Commonwealth vehicle regulations. This was agreed in November 2018 and is being implemented. Ministerial agreement has also been reached that the automated driving system entity (ADSE) is legally in control of a vehicle when the ADS is operating, and that the fallback-ready user must remain sufficiently vigilant to respond to ADS requests and failures and regain control when required.

Australia has also adopted a similar approach to trailing AVs across states. This approach allows the relevant Minister or statutory authority to issue individual trial permits that exempt trialling organisations from road rules and other laws that would otherwise prohibit the operation of highly automated vehicles, subject to a number of conditions. South Australia was the first state in Australia to enact laws allowing for the on-road trials of AVs. In June 2016, the South Australian Parliament enacted the Motor Vehicles (Trials of Automotive Technologies) Amendment Bill 2016. This legislation provides a framework to facilitate on-road trials, testing and development of driverless vehicles and other advanced automotive technology on South Australian roads. New South Wales and Victoria followed suit with the Transport Legislation Amendment (Automated Vehicle Trials and Innovation) Act 2017 and the Road Safety Amendment (Automated Vehicles) Bill 2017 respectively.

Canada

Approach to AV Deployment

Transport Canada's (TC) approach to AV technologies focuses on: safely deploying AVs on Canadian roads; improving road safety; increasing transportation efficiency and the free flow of goods and people; facilitating opportunities for innovation and growth among Canadian businesses; and ensuring privacy and cyber security.

The Motor Vehicle Safety Act (MSVA) sets safety regulations and standards for importing motor vehicles and designated motor vehicle equipment into Canada, and the shipment of newly manufactured motor vehicles and designated equipment across provincial/territorial boundaries. Vehicles with automated and connected features must comply with applicable legislation at the federal and provincial/ territorial levels, including the MVSA. The MVSA does not include standards for advanced automation technologies, but as vehicles with higher degrees of automation emerge on the market, TC has acknowledged that there may be a need to amend regulatory requirements on a permanent or a temporary basis.

The Strengthening Motor Vehicle Safety for Canadians Act came into force on 1 March 2018, introducing substantive amendments to the MVSA. In particular, the Act strengthened the Minister of Transport's enforcement and compliance authorities in the area of road safety, and afforded greater flexibility for addressing emerging technologies, such as AV and Connected Vehicles (CVs). These authorities include provisions for exempting, modifying or suspending vehicle safety standards and regulations.

TC anticipates that several standards will need to be temporarily or permanently amended to permit these highly automated vehicles to be imported or sold in Canada. Therefore, TC will continue to explore opportunities to incorporate AV/CV technologies into existing regulations or standards, or to create new ones, as required.

Prominent companies

Magna is a large auto-supplier and has been manufacturing a range of level 4 vehicles in Canada since 2019. It will supply Waymo with the majority of their AVs for their ride-hailing services. Magna has produced several thousand level 4 vehicles per year since 2019, predominantly for use by Waymo's services in Phoenix in the US. The company has the capability to dominate much of the US-Canadian market for Level 4 AVs, but is focused on the Level 1-3 market, at least until 2025.

China

Approach to AV Deployment

The Chinese interest in AV deployment has intensified in recent years. China only began testing AVs on local public roads in Beijing in 2018. More recently, however, Chinese authorities have drafted new regulations to allow for "road testing and example applications of smart connected vehicles", with highways permitted as test sites.

China's approach to regulation is primarily in response to industry developments and objectives. One such development is the establishment of a new four kilometre AV test site for autonomous and connected buses by technology giant Huawei. The objective is to test smart infrastructure, to support Huawei's goal of providing the communications equipment and software required for the intelligent-vehicle revolution.

China has also explicitly outlined its approach to successful AV integration in its Strategy for Innovation and Development of Intelligent Vehicles, published in 2020. This outlines the need for more research on ethical issues; the clarification of legal rights and obligations for all involved; the enactment of laws and regulations regarding testing, access, use, and supervision of AVs; and revision of existing laws and regulations to ease AV deployment.

China's interest in AVs is part of its wider goal of becoming a more high-tech industrial economy, including an ambitious goal of 50% of new auto sales containing at least some form of automation by 2025. This was outlined in their National Technology Road Map 2020, which also emphasised the need for infrastructure that allows vehicles to link to the internet and each other. In late 2019, the first 5G autonomous driving traffic management system in the world that integrates vehicles, roads, and smart cities officially landed in Shanghai and opened to the public. China has set aside a dedicated bandwidth on the 5.9 GHz spectrum solely for AV use, with plans to have the technology rolled out across 90% of major cities and highways in the near future. The development of intelligent vehicles has the added benefit for China in aiding its auto-related industries including chips, software, information telecommunication and data services.

The KPMG 2020 Autonomous Vehicles Readiness Index identified Beijing as one of the top five cities to watch. AVs are planned to play a huge role in the 2022 Beijing Winter Olympics and Paralympics, with $50 million being invested to develop a 100 square km testing zone.

Prominent companies

Similar to the United States, Chinese tech companies are increasingly investing in AV development and working with leading vehicle manufacturers to be first to commercialise the technology. Unlike the US, however, China is mostly targeting the low-cost vehicle market for mass production, earlier profit, and scale efficiencies.

Search-engine company **Baidu** is the leading Chinese company in the AV space. In September 2020, the company demonstrated its Level 4 AVs at its annual tech conference in Beijing, Baidu World. Baidu received the first license to test fully autonomous vehicles on public roads in China, in Beijing. Baidu has also recently been approved to test entirely unmanned fully driverless cars in Sunnyvale California using its open-source AV technology platform, Apollo. The tests must take place on roads with speed limits under 45 mph and in dry conditions. Baidu has a research and development centre in the city, and currently has more than 150 partners worldwide, including Chevy, Ford, Honda, Toyota, Volkswagen and Intel.

Ride-hailing giant **Didi Chuxing** started testing and developing autonomous vehicles in 2016, in partnership with car manufacturers and suppliers in China. The company now has more than 200 employees in China and the United States and has public road testing licences in Beijing, Shanghai, Suzhou and California. Unlike Uber, that sold its Chinese business to Didi and exited the Chinese market in 2016 in exchange for a minority stake, Didi is still pursuing the goal of owning a fleet of fully autonomous robo-taxis. In June 2020, Didi began trialling its own robotaxi service in Shanghai in a major step toward in its goal of operating more than 1 million autonomous vehicles by 2030.

Huawei, a telecommunications giant, is working with Audi and Chinese automakers GAC Group, Beijing New Energy Automobile, and Changan Automobile, with the goal of launching AVs commercially as early as possible. In 2017, Huawei partnered with Vodafone to work on connectivity technology, as part of its strategy to invest in the highly valuable information and communication technology, rather than the vehicles themselves. In late 2019, Huawei partnered with NavInfo to use its mapping data for navigation in its self-driving cars. Huawei later partnered with China-based electric car maker, BYD, using Huawei's Kirin chips in the vehicles and utilising AI and 5G technologies. Huawei is also planning to produce lidar sensors at an affordable price for use in all smart vehicles.

Volvo, a Swedish company acquired by China's Zhejiang Geely Holding Group Co in 2018, is publicly focusing on safety and building public trust in AVs and has notably accepted full liability when its vehicles are operating in autonomous mode. Volvo plans to launch a Level 3 system dubbed Highway Pilot, with the sensor suite at least built into select new vehicles from 2022. Highway Pilot, would enable hands-free highway driving that will not require drivers to keep their eyes on the road at all times. Interestingly, Volvo's chief technology officer has said "selling cars to individual consumers is the best way to commercialise autonomous technology, rather than betting on robotaxis or automated delivery vehicles." The company had teamed up with Uber in 2019 to trial AV technology inside Volvo vehicles, and has recently indicated plans to pilot a programme of AVs in China and the US.

Germany

Approach to AV Deployment

Germany has led the way in Europe for AV regulations. In 2017, Germany was the first country to legislate the use of level 3 AVs on public roads (under certain conditions). Along with Japan, Germany has since co-led the drafting of level 3 requirements to govern the usage of automated lane-keeping systems (ALKS) through the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonisation of Vehicle Regulations. Germany has also prepared a draft law that would likely set the level 4 standard for the rest of the European Union and further abroad.

Germany intends to integrate operational AVs (level 4 and 5) into the German transport system in 2022. Germany would become the first country in the world to allow level 5 AVs on public roads if it achieves this ambitious goal. Germany is also aiming to have autonomous trucks on the roads by 2030 and use truck platooning through connected wireless signals. The country is also leading the way in connected automated vehicles, with a G7 declaration on automated and connected driving in 2015, and another G7 declaration on cooperation for modern transport infrastructure and advanced technologies in transport in 2017, and a Joint Declaration of Intent on the Cooperation in the Area of Automated and Connected Driving with China in 2018.[1]

There is a high level of engagement in Germany around the regulatory approach to AVs. In 2019, German automaker Daimler instigated a white paper 'Safety First for Automated Driving' (SaFAD), in collaboration with ten other companies. The white paper aimed to unify safety approaches for level 3 and 4 AVs across countries and between automakers. Initially designed as a foundational paper, the next iteration of SaFAD is intended to be a proposal for international standardisation. Ethical concerns around the use of AVs have also been addressed in Germany with the creation of an ethics commission to look at the role of the human and that of the vehicle should an accident occur. A final report published in 2017 outlined 20 ethical rules and data protection guidance for AVs.

A key driver of the German approach is to create harmonised regulation that traverses the international market and aids standardisation. Underpinning this approach is Germany's desire to retain its competitive edge in automotive manufacturing. Germany is a leading vehicle exporter and modern mobility is viewed as key to the country's prosperity. Emphasised in the 'Industrial Strategy 2030' put forward by the Federal Ministry for Economic Affairs and Energy, is the need to "safeguard" the strengths of the nation's industries to 'regain commercial and technical expertise,

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[1] BMVI - Joint Declaration of Intent on the Cooperation in the Area of Automated and Connected Driving between the Federal Republic of Germany and the People's Republic of China (English)

competitiveness and industrial leadership.'[2] As the automotive, mechanical engineering and metals sectors account for half of industrial value creation in Germany, the country's approach to leading the development of AV regulation throughout Europe is likely to be to protect its industries and facilitate trade. Ultimately, it is within German policymakers' interest to maximise companies' performance and competitiveness to enable them to operate on a level playing field with countries such as the U.S. and China. As a bloc, the European Union has a similar objective on the world stage.

Despite the progress of Germany in the AV space internationally, the country has its own emerging regulatory challenges such as a need for standardised legislation and coordination across the country's more than 10,000 municipals.

Prominent companies

Audi has been at the forefront of AV development in Germany. Audi hired former Tesla Autopilot program manager to be CTO for its self-driving unit, but stepped back from launching Level 3 Traffic Jam Pilot system in 2019, despite the technology being approved for release and made street-legal. Audi perceived there to be a lack of a legal framework in Germany and other potential markets to support level 3 AVs. Audi are pursuing artificial intelligence alongside AV hardware and software towards full automation and the release of level 4 vehicles in the next few years. They have committed to spending $16B on self-driving and sustainable technology by 2023.

Volkswagen (VW) is another ambitious German automaker. VW entered into a US$7 billion joint venture with Ford and is also partnering with IT companies and third-party providers with a goal to expand its geographical reach. VW now has the largest reach of any AV technology to date. VW is expanding its engineering expertise and capacity as it wants to regain control of the entire vehicle architecture.

BMW-Intel-Mobileye-Chrysler-Magna is a coalition planning to bring the Level 2 BMW iNEXT to market in 2021. BMW teamed up with Daimler in 2019 but the alliance ended one year later. The coalition appears to be focusing on Level 2 for market ready vehicles but has two dedicated campuses for developing full self-driving technologies.

A joint venture between DAF, **Daimler**, Iveco, MAN, Scania and Volvo is developing level 4 trucks, and has been testing platooning trucks on public roads since 2017. The recent partnership between BMW and Daimler was aimed at having level 4 ready vehicles by the mid-2020s, but this ambition has been publically scrutinised.

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[2] BMWi - Federal Ministry for Economic Affairs and Energy - Industrial Strategy 2030

A number of other auto and tech companies, such as **Bosch, Continental AG, ZF** (in a venture with Nvidia and Baidu), are also working on AV technologies. These companies are developing parts and hardware for vehicles that are more focused on improving level 2 safety features, with a view to producing higher level automation technologies sometime in the 2020s.

Japan

Approach to AV Deployment

The Japanese government's approach to regulation is about promoting, supporting and strengthening its industries. Similar to Germany, Japan is pushing ahead with the regulation of level 3 and 4 AVs. The Government has set ambitious targets for AV deployment, including level 2 buses on expressways from 2022, and level 4 private vehicles and trucks on expressways by 2025. In early 2020, Japan amended existing regulation to support Level 3 vehicles on public roads, and Level 4 vehicles in prescribed areas. Both Honda and Nissan have proposed to have Level 3 capabilities in some of their consumer vehicles available in 2021. However, ambiguity around the legal liability if an AV accident were to occur is making some companies hesitant to test on public roads. Also similar to Germany, Japan has a strong domestic vehicle manufacturing industry. Approximately 10% of the population is employed in the auto-manufacturing industry, indicating a strong interdependence between the automotive sector and government employment policy direction.

A key driver of the Japanese approach is its aim to create a "super-smart society" or "Society 5.0" and set this as a precedent for the world. This approach leverages Artificial Intelligence (AI), the Internet of Things and Big Data. This is reflected in Japan's investment in AV research and development, with Japan in the top three countries globally for the number of AV-related patents registered. Facilitating this is the Strategic Innovation Promotion Program for Automated Driving as a Universal Service (SIP ADUS), a cross-ministerial effort in Japan through industry, academia and government cooperation to help fund and support the research and development of new technology right through to commercialisation.

Safety, efficiency, and an ageing population are also key drivers of Japan's approach to AV deployment and regulation. By 2050, at least one-third of Japan's population could be 65 years or older. AVs are seen as an option to support Japan's aging population, particularly through shared mobility in rural areas. However, private autonomous vehicles appear to be the main area of development in Japan and this is being led by the major automakers. Following a series of cyberattacks on Japanese automakers in recent years, there have also been efforts to strengthen the sector's cybersecurity, domestically and internationally.

Prominent companies

Honda launched an AV specific R&D centre in 2017 and has recently received approval from its government to mass-produce a level 3 Legend sedan equipped with Traffic Jam Pilot that can navigate through congested highways. Honda will be the first country in the world to introduce a Level 3 vehicle on public roads, which will begin in Japan from late March 2021. Its ambition is the mass production of AVs for the general public. Level 2 ADAS is already available on all Civic models. Honda is partnering with American company GM on AVs and batteries and has most recently announced a partnership with Microsoft to work on cloud computing and AI. This signals the companies ambition to take a significant share of the future market for AVs.

Toyota have been primarily focused on safety and aim to develop ride-sharing and ambulatory services before providing their AV technologies in personal use vehicles. The company has entered the AV industry by making small investments in dedicated AV research, notably through Universities. Investments to date include the US University for Michigan for robotics and AV research, a Ford spinoff dedicated to AV technology, and China-based self-driving start-up Pony.ai in 2020.

Toyota is working with Camera (an HD mapping and road intelligence start-up) looking at whether dash-cam-recording could be used to map roads. Toyota are also working closely with Nvidia on neural network training, using large-scale simulation tools for software validation and testing. A significant announcement in February 2021 was Toyota's partnership with Aurora innovation, and their intention to mass-produce AVs for Uber to use in its ride-hailing services.

Nissan's focus for AVs is on enhancing the driving experience by making it more relaxing and enjoyable. Nissan has introduced level 2 assistant system (ProPILOT Assist) which helps improve the driving experience (e.g. lane-centring and maintaining a safe distance from vehicles ahead). Nissan is expanding the current level 2 capabilities, in some of its models, into a level 3 option in 2021. After approval by the Japanese government in 2019, this includes ProPILOT 2.0 which will allow drivers to keep their hands off the wheel in a single lane, while being required to take full control of the vehicle at any time. ProPILOT 2.0 uses facial recognition to ensure that the driver is still maintaining focus on the road thus helps the company comply with Japan's regulatory requirements. The technology may be expanded to 20 models and 20 markets by the end of 2022.

Nissan Intelligent Mobility is also developing new technologies, such as Brain-to-Vehicle, which anticipates the driver's intended action, for quicker response time. The concept was developed through collaboration between AI and neuroscience start-up Bitbrain, the Swiss Federal Institute of Technology and the Canadian National Research Council. By using sensors in a wearable headpiece, any intentions from the driver are actioned faster than the typical brain-to-muscle rate.

Singapore

Approach to AV Deployment

Singapore is taking a "regulatory sandbox" approach to AV regulation. In 2017, an amendment was made to the Road Traffic Act to recognise that motor vehicles do not require human drivers. In the same year, Singapore enacted the Road Traffic (Autonomous Vehicles) Rules Act to provide prescriptive and comprehensive rules for AV deployment. Both legislative changes are designed to be a regulatory sandbox for five years, with either the permanent enactment of laws at the end of this time, or an extension of the sandbox period. In addition, the Technical Reference for autonomous vehicles (TR68) in 2019 outlined a set of rules to guide vehicle behaviour, functional safety, cybersecurity, and

> **Regulatory sandbox**
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> A regulatory sandbox allows companies to test innovative products, services or business models where regulatory obligations are partly not applicable. Authorities use legally provided discretion or levers with the intention to enhance innovation and waive the application of administrative provisions that typically apply for larger and established firms.

data formats, although these are not currently binding in legislation. In 2019 a voluntary AI framework was also created as the first in Asia to help guide companies around the ethical issues involved in AI development. A second edition was published in 2020.[3]

Singapore is marketing itself as an attractive and accessible country for international automakers to develop AV technologies because it does not have the vehicle manufacturing capabilities as some larger players, such as Japan or the United States. Autonomous vehicle trials have been operating in Singapore since 2015. With specific authorisation from the Land Transport Authority, level 3-5 AVs can be tested on public roads under certain conditions or designated areas. Currently, one tenth of Singapore's roads are open for AV testing.

Singapore has also embedded AV deployment into its broader goals, including greater use of public transport, wider use of Electric Vehicles (EVs) and economic development from research-focused jobs. This lines up with their 'car-lite' policy and goal of having 90 percent of journeys completed in 45 minutes by 2040. In 2021 Singapore began its first commercial autonomous bus service that is currently running on two routes over a three-month trial period to assess viability. The aim is to have autonomous buses integrated into three areas in Singapore by 2022. Like Japan, Singapore is also seeking to become a "smart nation" by using digital technology to boost the economy and improve government services.

While Singapore does not have any prominent vehicle manufacturing companies, Singapore ranks number one in the world in being most able to adopt and deploy new AV technology according to the KPMG 2020 Autonomous Vehicle Readiness Index. Hyundai (South Korea) is opening a global

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[3] sgmodelaigovframework2.pdf (pdpc.gov.sg)

innovation centre in Singapore in 2022 and Chinese vehicle electronics company Desay has set up its first overseas research and development centre in Singapore to work on AVs.

South Korea

Approach to AV Deployment

The regulatory landscape for autonomous vehicles is rapidly changing in South Korea. In October 2019, the government published a national strategy for AVs (the 'Future Vehicle Industry Development Strategy') with the goal to reduce road-deaths by 75% in 2030. The strategy included: (1) to revamp the relevant regulatory framework as well as major roads and other related infrastructure to accommodate fully autonomous driving by 2024; and (2) to commercialise Level 4 AVs on major roads across the nation by 2027. Out of the strategy came the Promotion and Support of Commercialisation of Autonomous Vehicles Act, which came into force May 2020. The Act allows vehicles with Level 3 capabilities to operate in specific test areas.

The changing focus by the South Korean government, to become a leading country in self-driving technologies and keep pace with the other AV-leading countries, has also resulted in significant investment in both infrastructure and regulation. The South Korean government is currently investing $1.1 trillion South Korea won (approximately $1.3b NZD) to strengthen its global market position in AVs. The Korean government has also had a "long-term promotion plan" to help domestic automakers develop original products, starting with local parts production. This has resulted in a strong relationship between these companies and the government, as well as large scale auto-manufacturing facilities to support infrastructure growth.

In 2018, South Korea opened an ambitious testbed for AVs (coined 'K-City') that leverages 5G capabilities. In 2020, South Korea announced safety standards on the manufacturing and commercialisation of Level 3 AVs, with plans to put forward safety standards for Level 4 in 2021. In 2020, the South Korean government granted regulatory sandbox clearance for a business to put self-driving robots on sidewalks, for delivery and security maintenance purposes.[4]

According to the KPMG 2020 autonomous vehicle readiness index, South Korea has seen the greatest recent rise in readiness of any country, partly due to this investment in infrastructure and changes to regulation.

Prominent companies

Hyundai Motor group is focused on affordability for mass-market opportunities. It is currently developing affordable Advanced Driver-Assistance Systems (ADAS), with plans to establish a new business unit to develop hyper-connected and self-driving cars in the near future. Hyundai is

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[4] See Singapore section for a description of "regulatory sandboxes".

investing US$35 billion over five years in electric and AV technologies, and teaming up with Russian and Israeli-based technology firms, as well as Aurora. Its partnership with Aurora hints at the company's ambition to bring fully autonomous vehicles to market by 2025 and continue to develop affordable ADAS in the meantime.

Samsung is a large technology company that is a strong Eastern bloc competitor for Apple and Google. They are focused on mobile network infrastructure, including 5G and vehicle-to-everything (V2X) networks. In 2017, Samsung purchased in-car technology company Harman for US$8B. It has also developed a "Digital Cockpit", which uses 5G to link vehicles with home and office spaces. In 2019, Samsung shifted its focus from pursuing full autonomy to just advancing level 2 autonomy, possibly due to economic reasons and wanting an earlier return on investment.

United Kingdom

Approach to AV Deployment

The United Kingdom (UK) is recognised as one of the most open testing environments in the world. The Government's approach is through investing in R&D and creating a unique integrated testbed ecosystem. The Department for Business, Energy & Industrial Strategy (BEIS) and Department for Transport (DfT) have established the Centre for Connected and Autonomous Vehicles (CCAV) to shape and lead the emergence of connected and self-driving vehicles in the UK. CCAV is develops regulation, invests in innovation and skills and engages with the public to realise the benefits of new transport technologies and to create a thriving connected and self-driving vehicle sector in the UK.

The UK Code of Practice for testing automated vehicles on public roads was published in 2015. This code makes clear that tests of automated vehicles are possible on any UK road, without the need to secure permits or surety bonds, as long as they comply with UK law, including having: a driver (in or out of the vehicle), who is ready, able, and willing to resume control of the vehicle; a roadworthy vehicle; and appropriate insurance in place. Building on the Code of Practice, in September 2019, the Government announced CAVPASS (Connected and Automated Vehicle Process for Assuring Safety and Security). This project aims to develop a world-first comprehensive safety and security assurance process to support the safe commercial deployment of automated vehicles.

To date, the UK has implemented the Automated and Electric Vehicles Act (2018), which sets out a framework for automated vehicle insurance. This is the first of its kind. The Act is designed to extend existing insurance provisions to cover automated vehicles to support access to compensation in the event of a collision.

To support and inform future regulation, the UK Government has asked the Law Commission of England and Wales and the Scottish Law Commission to undertake a far-reaching review of the legal framework for automated vehicles, and their use as part of public transport networks and on-demand passenger services. The Law Commission is aiming to build a flexible legal framework that will promote safety and technological advancement.

Prominent companies

Jaguar Land Rover is focussed on developing its driver assistance technologies. This includes a system that projects a series of bars onto the road to notify nearby vehicles and pedestrians if the AV is turning, stopping, or starting. The company has also developed software that reduces the severity of motion sickness in driverless cars. By optimizing braking, acceleration, and lane positioning, the system makes the ride more enjoyable. The software was released in August 2020 in Jaguar and Land Rover models.

Jaguar Land Rover partnered with Waymo in March 2018, to build a fleet of electric, self-driving cars. In 2019, test vehicles began appearing on the public roads around Waymo headquarters in Mountain View, California. Up to 20,000 new Jaguar I-PACE models will be built for Waymo's ride-hailing fleet, with production on the vehicles having commenced in 2020.

United States

Approach to AV Deployment

The United States (US) is slightly different to other jurisdictions in that there is currently limited federal regulation and a variety of regulatory approaches at the state-level. The federal system is focused on enabling innovation and competition and removing barriers to accelerate the growth of the AV industry. The US now has the highest number of AV patents of any country in the world. The Federal regulatory approach is penalty-based and retroactive, and functions as more of a safeguard rather than a proactive system. The federal government regulates the design, construction, and performance of AVs while each state regulates its own traffic laws, law enforcement, licensing, registration and driver education.

Some consistency is now beginning to emerge across Federal, State and local government by way of initiatives designed to standardise regulation for AVs. For example, in mid-2020 the U.S. Department of Transportation (DOT) established the 'Automated Vehicle Transparency and Engagement for Safe Testing' (AV TEST) Initiative. In January 2021, DOT released a comprehensive plan that brings together twenty regulations that are either already enacted, or forthcoming at the federal level.[5] The plan outlines potential use cases for AVs in the US, including

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[5] Automated Vehicles Comprehensive Plan | US Department of Transportation

vehicles without drivers for freight delivery and transport goods, passenger vehicles and automated trucking.

There is ongoing pressure from industry to shape or delay AV regulation in the US. For example, in 2016 Google, Uber, Lyft, Ford and Volvo formed a lobbying group (Self-Driving Coalition for Safer Streets) to promote AV safety and innovation. An underlying driver for the group is to have involvement in the development of regulations, particularly those that would impact their business models, such as regulation to shift the legal onus of insurance and liability from the driver onto the vehicle manufacturer.

While there are many strategic partnerships between US firms and AV developers from other parts of the world, the thrust of partnering within the US is being driven largely from the ease of testing and deploying new technologies in Arizona, and manufacturers opting to partner with Silicon Valley firms in California – one of the most advanced technology and innovation hubs in the world. Both are subsequently hubs for the testing and trialling of AVs on public roads.

California has established itself as a testing ground for local and international AV companies to stimulate and support innovation in the industry. California is also leading the way for AV regulation across the United States, since the Department of Motor Vehicles established AV testing regulations in 2014 (the Autonomous Vehicle Tester – AVT programme). Around 60 companies now have permits to test AVs in California. In 2018, the Office of Administrative Law in California approved Level 4 and 5 driverless testing (when a safety person was previously required). As of January 2021, six companies had received permits to allow driverless vehicle testing. Of note is that California has some of the strictest testing conditions in the US. Any automakers that are part of the AVT programme are required to submit 'disengagement reports' annually to show how frequently the autonomous mode was switched off and the reason behind disengaging the feature.

In 2018, the California Public Utilities Commission tested AVs as a ride-sharing option and in 2020 the Commission allowed commercial robotaxis to be operated on public roads. Nuro became the first company to receive a deployment permit in 2020 allowing vehicles to operate commercially as a driverless delivery service outside of a testing programme. The Department of Motor Vehicles also anticipates that AVs will be used for other commercial purposes including trucking and freight and are funding testing in these areas. The current focus from Californian authorities does not appear to be on private AVs.

In contrast to California, states like Florida and Arizona have some of the most permissive AV frameworks in the US. This is intended to create flexibility for AV innovation and testing. For example, in 2019, Florida signed an advanced bill into law to allow Level 4 and 5 vehicles without safety drivers to operate on public roads, prior to the technology being available beyond testing

zones. In Arizona, an executive order in 2018 allowed fully autonomous vehicles to test or operate after providing a written statement demonstrating they fulfil a set of criteria.[6]

Prominent companies

There are a large number of companies operating in the US that are working on AV deployment. These include start-ups, established automotive manufacturers and technology companies looking to carve out their own niche in the AV ecosystem. For example, companies like **Waymo** and **GM-Cruise** are focused on bringing shared fleets of robo-taxis to market at scale within the next 1-4 years. In December 2020, Waymo opened up their fully self-driving taxi service in Arizona to the general public, with no safety drivers. As of February 2021, Waymo began limited rider testing with employee volunteers in San Francisco as well. They are taking a commercial focus with a view to begin mass production as soon as practicably possible.

Uber also had similar ambitions, but in 2020 sold its self-driving arm to Aurora. Uber still retains a 26% stake in the company and has secured an agreement that Aurora's AVs will one day be deployed on Uber's platform.

Tesla is reasonably unique in its approach, developing the entire AV within its own brand. It is able to do this as it has a significant revenue stream from its core business of producing electric vehicles and batteries at scale.

Companies at the cutting edge of software and hardware development, such as **Aurora, Aptiv (Motional), Cisco, Nuro and Nvidia,** have also increased their investment and intellectual property (IP) in AVs. These companies are focused on creating the 'brain' and 'nervous system' for AVs around the world and are vehicle platform and company agnostic. Driving this is the understanding that next generation connected digital infrastructure, and massive data networks, will be essential to deliver the benefits AVs promise. The strategy for these firms is to become the preeminent supplier of parts and software for generic AV use, which automakers can purchase or subscribe to for use in their vehicles. Increasingly, these smaller specialist firms are seeking to develop affordable AV components for use in lower cost AVs, not just for high-spec, luxury vehicles.

Companies are focusing on a number of different use cases, such as last-mile goods delivery. **Ford**, for example, are pursuing AVs for commercial use in last-mile delivery for consumer goods like food and personal shopping. They are partnering with like-minded business, such as Walmart and Domino's Pizza. While Amazon is also focused on developing first and last-mile delivery AVs,

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[6] Executive-Order-2018-04.pdf (azdot.gov)

it is also working with companies such as Toyota on a multi-functional AVs that can deliver people, goods, or even operate as a mobile office.

Something that is shaking up the AV industry globally is the emergence of large technology companies as major investors in the autonomous vehicle (AV) manufacturing sector. In the US, **Apple, Amazon, Microsoft,** and **Google** are approaching the AV industry as a long-term investment opportunity. They have stepped outside their core business models and have begun forging strategic alliances with vehicle manufacturers within the US, but also across Canada, Asia and Europe. For example, Amazon has partnered with EV truck maker Rivian to receive 100,000 electric delivery vans by 2030. Amazon has also invested in autonomous driving developer Aurora Innovation to build out its capabilities in automated driving for logistics applications. In June 2020, Amazon bought self-driving car company Zoox in a deal that will give Amazon control of the nearly 1,000-person start-up that has been developing an electric self-driving vehicle. Microsoft is currently working with Toyota, Volvo and GM-Cruise. They are specialising in the software systems and bring their expertise in cloud-computing to their partnerships.

As a group, these US "tech giants" are ambitious and have cash reserves to invest in "risky" new technologies. This is likely to increase their reach and influence within the automotive industry for the foreseeable future. In the short-term, they are likely to continue to signal where they see their place in the AV ecosystem, and focus on building capability and technological expertise in that space. It is also likely they will ramp up their investment as AVs get closer to commercial viability at scale.

Themes and Insights

The following is some early thinking around the themes beginning to emerge across countries and companies.

1. **Governments of countries with strong automotive manufacturing sectors are in a symbiotic relationship with their manufacturers** where they rely on the each other to compete on the global motor vehicle stage. What we are seeing is greater lobbying in these countries, by industry, in order to standardise regulations in support of international trade. These Governments are also significant contributors to the discussions and debate occurring in UN Working Parties developing international regulations.

2. **Many automotive companies are focusing on the incremental development of ADAS, with some of these companies using this as a pathway to full autonomy** (like Tesla). Countries like Japan are passing legislation to support this, and manufacturers (like Honda) are already progressing with level 3 technologies. However, there are some companies only focussing on developing level 4 and 5 vehicles from the outset (like Waymo). These companies are hedging their bets that supportive regulatory environments will be in place once the technology reaches maturity.

3. **Several Asian countries are building AVs into wider plans and societal outcomes**. Japan and Singapore, for example, appear to be approaching AV deployment as part of a wider set of goals for society. This includes a focus on shared mobility options and a specific emphasis on public transport use cases. Some western nations are more focussed on the technology itself, and the potential economic benefits, with societal outcomes at the fringe of the discussion.

4. **Countries with no automotive industry (in contrast to those with automotive industries) have tended to focus more on ethical and liability issues** more, as well as amending existing laws to allow for AV testing (to be ready for the eventual deployment of AVs).