Israel
CENTRE FOR THE FOURTH INDUSTRIAL REVOLUTION

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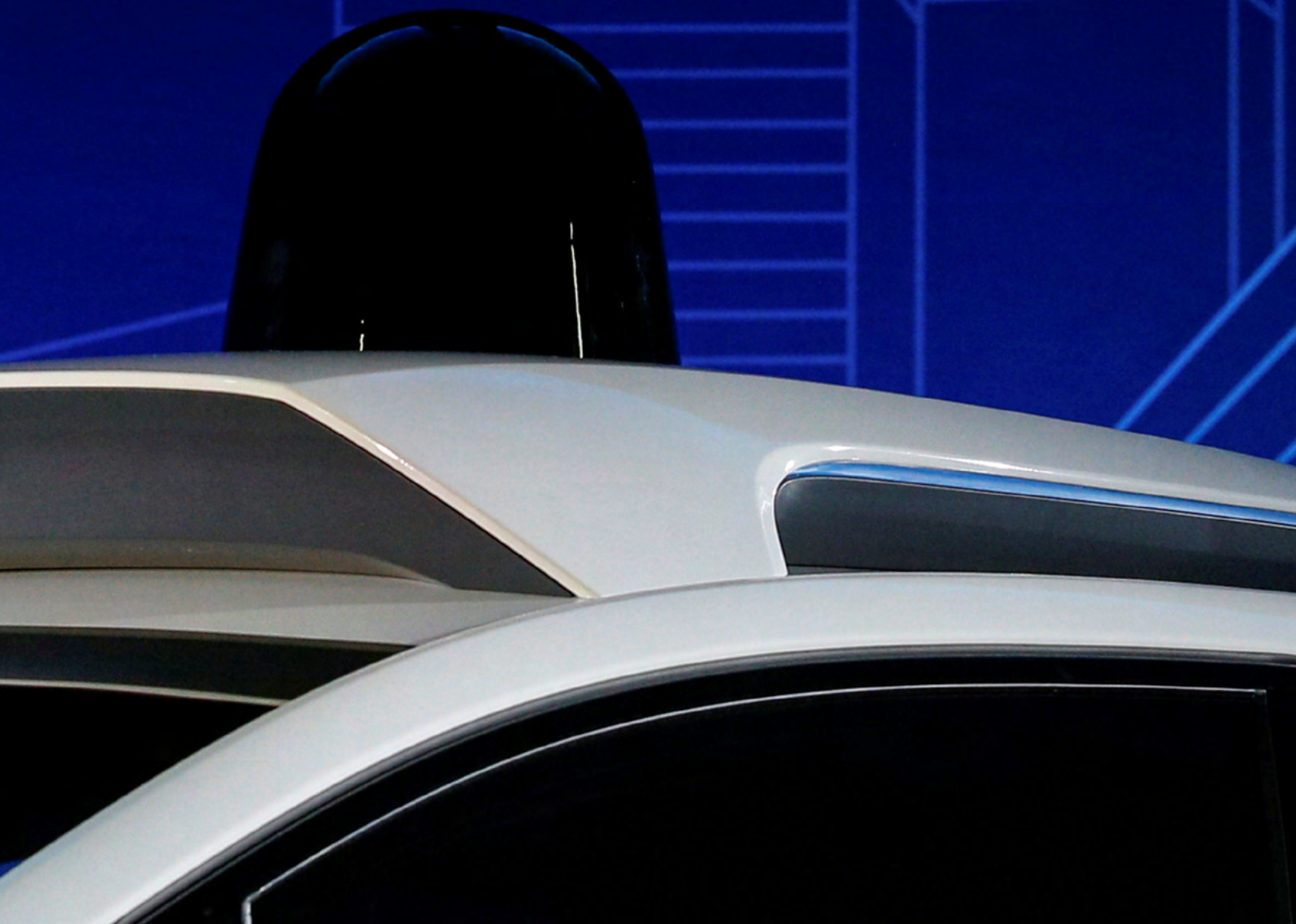
Autonomous Vehicle Policy Framework: Selected National and Jurisdictional Policy Efforts to Guide Safe AV Development

INSIGHT REPORT

NOVEMBER 2020



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Foreword

Miri Regev,
Member of the Knesset,
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The world is experiencing the Fourth Industrial Revolution and its impact on multiple domains like energy, health, transport, data science, among many others. The results of this revolution will be clearly visible in the coming years. The effects of this transformation may well dramatically and positively change the lives of many citizens in the State of Israel, especially as a result of innovative Israeli technology and the significant natural gas discoveries made off Israel's shore.

Israeli innovation abounds, but all forms of creativity must be accompanied by regulatory certainty and clear guidelines in order to prosper. This point is made clear in this report, which presents an autonomous vehicle (AV) policy framework. The public often views the safety of AVs with suspicion, a perception that will only subside if people fully believe they are entrusting their lives to a vehicle that has passed all possible safety tests.

As the head of the Ministry of Transport and Road Safety, I have taken decisive action. Rather than wait for regulations to be dictated from abroad, Israel is taking initiative. With the Israel Innovation Authority and the World Economic Forum, we have launched this comparative policy report, the first of its kind in the world, on the international regulation of autonomous vehicles.

Our vision is that this report will be used to shape the regulatory framework for the use of AVs in Israel. My ministry will lead a committee that will establish a roadmap for operational and regulatory AV reforms. Guided by the desire to implement the recommendations outlined in the OECD Economic Survey of Israel: September 2020, the Ministry of Transport's main goals are to reduce traffic congestion and increase public transport use. Therefore, we have decided that the first AVs to appear on our roads will form part of a concept called Mobility as a Service, a shift away from private car ownership.

Important technical and safety challenges in the use of AVs must be overcome. But AVs present a great leap forward in efforts to create a safe driving experience without human intervention. The success of this project will play a meaningful role in harnessing our tremendous technological abilities, for the well-being of the environment, society and humanity. I am fully committed to promoting this important vision.

I would like to thank all the people involved in this valuable project - at the Centre for the Fourth Industrial Revolution Israel, the Israeli Innovation Authority, the World Economic Forum, and the Israeli Ministry of Transport, as well as the committed authorities in Australia, the United Kingdom, Singapore, California and Arizona, for their thorough and professional collaboration. This report is the result of our combined efforts, for the benefit of all. We all hope the COVID-19 pandemic and social distancing measures will soon be behind us so we can pursue our efforts to drive safe AV development, which will make the world a more efficient, social and safer place.

Preface

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In recent decades, the State of Israel has established itself as a centre of global innovation, excelling in developing state-of-the-art technologies in ground-breaking companies in a variety of fields including software, communications, medical systems, agriculture, security and transport.

One significant factor in Israel's technological leadership has been its endorsement by the Israeli Government, which has been empowering innovation by supporting research and development processes. As disruptive technologies begin to enter heavily regulated industries such as transport, finance and health, an agile approach to regulation is needed to protect the public without stifling innovation. Regulation plays a key role in enabling and stimulating innovation.

To enhance Israeli market preparedness for the introduction of new technologies, the Government of Israel has decided to join as an affiliate of The Centre for the Fourth Industrial Revolution Global Network (hereinafter "C4IR"). The C4IR was founded by the World Economic Forum to create a new space for multistakeholder collaboration in developing policies, governance principles and protocols that accelerate the implementation of the disruptive technologies of the Fourth Industrial Revolution.

In its capacity as a centralized hub supporting innovative technologies and addressing the needs of the Israel Hi-Tech industry, the Israeli Innovation Authority was mandated by the Government of Israel to serve as the hosting entityof the Israeli C4IR affiliate centre.

This report is the first in an ongoing partnership between the World Economic Forum, the Centre for the Fourth Industrial Revolution Affiliate in Israel and the Ministry of Transport and Road Safety of Israel to support the Israeli Government in creating a successful policy environment to realize the benefits of autonomous vehicles (AVs).

AVs promise a safer and more sustainable future for mobility. The interim development of these systems, however, presents considerable challenges to policy-makers who are seeking to understand this technology while protecting the interests of their citizens, such that tensions arise between the industry and regulators where their priorities differ. As with other 4IR technologies, multistakeholder approaches have proven to be successful in assisting policy-makers to develop effective governance models capable of facilitating innovation while yielding safe solutions.

Through the C4IR network, the Government of Israel has the opportunity to engage with a range of government partners, industry experts and other stakeholders to study and evaluate global AV policy instruments with the aim of understanding best practices and recommending solutions suitable for the Israeli market.

In this exercise, we have been able to identify a range of policy solutions to inform the future mobility roadmap in Israel while strengthening the C4IR network by connecting Israeli stakeholders with their peers around the world to share knowledge on AVs in future. We hope this report will serve other decision-makers in their understanding of the challenges and opportunities of AV governance by highlighting the best practices of leading global regulators.

Executive summary

Autonomous vehicles have the potential to alleviate traffic congestion, improve air quality and yield better road safety if designed and operated accordingly. AVs are being tested on public roads around the world and will ultimately generate a projected $7 trillion market by 2050. The COVID-19 crisis has accelerated the urgency of investing in automated mobility systems to serve the movement of people and goods.

The industry's rapid development has encouraged regulators around the world to introduce AV policy frameworks to enable the safe experimentation and development of the technology. Approaches to AV policy vary greatly between nations and other jurisdictions, and all are relatively nascent. The purpose of this report is to assist Israeli policy-makers in shaping the regulatory framework for the deployment of AV technologies in Israel.

The report evaluates policy approaches in three countries, Singapore, the United Kingdom (UK), and Australia, and in two US states, California and Arizona, and includes contributions from the authors of those policies. The national and US state contexts reviewed demonstrate that an ideal AV regulatory environment is one that successfully advances technological improvements as well as market readiness while ensuring that AVs contribute to national and local mobility goals: safety, decongestion, equity in mobility, employment, economic growth and sustainable mobility development. They further show that the first step to enabling the technological maturity of AVs is to ensure the safe piloting and testing ofthe technology.

While each jurisdiction adopts differing approaches, the key commonalities lead to a number of general recommendations:

1. Establish dedicated authoritative bodies or committees capable of coordinating the complementary work of government agencies and ministries to ensure coherent and consistent AV regulation:

    1.1 Australia has established an *Office of Future Transport Technology*, within the Department of Infrastructure, Regional Development and Cities.

    1.2 Singapore has established a *Committee on Autonomous Road Transport for Singapore* (CARTS), comprising international experts, academics and industry representatives, and emphasizing constant discourse and feedback from the industry.

    1.3 The UK has established a *Centre for Connected and Autonomous Vehicles (CCAV),* a joint policy team comprised of representatives from the Department for Business, Energy and Industrial Strategy, and the Department for Transport.

2. Create regulatory processes designed for adaptation to the technology, i.e. establish an open and ongoing discourse between industry, academia and research institutes:

    2.1 The UK Law Commission is surveying academics, industry, insurance companies, and other AV stakeholders to guide the nation's long-term AV policy framework.

3. In the absence of harmonized international standards, consider participating in working groups informing the development of those standards (e.g. the Centre for Connected and Autonomous Vehicles, the Department for Transport, Innovate UK and Zenzic are partnering with BSI Group for advancing AV standardization in the UK[1]); and propelling standards (e.g. Singapore developed a national set of AV-specific standards known as Technical Reference 68, and more commonly TR 68.

4. Publish clear pilot guidelines and procedures, with the goal of facilitating safe trials, guiding the market and creating clarity for AV companies from around the world interested in AV piloting in your territory.

5. Conduct a thorough assessment of the need to add AV-specific requirements to human-driven vehicle laws and regulations in force:

    5.1 The UK Law Commission undertook a three-year consultation project to assess needs for delivering safety assurance, legal liability and regulation of remotely operated AVs.

    5.2 Australia's National Transport Commission is conducting a comprehensive Regulation Impact Statement (RIS) process examining AV tailored insurance, liability, data sharing and safety regulation.

6. Start small and build stronger, focus on pilots to inform the design of a robust policy environment for commercial application of AVs. Governments are monitoring AV trials to gather data and garner experience to serve as a foundation for the regulatory deployment framework:

    6.1 The State of California USA adopted regulations for pilots and more recently added a regulatory approach for public use of AVs.

    6.2 The UK released a non-regulatory code of practice on the basis of regulations in force and encourages ongoing communication among regulators while it develops its AV policy framework to enable commercial use.

    6.3 Singapore has initiated a regulatory sandbox for a period of five years, while the government develops longer-term legislation and reconsiders the extension of the sandbox.

Safety – Most AV safety policies in effect today are interim measures considering that the technology is evolving so they must balance the challenge of ensuring safety while facilitating trials and innovation. Some governments have invested heavily in research, joint pilots and other forms of sponsorship to study and develop new approaches to AV policy, such as scenario-based safety assessments (Pegasus Project, UK CertiCAV). Many technical standards are published for system (and sub-system) level safety by industry consortia, standard-setting institutions and other bodies such as UL4600, SAE J3018 and SAE AVSC Best Practice. Moreover, some industry stakeholders have proposed their own solutions to safety assurance through formal methods or other justified approaches but none of these solutions have been formally adopted.

Driverless testing and operation – Several nations and other jurisdictions have set regulatory frameworks to enable driverless pilots and operations. In Arizona, Waymo conducted driverless operations prior to COVID-19. In California, Nuro, Waymo and AutoX hold permits enabling them to conduct driverless pilots.[2] There have not, however, been substantial driverless pilots or operations thus far and most of the jurisdictions reviewed in this report still require an in-cabin safety driver.

Passenger transport – AV pilots enabling public use are operational in Australia, Singapore, the UK and in Arizona. In these pilots, the AV operator is generally required to comply with additional requirements. For example, in California, in addition to obtaining a Department of Motor Vehicles (DMV) permit, the AV operator is required to obtain California Public Utilities Commission (CPUC) authorization to transport passengers. At the time of writing, seven companies are authorized to carry passengers in California: Zoox, AutoX, Pony.ai, Waymo, Aurora Innovation, Cruise and Voyage.[3]

Data-sharing policies – Data collection and reporting are required in most of the reviewed policy environments and primarily in relation to disengagement and accidents.

Moving beyond basic safety requirements

AVs as a Service (AaaS) vs. personal use of AVs – In the absence of an effective regulatory framework, AVs are likely to increase congestion due to the decrease in cost per mile and ability to maximize productivity. **The regulators reviewed in this report emphasize the importance of testing autonomous shuttles and buses (e.g. in Singapore) as well as ride hailing pilots (e.g. in Arizona and California) rather than individually owned and operated vehicles.** Regulators are not limiting options for private ownership but signalling that AVs should operate as a service, and leading operators are dedicating efforts to on-demand commute and delivery services.

Public acceptance – **Governments consider public acceptance as paramount to the deployment of AVs.** Singapore has invested in reassuring vehicle safety through rigorous safety assessment and approval process and the UK is encouraging the reporting of trial information to increase public acceptance. AV pilots involving the public can also make the technology more familiar and less threatening. For example, ST Engineering and Navya's autonomous shuttles are being piloted in Australia and Singapore, as is Waymo's ride hailing service in Arizona.

Insurance – Regulators and insurers are developing insurance solutions for AVs. Some regulators specify a minimum amount of insurance required (e.g. in California), while others state only that insurance is required, without specification (e.g. in Arizona). Following a thorough review, Australia has decided to expand Motor Accidents Injury Insurance (MAII) to enable individuals involved in an automated vehicle crash to access MAII schemes. Similarly, the UK has also extended its compulsory insurance requirements to cover AV accidents. Singapore and California offer the alternative of self-insurance, in case an operator is unable to locate an insurer. Arizona requires the sharing of insurer information and contact details on the regulators' public website.

Liability – At the time of writing, no modifications to liability structures had been recorded, all jurisdictions were relying on laws and regulations in effect. While the UK and Australia are considering introducing a new regulatory sanctions system, to be enforced on the manufacturer/operator in the case of an offence committed while the ADS was preforming the driving task, it is still under examination and has not yet been introduced as an official policy.

Key terms

Advanced driver assistance system (ADAS)	Advanced systems designed to assist the driver while driving or during parking. When designed with a safe human-machine interface, their mission is to increase both vehicle and road safety. Refers to SAE levels 1 and 2.
Automated driving system (ADS)	The hardware and software collectively capable of performing the entire dynamic driving task on a sustained basis. The automation system used in vehicles with SAE levels 3, 4 or 5 of automation. (Source: SAE International J3016-20184)
Automated vehicle (AV)	A vehicle with conditional to full automation (SAE levels 3-5). It is equipped with an automated driving system that allows it to drive on a sustained basis without human intervention. It is distinct from vehicles with automated features to assist a driver (SAE levels 1-2) that require a human driver to perform part of the dynamic driving task. An automated vehicle is also referred to as an AV.
Conditional automation (SAE level 3)	The entire dynamic driving task for sustained periods in defined circumstances undertaken by the ADS. The human driver is not required to monitor the driving environment or the ADS but must be receptive to ADS requests to intervene and to system failures. Conditional automation is also referred to as level 3 (L3) automation.
Dynamic driving task	All real-time operational functions required to control a vehicle in on-road traffic, excluding the strategic functions (such as trip scheduling and selecting destinations and waypoints) and including, without limitation: – Lateral vehicle motion control via steering (operational) – Longitudinal vehicle motion control via acceleration and deceleration (operational) – Monitoring of the driving environment via object and event detection, recognition, classification and response preparation (operational and tactical) – Object and event response execution (operational and tactical) – Manoeuvre planning (tactical) – Conspicuous enhancement via lighting, signalling and gesturing, etc. (tactical)
Full automation (SAE level 5)	All aspects of the dynamic driving task and monitoring of the driving environment undertaken by the ADS. The ADS can always operate on all roads. No human driver is required. Full automation is also referred to as SAE level 5 (L5) automation.
High automation (SAE level 4)	The entire dynamic driving task undertaken by the ADS for sustained periods in some situations, or all the time in defined places. When the system is driving the vehicle, a human driver is not required to monitor the driving environment or the driving task (nor are they required to intervene, because the ADS can bring the vehicle to a safe stop unassisted). High automation is also referred to as SAE level 4 (L4) automation.
Minimal Risk Mode	A low-risk operating mode in which a fully autonomous vehicle, operating without a human drive achieves a reasonably safe state, such as a complete stop, when experiencing a failure of the vehicle's automated driving system and thereby preventing the vehicle from performing the entire dynamic driving task.

Mobility as a Service (MaaS)	A wide range of digital transport service platforms; taxis, private hire car services and online car-sharing schemes.
Operational design domain (ODD)	The set of environments and situations within which the item is intended to operate. This includes not only direct environmental conditions and geographic restrictions, but also a characterization of the set of objects, events and other conditions that will occur within that environment. (Source: ANSI/UL 4600)
Remote operator or fallback-ready user	A human inside or outside (depending on local definitions) a vehicle with conditional automation, who can take over vehicle operation. The fallback-ready user is typically expected to respond by taking control of the vehicle.
SAE Automation Levels	The international Society of Automotive Engineers (SAE) developed a classification system for self-driving cars in January 2014, last updated in 2016. It defines six levels of driving automation, from SAE Level 0 (no automation) to SAE Level 5 (full vehicle autonomy). It serves as the industry's most-cited reference for automated-vehicle (AV) capabilities and has been adopted by the US National Highway Traffic Safety Administration.

SAE J3016™ Levels of driving automation

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
What does the human in the diver's seat have to do?	You **are** driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			You **are not** driving when these automated driving features are engaged – even if you are seated in 'the driver's seat' When the feature requests you must drive		These automated driving features will not require you to take over driving
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **or** brake/ acceleration support to the driver	These features provide steering **and** brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example features	Automatic emergency braking Blind spot warning Lane departure warning	Lane centering **or** Adaptive cruise control	Lane centering **and** Adaptive cruise control at the same time	Traffic jam chauffeur	Local driverless taxi Pedals/ steering wheel may or may not be installed	Same as level 4. but feature can drive everywhere in all conditions

Adapted from data provided by SAE International

1 Introduction

AVs offer great potential, but unless their use is regulated effectively, instead of reducing they could increase safety hazards, distance travelled, emissions, congestion and societal inequities. Governments worldwide are consequently developing comprehensive regulatory frameworks to enable the commercial use of AVs on public roads, seeking to introduce regulatory frameworks that allow technological experimentation and development on the one hand while ensuring public safety and the positive impact of AVs on the other.

The State of Israel is developing such a regulatory framework for the safe deployment of AVs. Israel strives to be a global leader in the field of smart transportation and autonomous technologies while ensuring that AV commercialization advances Israel's mobility goals. The Israeli Ministry of Transport and Road Safety (MOT) is investing in the development and testing of AVs while focusing on applications of Mobility as a Service (MaaS) and public-transit solutions. It is taking significant steps to integrate innovative technologies in infrastructure, improve public transport and reduce private-vehicle use to alleviate congestion.

MOT is further considering the introduction of a transparent multistakeholder-informed regulatory framework prior to full market readiness of highly automated driving systems, explicitly to: 1. Forge coherent digital infrastructure and mobility system readiness to maximize the societal, environmental and economic benefits of AVs, and 2. Guide the development of AV products and business models aligned with its sustainable mobility system vision.

The Centre for the Fourth Industrial Revolution Israel (C4IR Israel) was established to support government in the adoption of more flexible and dynamic regulations suited to a rapidly changing technological environment. In support of this goal, C4IR Israel works with Israel's MOT to advance its regulatory landscape in rapid transition towards a shared, electric and automated mobility ecosystem.

One key approach to advancing agile regulatory frameworks is to engage and consult with local stakeholders: industry, academia, civil society, other government authorities and members of the public. The objective of the first engagement between MOT and C4IR is to foster the safe development of autonomous technology and innovation, enhance the government's mobility goals and position Israel as a leading market for AVs. Recognizing the early stage of AV technology and the need for global multistakeholder consultation, the framework was developed by way of the inclusive engagement described in Figure 2, and guided by the key work principles presented in Figure 3.

This is the first in a series of policy papers that will support the development of the Israeli MOT's AV regulatory framework. Israel's current AV policy will be outlined, followed by a review and comparison of AV policy approaches in five selected markets: Australia, Singapore, the United Kingdom, and the US states of California and Arizona. It concludes with a synthesis of best practices suitable for adoption in Israel.

Challenges in regulating autonomous vehicles

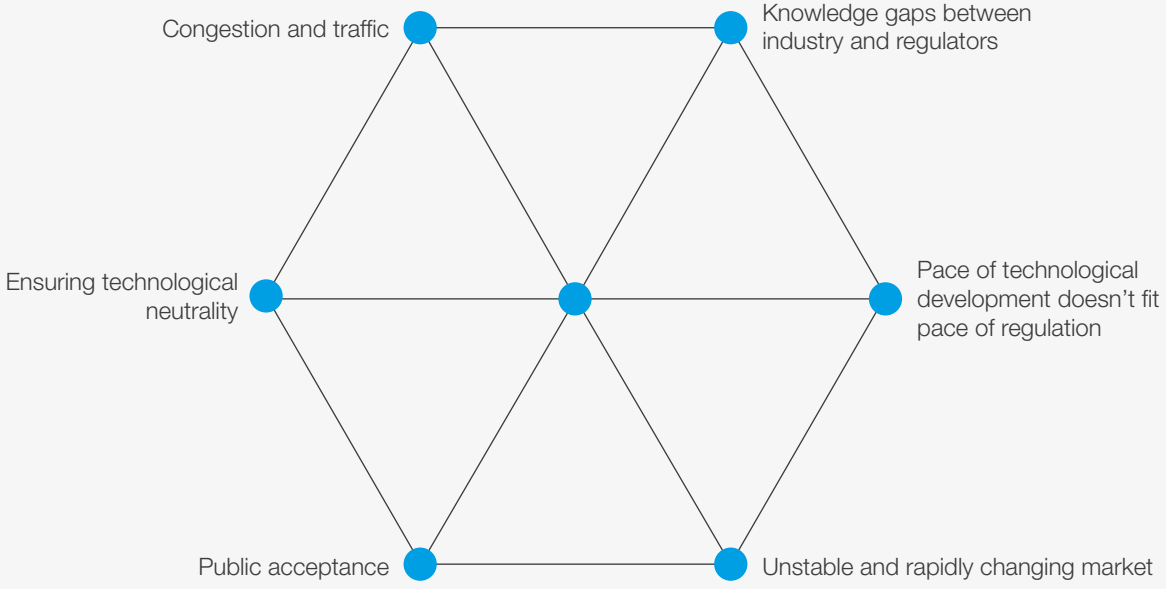
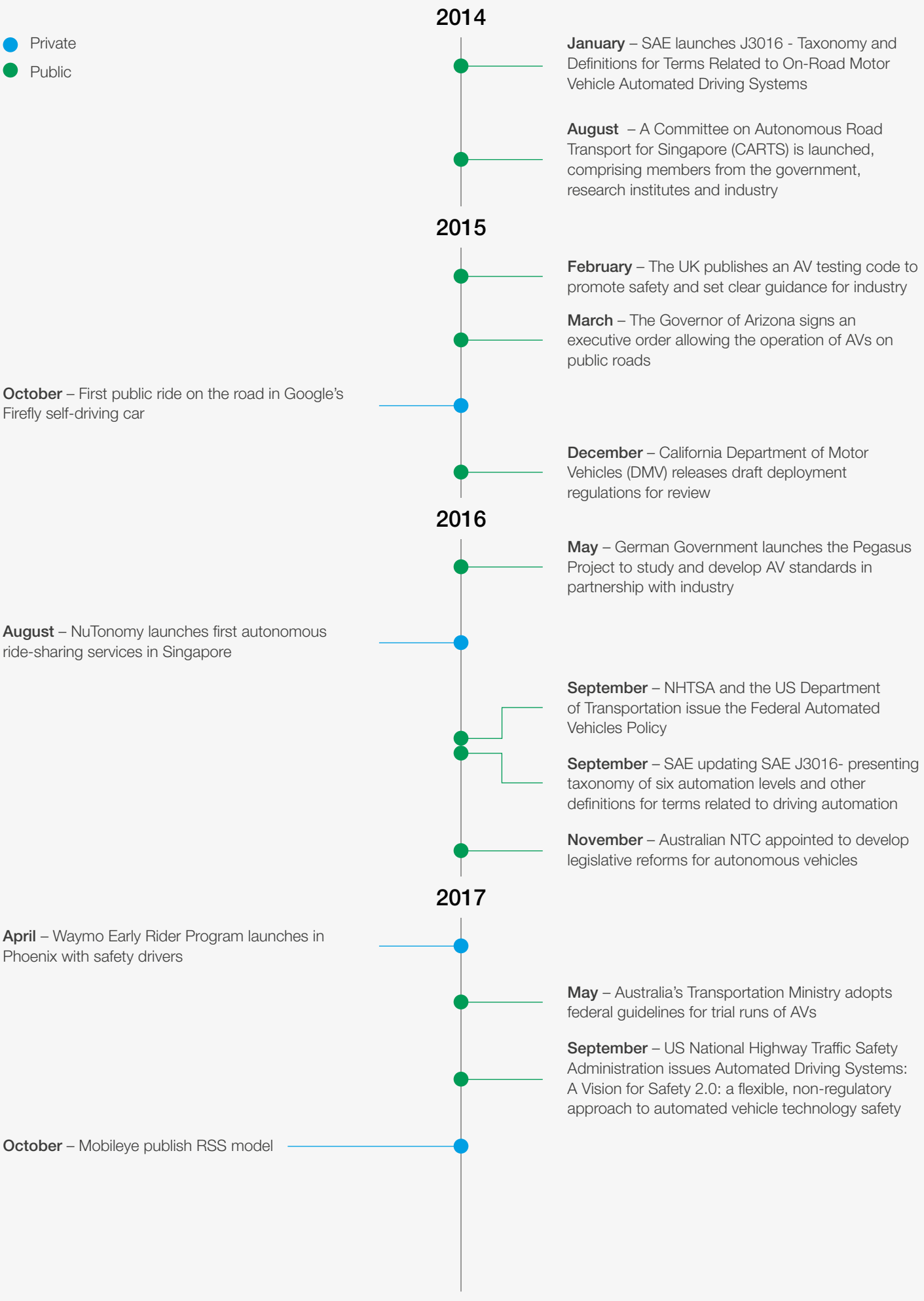


FIGURE 1 | **Private- and public-sector milestones in AV development**



2018

February – Chinese Government allows the first official tests of AVs on public roads

February – California's driverless testing regulations are approved, 30 days later the DMV begins approving applications

March – Governor of Arizona authorizes fully autonomous vehicles (without a human driver) on public roads

March – Self-driving Uber vehicle kills pedestrian in Arizona, state Governor suspends Uber's testing permit, NHTSA and NTSB launch investigation

April – California Department of Motor Vehicles lifts the requirement that AVs must have a human driver to take over in case of emergency

May – Mobileye begins testing AVs in Israel with Volkswagen and Champion Motors

May – European Commission Transport Commissioner announces plans for European rules governing AVs and investment in road and telecoms networks

June – ST Engineering to deploy on-road testing of autonomous shuttles at Sentosa Island in Singapore

June – Japanese Government announces testing of AVs on public roads with a view to offering autonomous car services at 2020 Tokyo Olympics

July – Beijing Municipal Commission of Transport grants Baidu first T4 test permits to allow piloting of AVs on public roads

August – Yandex launches allegedly first autonomous ride-hailing services in Europe, in Innopolis, Tatarstan and later in Skolkovo, Russia

August – UK Parliament passes legislation extending insurance schemes to cover damage caused by AVs

October – Waymo receives first driverless testing permit in California

October – In Phoenix, Arizona, Waymo starts charging passengers for AV transport

October – Australian Government establishes an Office of Future Transport Technologies to prepare for AVs

November – UK Law Commissions initiate a three-year process to identify, consult and recommend long-term reforms for AV deployment

2019

January – SAE releases updated version of J3016 Levels of Driving Automation standard

February – Singapore publishes Technical Reference 68

March – WeRide is first company to deploy long-distance autonomous driving technology in Guangzhou, China

March – Waymo and Zoox authorized by California Public Utilities Commission to carry passengers in robo-taxis on California roads free of charge in vehicles equipped with a safety driver

June – Release of UL 4600 Safety Standard for the Evaluation of Autonomous Products

July – Waymo receives first commercial driverless permit in California

July – Bosch and Daimler authorized by German regulators to operate their autonomous parking feature without a human safety driver

August – Didi Chuxing introduces AV rides free of charge in Shanghai

October – Australian NTC publishes new AV regulations following 3-yearpublic reviews and research

October – Singapore expands testing areas for AVs to over 600 miles of public roads

2020

January – US Department of Transportation releases new AV principles – Automated Vehicles 4.0

February – Exempted from FMVSS (Federal Motor Vehicle Safety Standards) by US NHTSA, Nuro R2 to produce and deploy up to 5,000 AVs in two years

April – Nuro obtains second driverless delivery permit by CA DMV

May – UK Law Commission publishes responses to second consultation paper on Highly Automated Road Passenger Services (HARPS

July – AutoX obtains third driverless permit by CA DMV

August – Israeli Ministry of Transport and Road Safety proposes draft legislation enabling driverless AV pilots

FIGURE 2 **AV policy framework development process in Israel**

Process stage	Key objectives and tactics
Step 1 Identify policy needs and develop framework structure	– Review MOT mobility goals, strategy and AV approach to date – Collect information on AV policy challenges and opportunities from the perspective of global private and public stakeholders – Develop key elements of the framework according to identified needs
Step 2 Build an open multistakeholder community for the AV policy framework	– Screen and engage AV stakeholders – Establish one-on-one interactions to set expectations and explore synergies with government and public-sector representatives – Scope key interest areas at an initial community meeting – Finalize project plan and launch the project

Step 3
Co-develop the AV policy framework
	– Release the framework
	– Method:
	  – Outline and review the draft
	  – Solicit contributions
	  – Draft and review the document
	  – Discuss key challenges in workshops throughout the process
	  – Make policy recommendations

Step 4 Iteration and scaling	– Present key policy framework learnings and its development process in international forums and events – Forge collaborations with countries considering adopting elements of the Israeli policy framework and/or its development process

Source: World Economic Forum Centre for the Fourth Industrial Revolution Israel

FIGURE 3 **Key AV policy framework principles**

Accelerate technological development through experimentation

Engage with external stakeholders including regulators, private sector, academia and civil society

Create dynamic governance conducive to a changing landscape

Establish performance indices and risk management guidelines in advance of full commercialization

Ensure efficient, transparent and authoritative management, evaluation and enforcement

Minimize regulatory patchwork, proactively pursue continuous improvement via timely real-world governance impact evaluation

Source: World Economic Forum Centre for the Fourth Industrial Revolution Israel

2 What is an autonomous vehicle?

An autonomous vehicle (AV) is a car, van or truck which has been fitted with sensors, additional hardware and software with the aim of automating the task of driving.

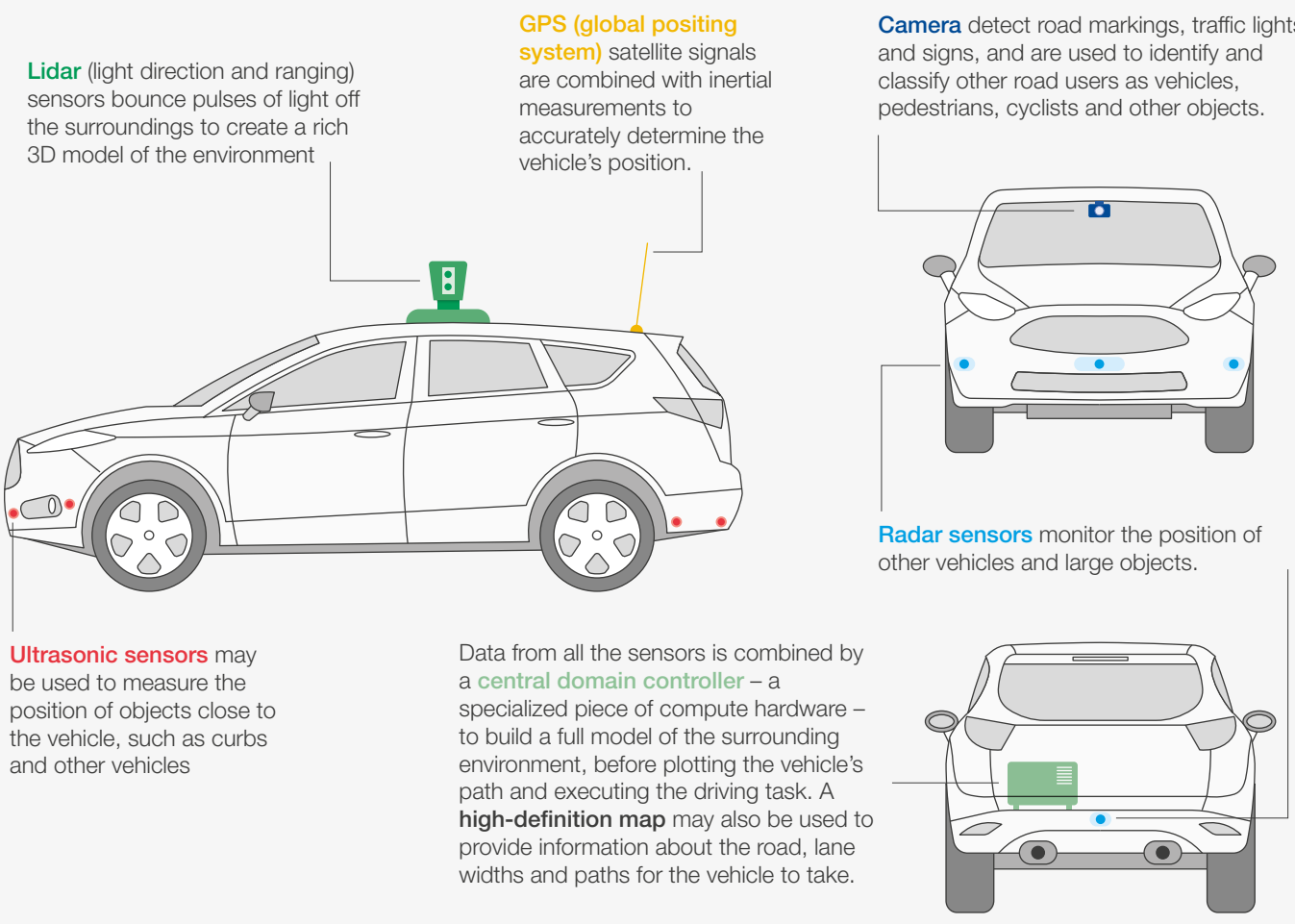
The development of AVs has been enabled by a range of revolutionary technologies across multiple domains, including AI, software, sensors, semiconductors and in-vehicle networking.

An AV can be based upon a conventional car, van or truck, or may be an entirely purpose-built vehicle designed specifically for autonomous driving. Whether purpose-built or an upfitted vehicle, an AV will feature a suite of sensors enabling localization of the vehicle and monitoring of its environment and other road users. The type and configuration of sensor will vary depending on the vehicle's intended use, and the developer's engineering and design choices. The AV developer will also develop a control system, comprising hardware and software, to drive the vehicle.

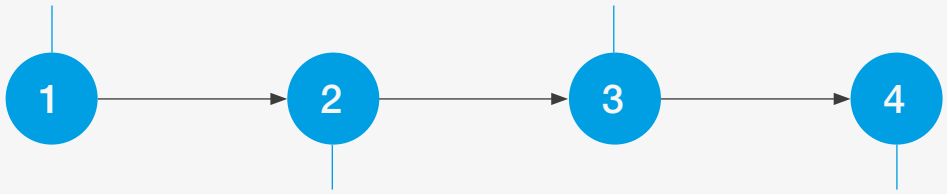
The AV's software processes the inputs collected from the various sensors to build a three-dimensional model of the vehicle's environment, sensing the roadway, other vehicles, pedestrians and other objects. The software will then deduce the optimal path for the vehicle to take in a given situation, and execute the required path through control of the steering, acceleration and brakes.

Combined, the hardware and software installed on the vehicle for the purposes of performing this dynamic driving task are referred to as an automated driving system (ADS).

FIGURE 4 **How an autonomous vehicle works**



The key subtasks of autonomous driving are commonly referred to as Object and Event Detection and Response (OEDR):



1. Data from the sensors is collected and pre-processed before being sent to the central domain controller
2. The software combines the data inputs in a process called sensor fusion, and classifies key objects, such as vehicles, pedestrians and signage, detected around the vehicle, to build a 3D model of the environment.
3. Having initially classified objects, vehicles and pedestrians, the software monitors their trajectory and predicts their future movement, and determines if that movement is likely to intersect with the path of the AV
4. The ADS plots and executes a path based upon the free space in front of the vehicle and the likely paths of other actors around the AV; this path must also comply with the traffic laws and reach the intended destination.

How AI enables autonomous driving

Many of the algorithms essential to the OEDR process (object and event detection and response) are developed using AI and machine-learning techniques to replace the decision-making processes of human drivers.

AI-based algorithms fulfill a number of key steps of the process described above, particularly in the perception phase, through understanding the driving scene, the detection and classification of objects and estimating the free space in front of the vehicle. Additionally, many of the behavioural functions of the OEDR process can also be developed with AI-based techniques, such as behaviour arbitration for path planning, and training motion controllers.[5]

Commonly, these functions are developed using deep-learning methodologies such as Convolutional Neural Networks, Recurrent Neural Networks and Deep Reinforcement Learning. Each of these techniques requires a considerable volume of training data to "instruct" an algorithm to perform a task and achieve a desired output. In a simple application, AI can be used to segment an image to detect a pedestrian, whereas more complex applications may attempt to train an end-to-end driving system through observing human driving. In both cases, a vast amount of data is used to train an algorithm to detect a pattern and register a desired output. The greater the volume of data used, the greater the probability that the system will generate the desired outcome.

3 AV policy in Israel

Challenges

- Insufficient network of public transit infrastructure and mass transit systems
- A growing, high-density population in metropolitan areas whereas many newly developed areas were planned without sufficient infrastructure for public transit services
- Heavy reliance on private car use resulting in high congestion, mainly in metropolitan areas, economic loss and high emissions
- Motorization rate is comparatively low to OECD countries and expected to continue growing
- Shortage of transit depots and drivers

Opportunities

- Making Israel a global hub and prime location for AV pilots and AV companies from the world over
- Increasing automobile electrification and reducing greenhouse emissions and pollution
- Improving road safety, reducing casualties and economic loss
- Deploying AVs in Israel in MaaS mode to improve the quality of public transit services and reduce use of private cars and individual rides

Strategy

Israel is home to $35 billion worth of mobility innovations that are re-shaping the global industry, with over 250 autonomous and connected start-ups.[6] It strives to be a global leader in the field of smart transportation and autonomous driving, and is making significant progress in integrating advanced technologies in infrastructure, on-demand transportation, connectivity and MaaS.

In a comprehensive report[7] published in September 2019, the Israeli MOT shared its vision and goals for smart transport. It aims to harness the smart transport revolution to provide optimal mobility for all road users through four key principles:

- Using agile governance and regulation to enable the development and deployment of innovative mobility services by the private sector
- Increasing the number of passengers using a vehicle in any given ride
- Improving user experience, with emphasis on public and shared transport services
- Preparing for a transition phase in which novel infrastructure is not yet available and operational and smart transport solutions will have to focus on efficient use of existing infrastructure

Charting its strategy for the commercial deployment of AVs in Israel, MOT aims to create a regulatory framework prior to full market readiness that will assist in guiding market development and attract new players to conduct pilots and operate in Israel.

Tactics

The Ministry has approved pilots of advanced transport technologies since 2017 and the regulatory landscape has been evolving ever since:

- In 2018, MOT amended its traffic regulations, empowering the Traffic Controller Officer to approve waivers and enable exemptions for AV testing purposes.[8] These exemptions include, for example, the option to remove hands from the steering wheel or to exceed the speed limit.
- To obtain a permit to conduct AV pilots on public roads, a company must receive approval from two professional committees:
  - **Vehicle Divisions Committee:** Chaired by MOT Head of Engineering and Standardization Department, comprised of representatives of relevant MOT divisions and other relevant government agencies in relation to the technology and type of authorization requested
  - **Advising Committee to the Traffic Controller Officer:** Chaired by the Chief MOT Scientistand comprised of representatives from Infrastructure Division, Vehicle Division, Public Transport Authority, Police and the Technion Technological Institution

MOT is currently revising its pilot procedure and considering establishing an innovative regulatory sandbox mechanism. This framework will enable the approval of driverless pilots (or other forms of testing such as having only a designated controller but no driver on board) to make the Israeli pilot procedure more accessible to the global AV industry. On 19 August 2020, MOT presented draft legislation enabling the approval of driverless pilots (or other forms of testing such as having only a controller but no driver on board).

MOT intends to establish an Advisory Committee, headed by MOT Director General with members from the Ministry of Justice, Ministry of Finance, Prime Minister's Office, Innovation Authority, Israeli Police and two experts from industry/ academia. C4IR Israel will participate in committee discussions, representing the Innovation Authority.

The Advisory Committee shall:

1. Follow up on technological developments and operation methods in the field of autonomous vehicles around the world
2. Study the results of AV trials conducted in Israel and around the world
3. Collect data from Israel and the world concerning severe safety breaches involving AVs, analyse their causes and recommend means of prevention
4. Propose the terms and conditions required, in its opinion, for the approval of AV trials

See Appendix A for an English translation of the key driverless pilot draft legislation principles.

The Approval Process

- The AV operator is required to submit an application including a trial portfolio to the Vehicle Division Committee, operating in accordance with procedure H-02-2017, "Approval of Trial Vehicle for the Purpose of Research and Development of New Technology Systems" (last updated in 2019).[9] The procedure outlines a set

of rules, terms and milestones required for the approval of vehicles conducting trials on public roads in Israel.

– To perform AV trials, an exemption from Transport Ordinance and Regulations is required. In this case, the Vehicle Division Committee shall inform the Traffic Ordinance Officer and they shall summon the Advising Committee to the Traffic Controller Officer to examine the request.

The committees shall examine safety assessment and safety risks, technological readiness and maturity, training methods of test drivers, the ability to investigate safety events, insurance coverage and the exemptions required by Israeli Traffic Ordinance and Regulations.

Safety

– Israel is rigorous on the safe deployment of AVs. All trial vehicles must go through a stringent safety assessment conducted by the technical service/type approval authority. The assessment includes:
  - Evaluation of the functional and operational safety of automated system design
  - Functionality testing
  - System failure testing
– As of October 2020, the Ministry requires the presence of a safety driver in the vehicle. According to the Ministry, to date there has been only one safety incident, with no recorded damage to property or bodily injury.
– MOT is currently collaborating with the Technion Israeli Institute of Technology – to develop asimulator for safety scenarios that will ensure AV safety prior to operating on public roads. The Ministry has collected 42 safety scenarios typical of the Israeli environment and infrastructure for the purposes oftesting the simulator.

AV Deployment Status

– Three companies are conducting AV trials on public roads in Israel: Intel's Mobileye, GM and Yandex.
– In December 2017, MOT launched an innovative testing centre operated by Ayalon Highways Co. Ltd. The testing centre enables examination of AV technology in a natural yet sterile environment by using closed sections of the Ayalon Highway and other roads. Mobileye, General Motors, Innoviz, Argus Cyber Security, Nexar Ltd and others have all tested their technological solutions at the centre. The Ministry is planning to expand the current testing centre to establish and operate a large and modern centre in a permanent location.
– In December 2017, the Russian multinational technology company Yandex NV announced that it had obtained authorization to conduct trial drives of its AVs in Tel Aviv.
– In October 2018, Volkswagen Group, Mobileye and Champion Motors announced plans to commercialize Mobility-as-a-Service (MaaS) with self-driving vehicles in Israel by 2022.
– In the past year, Singapore Technologies has also been conducting testing in Israel and is planning to deploy its Autonomous Shuttle (Navya) after obtaining regulatory approval.
– The Ministry of Transport and Road Safety is collaborating with the Israeli Innovation Authority to support pilot programmes for Israeli technology companies in the field of smart transportation. Participating companies receive financial support of between 20% and 50% of the approved expenditures for the trial. An exceptional support rate of 75% of approved R&D expenditures is awarded to programmes with potential for exceptional impact on streamlining and improving transport in Israel. This incentive programme supports, among others, the piloting and implementation of autonomous driving technologies.

4 National and jurisdictional AV policies: A comparative review

4.1 National and jurisdictional AV policies

This section reviews the development of AV policy in jurisdictions similar to that of Israel: Australia, Singapore, the United Kingdom and US states California and Arizona.

4.1.1 AV policy in Singapore

Challenges

- A population of 5.7 million (and growing) on a mere 700 sq.m. of land, causing congestion.
- Human resource constraints (lack of drivers, dependence on immigration).

Opportunity

AVs can play an important role in the creation of a sustainable mobility system, and although the technology is an estimated 10-15 years from maturity, the Government of Singapore has been embedding it in its mobility development since 2013, Singapore considers AVs to be part of the solution to the city- state's growing mobility demands within its limited geographic space.

Approach

The Singapore Land and Transport Authority (LTA), an executing body of the Singapore Ministry of Transportation, is coordinating government efforts on AVs by regulating pilot permits and working closely with the industry in support of technological development. The United Nations Economic and Social Commission for Asia and the Pacific ranked Singapore first in AV readiness, among four Asian countries (others were Japan, China, South Korea) for its relatively clear and comprehensive policies and new laws governing AV deployment and high consumer acceptance.[10]

In 2017, the Singapore Ministry of Transport introduced AV rules for prospective trials and use of AVs. The AV Rules and broader legislation framework enable the LTA to create and amend rules governing autonomous mobility activities and implement a regulatory sandbox in relation to such trials or use. The regulatory sandbox has been limited to a five-year period, after which the government can enact a more permanent legislation or reconsider extension of the sandbox.

A three-stage roadmap was initiated approximately seven years ago in collaboration with the industry and universities. This consultation process allowed Singapore to develop a land transport vision and roadmap for AV development. Singapore is currently finalizing Stage 1 and will start Stage 2 in 2020:

- *Stage 1*: Understand AV technology through trials and pilots to ensure it meets satisfactory safety and security levels in urban settings.

– *Stage 2*: Increase trial and pilot deployment at the town level in 2020. Three towns with different characteristics were selected: 1) a mature town with a population of 250,000; 2) a greenfield town under development; and 3) a town that includes a mix of business and industrial land-use features.

– *Stage 3*: Expand AVs to more towns and eventually deploy them nationwide following lessons learned from Stage 2. No timetable has been established because the Ministry is dependent upon AV technology advancements. It is also awaiting the economies of scale gained by the commercialization of AVs.

Tactics

Inclusivity

– The Committee on Autonomous Road Transport for Singapore (CARTS) was established in 2014 to chart the strategic direction for AV-enabled land mobility concepts in Singapore.[11] Members include renowned international experts, academics and industry representatives. Constant discourse and feedback from the industry are key features.

– To support the vision and work of CARTS, the LTA signed a memorandum of understanding with Singapore's lead R&D agency A*STAR[12] to set up the Singapore Autonomous Vehicle Initiative (SAVI), which explores the technological advantages that AVs can create for Singapore.

– The LTA has made public awareness and acceptance of AVs a top priority, largely because of the potential benefits of AVs n public transport applications. The LTA promotes public acceptance by enabling the public to experience the technology in several pilot projects.

– Clear standards and definitions are a main objective. In 2019, the LTA published Technical Reference 68 for AVs (TR 68) to guide the industry in the development and deployment of fully automated vehicles. The standards cover four key areas of AV deployment: basic vehicle behaviour, safety, cybersecurity principles, and assessment and vehicular data types and formats.

Safety

– Each AV trial undergoes a rigorous safety assessment jointly administered by the LTA, the traffic police and the Centre of Excellence for Testing and Research of AVs-NTU (CETRAN) to demonstrate the ability to handle basic manoeuvres and stop safely upon detecting an obstacle.

– LTA requires at least one safety driver per vehicle, with their access to a steering wheel and/or emergency brake. Most of the pilots are conducted with two persons in the cabin – an engineer and a safety driver.

Sustainability

– Singapore's Land Transport Master Plan 2040 was revised in the third quarter of 2019 to adopt a 2040-time horizon (LTMP2040).[13] The plan emphasizes public transport as well as shuttles and dynamic (on-demand) routes, including robo-taxis. Various products available in different places and at various times of day are other key planning considerations.

Infrastructure

– Due to its small geographical size, Singapore is not planning to allocate dedicated lanes to AVs but will include them with regular traffic on high-occupancy vehicle lanes and public transport lanes.

AV deployment status

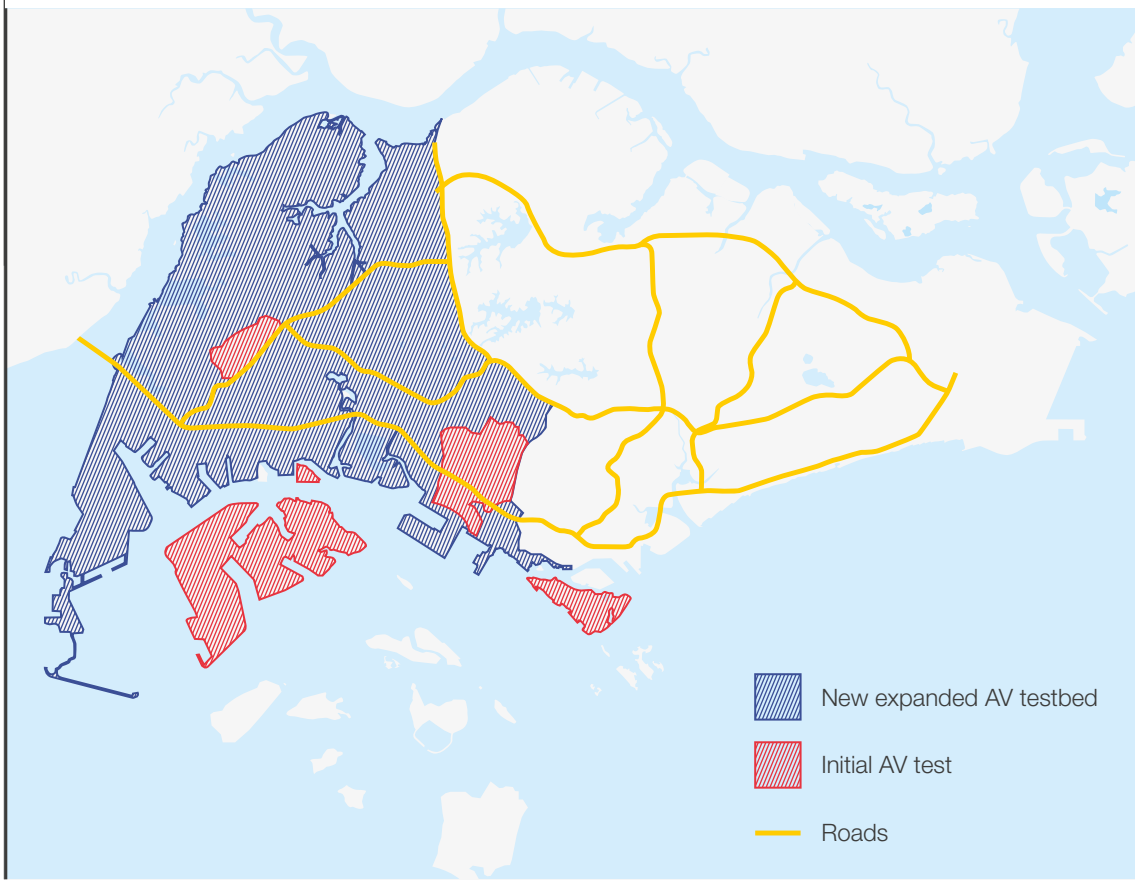
– Since 2015, the public has been able to experience driverless buggies in the Jurong Lake District and on the National University of Singapore (NUS) campus, as well as the autonomous shuttle bus from the Nanyang Technological University (NTU) campus to CleanTech Park.

– Since 2015, One-North business district has hosted a public road network to test driverless vehicles. It connects the Biopolis, Fusionopolis and Mediapolis hubs and is comprised of both light and heavy traffic routes under real traffic conditions. It has since been expanded from the initial six kms to allow for further scenario testing.

– Since 2017, the CETRAN AV Test Centre, designed to replicate various aspects of Singapore's roads (including a rain simulator and flood zone) has been used to test AV capabilities under varying weather conditions.

– Since 2019, the AV testing area has been expanded from four main test beds in the western part of Singapore to over 600 miles of public roads to conduct tests (see Figure 5 below).

FIGURE 5 **AV Testing Area in Singapore**



Source: Abdullah, Zhaki, "Entire western part of Singapore to become testing ground for driverless vehicles", CNA, updated 10 January 2020, https://www.channelnewsasia.com/news/singapore/autonomous-vehicles-western-singapore-testbed-12029878

Policy summary

Singapore Road Traffic Autonomous Motor Vehicle Rules, 2017 (January 2020 update)[14]

	Trial	Use
Definitions	Road trial of an AV or AV technology	Road use of an AV, including authorization to operate a service to transport passengers and charge a fee for the service
Prohibition exemption	If the AV or AV technology is not enacted, the vehicle is not prohibited from road operation (e.g. for mapping needs).	
Permit application	The application should include: – Types of AV and AV technology – Number of vehicles – Nature of modifications for trials – Safety documentation – Objectives – AV system	
Authorization	Fees (*as at October 2020*): $25.68 per vehicle (under this Act) or $30/day, $250/month, $800/half a year, $1,600/year (under the previous rule). Conditions may apply, relating to: – Geographical area – Qualified safety driver (not specified) – Safety operator (not specified) – Prohibition of carrying passengers – Prohibition of being used for hire or as a reward – Lists of personnel permitted – Other	
Modification	The authority will give 14 days' written notice of any modifications. The modification date will be as stated regardless of any objections raised.	
Extension	Six months' notice is required by the requesting party. The period of extension is not specified (or limited). Flexible and open policy regarding extension, tailored to company needs.	
Cancellation/ suspension	Cancellation or suspension may apply: – If the authority deems it is no longer in the public interest – In case of failure to comply – If the person authorized is no longer considered fit Appeals are possible but the authority rules until otherwise decided.	
Liability/ insurance	Valid liability insurance is an obligation, including during use or trials. The insurer must be registered in Singapore. A fine, limited to $2,000, applies if no Singapore registered liability insurance has been contracted. If insurance according to the above cannot be obtained, a deposit of $1.5 million can be paid to the authority to be allocated as needed in case of cause of death, bodily injury and/or property damage (if activated, the deposit must be replaced to meet the required amount within 14 days).	
Maintenance	Ensuring good operating conditions of the AV, ADS and parts is required at all times.	

	Trial Use
Reporting	**Data collection:** – Data must always be recorded, even when the AV technology is not in operation – Data must be collected in the format specified by the authority and kept for at least three years (regardless of the authorization period) **The data should include:** – Date and time stamp – Location (latitude and longitude) in at least 2 Hz frequency – Speed in at least 2 Hz frequency – Status of vehicle operation (manual, automated, etc.) – Operator override history (during autonomous mode) – Sensor information – Camera and video footage from three sources: internal facing, external front and rear **Data recording:** – Data cannot be edited and copies must be provided to the authority – An editing transgression fine may be imposed: $5,000. Other non-compliance penalties may apply: $2,000 – The authorized person must demonstrate that everyone participating in the trial adheres to the data requirements **Incident reporting:** – Reporting is required in case of 1) malfunctions of the AV or ADS; 2) incidents involving personal injury or property damage – The non-reporting penalty is capped at $2,000
Test requests	The authority can require tests of the AV, ADS or its parts at any time.

4.1.2 AV policy in the UK

Challenges

- Innovation and industry development
- Road safety
- Greater accessibility to those with mobility issues

Opportunities

- To support and promote the safe trial and use of AV technologies
- To build public confidence in AV technologies and services
- To support cooperation between trialling organizations and those responsible for the management of traffic, infrastructure, law enforcement and other areas to achieve maximum road safety
- To encourage the sharing of information to help uphold and develop the highest standards of safety in the UK and internationally
- To oversee various AV models, including pods and shuttles, and a variety of purposes, including goods and passenger mobility

The policy is designed to identify and test vehicles capable of safely driving themselves. It is not intended to cover driver assistance technologies.

Approach

To enable AV trails on public roads in the UK, the government conducted a detailed review of legislation and concluded that AV trialling is possible within the current vehicle and driving legal framework as long there is a safety driver in the vehicle and the vehicle complies with road traffic law. Therefore, in 2015, the UK government laid out a non-regulatory Code of Practice for automated vehicles trialling (updated in 2019),[15] while relying on rules and regulations in effect (e.g. insurance, driving licence, vehicle age) and promoting ongoing voluntary communication with regulators.

According to the guidelines, no permit is required to trial any level of automated technology provided there is a driver or operator inside or outside of the vehicle, ready to take control. Choosing this approach was a strategic decision the UK undertook to differentiate itself from other countries, mainly US states, that chose regulatory approaches, and to enable AV companies with maximum flexibility.

The Centre for Connected and AVs (CCAV)[16] governs public-sector efforts in support of connected and automated vehicle (CAVs) development. CCAV is part of the Department for Transport and Department for Business, Energy and Industrial Strategy.

In 2018, British Parliament passed the Automated and Electric Vehicles Act 2018[17] to articulate that (i) The Secretary of State will keep a list of all motor vehicles that are capable of safely driving themselves (even if only in certain circumstances) and (ii) that compulsory motor insurance applies to AV operations to cover damage to property or persons other than the AV, property of the person driving or operating the AV, and any goods carried for hire or reward by the AV.

CCAV asked the Law Commissions of England and Wales and the Scottish Law Commission, statutory independent bodies created to keep the law of Great Britain under review and recommend reform where it is needed, 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. Therefore, in 2018, the Law Commissions initiated a three-year process to identify, consult and recommend long-term reform of passenger transport:

- *Phase 1* (November 2018-February 2019): a three-month consultation on safety assurance and legal liability resulting in a paper on the findings on the findings from 178 respondents published in June 2019[18].
- *Phase 2* (October 2019-February 2020): a second consultation paper on highly automated road passenger services (HARPS) covering the regulation of remotely operated fleets of AVs and their relationship with public transport, resulting in a paper on the findings from 109 respondents published in May 2020[19,20].
- *Phase 3* (2020): formulation of overarching proposals on the way forward that draw on responses to both previous papers, for final recommendations expected Q4 of 2020.

Tactics

Safety

- Safety is embedded in three requirements for piloting to take place:
  - A driver present and ready to take over either inside or outside the AV
  - A roadworthy vehicle compliant with existing type approval and road traffic regulations
  - Appropriate insurance coverage
- Safety features are expected to be shared publicly prior to conducting the trials (information about the trial, driver and operator training, compliance, points of contact with related agencies, safety plans); the recommendation is to use the BSI guidelines (British Standards Institution). BSI has a Connected and Autonomous Vehicle PAS Programme including PAS 1880 Guidelines for Developing and Assessing Control Systems for Automated Vehicles, and 1881 Assuring Safety for Autonomous Vehicle Trials and Testing.[21]
- Data must be provided if needed, as well as full compliance in case of an investigation. On 17 July 2020, the BSI published PAS 1882 for consultation on the subject of AV trials data collection to support incident investigation.
- Safety includes compliance with the eight cybersecurity principles developed by the Department for Transport in conjunction with the Centre for the Protection of National Infrastructure (CPNI) in 2017.[22]
- Contingency planning and agreements must be in place with relevant authorities in case an unintended situation or accident occurs (including public communication, key points of contact, processes for scaling down, pausing or ceasing activities, and rehearsals of the contingency plans).

Public awareness and inclusivity

- An explicit call is issued for greater visibility of trialling plans and reports to be communicated to relevant governing entities and the public.

Key suggestions for a long-term policy that emerged from the two consultations to date:

- Provide clear definition of the User in Charge - shifts between unmanned and manned modes in both planned and unplanned circumstances.
- Ensure that the Automated Driving System Entity (ADSE) vouches for the system's safety as part of the new safety assurance scheme and bears legal responsibilities to ensure safety of the system.
- Establish a new safety assurance scheme to authorize autonomous driving systems, to any complement required to the current system of international type approval. The safety assurance scheme shall include driver training, software updates, roadworthiness and data management.
- Consider a Highly Automated Road Passenger Services (HARPS) operator license – this would be applicable for passenger services which use highly automated vehicles to supply road journeys to passengers without a human driver or user-in-charge. The license would apply to all vehicle types (instead of current differences between taxi, private hire and public service vehicle licensing). HARPS licensing draws mainly from public service vehicle requirements. HARPS operators would have a duty to supervise their vehicles and intervene in the event it runs into any problems during operation. The supervision requirement is in addition to the existing requirements from current passenger service operators, including proper capital requirements, ensuring proper vehicle maintenance and cleaning, passenger safety, insurance and reporting of collisions.
- The emphasis of incident investigation should shift from allocating blame to learning to improve safety. There is a need to accompany any police investigation with professional support.
- Regulatory sanctions:
  - A suggestion for creating a new non-criminal system of sanctions for automated vehicles: each automated driving system listed under the 2018 Act would be subjected to a system of graduated regulatory sanctions, such as improvement notices, fines, suspension or withdrawal of approval. In the event of an accident or driving offence while the autonomous driving system is engaged, the police shall refer the matter to a regulatory authority that shall apply the sanctions listed above. This does not apply to problems related to providing the safety assurance scheme with information that is false or misleading. Criminal sanctions: A need to review the law on corporate criminal offences in cases where wrongs on the part of the developer led to death or serious injury.

Industry growth

- Pilots and trialling: Legal barriers and requirements remain low for AV trialling, with most current regulations aligning AV testing with current institutions' governing obligations (e.g. insurance, driving licence, vehicle age), encouraging point-to-point contacts and ongoing voluntary communication with a set of regulators.
- Deployment: The Law Commissions are currently working on finalizing the results of two public consultations and preparing to release a consultation paper at the end of 2020, with final reform recommendations planned for publication in 2021.

AV deployment status

- Prototype vehicles are allowed on the road if reported as such and they can be granted exemption from regular vehicle compliance requirements.[23]
- In 2014, four cities participated in three AV trials funded by the UK Government that ran for 24-36 months. The projects were backed by a £10 million grant from Innovate UK aimed at establishing the UK as the global hub for the research, development and integration of driverless vehicles and associated technologies:
  - GATEway Project, Greenwich, South East London[24]
  - UK Autodrive, Milton Keynes and Coventry (working together as one project)[25]
- Transport for London (TfL), a local government body, is responsible for the principal road network in London and has supported several open AV pilot initiatives:
- The StreetWise consortium, including hardware developer FiveAI, insurer Direct Line and safety standards body Transport Research Laboratory (TRL), advanced to suburban London in October 2019.
- The DRIVEN consortium, including Oxbotica, Oxford Robotics Institute, Axa XL, Nominet, Telefonica, TRL, RACE, Oxfordshire County Council and TfL, completed a 30-month government-supported project (£13.6 million), demonstrating the capabilities of a fleet of self-driving vehicles in the capital's challenging and complex urban environment in October 2019. Part of the trial included a week-long demonstration in Queen Elizabeth Olympic Park in Stratford.
- The Smart Mobility Living Lab, a co-innovation project seeded by Innovate UK, is led by TRL and a consortium of global leaders (Cisco, Cubic, DG Cities, Loughborough University, London Legacy Development Corporation and TfL) to deliver the UK's most advanced real-world connected environment for testing future mobility technologies, services and business models.

Policy summary

UK Code of Practice: Automated Vehicle Trialling, 2019 (2015 version update)[26]

	Trial[27]
Definitions	Oversee various AV classes, including pods and shuttles, and a variety of purposes, including goods and passenger mobility NOT for the purpose of testing driver assistance technologies
Engagement	**Minimal requirement:** – Establish contact and engage with landowners, members of the public, highway, transport and local authorities, the police, traffic commissioners and CCAV – Receive more detailed requirements and processes from each of the above that the trial entity is expected to follow, and reach agreement on the sharing of information (e.g. traffic lights and road repair) – Ensure the trial entity maintains engagement throughout the project **Public communication:** – Share information about the trial for broad visibility – Report incidents and relevant data to the police, Department for Transport, CCAV and all relevant authorities as well as the public – Educate the public (for example, public-facing versions of safety cases) – Consider how to provide for vulnerable stakeholders **Safety cases:** – Develop detailed safety cases prior to commencing operations, including information about the trial, operator training, compliance, points of contact with related agencies, safety plans, etc.; it is recommended to use the BSI PAS 11281:2018 code of practice[28] – Adhere to the Freedom of Information Act 2000 (FOIA)[29]

	Trial
Driver and operator safety	**Oversight requirements:** The entity conducting an AV trial: – Must have a driver ready to take over, either in-cabin or remotely – Should preferably have more than one safety driver and a backup driver – Must establish an authorization process for drivers – Must obey all traffic laws, even if not trialled on public roads – Must ensure the driver is at a minimum able to apply an emergency stop control if the vehicle's maximum speed is 15 mph **Licence requirements:** – A UK driving licence or recognized equivalent appropriate for the vehicle class – Preferably several years of driving experience – A driving history that shows no risk to the public **Training:** – Drivers understand (and preferably have extensive experience of) the capabilities and limitations of the system – Drivers undergo continuous training, particularly in the transitioning between automated and manual modes **Safety driver hours:** – Set a maximum number of driving hours per driver per day – Set a maximum driving duration **Behaviour:** – The operator should clarify, and the driver should follow strict driving behavioural rules, in accordance with the law and beyond (e.g. driving sober, observing speed limits, exchanging insurance details in case of an accident, etc.) – It is important to be conscious of the appearance to other road users (other road users tend to gaze at the AV and get distracted)
Vehicle requirements	**General vehicle requirements:** – The vehicle must be able to comply with road rules – If over 3 years old (4 years in Northern Ireland), the vehicle must have a valid MOT certificate **In-house trials and progress:** – Enough trials and testing must have occurred in a controlled environment prior to trials on public roads (e.g. test beds) – The safety cases submitted should demonstrate that enough trials and testing have occurred in a controlled environment prior to trials on public roads (e.g. test beds) **Remote controlling:** – Should deliver the same level of safety as an in-cabin driverand must include two-way, real-time communications links – Must include full processes to deal with failures – Must involve a complete understanding of any remote-control operation communication dependencies and systems

	Trial

	Data recording:
	– At a minimum, record data capable of determining who controls the vehicle
	– Record data at a minimum of 10 Hz, including:
	  – Details of automated system
	  – Status of vehicle operation (manual, automated, etc.)
	  – Longitudinal acceleration in the vehicle's driving direction
	  – Lateral acceleration when the vehicle is moving sideways
	  – Vertical acceleration when the vehicle mounts a curb or similar
	  – Speed
	  – Steering command and activation
	  – Braking command and activation
	  – Operation of vehicle lights and indicators
	  – Geolocation
	  – Connectivity and network access
	  – Audible warning system (e.g. horn)
	  – Sensor data of other road users
	  – Remote command impacting vehicle movement (if applicable)
	  – Operator override history, including the time of occurrence (during autonomous mode)
	– In case of an accident, data should be recorded and protected for a period of 30 seconds before and 15 seconds after the incident at a minimum frequency of 50 Hz
	– The data recorded should include elements such as sensors, control system, video, audio (not as an alternative to the above specifications)
	Transition between modes:
	– Should be easily understood, with enough warning
	– Must allow easy override with minimal risk (demonstrated through tests)
	– Must include monitoring of situational awareness of the driver and subsequent response processes
	Failure warning:
	– The driver must receive audible and visual warnings of a malfunction or failure
	– The vehicle's braking and steering systems should include a minimal risk condition (e.g. manoeuvrability to a safe location) in case of a system failure

Insurance	Compulsory Motor Insurance was extended in 2018 to apply on damage caused by AVs

4.1.3 AV policy in Australia

Challenges

- Technological and institutional development barriers to the deployment of AVs (a 2016 National Transport Commission study identified 700 barriers[30])
- Economic challenges: gaps in vehicle ownership and business models
- Role of the government in ensuring the safety of the technology

Opportunities

- AV policy and regulatory leadership while ensuring national consistency and international alignment
- Improvements in road safety as a result of a dedicated national law and the autonomy of the industry to determine how best to achieve safety goals (self-certification of AVs)
- Accessibility to mobility options for deprived communities
- Congestion reduction and associated economic benefits

Approach

The National Transport Commission (NTC)[31] is a statutory body created to develop regulatory and operational reforms to improve the productivity, safety and environmental outcomes of the Australian transport system. Since 2016, the NTC serves as the Commonwealth Office of Future Transport Technology (encompassing the Transport and Infrastructure Council and its advisory body and the Transport and Infrastructure Senior Officials Committee[32]) through a partnership with Austroads[33] and the Department of Infrastructure, Transport, Regional Development and Communications[34] (which represents Australia in the UN World Forum for Harmonization of Vehicle Regulations WP.29[35]) and territory transport road agencies.[36]

In November 2016, the Transport and Infrastructure Council tasked NTC with leading several reforms to the regulation of AVs. In response, the NTC published a policy paper comprised of a proposed timetable for regulatory reforms of automated vehicles in the near, medium and long term. The following year, Australia's Transport Ministers endorsed the goal of an end-to-end regulatory system to be enacted in 2020 aimed at supporting industry's safe and efficient development. The NTC is currently working toward this goal although timelines have shifted due to the lack of technological readiness and consultation complexities.

The guiding principles of NTC's policy framework are as follows:

- Reforms are outcome based, with safety as a key result, allowing the industry to determine how best to achieve those outcomes
- Reforms are neutral as regards the technologies, applications and business models that the industry develops
- Reforms are nationally consistent and internationally aligned
- Reforms provide flexibility to allow the technology to continue to evolve

Tactics

In May 2017, Australian ministries adopted the "Guidelines for Trials of Automated Vehicles in Australia".[37] States and territories also reviewed their legislative powers to support trials, as they are granting the exemptions and permits required to perform AV trials and pilots.[38] As of May 2020, South Australia, New South Wales and Victoria have enacted legislation to enable trials, and other jurisdictions allow trials through permit or exemption schemes. Victoria has developed its own trial guidelines.[39]

In May 2018, Australian ministries agreed to develop comprehensive and consistent regulation on vehicles and drivers to ensure a single market approach.

Four elements of AV regulation were agreed:

- *Control* (May 2018): The automated driving system entity (ADSE) is legally in control of a vehicle when the ADS is operating in automated mode; once control is handed over the fallback user becomes the legal driver.
- *Driving laws* (May 2018): The laws are purpose-built national legislation that regulates the on-road operation of AVs.
- *Safety at market entry, "first supply"* (November 2018): The first supply approach is mandatory self-certification against safety criteria for vehicle supply:
  - Safe system design and validation processes
  - Operational design domain
  - Human–machine interface
  - Compliance with relevant road traffic laws
  - Interaction with enforcement and other emergency services
  - Minimal risk condition
  - On-road behavioural competency
  - Installation of system upgrades
  - Verification of the Australian road environment
  - Cybersecurity
- Three other obligations on ADSEs to manage liability include data recording and sharing, corporate presence in Australia and minimum financial requirements.
- *Motor accident injury insurance* (August 2019): This national approach requires existing motor accident injury insurance (MAII) schemes to expand to cover crashes caused by AVs. It will require the consideration of ministers who have primary responsibility for MAII schemes.[40]

Three AV reforms are under way:

- *In-service on-road operation safety for AVs* (since July 2019): This aims to regulate the safety of the ADS on the road, articulated in the Regulation Impact Statement (RIS) consultation paper.[41] It includes the role of different parties in the in-service safety of AVs (ADSEs, manufacturers, repairers, owners and others), any additional safety duties that should apply to these parties, and institutional and regulatory arrangements to support these duties.
- *Motor accident injury insurance* (since August 2019): The three key elements of the national approach to MAII and AVs under way are to 1. Review insurers' mechanisms to recover their claim costs; 2. Create provisions enabling people involved in an AV crash to access MAII schemes, and 3. consider data access for MAII insurers to assess liability as part of the AV reform programme.[42]
- *Government access to vehicle-generated data* (since August 2019): Ministries have agreed that ADSEs must show how they meet a set of safety criteria and obligations at first supply (as detailed above). One criterion is data recording and sharing, which requires ADSEs to record and provide certain data (such as crash data and data about who is in control of the vehicle) to relevant parties, including law enforcement and other government agencies.

AV Deployment status:
According to a review of the Guidelines for Trials of Automated Vehicles in Australia, published on May 2020 by the NTC:[43]

- Since National Guidelines for Automated Vehicle Trails were published in 2017 approximately 15 AV trails have taken place in Australia
- To date, there have not yet been trials of a large number of AVs in Australia
- Most trials involved shuttle buses in limited operating domains[44]
- Other technologies being trialled in Australia include small automated vehicles (SAVs) that are used to make deliveries mainly on footpaths and other road-related areas. For example, Australia Post conducted a trial of SAVs to deliver packages to customers' doors in Brisbane in 2017.
- There have not been many trials involving automated heavy vehicles in Australia. New South Wales is currently trialling heavy vehicle safety applications using C-ITS.

Policy summary

Australian National Guidelines for Automated Vehicle Trials, 2017[45]

	Trial
Compliance with Australian law	Trialling organizations must ensure that trial AVs meet all relevant vehicle requirements and comply with existing road traffic laws unless a specific exemption or permit has been granted
Engagement	– Contact the relevant road transport agency to determine if exemptions or permits are required – Contact local government agencies, utility agencies or private road managers to access local roads or other infrastructure

Permit application	The permit application should:
	– Clarify trial location
	– Describe the technology being trialled
	– Provide a safety management plan, including anticipated risks and mitigating actions:
	  – Traffic density/vehicles
	  – Pedestrians
	  – Signage
	  – Irregular events - construction, crash scenes, flooding
	  – Complex intersections and merges
	  – Regional variations in road design
	  – Railroad interfaces
	– Inform road transport agencies of any infrastructure or network requirements for the trial
	– Engage with stakeholders and/or the public as part of the trial
	– Set out how modifications to the vehicle or infrastructure over the course of a trial will be managed

Safety	All trialling organizations must develop a safety management plan to identify and manage key safety risks, including: – Security against hacking – Risks to road infrastructure – Appropriate transition processes for vehicles that can move between automated and human driving modes – Risks to other road users – System failure, elaborating on the management of system failures including hardware failures, software errors and human errors, system redundancy and fallback options – The presence of a human driver in the vehicle, unless a specific exemption or permit has been granted (as at October 2020, all trails in Australia require the presence of a safety driver in the vehicle) – Training provided for the driver/operator – Vehicle identifiers will be used to signal to other road users that the vehicle is autonomous
Cancellation/ suspension	If any condition of the exemption or permit is not complied with, the exemption or permit may be suspended or revoked Penalties may also apply, depending on the state or territory's enabling legislation or regulations
Liability/ insurance	Appropriate insurance must be provided to protect against risks included during the trial, such as a state-based insurance scheme

	Trial
Reporting	Data recording in case of serious incidents:[46] All information relevant to a "serious incident" and the performance of the system must be collected and provided so the circumstances of the event can be reconstructed. **Data could include:** – Time – Date – Location – Automation status – Traffic conditions – Road and weather conditions – Vehicle information – Sensor information – Identity of the vehicle operator at the time of the incident End-to-end trial report on research outcomes: high-level summary with no requirement for any commercially sensitive information Incident reporting: Any serious incident must be reported to the relevant road transport agency with data in a form that can be easily read and interpreted by the agency *Time frame:* – The data must be provided within 24 hours of the incident – A full report including relevant data and information must be provided within seven days of the incident **Other cases requiring reporting include:** – Near misses – When a human takes back control of the vehicle – When a public complaint is received regarding the performance of the vehicle. *Time frame:* – On a monthly basis – If requested, within 7 days
Commercial Trials	Trials of automated vehicles can be commercial in nature and operate as fee for service during a trial (ride sharing or taxi operations). However, the guidelines process is not intended to support large-scale commercial deployment of automated vehicles.

4.1.4 AV policy in two US states: California and Arizona

The US Department of Transportation National Highway Traffic Safety Administration (NHTSA) issued an initial Federal Automated Vehicle Policy in 2016, after which three versions of "Automated Driving Systems" policy documents were released: in 2017 ("AV 2.0"), 2018 ("AV 3.0") and 2020 ("AV 4.0").

The Department of Transportation's goal is to engage with new technologies to address legitimate public concerns about safety, security and privacy, without hampering innovation.

With the release of AV 2.0 ("A Vision for Safety"), voluntary guidance to industry, technical assistance and best practices to states was provided, paving the way for the safe testing and integration of the ADS. Following AV 2.0, companies started to publish voluntary safety reports on the 12 safety elements outlined in the document. *For elaboration of the safety criteria set by NHTSA on AV 2.0 and a comparative review of the safety reports of five leading companies in the AV industry, see Appendix B.*

AV 3.0 ("Preparing for the Future of Transportation") extended guiding principles for all surface AV modes and described the Department of Transportation's "strategy to address existing barriers to potential safety benefits and progress".

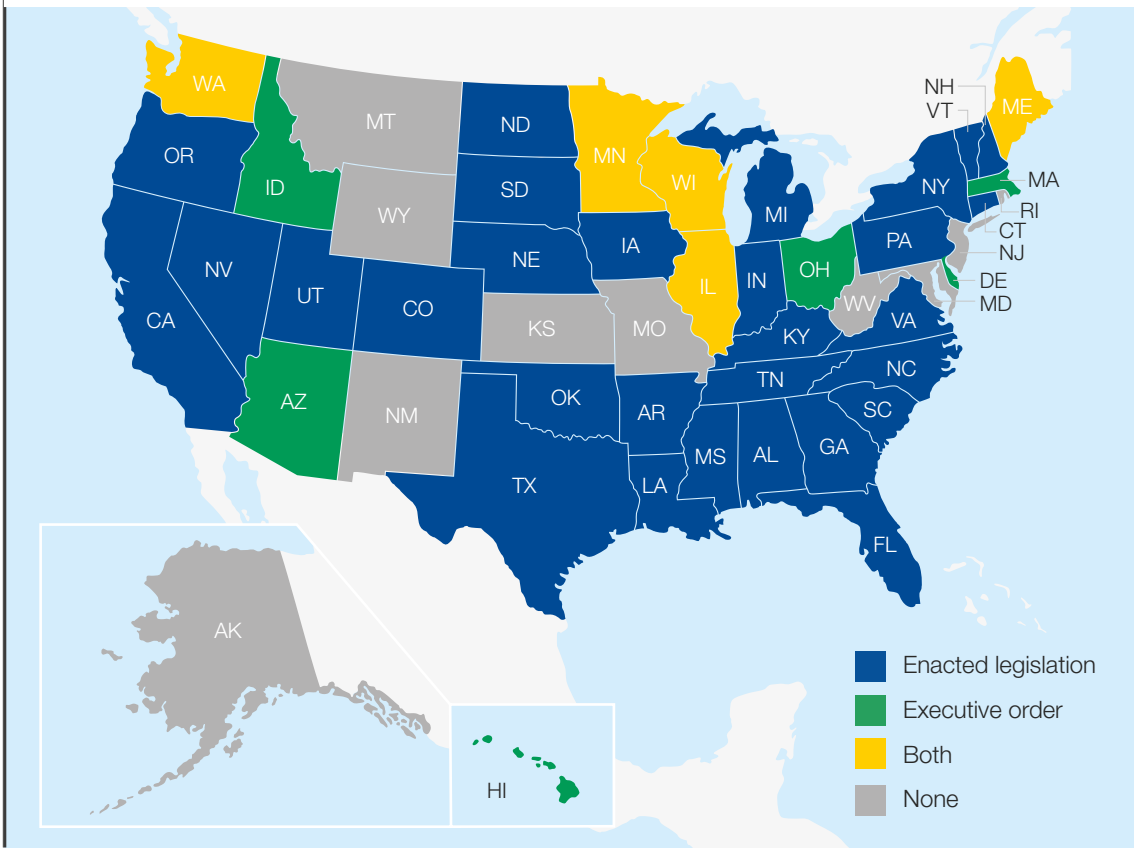
AV 4.0 ("Ensuring American Leadership in Automated Vehicle Technologies") clarifies responsibilities of authorities concerned and unites the strategy of 38 US Government (USG) efforts to enhance AV technology development and integration

while prioritizing safety, security and privacy.[47] It is structured around three key areas: USG AV principles, administration efforts supporting AV technology growth and leadership, and USG activities and opportunities for collaboration.

States maintain authority over permit prescriptions, implementation and enforcement mechanisms. Governors of eleven US states have issued executive orders encouraging growth in the AV tech sector.

Each year, the number of states considering legislation related to AVs gradually increases. As of October 2020, 29 US states[48] have enacted legislation related to AVs. Governors in Arizona, Delaware, Hawaii, Idaho, Illinois, Maine, Massachusetts, Minnesota, Ohio, Washington and Wisconsin have issued executive orders related to AVs. The National Conference of States Legislators recently introduced a database for tracking AV legislation[49]. This section covers the ADS permitting regulation of two states: California and Arizona.

FIGURE 6 **State actions on autonomous vehicles**



Source: CRS map based on data from National Conference of State Legislatures, Autonomous Vehicles/Self-Driving Vehicles Enacted Legislation, viewed February 10, 2020. http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

AV policy in California

Challenges

- Congestion, carbon emissions and air quality, which have been high on the state's agenda for the past four decades
- Steady growth in transportation demand (AVs are viewed as a potential technology to tackle certain issues, if regulated appropriately)

Opportunities

- Reduction in the number of personal cars on the road, with associated reduction in road fatalities, traffic, emissions and pollution
- Improvement in mobility for the elderly or physically challenged

Approach

In response to California Vehicle Code (CVC) Section 38750 that requires California's DMV[50] to adopt regulations governing both the testing and public use of AVs on California roadways from 2012 (also known as SB1298), DMV conducted two public workshops related to AV testing regulation already in the spring of 2013. The proposed AV testing regulations,[51] requiring a driver, were published for public comment in the fall of that year, finalized by DMV and released by the Office of Administrative Law in September 2014. Further public workshops designed to shape regulation in California were held in 2014, 2015 and 2019.[52] In February 2018, the regulatory text was amended to enable testing with a driver, following a process that included workshops and public hearings.

Tactics

The DMV developed three AV permit types through open public consultations. It introduced the following:

- Regulations for manufacturers testing AVs
  - A testing permit with a driver (since 16 September 2014)
  - A driverless testing permit (since 2 April 2018)
  - A public-use permit (since 2 April 2018)
  - Autonomous delivery vehicle[53] testing and deployment (since 16 December 2019)
- Information for manufacturers testing AVs with a driver
  - The AV Tester Program administered by DMV AVs Branch is currently accepting applications
  - Applications can be made after the requirements and application process are reviewed and approval is obtained Requirements include vehicle registration, the disposal of test vehicles and annual application fees ($3,600 for 10 vehicles and 20 drivers/operators per vehicle).[54]
  - List of permit holders
  - The DMV publishes the list of active permit holders and updates it periodically; as of 6 May 2020, there are 67 AV testing permit holders, covering 881 test vehicles and 6.5 million miles[55,56]
  - Two companies have obtained a permit for testing without a driver, Waymo and Nuro.
  - Seven companies are authorized to carry passengers in California; Zoox, AutoX, Pony.ai, Waymo, Aurora Innovation, Cruise and Voyage[57]
- ***Permit for public use*** **(passengers commute)** Where a permit holder wishes to transport members of the public who are not employees, contractors or designees of the manufacturer, the manufacturer must apply to the California Public Utilities Commission (CPUC), to participate in California's Autonomous Vehicle Passenger Service Pilot. As of June 3, 2020, seven permit holders operating in California can transport members of the public who are not employees, contractors or designees of the manufacturer: Zoox, Autox Technologies, Pony.ai, Waymo, Aurora Innovation, Cruise and Voyage Auto

- **AV collision reports**
  Under the testing regulations, manufacturers are required to provide the DMV with a Report of Traffic Collision Involving an Autonomous Vehicle (Form OL 316) within 10 days of the collision

- **AV disengagement reports**
  Every manufacturer authorized to test AVs on public roads is required to submit an annual standards report summarizing the disengagement of the technology during testing (the 1 December to 30 November period must be reported by 1 January);[58] archived reports are available to the public upon request[59]

- **Hearings and workshops**
  Hearing and workshop video recordings are made available online[60]

- **Contingency plans**
  A law enforcement interaction plan for "first respondent" (law enforcement, fire department, emergency medical personnel) is required for emergency and traffic enforcement situations; such a plan should be made available online and communicated with relevant authorities

Policy summary

California Autonomous Vehicle Testing Regulations

	Testing (with a driver)	Testing (without a driver)	Public use
Definitions[61]	Autonomous mode, autonomous test vehicle, dynamic driving task, minimal risk condition, operational design domain, disengagements, testing, deployment, personal information[62]		
Compliance with California law	All local regulations applicable to the operation of motor vehicles, whether the vehicle is in autonomous or conventional mode, must be obeyed		
Vehicle registration	Vehicles not operating under manufacturer or distributor plates (either occupational or a state licensing) are required to have current California registration[63]		
Permit application for testing or operating vehicles	The manufacturer must submit Autonomous Vehicle Tester (AVT) Program Application for Manufacturer's Testing Permit,[64] including: – Tester information – List and details of all vehicles in fleet – List and details of all potential vehicle drivers, employees, contractors and designees – Completion of the autonomous vehicle test driver training programme – Acknowledgement that the vehicle has been tested under controlled conditions that simulate each ODD – Acknowledgement that the test driver is in immediate physical control or actively monitoring the vehicle and can take over immediate control of the vehicle – Evidence of insurance, safety bond or application for self-insurance in the amount of $5 million	The manufacturer must submit the Autonomous Vehicle Form OL 318 Driverless Testing Permit Checklist,[65] including: – Tester information – Vehicle information – Copy of the Articles of Incorporation, Corporate Minutes or other document filed with the Secretary of State that identifies the officers, shareholders and managers – Acknowledgement that the vehicle has been tested under controlled conditions that simulate each ODD – Acknowledgement that the vehicle has a communication link with a remote – operator to allow two-way communication with the passengers – Acknowledgement that the vehicle can operate without the presence of a driver and meets the description of L4 and L5 automation of the ADS	The manufacturer must submit the Autonomous Vehicle Form OL 321 Deployment Checklist,[66] including: – Copy of Articles of Incorporation – Description of the ODD in which the vehicle is designed to operate – Description of any commonly occurring or restricting conditions, such as snow, fog, black ice, wet road surface, etc. – Description of how the vehicle is designed to react when it is out of its ODD – Consumer or end user education plan in case a vehicle is sold or leased to persons other than the manufacturer – Description of how L4 and L5 vehicles (and L3 vehicles when the driver is unable to take manual control) will safely come to a complete stop in case of a technological failure

	Testing (with a driver)	Testing (without a driver)	Public use
	– Copy of course outline and description of the autonomous vehicle driver testing programme – Copy of the Articles of Incorporation, Corporate Minutes or other document filed with the Secretary of State that identifies the officers, shareholders and managers – Driver/operator training programme outline	– Submission of the law enforcement interaction plan to the California Highway Patrol within 10 days of application approval – Enough completed training of remote operators – Notification to local authorities for each jurisdiction in which the vehicle is tested – Description of intended ODD – Course outline and description of the remote operator training programme – Explanation of how all vehicles tested will be monitored – Description of how the manufacturer will monitor the communication link	– Copy of the law enforcement interaction plan – Summary of manufacturer testing in the ODD in which the vehicle will operate – Voluntary assessment showing how safety can be achieved
Safety	The vehicle must be tested under controlled conditions to simulate as closely as practicable each ODD in which the manufacturer intends to operate, and to reasonably determine it is safe to operate the vehicle in each ODD. The test driver must be in immediate physical control or be actively monitoring the vehicle and capable of taking immediate control of the vehicle. The vehicle has a mechanism that is easily accessible to the operator to engage and disengage the autonomous technology. Remote operators have completed enough training programmes. **Driverless testing:** – a law enforcement interaction plan to be submitted to the California Highway Patrol within 10 days of application approval – an assessment from manufacturers showing how safety is pursued		Description of any commonly occurring or restricted conditions (including weather limitations) under which the vehicle is unable to operate Description of how L4 and L5 vehicles (and L3 vehicles when the driver is unable to take manual control) will safely come to a complete stop in case of a technological failure Description of how the vehicle is designed to react when outside its ODD Copy of the manufacturer's law enforcement interaction plan[67] A summary of the technology testing in the ODD in which the vehicle is designed to operate, describing all locations in which the vehicle has been tested
Modifications	– A new application form must be submitted with updated changes – $70 – Change of address, authorized representative, driver/operator or vehicles – $50 – Additional permits for driver/operators and vehicles		Not specified

	Testing (with a driver)	Testing (without a driver)	Public use
Cancellation/ suspension	*Upon 15 days written notice* Any act or omission by the manufacturer or one of its agents, employees, contractors or designees, which the department considers renders the conduct of autonomous vehicle testing on public roads by the manufacturer an unreasonable risk to the public Additional grounds for suspension of driverless testing: The manufacturer's driverless AVs are operating outside the operational design domain specified in the application submitted pursuant to Section 227.38 of this article The manufacturer fails to make the disclosures required by subdivision (i) of Section 227.38		*Upon 30 days written notice* – The manufacturer failed to maintain financial responsibility in the amount required by Vehicle Code section 38750, subsection (c)(3), and section 228.04 of this Article – The manufacturer submitted incorrect or misleading information in the Application for a Permit to Deploy AVs on Public Streets – The manufacturer failed to report to the department any change to the information or certifications required and provided in the application under Section 228.10 within 10 days of the date of the change – The manufacturer failed to comply with any of the provisions of this article related to the deployment of AVs *Immediate suspension* – If a manufacturer, distributor or remanufacturer licence has been suspended or revoked by the department – If the manufacturer deploys any vehicle equipped with autonomous vehicle functions that were not disclosed in the manufacturer's Application for a Permit to Deploy AVs on Public Streets – If the manufacturer has misrepresented any information related to safety of the autonomous technology of its vehicles – If the NHTSA determines that the autonomous technology of the manufacturer's vehicles makes inoperative any federally required motor vehicle safety systems – If the manufacturer's AVs are subject to an open NHTSA recall related to the vehicle's autonomous technology. If the manufacturer's vehicles are not safe for the public

	Testing (with a driver)	Testing (without a driver)	Public use
Liability/ insurance	The manufacturer must provide evidence of insurance, surety bond or application for self-insurance in the amount of $5 million.[68] However, according to current regulations, courts will address liability on a case-by-case basis unless the legislature steps in to provide clarity		Autonomous vehicle deployment surety bond; autonomous vehicle tester permit application for certificate of self-insurance; instrument of insurance issued by an insurer admitted to issue insurance in California
Data collecting			The manufacturer will equip vehicles with an autonomous technology data recorder that captures and stores autonomous technology sensor data for all vehicle functions that are controlled by the autonomous technology at least 30 seconds before a collision with another vehicle, person or object while the vehicle is operating in autonomous mode. The data captured and stored by the autonomous technology data recorder, in read-only format, must be capable of being accessed and retrieved by a commercially available tool.[69]
Reporting	Collision report: Manufacturers are required to provide the DMV with a Report of Traffic Collision Involving an Autonomous Vehicle (Form OL 316) within 10 business days of the incident Disengagement report: Manufacturers are required to submit an annual report summarizing the disengagements of the technology during testing[70]		
Disposal or transfer of test vehicles	– The transfer of ownership is authorized only to a manufacturer holding a valid autonomous vehicle manufacturer testing permit – The transfer of ownership to an educational or research institution or a museum is possible for display or study – The manufacturer disposing of the vehicle has obtained a Non-repairable Vehicle Certificate[71] ensuring that the vehicle is not retitled or resold and ownership of the vehicle is transferred to an auto dismantler, or the manufacturer has internally dismantled or disposed of its own vehicle and its major component parts		
Annual application fees	The non-refundable original application fee is $3,600 (covering 10 vehicles and 20 drivers/operators per vehicle). The non-refundable renewal fee is also $3,600.		$3,275 application fee
Permit duration	The permit is valid for two years.		
Commercial trials	It is prohibited to charge members of the public a fee or receive compensation for providing a ride. AV operators are only permitted to carry company employees, contractors or designees. It is prohibited to charge members of the public a fee or receive compensation for transporting property in motortrucks as defined in Section 227.28 of the California Code of AV Regulations		

AV policy in Arizona

Challenges

- Public acceptance and regaining public trust after the fatal Uber crash on 18 March 2018 leading to a $10 million lawsuit against the state[72]
- Expanding the variety of Mobility as a Service (MaaS) options to improve mobility accessibility and efficiency for those who cannot afford or are unable to drive a car

Opportunities

- Benefits to economic growth through strategic investment in the growing AV industry, including direct and indirect job creation, investment and gross development product growth[73]
- Improved transport safety, reduced transportation costs, road congestion and travel time, reduced fuel consumption and increased productivity, according to the Arizona Commerce Authority[74]

Approach

The State of Arizona made a strategic decision to lead on AV development and has therefore taken a permissive approach to regulation since 2015. Governor Doug Ducey's 2015 executive order states that all agencies of Arizona should support the testing and operation of self-driving cars on public roads in Arizona.[75] Together with year-round dry weather, Arizona has established a reputation as an AV-friendly state, attracting 600 ADS vehicles testing on its roads in 2016.[76]

Tactics

Two milestone executive orders promote the state's favourable conditions for AV testing on public roads:

- First executive order (25 August 2015) encouraging self-driving system cross-agency collaboration in support of ADS testing on public roads[77]
- Second executive order (1 March 2018) leading to:[78]
  - The establishment of the Institute of Automated Mobility[79] under the Arizona Commerce Authority, a public-private consortium of businesses, higher education institutions and government officials to promote greater collaboration in the AV industry[80]
  - The establishment of a Self-Driving Vehicle Oversight Committee within the governor's office to advise how best to advance the testing and operation of self-driving vehicles in Arizona[81]
  - The authorization of fully driverless cars without a person behind the wheel to operate on public roads, and subsequent requirements:[82]
    - Compliance with all applicable federal law and federal motor vehicle safety standards and obligation to bear certification label(s), unless an exemption or waiver has been granted by the National Highway Traffic Safety Administration
    - Compliance with all applicable traffic and motor vehicle safety laws and regulations of Arizona state; the person testing or operating the AV may be issued a traffic citation or other penalty in the event of non-compliance
    - Compliance with all certification, title registration, licensing and insurance requirements
    - Compliance with the Law Enforcement Protocol and submission of a copy of a law enforcement interaction protocol[83]
    - Obligation to operate in minimal risk mode when a failure of the ADS occurs that renders the AV unable to perform the dynamic driving task required in the ODD

AV deployment status:
Over 12 AV companies are piloting and operating more than 600 automated test vehicles on Arizona roads.[84]

Arizona was the first US state to enable commercial operations by autonomous vehicles launched by Waymo, prior to the COVID-19 pandemic.

Policy summary

	Trial	Use
Definitions	Automated driving system: The hardware and software that are collectively capable of preforming the entire dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational design domain Dynamic driving task: All the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation: – Lateral vehicle motion control via steering – Longitudinal motion control via acceleration and deceleration – Monitoring the driving environment via object and event detection, recognition, classification and response preparation – Object and event response execution – Manoeuvre planning – Enhancing conspicuousness via lighting, signalling and gesturing Fully autonomous vehicle: A motor vehicle that is equipped with an ADS designed to function as a L4 or L5 automation system under SAE J3016 Minimal risk condition: A fully autonomous low-risk operating mode that can achieve a reasonably safe state, such as bringing the vehicle to a complete stop upon experiencing a failure of the vehicle's ADS	
Compliance with federal and state law	All testing or operation, with or without a natural driver, is required to observe all federal laws, Arizona state statues, Title 28 of the Arizona revised statutes, and all regulations and policies set forth by the Arizona Department of Transportation (ADOT), in this order.	
Permit application for testing or operating vehicles	Testing/operating (with a driver) Submission of a written statement to the ADOT acknowledging that: – The vehicles meet and follow all applicable federal law, regulations and guidelines, meet all applicable certificate, title and registration, licensing and insurance requirements and can comply with all applicable traffic and motor vehicle safety laws and regulations of the State of Arizona – The person testing or operating the ADS may be issued a traffic citation or other applicable penalty in the event of a failure to comply with traffic and/or motor vehicle laws – Only a trained employee, contractor or other person authorized by the company developing the autonomous technology can operate or monitor the vehicles	Testing/operating (without a driver) Submission of a written statement to the ADOT acknowledging that: – The ADS follow all applicable federal law and federal motor vehicle safety standards unless an exemption or waiver has been granted – The AV can operate in minimal risk condition in case a failure prevents the system from preforming the entire dynamic driving task relevant to its ODD – The vehicle can comply with all traffic and motor vehicle safety laws and regulations of the state of Arizona – The vehicle meets all applicable certificate, title registration, licensing and insurance requirements – The vehicle follows the Law Enforcement Protocol and submission of a company's law enforcement interaction protocol

	Trial	Use
Safety	n/a	The operating entity must provide a law enforcement interaction protocol, including: – How to communicate with a fleet support specialist available during the times the vehicle is operating – How to safely remove the vehicle from the highway – A description of the cities in which the vehicle will operate – How to recognize the vehicle is in autonomous mode and steps to safely tow the vehicle – Any additional information regarding hazardous conditions or public safety risks
Cancellation/ suspension	If the statements are not submitted, the Director of the ADOT can immediately issue a cease and desist letter revoking permissions to operate	
Liability/ insurance	– Documents on file with the MVD must show the vehicle meets the financial responsibility requirements under ARS section 28-4135[85] – The insurance details of AVs operating on public roads without a driver are made public in Arizona on websites (e.g. Waymo)[86]	
Reporting	There are no reporting requirements apart from insurance details and collision reporting collaboration with enforcing entities	
Disabled vehicles	In case a fully autonomous vehicle becomes disabled as a result of a collision or malfunction and the owner cannot provide for its custody or removal, a police officer will have the vehicle removed: – Pursuant to ARS section 28-871, 28-872[88] – For seizure pursuant to law – For obstruction of traffic – When disabled in a gore point – When disabled or abandoned in a hazardous location	
Commercial trials	Arizona was the first state in the US to introduce a commercial self-driving taxi service, launched by Waymo in the cities of Chandler, Tempe, Mesa and Gilbert	

4.2 A comparative review of selected AV regulations

This section compares, to the extent possible, the selected national and US state-level regulation policies outlined in section 3.1. The sub-sections in Appendix C were designed in response to the regulation principles proposed by Israel, as articulated in the AV sub-proposal.

	Singapore	UK	Australia	California	Arizona
Regulatory framework for AV pilots with safety driver	Yes				
Companies conducting AV pilots with safety driver	Yes				
Regulatory framework for AV pilots without a safety driver	No			Yes	
Companies conducting AV pilots without safety driver	No				Yes
Regulatory approach for pilots	Regulatory Sandbox	Code of Practice	Federal Code of Practice, combined with waivers from the states	Regulations	Executive Order
Regulatory framework for commercial deployment	No			Yes	
Companies conducting commercial deployment	No				Yes
Regulatory approach for commercial deployment	A thorough consultation process with the public and experts from industry/academia			Regulations	Executive Order

For a more detailed comparison between the different nations and US states reviewed, please see Appendix C

5 Synthesis and recommendations

Regulation in all the reviewed national and US state jurisdictions is still nascent and constantly evolving. This review sought to identify commonalities and highlight distinctions. By synthesizing regulatory decisions from various contexts, we formulate initial recommendations that may advance the work of Israel's Ministry of Transport and Road Safety and related entities poised to steer and govern AV development in Israel.

Motivation for regulating AVs: All reviewed AV policy environments acknowledged the nascent state of the technology and the market benefits of supporting its development. The need to ensure public safety while the technology development progresses through road experimentation has motivated the introduction of a spectrum of safety requirements. The potential pitfalls of AV commercialization have also been broadly acknowledged, including sustainability and inclusivity impediments, but have been only lightly addressed in current regulation. Some of the reviewed regulatory environments advocate electrification and shared rides to mitigate the adverse effects of AVs and plan to introduce related measures in the future.

Short-term versus long-term regulatory approaches: All three nations reviewed in this publication have established dedicated entities to coordinate and lead governmental efforts in creating an AV policy framework. All three are promoting a regulatory setting for enabling the testing and piloting of AVs, for advancing technological readiness while forming comprehensive strategy to inform more robust policy frameworks to steer and govern commercial applications of the technology.

Formulating regulation through multistakeholder consultation and ongoing discourse: Multistakeholder efforts range from consultations designed to distil policy recommendations and generate consensus around regulatory approach (e.g. the UK), to dedicated, hand-picked workgroups designed to develop standards (e.g. Singapore).

Definitions and terminologies: Regulators reviewed in this paper target L4 and L5 automation, which concern highly and fully AVs. Through consultations with stakeholders, the need to articulate such terminologies has been expressed.

Permit application requirements: The UK does not require a special permit to conduct trials and pilots but sets comprehensive and detailed codes of conduct (expected vehicle, driver and operator behaviour and compliance). Singapore, in contrast, requires a special permit while allowing for authoritative flexibility of ruling on the one hand and setting operating expectations on the other (permit extension, penalties, etc.).

Driver and operator requirements: Each of the three nations reviewed adopts a slightly different approach: Australia's guidelines allow AVs without a human driver or operator, but the country requires safety issues to be addressed as part of an essential safety management plan (self-certification is under way). The UK makes a clear distinction between the driver (in-cabin or remote), the vehicle and the operating entity governing the AV, and outlines specific requirements that are largely aligned with current regulatory systems. Singapore differentiates between the driver and operator and requires information in advance on all the individualsto be involved in AV operations, prohibits the hiring of AVs and their use as a reward (e.g. in a commercial service), and has the power to modify requirements at any time.

Vehicle requirements: All states and nations reviewed require the vehicle to comply with all applicable vehicle requirements and existing road traffic laws, unless a specific waiver or exemption has been granted. The UK limits vehicle age and requires compliance with requirements nascent within other regulatory framings (e.g. CPNI cybersecurity principles).

Reporting requirements: Reporting is often required upon disengagement or a collision, yet specifications of the required data vary greatly. The UK and Australia have explicit reporting requirements, while Singapore is less precise but requires information on technological malfunction to be reported. California requires reporting on collisions, miles driven and annual disengagement, and makes that information publicly available. Arizona does not yet require ongoing data reporting but is considering adding reporting requirements to its current regulation.

Insurance: According to existing vehicle insurance requirements (the driver must provide insurance details in case of an accident); Singapore and California enable self-insurance, and Australia and the UK have extended their compulsory insurance to cover AV accidents.

Liability: Specification of operator and driver responsibility is not always clear. In the UK, the driver is responsible when the ADS is not operating. However, clarifying responsibility handover during fallback was emphasized in the Law Commission's first consultation paper (2019). Similarly, ODD definitions and disengagement events can be better specified. Australian ministries agreed that the ADSE is legally in control of a vehicle when the ADS is operating in automated mode, and once control is handed over, the fallback user becomes the legal driver.

Emergency contingency plans: Requiring a detailed contingency plan to be developed, communicated with relevant first responders and made publicly available is a requirement in California, Arizona and a code of practice in the UK.

Criminal liability: The UK and Australia are examining creating a new system of regulatory sanctions to replace criminal sanctions in driving offences committed when the autonomous driving system is operating, based on the understanding that enforcement should be part of a feedback to manufacturers and operators, aimed at improving safety. This approach is still being examined and has not been yet introduced as a policy.

In summary, AV regulation requires a profound change in the perception of driving, enforcement, road safety and privacy. It is crucial to engage all relevant governmental agencies as early as possible. While AV policy approaches depend on regulatory environments already in effect, institutional structures, cultural settings, technological capacities and other unique characteristics and commonalities point to several AV Policy Framework recommendations that extend beyond the safety elements synthesized above:

In order to advance AV technology, piloting and testing is required. While it is instrumental to enable safe AV development, it is critically important to steer technological innovation in AVs in a manner that advances a nation's or jurisdiction's mobility

goals and improves its overall mobility system. It is therefore critically important to invest in a policy framework that includes not only safety considerations but also the implications of AV commercialization for congestion, multimodality, emissions, access and economic growth. AVs can shape a better mobility ecosystem, if effectively designed towards that end.

A guide for AV regulation

Define and communicate policy goals
Form an authoritative body capable of designing an AV policy
Design pathways for engaging multistakeholders, (public and private sectors, and civil society), in a sustainable and collaborative manner
Consider bi-directional exchange of information with the general public, not only for the purpose of user education and awareness building, but also to account for concerns and various needs of road and mobility users (i.e. disadvantaged groups)
Communicate regulation and regulatory processes effectively to ensure clarity
Exchange knowledge and best practices with regulators in other countries and align with policy and standardization efforts in the world
Take an active part in policy groups and international standardization bodies (ISO, SAE, UNECE)
Consider an agile short-lived approach to testing and piloting, while investing in well-informed long-term policy approach for AV commercialization
Iterate policy and regulation according to insights, knowledge and data collected through piloting and trialling
Use agile policy tools such as regulatory sandboxes to keep up with rapidly changing technology and enable testing and iteration of policy tools
Formulate robust data collection and reporting processes
While existing insurance schemes may suffice, consider expanding existing schemes to and/or enable option for self-insurance. Make insurance information accessible to the public.

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C4IR Israel

The Israeli Centre for the Fourth Industrial Revolution at the Israeli Innovation Authority (C4IR Israel) was established on July 2019 to help government offices adopt agile regulation of international standards to enable the implementation of advanced technologies.

C4IR Israel is assisting Israeli policy-makers in paving progressive and agile governance for the deployment of AVs in Israel, to improve the state of mobility through consultation with global industry leaders and regulators as well as other significant stakeholders from around the world.

The C4IR Israel autonomous mobility objective is to foster the safe development of autonomous technology and innovation, enhance Israeli government mobility goals, and position Israel as a leading player in the field.

Appendix A

Key principles of draft legislation governing driverless AV trials

A Title of the proposed law

Traffic Ordinance (Amendment No. 129) (Autonomous Vehicle Trials), 2020

B Objective of the bill, the rationale for it, main provisions and consequences on law in effect

In recent years, the development of autonomous vehicles has been advancing all over the world, namely vehicles capable of travelling on the road where, instead of a human driver at the wheel, an autonomous driving system combines hardware and software components enabling it to control the vehicle. Such a system operates the actions driving the vehicle on the basis of data collected by sensors and other means, and which are processed using artificial intelligence technology.

The State of Israel is at the forefront of such development and there are a number of companies, both Israeli and foreign, conducting AV trials in Israel. During these trials, the autonomous driving system drives the vehicle but there is a driver in the cabin whose role is to take control of the vehicle in case of an emergency. In this scenario, there are no passengers in the vehicle. These trials are conducted in accordance with authorization granted by the National Transport Inspector under Regulation 16a of the Transport Regulations, 1961. Pursuant to government resolution No 2316, dated 22 January 2017, the State of Israel aims to be among the leading countries in this sector. The purpose of this bill is to regulate the transition phase, from trials in which AVs with a safety driver transition to AV trials with no human driver at all, whether in conditions of paid or unpaid passengers in the vehicle, by means of a variety of technological solutions for the operation of autonomous vehicles.

Alongside these trials, it is proposed to form a legal infrastructure for trials of less-advanced vehicles that carry out only certain driving tasks by means of autonomous systems, with a human driver performing the rest.

This bill presents the intentions of the Israeli Ministry of Transport and Road Safety with regard to further promotion of AV development in Israel, while various details continue to be examined.

Article 1
It is proposed to authorize the Minister of Transport and Road Safety (Herein: the "Minister") to stipulate the regulations governing AV trials that are conducted without the presence of a human driver but with passengers in the vehicle.

Article 2
It is proposed to authorize the National Transport Inspector to grant authorization to conduct AV trials to any person who complies with the terms and conditions set forth in the regulations. Said authorization shall stipulate the terms and conditions for the trial, the terms and conditions for its cessation, and exemption from the applicability of the rules of conduct on the road, as stipulated in Part B of the Transport Regulations, and which do not apply to autonomous vehicles, exempted from conventional vehicle licence conditions in that these are not relevant.

Article 3
It is proposed to establish an Advisory Committee, headed by the General Director of the Ministry of Transport and Road Safety (herein "Ministry of Transport"), to be comprised of members of the Ministry of Transport, Israeli Police, Fuel Substitutes and Smart Transport Administration, the Innovation Authority, the Ministry of Justice and representatives of the public. The committee shall serve as a knowledge hub in all matters concerning AVs, originating in Israel and from overseas, on the basis of which it shall prepare reports and advise the Minister on matters concerning autonomous vehicles.

Article 4
It is proposed to oblige any entity conducting AV trials to immediately report to the National Transport Inspector any severe safety incident occurring during the trial. Subsequent to the reporting, the Inspector shall be empowered to order trial cessation or to amend its terms and conditions.

Article 5
It is proposed to notify publicly information concerning autonomous vehicle trials.

Article 6
Alongside cases of autonomous vehicles that do not require the presence of a human driver, in some cases companies are developing vehicles with a lower level of autonomy, in which some of the driving tasks are performed using autonomous systems yet require the physical presence of a driver to perform tasks that exceed the capabilities of such systems. It is proposed to authorize the Minister to set regulations that will enable the National Transport Inspector to grant authorization to perform trials on such vehicles, including when transporting passengers.

Explanatory Notes

In general
This bill proposes regulation that will enable trials to be conducted of autonomous vehicles with no human driver and transporting passengers in the cabin. To date, trials have been conducted in Israel of autonomous vehicle operation, in a manner that examines only the very functions of the vehicle under different conditions. The purpose of this proposal is to enable trials of autonomous vehicles in a manner that simulates commercial operation, in which – unlike in trials conducted to date – vehicles will have no human driver but will carry passengers, including paid passengers, on public roads and not only in closed compounds.

Section 9B
Among the definitions proposed in this bill, it is proposed to define an "Autonomous Driving System", as a system capable of carrying out all the driving tasks of the vehicle. There are two types of such systems – a highly independent driving system, one that is able of carrying out said tasks pursuant to pre-defined terms and conditions, such as only during daylight hours, and a fully independent driving system, which does not have such limitations. In professional terminology these are called autonomous driving systems, level 4 and level 5, respectively.

In addition, there exists a conditionally independent driving system, which can carry out some of the driving actions independently. In professional terminology this is known as autonomous driving system level 3. According to what is proposed, a vehicle with said driving system shall not be considered an autonomous vehicle, and the majority of the provisions of the law shall not apply to it.

Section 9C
It is proposed to authorize the Minister, in consultation with the Advisory Committee, to stipulate regulations for the authorization of trials of autonomous vehicles. The proposal acknowledges that this is indeed a learning process in a rapidly evolving technological world, and that it is mandatory for the law to be able to respond quickly and accordingly.

The purpose of the regulations is to ensure road safety and other public interests, including the reduction of road congestion, building trustworthiness into smart traffic technologies and formulating terms and conditions that will enable competition in the field, all in such a manner that will be neutral from a technological point of view, so that trials by means of a variety of technological developments are enabled.

The regulations to be defined shall regulate the following:

1. *The autonomous vehicle*: The technological requirements that the autonomous vehicle and the systems installed therein shall comply with – including the standardization requirements stipulated pursuant to the Traffic Regulations and the standardization requirements from which the vehicle will be exempted - shall be stipulated by the fact that the vehicle is operated not by a human driver but by an autonomous driving system.

2. *The autonomous driving system*: This system is the core of the autonomous vehicle. The authorization of a vehicle driven by such a system may be granted only on the basis of evidence that the system is capable of safely driving a vehicle and that it is reliable. The applicant for authorization of such vehicles shall present supporting documentation, including of trials conducted and a declaration from the manufacturer of the system, the manufacturer of the vehicle and authorization for conducting trial(s), including the abilities of the system.

3. *Authorization of autonomous vehicle trials*: This approval shall be granted to an applicant presenting a plan for the trial, and the operating space and conditions. In addition, the applicant will be required to justify capabilities for the implementation of the operation plan and control over the autonomous vehicles by means of a control centre, data collection infrastructure and data concerning the activation of autonomous vehicles. They must also demonstrate compliance with cyber and communication standards as well as any other information that the National Transport Inspector may require to authorize the trial.

4. The Bearer of Authorization to Conduct Trials of an Autonomous Vehicle is obliged to deliver information regarding the course of the

experiment to the National Inspector of Transport, provided that no information is delivered that enables the identification of a person.

5. The Bearer of Authorization to Conduct Trials of an Autonomous Vehicle is obliged to deliver information to the National Cyber Security Authority about any cyberattack incident on the autonomous vehicle systems.

Section 9D
It is proposed to stipulate prohibition of any autonomous vehicle trials that have not previously obtained authorization from the National Inspector of Transport. Although it is possible that the operation of an autonomous vehicle without authorization will involve offenses that already exist, it is proposed to single out a specific offense in a way that will facilitate enforcement.

It is proposed that authorization to conduct a trial of an autonomous vehicle be issued to anyone compliant with the regulations pursuant to Section 9C, and holding insurance applicable to such an operation.

It is proposed that the National Transport Inspector stipulate the terms and conditions of authorization notably in the following matters, among others:

1. The validity of the authorization shall not exceed three years

2. The maximum number of vehicles to be taking part in the experiment shall be stipulated

3. The obligations to which the Bearer of the Authorization is subject and the terms and conditions for annulment of the authorization

It is suggested to stipulate that the National Transport Inspector shall be entitled to grant trial vehicles exemption from provisions under the Traffic Ordinance that regulate paid driving, and – in consultation with the Licensing Authority – exemption from the provision under the Vehicle Licensing Ordinance. In addition, in consultation with a police officer, the National Transport Inspector shall be entitled to prescribe in the authorization, exemption from provisions in the Traffic Regulations pertaining to behaviour on the road. Furthermore, the National Transport Inspector shall be entitled to stipulate provisions in substitution of the exemptions, all in order to ensure the safety of all road users and persons participating in the trial, to reduce any disturbance to traffic caused by the operation of an autonomous vehicle and providing the required response to emergency events.

In addition, it is proposed to stipulate that the provisions of the Traffic Law shall apply to the operators of autonomous vehicles within the framework of the trial, to the extent that no exemption has been granted.

Section 9E
It is proposed to grant the National Transport Inspector powers that will give him effective supervision over autonomous vehicle trials, including requiring a Bearer of Authorization,

pursuant to this Article, to identify himself; to require a Bearer of Authorization or any other person taking part in the trial to present information and documents required for supervision; to enter the control centre of the trial and any place where operations are taking place within the framework of the trial, including an immobile vehicle, but no entry to a place of residence shall be allowed without a court order.

Section 9F
It is proposed to establish an Advisory Committee to monitor the trial(s). The head of the Committee shall be the Director General of the Ministry of Transport and Road Safety and the members of the Committee shall include representatives of the Ministry of Transport, to be appointed by the Minister, the head of Fuel Substitutes and Smart Transportation in the office of the Prime Minister or his representative, the head of the Innovation Authority in the Ministry of Economy and Industry or a representative thereof, the head of the Traffic Division of the Israeli Police or his representative, the Deputy Attorney General (Economic) or his representative, and two public experts from the field who will be appointed by the Minister.

The role of the Committee shall be to submit to the Ministry reports that will include the relevant infrastructure of knowledge for the activation of an autonomous vehicle. For this purpose, the Committee shall carry out the following:

1. Follow up on the technological developments and operation methods in the field of autonomous vehicles around the world

2. Study the results of trials conducted in the operation of an autonomous vehicle, in Israel and worldwide

3. Collect data from Israel and the world, concerning severe safety incidents involving autonomous vehicles, analyse their causes and recommend means to prevent them

4. Propose the terms and conditions required for the purpose of approving an autonomous vehicle trial

It is proposed to obligate the National Transport Inspector to provide the Advisory Committee with information in his possession concerning severe safety incidents that occur with autonomous vehicles in operation.

It is proposed to stipulate the subjects that the Advisory Committee is required to consider, among which are: maintaining safety and responding to bodily harm and damage to the property of the road

users, preventing disruption to other operations, sharing information, encouraging competition and technological innovation, and improving transport in Israel. It shall further consider the manner of response in matters such as cyber defence, insurance and handling emergency occurrences.

Furthermore, the Committee shall advise the Minister on matters concerning the stipulations regulating trials in autonomous vehicles. To ensure the effectiveness of the advisory procedure and to prevent it from becoming a barrier to the process, it is proposed to allow the Committee 30 days for response from the day on which the Minister requests said advice. The Minister is entitled to extend said period by another 30 days. In the event that the Committee has failed to respond to the request for advice through expiry of the allotted period pursuant to this section, the Minister shall be entitled to stipulate such provisions without consulting the Committee.

Section 9G
It is proposed to stipulate that the provisions of any law, including the Law of Tort and the Privacy Protection Law shall apply to trials of an autonomous vehicle.

Section 9H
It is proposed to obligate the Bearer of Authorization to immediately report any severe safety incident occurance, and no later than one working day after the fact, to the National Transport Inspector. In this respect, it is proposed to define a “severe safety incident” as stipulated in Section 46(29) of the Railways Ordinance [New Version], 1972.

Subsequent to such reporting, the National Transport Inspector is entitled to decide provisions pertaining to continuation of the trial, including its cessation, provided that the Inspector will not order the cessation of a trial for a period exceeding 10 days without the Bearer of Authorization being given an opportunity to state their claim.

Section 9I
It is proposed to oblige the National Transport Inspector to notify on the Ministry website any authorization of autonomous vehicle trials that is granted.

The information published shall contain information concerning the trials carried out, including the details of the Bearer of Authorization to Conduct Trials of an Autonomous Vehicle, the timeframe of the experiment and scope thereof, as well as the main terms and conditions that will apply to them. In addition, the Transport Inspector shall publish information concerning annulled or ceased trials, as well as any other detail that, in his opinion, the public need be aware of. However, the Transport Inspector shall not publish any information which is prohibited under Section 9 of the Freedom of Information Law.

Section 9J
It is proposed to authorize the Minister to regulate trials in vehicles at lower autonomous level and requiring a driver for some of the driving actions. Since there is a driver in these vehicles, there is no need for the broad arrangement proposed for more autonomous vehicles. Current law, however, does not allow their trial on public roads. To encourage technological variation, it is proposed to include in the bill authorization to stipulate in the regulations exemptions from the existing law in respect of these vehicles, for the purpose of carrying out trials in them.

Section 9K
It is proposed to authorize the Minister to stipulate provisions concerning the method for submitting applications for trial authorization. The Bearer of Trial Authorization must file reports concerning its progress, any special incidents transpiring in the course of the trial, and summary of the trial once the trial period has expired.

Appendix B

Analysis of US AV company safety reports

To date, 18 companies have submitted voluntary safety reports pertaining to the 12 criteria outlined in the NHTSA Safety Elements and Safety Principles: 1. system safety 2. operational design domain 3. object and event detection and response 4. fallback 5. validation 6. human–machine interface 7. vehicle cybersecurity 8. crashworthiness 9. post-crash behaviour 10. data recording 11. consumer education and training, and 12. state and local laws. The chart below outlines the self- reported efforts of Waymo, Uber, GM Cruise, Apple and Zoox as well as industry standards that have emerged across the reports for each of the 12 safety principles.

	NHTSA guidelines NHTSA Automated Driving Systems 2.0[87]
Safety system	ADS programmes should follow a robust design and validation process, adopting industry standards such as: – International Organization for Standardization (ISO) and SAE International Standards – Safety and risk assessments for individual ecosystems and the broader transport industry – Software design that should be well tested, validated and controlled – Design decisions linked to the assessed risks that could impact safety-critical system functionality – Designs tested and validated as both individual subsystems and as part of the entire vehicle architecture
Operational design domain (ODD)	ODD should describe and define the specific conditions under which a given ADS or feature is intended to function. Each entity should define and document ODDs using the following minimal information to define each ADS's capability limits/boundaries: – Roadway types (interstate, local, others) on which the ADS is intended to operate safely – Geographic area (city, mountain, desert, etc.) – Speed range – Environmental conditions (weather, daytime/night-time) – Other domain constraints
Object and event detection and response (OEDR)	ADS programmes should follow a robust design and validation process, adopting industry standards such as: – International Organization for Standardization (ISO) and SAE International Standards – Safety and risk assessments for individual ecosystems and the broader transport industry – Software design that should be well tested, validated and controlled – Design decisions linked to the assessed risks that could impact safety-critical system functionality – Designs tested and validated as both individual subsystems and as part of the entire vehicle architectures
Fallback	Defined as "A process for transitioning to a minimal risk condition when a problem is encountered, or the ADS cannot operate safely". Fallback procedures should consider the fact that human drivers may not be observing laws or regulations and could be under the influence, drowsy, etc. At later stages, the ADS must be able to fall back into a minimum risk condition (MRC) without need for human intervention. An MRC will be case-dependent but may include automatically halting of the vehicle to a safe stop, preferably outside of a traffic lane.

Validation	Validation methods should demonstrate the behavioural competencies an ADS would be expected to perform during normal operation, crash avoidance situations and fallback strategies. Entities should consider simulation and course testing.
Human–machine interface (HMI)	An ADS should be capable, at the least, of conveying information to the human operator or occupant through various indicators that the ADS is: – Functioning properly – Currently engaged in ADS mode – Currently "unavailable" for use – Experiencing a malfunction – Requesting control transition from the ADS to the operator
Vehicle cybersecurity	Entities are encouraged to consider and incorporate voluntary guidance, best practices and design principles published by the National Institute of Standards and Technology, the NHTSA, SAE International, the Alliance of Automobile Manufacturers and other relevant organizations when developing vehicle cybersecurity programmes.
Crashworthiness	Occupant-protection systems should be maintained at the intended performance level regardless of whether they are human- or ADS-operated. Unoccupied vehicles equipped with ADS should provide geometric and energy absorption crash compatibility with existing vehicles on the road.
Post-crash behaviour	Entities should establish methods to return ADS to a safe state after involvement in a crash. Technical measures should include actions such as shutting off the fuel pump, removing motive power and moving the vehicle to a safe position off the roadway. All relevant data should be shared with communications centres and vehicle repair centres to reduce harm resulting from a crash and ensure safe operation after repairs.
Data recording	Entities should establish a documented process for testing, validating and collecting necessary data related to the occurrence of malfunctions, degradations or failures in a way that can be used to establish the cause of any crash. Data should be retrievable in the event of a crash. Data should be collected and analysed when associated with 1. fatal or non-fatal personal injury, or 2. damage that requires towing.
Consumer education and training	Consumer education programmes are encouraged to cover topics such as ADS functional intent, operational parameters, system capabilities and limitations, engagement and disengagement methods, HMI, emergency fallback scenarios, ODD parameters (i.e. limitations) and mechanisms that could alter ADS behaviour while in service. Programmes should include explicit information about what the ADS is capable and not capable of, to minimize potential risks from user system abuse or misunderstanding.
State and local laws	ADS programmes should document how they intend to demonstrate compliance with local laws (including traffic laws). ADS programmes should also account for situations in which it is preferable for the ADS to break the law (e.g. having to cross double lines so as to travel safely past a broken-down vehicle).

Waymo 2018 Safety Report[89]	Uber 2018 Safety Report[90]	GM Cruise 2018 Safety Report[91]	Apple 2019 Safety Report[92]	Zoox 2018 Safety Report[93]
Safety system				
Waymo employs a multipronged system called "Safety by Design", comprising the following categories: – Behavioural safety – Functional safety – Crash safety – Operational safety – Non-collision safety	Uber uses a system engineering approach to ODD selection and characterization along with object and event detection and response (OEDR) Uber's safety system is based on the following "safety principles": – Proficient – Fail-safe – Continuously improving – Resilient – Trustworthy	Cruise highlights its use of a variety of system safety engineering tools grouped into the following categories: – Deductive analysis: studies all safety decisions via fault tree analysis – Inductive analysis: includes design and process analysis (a step-by- step approach to identifying all possible design hazards) – Exploratory analysis: includes a hazard and operation study, identifies potential risks by analysing the systems – The three core analysis groups, combined with a requirements traceability analysis, seek to ensure that the vehicle can bring itself to a safe stop even in the unlikely event of primary and secondary systems failures. *GM highlights its decision to test in an urban environment (San Francisco) in addition to suburban areas, which allows its cars to encounter more scenarios that can then be incorporated into the model.*	Apple states that its ADS design and integration are analysed using an "industry safety analysis method and best practices". The hazard analysis is based on the planned use case of typical street driving and the assumption that a human driver will be present	Zoox defines its safety innovation strategy as "Prevent and Protect". Its report does not include itemized principles like those of the other companies

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
Operational design domain (ODD)				
Waymo has designed its ODD to operate day or night and in inclement weather Vehicles are designed so they cannot go outside of their approved geographies. They can identify sudden changes and revert to a minimum risk condition (MRC), e.g. in a snowstorm The ODD is designed to comply with federal, state and local laws, with changes in such laws identified by the system	Uber creates a roadmap for a given ODD based on several factors, including the "regulatory environment and financial viability" Steps to create an Uber ODD include: – Manually driving the area – Adding data tags to camera and LIDAR (light detection and ranging) footage – Synthesizing tagged data to identify and break down information and all scenarios and system requirements for all scenarios – Creating representative simulation and track tests	The vehicle ODD includes the streets of the city in which it is currently operating – day and night as well as in light to moderate inclement weather GM Cruise uses a strict geofence in which vehicles can comply with the traffic laws defined	Apple's report does not include information on the company's ODD	The Zoox ODD is in San Francisco CA. Testing occurs in various weather and road conditions on private roads Zoox's ODD is designed "to ensure vehicles are prepared to navigate roadways, comply with local traffic laws and regulations, maintain safe speed ranges, and navigate environmental conditions (e.g. weather and time of day)"
Object and event detection and response (OEDR)				
Waymo presents its OEDR programme in three parts: – **Perception:** Software trained to recognize and classify objects on the road – **Behaviour prediction:** Software that models and predicts the behaviour and intent of each object on the road – **Planner:** Software that includes defensive driving behaviours, such as staying out of a driver's blind spot and leaving extra room for cyclists and pedestrians	Uber presents its OEDR programme as follows : – **Mapping:** Precise road data informs the system about an environment before it receives real-time information – **Perception:** Perception software detects and tracks individual objects and actors to generate estimates of their position and velocity that may inform further motion	In addition to a high-level description of OEDR technology, GM Cruise's report emphasizes its iterative design process and on-road testing in normal and edge case situations to optimize items such as the number, location and type of sensors on vehicles	Apple's system comprises the following three components: – **Sense:** The vehicle's ability to determine its position in the world via sensors that include LIDAR, radar and cameras – **Plan:** Detailed maps and "accurate positioning" technology, along with sensor updates to predict where the vehicle and surrounding objects will be in the future	Zoox organizes its OEDR system into the following categories: – **Perception:** Computer vision technologies that take data and images to track and avoid objects (other vehicles, traffic lights, cyclists, etc.) – **Prediction:** The likelihood of future actions of dynamic road objects using domain-specific rules, physics-based modelling and data-driven machine- learned behaviour

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
	– **Prediction:** Machine learning models to predict what actors in the environment may do; they include a motion planning system that uses probabilities to affect an appropriate amount of caution in response to less predictable actors or responses – **Vehicle control:** Software that executes the trajectory supplied by Motion Planning by controlling the actual vehicle The report includes a detailed discussion on the screening and training process for human vehicle operators		– **Act:** Software that converts the planning component's location and trajectory information into commands for vehicle steering, braking and propulsion systems	– **Planning:** Software that continuously evaluates the vehicle's surroundings and prediction models to plan its future moves – **Localization:** Software that allows the vehicle to always identify its location, with accuracy to the centimetre, based on inertial sensors, LIDAR and cameras, GPS and proprietary mapping data – **Mapping:** Proprietary maps and mapping technology to guarantee a high level of resolution and quality The report notes that since Zoox manages its own fleet, maps can continuously be updated as cities grow
Fallback				
The Waymo fallback system rests on the following redundancies: – Backup computing – Backup breaking – Backup steering – Backup power systems – Backup collision detection and avoidance system – Redundant inertial measurement systems for vehicle positioning	The Uber criterion for fallback to a minimum risk condition (MRC) is a type of failure that may result in harm to a person Fallback is accomplished by portioning safety features to different parts of the system, thoroughly testing components and designing key system redundancies Uber provides extensive training on procedures to operators in multiple types of system failures	GM Cruise fallback systems are comprised of one primary and one backup system that operate independently and simultaneously for self-driving decision-making and the capability to diagnose the other computer and other elements of the system Key systems, such as steering and braking, also have separate and redundant controllers and actuators	Apple outlines the following policies to ensure "Operational Safety": – Daily vehicle checks and meetings with human vehicle operators – The ability of safety drivers to assume control of the vehicle at any time	The Zoox fallback system uses remote operators to "help" the vehicle navigate uncertain scenarios It includes the use of redundant safety features and, to mitigate the risk of hardware failure, a mixed hardware strategy with hardware elements whose unique features guard against a common failure, including steering, braking and battery and powertrain

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
Validation				
Waymo tests on public roads, within closed courses and in simulations that include thousands of real-world scenarios – All vehicles can demonstrate the 28 core competencies recommended by the US Department of Transportation, as well as other behaviour competencies – Each competency is tested against a wide variety of closed-course and simulated tests – Waymo engages in crash avoidance testing across scenarios identified by the NHTSA as being among the most common	The Uber report describes processes for software, hardware and on-road testing and reporting systems **Software testing:** – Map compatibility test – Onboard integration tests – Unit tests – Virtual simulation regression set test – Reaction time metrics test **Hardware testing:** – Simulation involving test scenario development across multiple scenarios including: 1. normal driving scenarios 2) crash avoidance scenarios 3) crash situations **On-road testing:** – Reliance on high manufacturing standards and traceability of assembly **Reporting system:** – A robust system for reporting all system faults	GM Cruise validation processes employ both conventional and SOTIF (safety of the intended function) validation processes **Conventional validation processes:** – Vehicle-, system-, subsystem- and component-level performance testing – Requirements-based validation of system, subsystem and components – Faults injection testing of safety-critical control input, outputs, computation and communication – Validation of fail-over and safe state transitions within the fault tolerant time interval – Intrusion testing, such as electromagnetic interference and electromagnetic compatibility testing, as well as other environmental element exposure tests – Durability tests – Regression and stimulation-based software validation **SOTIF validation processes:** – Systematic exposure of the self-driving system to performance requirements of the ODD – Identifying and iteratively testing driving scenarios and edge cases that challenge the self- driving system	Apple's validation process begins when a new ADS capability is identified. Verification tests are designed to exercise the hardware and software in a manner that mimics the operating environments and inputs that would be expected at each level of integration All proposed changes are subjected to rigorous and comprehensive simulation testing that evaluates the software against pre-determined criteria After passing simulation testing, the entire system undergoes on-road testing at closed-course testing grounds before being endorsed for operation on public roads	Zoox tests in highly detailed simulations and on the road, prioritizing significant investment in in-house simulation capabilities Vehicles are used as tools by the engineering teams to test and validate the sensor suite and autonomous driving software Zoox focuses on a robust training programme and high standards for all vehicle operators

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
		– Exercising OEDR capabilities of the vehicle and its ability to identify environmental objects and situations that require a safe behaviour response – Evaluation of self-driving behaviour against safe driving standards with both quantitativ e and qualitative criteria		
Human–machine interface (HMI)				
Waymo's HMI includes the following features: – Display: Shows trip information, static road elements such as lights and dynamic agents such as vehicles, cyclists and pedestrians; it aims to show riders what the vehicle is perceiving, allowing them to be confident in the car's abilities – "Start ride" button: Is accessible inside the vehicle or on a mobile app – "Pull over" button: When engaged, the vehicle will identify the nearest location to safely stop so the rider can exit the vehicle – Mobile app: Participants in the early-rider programme use a mobile app to hail rides – Rider support team: Team members are available to answer questions, speak with riders and assist in an emergency	Uber has strict policies for vehicle operator behaviour: Self-driving vehicles are equipped with a touchscreen that follows the NHTSA's *Human Factors Guidance for Driver-Vehicle Interfaces* to minimize distractions Future rider experiences will be based on transparency, control and comfort and will include remote assistance for riders as well as a clear process in case of a crash	The GM/Cruise HMI interacts with vehicle occupants, user ride-hailing app controls and other core vehicle controls (heating, ventilation and air conditioning, radio, etc.) It uses GM OnStar Automatic Crash Response, which automatically responds in the event of a crash using OnStar established systems to communicate with first responders. Currently, the ride-hailing app and service is available only to employees	The Apple HMI includes the following measures: – A persistent visual display of the system mode (e.g. "ADS active") – A visual and audible signal when the system needs to return control to the safety driver – Multiple, redundant and fault-tolerant mechanisms for taking control of the vehicle	Zoox does not provide specifics on the way its HMI operates but indicates that human AV operators are "trained on autonomous mobility software to ensure proper testing and validation"

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
Vehicle cybersecurity				
Waymo's cybersecurity practices "are built on the foundation of Google's security processes and are informed by publications like the *NHTSA Cybersecurity Guidance and the Automotive Information Sharing and Analysis Centre's (Auto- ISAC) Automotive Cybersecurity Best Practices* Programme features include: – Building verifiable software and systems – Encrypting and verifying channels of communication – Building redundant security measures for critical systems – Limiting communication between critical systems – Providing timely software updates – Modelling and prioritizing threats – Ensuring safety-critical systems are inaccessible from the vehicle's wireless connections and systems – Ensuring systems do not rely on a constant connection to operate safely	Uber cybersecurity is comprised of the following hardware, software, and security architecture controls: **Hardware security:** – Key management – Functional separation – Secure networking devices **Security architecture:** – Cryptographic signatures – Data access control – Remote network access policies **Software engineering:** – Minimizing attack surface – Adversarial simulation	GM Cruise cybersecurity is built into the Systems Safety engineering process It includes analysis via evaluation tools, such as software scans and threat models, driving design decisions that use a "defence-in-depth" approach It regularly employs third parties to maintain and advance cybersecurity practices GM Cruise assesses security practices against guidance from the NHTSA, the National Institute of Standards and Technology, the Auto-ISAC, etc.	Apple conducts threat assessments and takes steps to mitigate known and anticipated risks	Zoox's cybersecurity best practices consist of: – Using established best practices – Developing new cybersecurity architectures – Constantly upgrading functional security

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
Crashworthiness				
Waymo uses vehicles that are compliant with FMVSS Waymo's current vehicle is the 2017 Chrysler Pacifica Hybrid Minivan	The crashworthiness of the base vehicle is defined by the vehicle structure, occupant restraint systems and other factors The self-driving system works with the base system to be geometrically compatible with standard vehicles on the road Uber's current testing uses the Volvo XC90	GM Cruise analysed the car to account for new systems and included the following additions: – Engineered load paths to protect the occupant space during frontal, side, rear and rollover crashes – A battery housing structure that protects the internal battery space in a crash – Vehicle floor reinforcements to distribute loads and maintain occupant space in a crash Currently, the GM Cruise ADS is mounted on the Chevrolet Bolt base	Apple uses test vehicles certified to the FMVSS and has "top crashworthiness ratings in consumer crash tests"	Zoox uses a testing fleet that meets the FMVSS Currently, Zoox's testing fleet includes the Prius C and Toyota Highlander
Post-crash behaviour				
Waymo software can detect when it has been involved in a collision and will notify the Waymo operations centre automatically Post-crash procedures involve interacting with law enforcement/first responders and riders via trained crash specialists Vehicles are tested for safety after they return to the road	In the event of a crash, the base Volvo platform of the Uber ADS performs safety actions depending on the type of collision: – Passive safety features activation (airbags, etc.) – Post-impact braking – High-voltage battery disconnection – Hazard lights illumination – Emergency services notification Uber's human operators remain post-crash to provide reasonable assistance to the involved parties, law enforcement officers, etc.	Post-crash vehicles will enter a safe state and immediately alert an OnStar Advisor. Doors automatically unlock and hazard lights turn on following a crash	In the event of a crash, testing is paused until the data is logged and analysed. Testing is resumed if the data reveals that the ADS and human operator acted appropriately If an investigation determines that the safety driver or ADS contributed to a crash or other incident, testing is resumed once all corrective actions (software, driver training or operational policy changes) are implemented	The Zoox report does not outline explicit post-crash behaviour but indicates that part of its operator training includes various response protocols for crashes of varying severity. It indicates the use of remote operators in uncertain situations in order to facilitate a return to a minimum risk condition (MRC)

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
Data recording				
Waymo describes a "robust" system for collecting and analysing data for all on-road encounters, and states that all crashes are reported in compliance with state and local laws	Uber data collection systems are equipped with ADS record telemetry, control signals and a Controller Area Network which manages overall system health as well as sensor and camera data Data is stored in real time on the vehicle and offloaded to data centres for storage, cataloguing, review and labelling. All data, at a minimum, must provide a baseline for crash reconstruction, as indicated by NHTSA guidance	GM Cruise employs two data recording features: a conventional Event Data Recorder and a robust data logging system that includes self-diagnostics and stores data securely, protecting it against loss The data recording system is designed to keep data intact even in the event of a crash. In addition to crash data, the vehicle records info on vehicle performance during normal driving and avoided crashes	Apple does not indicate specific data-recording practices but notes extensive data collection and analysis, particularly as it relates to post-crash data	Zoox data collection continues when a vehicle is involved in a crash Data is stored securely on vehicles as well as backed up at operation centres
Consumer education and training				
Waymo has launched "Let's Talk Self-Driving (letstalkselfdriving.com), the world's "first public education campaign" about fully self-driving vehicles, working in partnership with national and local safety, mobility and senior groups	Uber seeks to proactively "educate consumers on safety features… through blog posts, marketing campaigns, and direct exposure to self-driving vehicles" and engage communities in which it operates Uber plans to create a self-driving safety and responsibility advisory board	Upon the launch of the GM Cruise mobile app, in-vehicle touchscreens and other user interfaces will provide "helpful information and safety reminders" At the launch, GM plans to publish consumer information about what to expect when using the service to obtain rides	Apple states it "stand[s] ready to be a resource on current and future technological, regulatory and public policy matters"	Zoox provides the following educational resources for law enforcement and first responders: – Immersive educational information – Operational training exercises – A vehicle disengagement guide

Waymo 2018 Safety Report[95]	Uber 2018 Safety Report[96]	GM Cruise 2018 Safety Report[97]	Apple 2019 Safety Report[98]	Zoox 2018 Safety Report[99]
State and local laws				
Waymo software is designed to comply with federal, state and local laws; changes in these laws are identified by the system which also considers differences in traffic laws in different testing jurisdictions	Uber uses base vehicles certified by FMVSS Uber assesses relevant traffic laws for a given ODD and assures all vehicles are in accordance with insurance and financial responsibility laws in each jurisdiction in which it operates	All GM Cruise self-driving vehicles will meet applicable FMVSS; when these standards cannot be met because they are human-driver-based requirements, GM will file for exemption The programme is designed to comply with local and state laws in each AV ODD as well as with local non-traffic laws such as insurance requirements, etc. GM Cruise is working with industry groups and the NHTSA to develop new FMVSS that consider ADS technology	Apple reports that: "we vigilantly adhere to relevant regulations and requirements"	Zoox reports that: "as we prepare to deploy our technology safely for the public, we appreciate the opportunities to collaborate and share knowledge with regulators at the federal, state and local levels as they devise effective safety policies"

Appendix C

A comparative review of selected AV policy elements

Definitions

Singapore	UK	Australia	USA – California	USA – Arizona
Is automation level defined?				
Assumes L4 and L5 automation		Human driver responsibilities are clarified in L3 versus in L4/L5 automation	Regulations refer to L3, L4 and L5	Regulations relate to Levels 4-5, besides exposure to traffic citation or other applicable penalty
Is a minimal risk mode defined?				
Not explicitly; Reporting is required in case of 1. malfunctions of the AV or ADS 2. incidents involving personal injury or property damage	No. A trial on a non-public road is required to follow the laws and rules of the road	Not explicitly – the national pilot guidelines require testing organization to set out how they intend to manage any system failures, which could include system redundancy and fallback options	Yes. Defined as "a low-risk operating condition that an AV automatically resorts to when either the automated driving system fails or when the human driver fails to respond appropriately to take over the dynamic driving task"	Yes. Defined in Executive Order 2018-04 as a "low-risk operating mode in which fully autonomous vehicle operating without a human person achieves reasonably safe state, such as bringing the vehicle to a complete stop, upon experiencing a failure of the vehicle's automated driving system that renders the vehicle unable to perform the entire dynamic driving task
Is a "severe safety event" defined?				
No	No. Minimal accident data reporting requirements are defined (data should be recorded 30 seconds before and 15 seconds after an incident at a minimum frequency of 50 Hz)	"A serious incident" is defined as: a crash involving a trial vehicle or a violation of any law (e.g. exceeding the speed limit, committing a red-light violation, etc.)	No. There is a definition for "Disengagement"- a deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous vehicle test driver disengage the autonomous mode and take immediate manual control of the driverless vehicles, when the safety of the vehicle, the occupants of the vehicle, or the public requires that the autonomous technology be deactivated	No

Permit application requirements

Singapore	UK	Australia	USA – California	USA – Arizona
Required engagement with stakeholders				
Contacts with authorities	Contacts with landowners, members of the public, highway, transport and local authorities, the police, traffic commissioners and CCAV, with engagement throughout the project	Contacts with authorities	Contact the local authorities within the jurisdiction where the vehicles will be tested	Contact ADOT and the Arizona Department of Public Safety for the submission of Law Interaction Protocol
n/a	Public communication about an AV trial to inform and educate	Public communication about the trial to inform and educate	n/a	n/a
n/a	Consideration given to how to provide for vulnerable stakeholders	n/a	n/a	n/a
Type of information to be provided prior to trial/use				
– Types of AV and AV technology – Number of vehicles – Nature of modifications for trials – Safety documentation (additional information in the case of an ADS trial: objectives and ADS specifications)	Safety cases shared with the regulator and general public, including: – Trial information – Driver and operator training – Law compliance – Points of contact with related agencies – Safety plans	First supply for commercial deployment: Self-certification, including risk anticipation and responses incorporating: – Safe system design and validation processes – Operational design domain – Human–machine interface – Compliance with relevant road traffic laws – Interaction with enforcement and other emergency services – Minimal risk condition – On-road behavioural competency – Installation of system upgrades – Verification of the Australian road environment – Cybersecurity – Education and training	The manufacturer must submit the Autonomous Vehicle Form including: – Copy of Articles of Incorporation – Description of the ODD and how the vehicle reacts once outside the ODD – restrictive conditions – Consumer or end-user education plan – Copy of the law enforcement interaction plan – Voluntary assessment showing how safety can be achieved – Minimal risk mode	Written statement acknowledging that: – The vehicle is equipped with an ADS that follows all federal law and all Arizona State laws (unless exemption has been granted) – In case of failure the system will achieve minimal risk condition – The vehicle meets all applicable licensing, registration, certification and insurance requirements – Law enforcement protocol

Singapore	UK	Australia	USA – California	USA – Arizona
Related regulations				
ST 68	– Adherence to the Freedom of Information Act 2000 (FOIA) – Recommendation for safety cases to use the BSI PAS 11281:2018 "Connected automotive ecosystems. Impact on security of safety – code of practice" Automated and Electric Vehicles Act 2018	n/a	n/a	n/a
Conditions				
Conditions may apply, relating to: – Geographical area – Qualified safety driver (not specified) – Safety operator (not specified) – Prohibition to carry passengers – Prohibition to use for hire or as a reward – Lists of personnel permitted – Other	No conditions other than those related to existing laws on road use, insurance and licensing; TfL, in addition to other entities, should be contacted for trials in London	n/a	n/a	n/a
Modification				
Modifications to permits by the authority may occur, with notice, either in response to a trial or to non-compliance, or due to a ruling by the authority n/a	n/a	n/a	n/a Manufacturer can make modifications to permit by submitting a new form and a fee of $70	n/a
Extension/renewal of permit				
Application is required six months before the expiration of an existing permit; the period of extension is not specified	n/a (no permit specification)	n/a	Application is required 60 days prior to expiration date, payment of renewal fee	n/a

Singapore	UK	Australia	USA – California	USA – Arizona
Suspension/Cancellation of permit				
	n/a			
Fees				
Specified	n/a (no special permit required)	n/a	Specified	n/a
Application review timeframe				
Not specified	No review	n/a	10 days for testing and 30 days for deployment	No review
Safety				
TR68 part 2 sets detailed safety recommendations, including safety management system and risk mitigation strategy. A rigid safety assessment in a controlled environment is done prior to trial run	Safety features are expected to be shared publicly prior to conducting the trials Proposed safety assurance scheme for the future deployment of AVs	Safety Management plan is required when piloting Commercial deployment first supply approach - mandatory self-certification against safety criteria for vehicle supply	Testing the vehicle under controlled conditions that simulate ODD prior to piloting on public roads	n/a
Contingency plans				
Not required	Required	n/a	Law enforcement protocol is required in driverless piloting/ operating	Law enforcement protocol is required in driverless piloting/ operating

Operator requirements

Singapore	UK	Australia	USA – California	USA – Arizona
Distinction between entities				
n/a	A distinction is made between the driver (in-cabin or remote), the vehicle and the operating entity governing the trial	The human driver and the ADSE are distinct	Distinction is made between the test driver/ remote operator and the manufacturer	Distinction between safety driver, vehicle and automated driving system
AV driver requirements				
List of personnel permitted to drive	n/a	n/a	List of personnel permitted to drive	
Safety driver and safety operator	Safety driver and recommended backup	Human fallback driver in L3 automation; the guidelines allow testing without a human driver or operator, but safety issues must be addressed as part of an essential safety management plan	Safety driver/ remote operator depending on the type of permit	Safety driver/ remote operator depending on the type of permit

Singapore	UK	Australia	USA – California	USA – Arizona
			Safety driver is issued an Autonomous Vehicle Testing Program Test Vehicle Operator Permit	
			Training program to safety drivers and remote operators is required	Only a trained employee, contractor, or other person authorized by the company developing the autonomous technology can operate or monitor the vehicles
Valid licence	A valid licence, several years of driving experience and ongoing training are recommended		Valid driving licence, must be an employee, contractor or designee of the manufacturer, completion of manufacturers training programme is required. Safety driver was not involved as a driver in an accident causing injury or death, doesn't have more than one violation point, no conviction for driving under the influence of alcohol or any other drug.	
n/a	A maximum duration per drive and maximum daily driving hours are required		n/a	n/a
n/a	Drivers should be conscious of other road user presence and behaviour		Drivers should be familiar with the technology and its limitations	
n/a	The remote operator should deliver the same level of safety as the in-cabin driver, with two-way, real-time communication links and full processes to deal with failures			

Singapore	UK	Australia	USA – California	USA – Arizona
Operator requirements				
Authorization is given to "specified person"	A consultation paper by the Law Commission suggests Highly Automated Road Passenger Service (HARPS) operator licencing	Trials currently enable each state and territory to define the operator's safety duties and obligations; a new in-service Regulation Impact Statement (RIS) consultation paper suggests other methods for setting national operator requirements	Requirements apply only to manufacturers	n/a
Commercial pilots				
Offering the AV for hire or as a reward is prohibited	Commercial pilots are not prohibited, but relevant existing regulations apply (e.g. for-hire licensing and caps)	Trials of automated vehicles can be commercial; However, pilot guidelines are not intended to support large-scale commercial deployment of AVs	Commercial pilots are prohibited	Commercial pilots and operation are allowed. Waymo is operating automated ride hailing services
Modes transition				
n/a	Drivers should undergo training to transition between automated and manual driving modes	Appropriate transition between automated and human driving modes is key safety criteria in piloting safety management plan	Manufacturer shall describe how the vehicle is transitioning control to the driver once it is outside its ODD	n/a
AV/ADS security and safety from malicious interferences				
TR 68 part 3 suggests cybersecurity assessment framework and threat/risk analysis based on existing methodologies (such as Tara, EVITA, THROP, etc.)	Safety includes compliance with the eight cybersecurity principles developed by the Department for Transport in conjunction with the Centre for the Protection of National Infrastructure (CPNI) in 2017	Part of the safety assurance approach for first supply of AVs for commercial deployment is demonstrating the capacity of anticipating and mitigating cybersecurity risks as part of the ADS safety self-certification process	Manufacturer shall submit certification that the vehicle meets appropriate and applicable industry standards to help defend against, detect, and respond to cyberattacks	n/a
Software updating processes				
TR 68 part 2 requires AV developer to manage system updates in a transparent and verifiable manner, including providing an assessment of update implications on the compliance of the approved AV system	n/a	The operating entity needs to demonstrate risk mitigation efforts relating to technology updates and upgrades as part of the ADS safety self-certification process in first supply of AVs and as part of pilot's safety management plan	n/a	n/a

Singapore	UK	Australia	USA – California	USA – Arizona
Vehicle requirements				
n/a	Vehicle should be able to comply with road rules	The vehicle should: 1. be capable of complying with road rules 2. possess on-road behavioural competency 3. verify road conditions as part of the ADS safety self-certification process	Comply with all required Federal and state Motor Vehicle Safety Standards In driverless pilots/use: – vehicles should be capable of operating without a driver, and the technology meets L4-L5 requirements – There is a communication link between the vehicle and the remote operator	Vehicle should: – Comply with all federal and state laws applicable – Meet all applicable certificate, title registration, licensing and insurance requirements – Achieve a minimal risk condition once a failure occurs Driverless testing/use: vehicles should be fully autonomous
	If over 3 years old (4 years in Northern Ireland), the vehicle must have a valid MOT certificate	n/a		
Validation/conformity tests				
The authority has the power to request tests	n/a	n/a	n/a	n/a

Reporting requirements

Singapore	UK	Australia	USA – California	USA – Arizona
Data recording				
– Data cannot be edited and copies must be provided to the authority – Fines can reach $5,000	n/a	Data recordings should be kept for 7 days; data should be reported within 24 hours of an incident	To receive deployment permit, manufacturer should equip the vehicle with a data recorder	n/a
Some data must be recorded at a minimum 2 Hz frequency (speed, location)	Data must be recorded at a minimum 10 Hz	n/a	n/a	n/a
Data type				
Date and time stamp	n/a	Date and time stamp	n/a	n/a
Status of vehicle operation (manual, automated, etc.)	Status of vehicle operation (manual, automated, etc.)	Status of automation and vehicle information	n/a	n/a
Operator override history (during autonomous mode)	Operator override history, including the time of occurrence (during autonomous mode)	n/a	n/a	n/a

Singapore	UK	Australia	USA – California	USA – Arizona
Location (latitude and longitude)	– Location – Lateral acceleration when the vehicle is moving sideways – Longitudinal acceleration in the vehicle's driving direction	Location	n/a	
n/a	Vertical acceleration when the vehicle mounts a curb or similar action	n/a	n/a	
Speed	Speed	n/a	n/a	
Sensor data	Sensor data of other road users	Sensor information	n/a	
n/a	– Steering command and activation – Braking command and activation	n/a	n/a	
n/a	– Operation of vehicle lights and indicators – Connectivity and network access – Audible warning system (e.g. horn) – Remote command impacting vehicle movement (if applicable)	n/a	n/a	
n/a	n/a	– Traffic conditions – Road and weather conditions	n/a	
Data type				
Data always recorded, even when the AV technology is not in operation	At a minimum, recorded data capable of determining who controls the vehicle		Sensor data of all vehicle functions that are controlled by the autonomous technology at least 30 seconds before a collision	
Data collected in the format specified by the authority and kept for at least three years (regardless of the authorization period)			Data must be stored in a read-only format, must be capable of being accessed and retrieved by a commercially available tool	
Camera and video footage from three sources: internal facing, external front and rear	Recorded data that preferably includes elements such as sensors, control system, video, audio (not as an alternative to above specifications)			

Singapore	UK	Australia	USA – California	USA – Arizona
Event reporting				
Of any: – Malfunction of the AV or ADS – Incidents involving personal injury or property damage	In case of an accident, data recorded 30 seconds before and 15 seconds after the incident at a recommended minimum frequency of 50 Hz	Incident reporting: Any serious incident must be reported to the relevant road transport agency with relevant data in a form that can be easily read and interpreted by the agency **Time frame:** – Data must be provided within 24 hours of the incident – A full re port including relevant data and information must be provided within seven days of the incident **Other cases requiring reporting include:** – Near misses – When a human takes back control of the vehicle – When a public complaint is received regarding the performance of the vehicle **Time frame:** – On a monthly basis – If requested, within seven days **Data recording in case of serious incidents:** All information relevant to a "serious incident" and system performance must be collected and provided so that the circumstances of the event can be reconstructed **Data could include:** – Identity of the vehicle operator at the time of the incident	Collisions - Bodily injury or damage to property - within 10 days after the collision Disengagements - annual report including total number of miles driven	

AV liability requirements and legal aspects

Singapore	UK	Australia	USA – California	USA – Arizona
Insurance				
According to existing vehicle insurance requirements; an alternative exists if insurance cannot be obtained: a deposit of $1.5 million paid to the authority, to be used in case of death, bodily injury and/or property damage	According to vehicle insurance requirements (the driver must provide insurance details in case of an accident); Compulsory insurance was extended to cover accidents involving AVs in 2018	Inclusion of AV insurance in current schemes (each is governed slightly differently in various states and territories); as of August 2019, ministries agreed to pursue changes to the existing MAII to favour a national approach led by the Board of Treasurers, primarily by: – Reviewing insurers' mechanisms to recover their claim costs – Creating provisions enabling people involved in an AV crash to access MAII scheme. – Considering data access for MAII insurers to assess liability and next stage in-service safety work	– According to existing vehicle insurance requirements; – Surety bond in the amount of $5 million. – Certificate of self-insurance- with audited financial statements reflecting a new worth of not less than $5 million	According to existing vehicle insurance requirements
The insurer must be registered in Singapore	n/a	The insurer must have a corporate presence in Australia		
Criminal Liability				
n/a	A new system of sanctions to replace some criminal offences for AVs has been proposed but not yet introduced as policy	A new system of sanctions to replace some criminal offences for AVs has been proposed but not yet introduced as policy	n/a	n/a

Endnotes

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25. UK Autodrive, "About UK Autodrive", http://www.ukautodrive.com/the-uk-autodrive-project.
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35. UNECE, "World Forum for Harmonization of Vehicle Regulations (WP.29)", https://www.unece.org/trans/main/wp29/meeting_docs_wp29.html.

36. In October 2018, the federal government established the Commonwealth Office of Future Transport Technology, a 9.7 million Australian dollar (US$ 7.1 million) initiative to unify the state and territory governments and agencies to deliver future transport technologies in a safe and responsible manner (see https://www.infrastructure.gov.au/transport/land-transport-technology/office-of-future-transport-technology.aspx). The Office is coordinating the Australian Government's efforts to prepare for AVs, working closely with state and territory transport and road agencies through the Transport and Infrastructure Council.

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38. <?> South Australia, New South Wales and Victoria implemented changes to legislation to support trials through either exemptions (South Australia and New South Wales) or permits (Victoria). Austroads (the peak organization of Australian road transport and traffic agencies) tracks trials taking place in Australia and New Zealand (see Austroads, "Trials", https://austroads.com.au/drivers-and-vehicles/future-vehicles-and-technology/trials).

39. https://www.ntc.gov.au/sites/default/files/assets/files/NTC%20Discussion%20Paper%20-%20Review%20of%20guidelines%20for%20trials%20of%20automated%20vehicles%20in%20Australia.pdf

40. See National Transport Commission (NTC), "Motor Accident Injury Insurance and Automated Vehicles Discussion Paper", October 2018, https://www.ntc.gov.au/sites/default/files/assets/files/NTC%20Discussion%20Paper%20-%20Motor%20Accident%20Injury%20Insurance%20and%20Automated%20Vehicles.pdf.

41. See National Transport Commission (NTC), "In-service safety for automated vehicles: Consultation regulation impact statement", July 2019, https://www.ntc.gov.au/sites/default/files/assets/files/NTC%20Consultation%20RIS%20-%20In-service%20safety%20for%20automated%20vehicles.pdf.

42. The NTC published a policy paper on regulating government access to cooperative intelligent transport systems (C-ITS) entitled "Regulating government access to C-ITS and automated vehicle data" (August 2019, https://www.ntc.gov.au/sites/default/files/assets/files/NTC%20Policy%20Paper%20-%20Regulating%20government%20access%20to%20C-ITS%20and%20automated%20vehicle%20data.pdf) and received submissions from the public regarding key principles to consider in the process. Since the end of 2019, the NTC has been considering specific legislative compliance and enforcement mechanisms for the government to manage AVs.

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