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CENTRE FOR THE FOURTH INDUSTRIAL REVOLUTION

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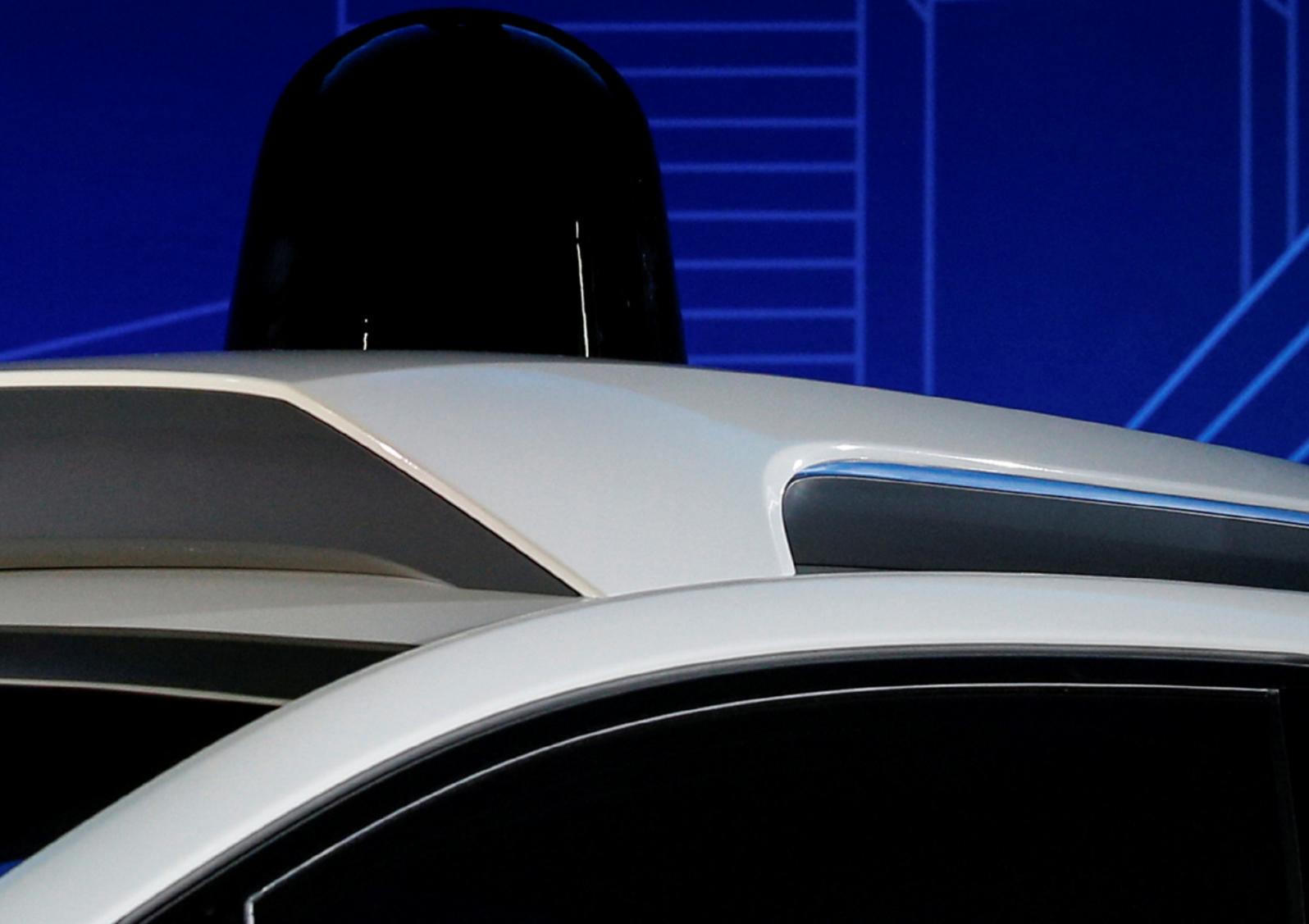


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Autonomous Vehicle (AV) Policy Framework, Part I: Cataloging Selected National and State Policy Efforts to Drive Safe AV Development

INSIGHT REPORT

OCTOBER 2020



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Foreword



Miri Regev M.K.
Minister of Transport &
Road Safety

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, 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.

Foreword



Dr. Ami Appelbaum
Chief Scientist and Chairman
of the Board of Israel
Innovation Authority



Murat Sönmez
Managing Director, Head of the
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Revolution Network, World
Economic Forum

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

A significant factor in Israel's technology leadership has been the support of the Israeli government, who has been empowering innovation by supporting research and development processes. As disruptive technologies begin to enter heavily regulated industries, such as transportation, finance and health, an agile approach to regulation is needed to protect the public without stifling innovation, as regulation plays a key role in enabling and stimulating innovation.

To enhance the readiness of the Israeli market for the entrance of new technologies, the government of Israel decided to join as an affiliate to The Centre for the 4th Industrial Revolution Global Network (Hereinafter: "C4IR"). The C4IR was founded by the World Economic Forum to create a new space for multi-stakeholder collaboration in developing policies, governance principles and protocols that accelerate the implementation of the disruptive technologies of the Fourth Industrial Revolution.

The Israeli Innovation Authority was mandated by the Government of Israel to serve as the hosting entity of the Israeli C4IR affiliate center, as it is a central hub for supporting innovative technologies and addressing the needs of the Israeli Hi-Tech industry.

This paper is the first in an ongoing partnership between the World Economic Forum, the Israel

Center for the Fourth Industrial Revolution and Israel Ministry of Transportation 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 transportation future, but the interim development of these systems presents considerable challenges to policymakers who are seeking to understand this technology while protecting the interests of their citizens and creating tensions between the industry and regulators where their priorities differ. As with other 4IR technologies, multi-stakeholder approaches have proven to be successful in assisting policymakers to develop appropriate governance models which facilitate innovation and yield 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 in order to understand best practices and recommend 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 autonomous vehicles in future. We hope this paper further serves other decision-makers in understanding the challenges and opportunities in autonomous vehicle governance by highlighting best practices from leading global regulators.

Executive summary

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

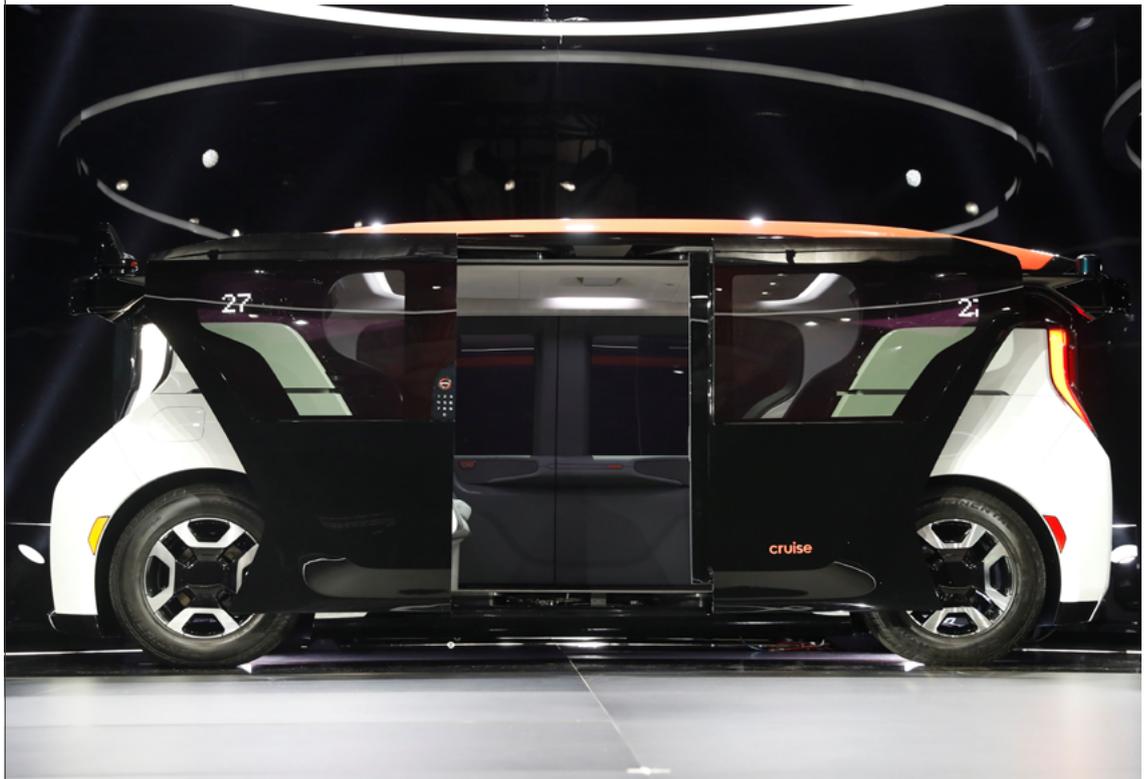
The industry's rapid development has encouraged regulators around the world to introduce AV policy frameworks to enable the safe experimentation and development of the technology. Approaches to AV policy vary greatly between nations and states and all are relatively nascent. This paper intends to assist Israeli policy makers to shape the regulatory framework for the deployment of AV technologies in Israel.

This paper evaluates policy approaches in three nations Singapore, the UK, Australia and two American states: California and Arizona; with input from the authors of the policies themselves. The reviewed nations and states recognise that an ideal AV regulatory environment is one that successfully advances technological improvements as well as market readiness, whilst ensuring AVs contribute to national and local mobility goals: safety, congestion reduction, equity in mobility, employment, economic growth, and sustainable mobility development. They further recognize that

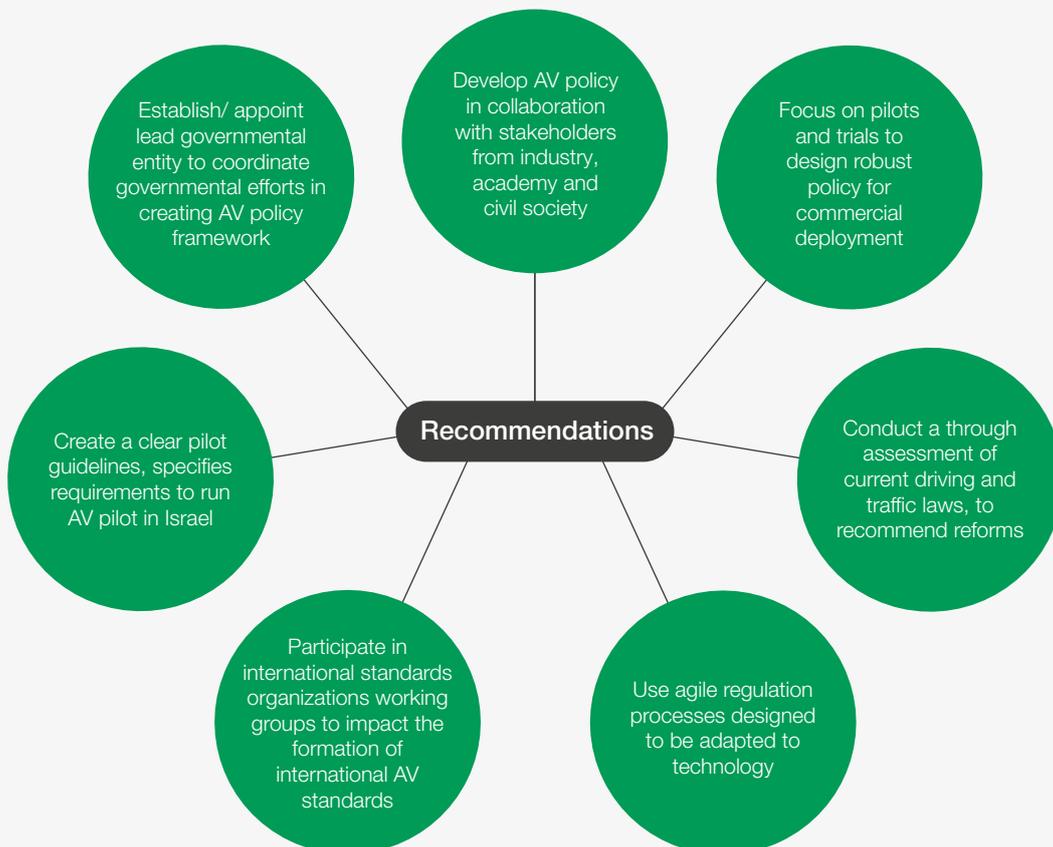
the first step to enabling the technological maturity of AVs is ensuring the safe piloting and testing of the technology.

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

- Establish dedicated authoritative bodies or committees capable of coordinating the complementary work of governmental agencies and ministries for ensuring consistent and coherent AV regulation:
 - Australia has established the Office of Future Transport Technology, within the Department of Infrastructure, Regional Development and Cities.
 - Singapore established the Committee on Autonomous Road Transport for Singapore (CARTS), comprised of international experts, academics and industry representatives, and emphasized on constant discourse and feedback from the industry.
 - The UK established the Centre for Connected and AVs (CCAV) a joint policy team comprised of representatives from the Department for Business, Energy & Industrial Strategy and Department for Transport.



- Create regulatory processes designed to be adapted to the technology. For example, establish an open and ongoing discourse between industry, academia and research institutes:
 - The UK Law Commission is surveying academics, industry, insurance companies, etc, as means to guide the nation's long-term AV policy framework.
 - Singapore established the Committee on Autonomous Road Transport for Singapore (CARTS), comprised of international experts, academics and industry representatives.
- In the absence of harmonised international standards, consider participating in working groups informing the development of those standards (e.g. the Centre for Connected and AVs, the Department for Transport, Innovate UK and Zenzic are partnering with BSI Group for advancing AV standardization¹); and propelling standards (e.g. Singapore created a national set of AV-specific standard termed Technical Reference 68.
- 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.
- Conduct a thorough assessment of the need to add AV specific requirements to existing human-driven vehicle laws and regulations:
 - 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.
 - Australia's NTC is conducting a comprehensive Regulation Impact Statement (RIS) process examining AV tailored insurance, liability, data sharing and safety regulation.
- 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 accumulate data and garner experience to be used as a foundation for the regulatory deployment framework:
 - California adopted regulations for pilots and more recently added a regulatory approach for public use of AVs.
 - The UK released a non-regulatory code of practice, which relies on existing regulations and encourages ongoing communication within the regulators, while it develops its AV policy framework to enable commercial use.
 - Singapore has initiated a regulatory sandbox for the period of five years, while the government develops a longer-term legislation and reconsiders the extension of the sandbox.





Safety – Most AV safety policies that exist today are interim measures because the technology is evolving – and must balance the tension between safety assurance and 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 autonomous vehicle policy, such as scenario-based safety assessments (Pegasus Projekt, UK CertiCAV). There are many technical standards for system (and sub-system) level safety published by industry consortia, standards 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 arguments-based approaches but none of these solutions have been formally adopted.



Driverless testing and operation – Several nations and states 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 However, there have not been substantial driverless pilots or operations thus far, and most of the states and nations reviewed in this paper still require an in-cabin safety driver.



Passenger Transport – AV pilots enabling public use are operational in Australia, Singapore, Arizona and the UK. 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 receive California Public Utilities Commission (CPUC) authorization to transport passengers. Currently, 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 reviewed policy environments and primarily in relation to disengagements and accidents.

Moving beyond basic safety requirements

AVs as a Service (AaaS) vs. personal utilisation of AVs – In the absence of the right 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. Singapore) as well as ride hailing pilots (e.g. Arizona, California) rather than individually owned and operated vehicles.** Regulators are not limiting options for private ownership but signalling AVs should operate as a service, and leading operators are dedicating efforts to on-demand commute and delivery services.

Public acceptance – Governments see public acceptance as paramount in 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, and Waymo's ride hailing service is being piloted in Arizona.

Insurance – Regulators and insurers are currently developing insurance solutions suitable for AVs. Some regulators specify a minimum amount of insurance (e.g. California), while others only state that insurance must be held (e.g. 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 for 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 – Currently, no modifications to liability structures have been made, and states and nations are relying on existing laws and regulations. While the UK and Australia are considering creating a new regulatory sanctions system, to be enforced on manufacturer/ operator in the case of an offence committed while the ADS was performing the driving task, it is still being examined 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, they are intended to increase both vehicle and road safety. Refers to SAE levels 1 & 2.
Automated driving system (ADS)	<p>The hardware and software collectively capable of performing the entire dynamic driving task on a sustained basis.</p> <p>The automation system used in vehicles with SAE levels 3, 4 or 5 of automation. (Source: SAE International J3016-20184)</p>
Automated vehicle (AV)	A vehicle with conditional to full automation (SAE levels 3-5) The vehicle has an automated driving system, which means it can perform the entire dynamic driving task on a sustained basis without human input. It is distinct from vehicles with automated features to assist a driver (SAE levels 1-2) that still 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)	<p>The entire dynamic driving task for sustained periods in defined circumstances undertaken by the ADS.</p> <p>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.</p>
Dynamic driving task	<p>All the 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:</p> <ul style="list-style-type: none"> – 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)	<p>All aspects of the dynamic driving task and monitoring of the driving environment undertaken by the ADS.</p> <p>The ADS can always operate on all roads. No human driver is required. Full automation is also referred to as level 5 (L5) automation.</p>
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 level 4 (L4) automation.
Minimal Risk Mode	A low risk operating mode in which a fully autonomous vehicle, operating without a human person achieves a reasonably safe state, such as complete stop, when experiencing a failure of the vehicle's automated driving system causing the vehicle not to be able to perform the entire dynamic driving task.
Mobility as a Service (MaaS)	A wide range of digital transport service platforms; taxi, private hire car services and online car sharing schemes.

Operational design domain (ODD)	The set of environments and situations the item is intended to operate within. 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 in 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 Society of Automotive Engineers (SAE) developed a classification system for self-driving cars in January 2014, which was 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 was adopted by the U.S. 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 driver'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 are not driving when these automated driving features are engaged – even if you are seated in 'the driver's seat'		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests	These automated driving features will not require you to take over driving	
				you must drive		

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

Whilst the potential of AVs is great, without proper governance, AVs may increase safety hazards, distances travelled, emissions, congestion and societal inequities. Therefore, governments worldwide are developing comprehensive regulatory frameworks that will enable the commercial use of AVs on public roads. Governments seek to introduce regulatory frameworks that allow for technological experimentation and development on the one hand and ensure public safety and positive impacts of AVs on the other.

The state of Israel is currently developing 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 commercialisation advances Israel's mobility goals. Therefore, 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 transportation and lessen private vehicle usage to reduce congestion. MOT is further considering the introduction of a transparent multi-stakeholder-informed regulatory framework prior to the 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

entities 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 to suit a rapid transition towards a shared, electric and automated mobility ecosystem. A key approach in the advancement of agile regulatory frameworks is engaging and consulting with local and including industry, academia, civil society, other government entities and members of the public experts. 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 as a leading market for AVs. Recognizing the infancy of AV technology and the need for global multi stakeholder consultation, the framework was developed through inclusive engagement, outlined in Figure 2, and guided by the key work principles, outlined in Figure 3.

This document is the first in a series of policy papers that will support the development of the MOT's AVs regulatory framework. First, Israel's current AV policy will be outlined. Followed by the review and comparison of AV policy approaches in five selected markets: Australia, Singapore, the United Kingdom, California and Arizona. In closing, the paper catalogues and synthesizes best-practices suitable for adoption in Israel.

The authors of this paper and the MOT aim to achieve multi stakeholder participation in the preparation of the framework, garnering best practices to create the most suitable regulatory framework for the deployment of AVs in the state of Israel.

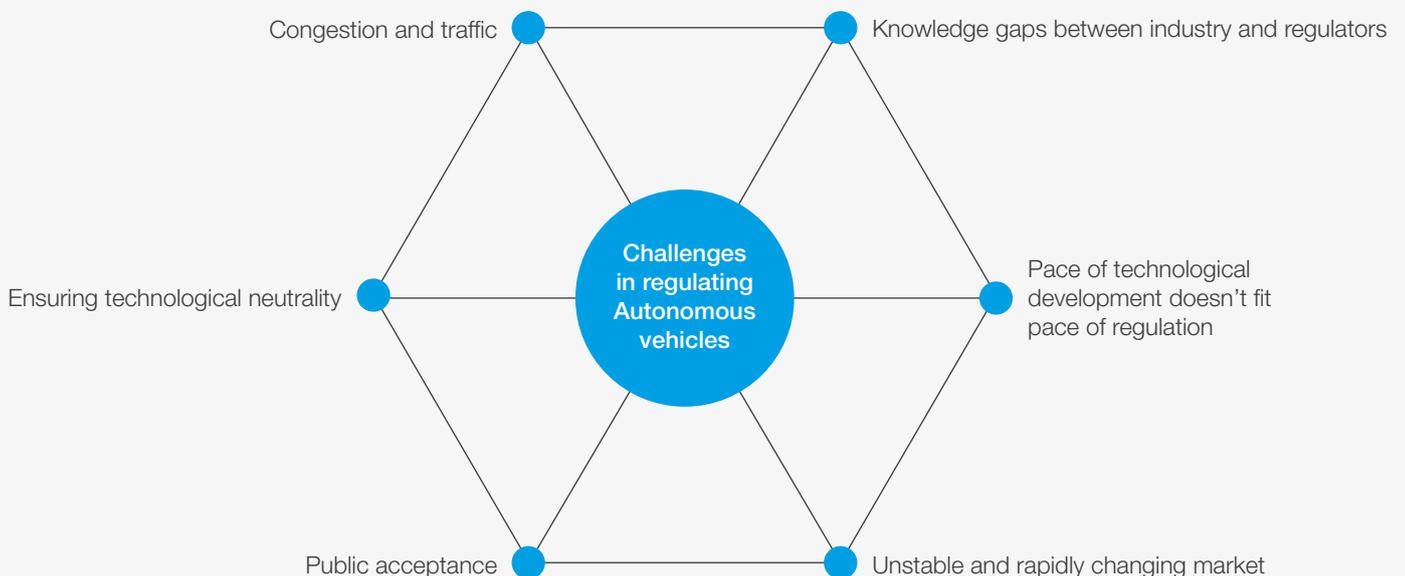
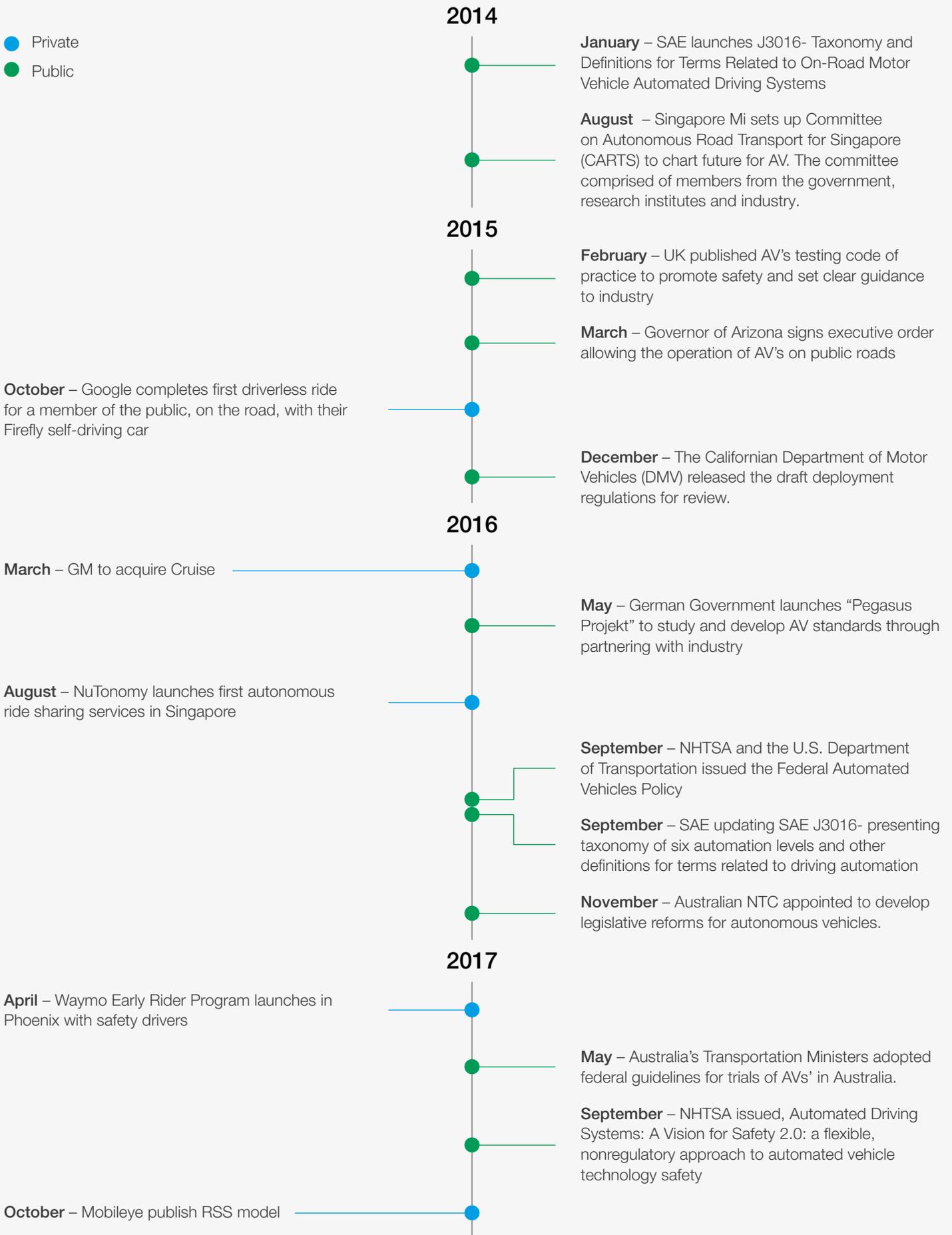


FIGURE 1 | Private- and public-sector milestones in AV development

- Private
- Public



2018

March – Uber vehicle kills pedestrian, Governor suspends Uber's testing permit one week later, NHTSA & NTSB launch investigation

May – Mobileye to begin testing AV in Israel together with Volkswagen and General Motors

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

July – Beijing Municipal Commission of Transport granted Baidu its first batch of T4 test permits to allow piloting of AV on the public roads.

August – Yandex launches what it claims is the first autonomous ride-hailing services in Europe, in Innopolis, and later in Skolkovo, Russia

October – Waymo receives first driverless testing permit in CA

October – Waymo starts charging passengers in Phoenix, Arizona, for rides in its AVs

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

February – California's driverless testing regulations were approved, 30 days later the DMV began approving applications.

March – Arizona's governor updating autonomous vehicles autonomous vehicles, allowing fully autonomous vehicles without a driver behind the wheel to operate on public roads.

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

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

June – The Japanese Government plans to start tests of AVs on public roads with the goal of offering autonomous car services for the 2020 Tokyo Olympics

August – The UK Parliament passes legislation expanding existing insurance schemes to cover damage caused by AVs.

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

November – UK Law Commissions initiated a three-year process to identify, consult and recommend long-term reforms for the deployment of AVs'

2019

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

March – Waymo and Zoox receive permission from the California Public Utilities Commission to carry passengers with their robo-taxis on California roads. They cannot charge for rides and vehicles must have a safety driver behind the wheel

June – WeRide is the first company to deploy long-distance tunnel crossing autonomous driving technology in Guangzhou, China

July – Waymo receives first commercial driverless permit in CA

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

February – Singapore publishes Technical Reference 68

June – The UL 4600 'Standard for safety for the Evaluation of Autonomous Products' is released

July – Bosch and partner Daimler receive approval from German regulators to operate their autonomous parking feature without having a human safety driver

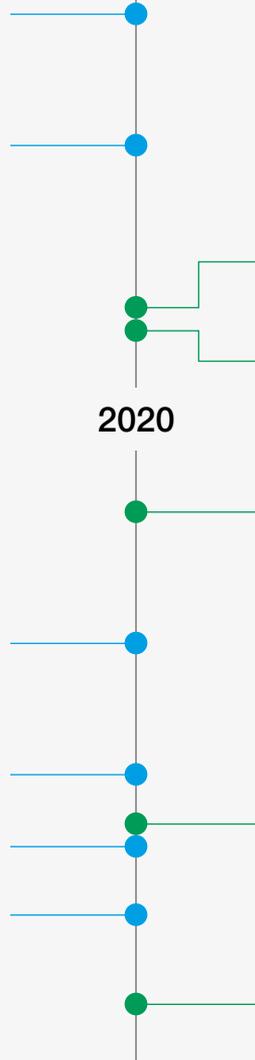
August – Didi Chuxing to start using self-driving vehicles to offer free rides in AV to its customers in a district in Shanghai city

February – Nuro R2 granted exemption from FMVSS (Federal Motor Vehicle Safety Standards) by NHTSA, allowing them to produce and deploy up to 5,000 of their driverless delivery vehicles over 2 years

April – Nuro given second driverless delivery permit by CA DMV

May – Amazon acquires Zoox

July – AutoX given 3rd driverless permit by CA DMV



October – The Australian NTC publishes its new AV regulations following a 3-year process of public reviews and research

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

January – The US DOT release new AV principles – Automated Vehicles 4.0

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

August – Israeli Ministry of Transportation releases a legislation draft for enabling driverless AV pilots



FIGURE 2 AV policy framework development process

Process stage	Key objectives and tactics
Step 1: Identify policy needs and develop subsequent framework structure	<ul style="list-style-type: none"> – Review the MOTs mobility goals and strategy and its AV approach to-date. – Collect information on AV policy challenges and opportunities from the perspectives of global private and public stakeholders – Develop key elements of the framework according to identified needs:
Step 2: Build a multi-stakeholder community* for devising the AV Policy Framework	<ul style="list-style-type: none"> – Screen and engage AV stakeholders. – Establish one-on-one interactions to set expectations and explore synergies with government and public representatives. – Scope key interest areas at an initial community meeting. – Finalize project plan and kick-off the project.
Step 3: Co-developing the AV policy framework	<ul style="list-style-type: none"> – Release the framework listed in Step 1. – Method: <ul style="list-style-type: none"> – Outline and review the draft. – Solicit contributions. – Draft and review the document. – Discuss the key challenging aspects in workshops throughout the process. – Suggesting policy recommendations.
Step 4: Iterating and scaling	<ul style="list-style-type: none"> – Present key learnings from the policy framework and the process by which it was developed in various international forums and events. – Forge collaborations with various countries that consider adopting elements of Israeli policy framework and/or the process by which it was developed.

*The community isn't a close one but rather remains open to new stakeholder engagement and impact

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

FIGURE 3 AV policy framework principles

Key policy framework development work principles



Accelerate technological developments through experimentation.



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



Create dynamic governance in harmony with a changing landscape.



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



Form efficient, transparent and authoritative management, evaluation and enforcement.



Minimize regulatory patchwork, tread lightly around the use of preemption and proactively pursue continuous improvement based on timely realworld governance impact evaluations.

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

2

What is an autonomous vehicle?⁵

Autonomous vehicle is the end-product of several technologies, developed over time, co-actively working to provide driverless transportation.⁶

Some technologies are new and innovative, and others are more established. At the foundation of AV's is the established mechanical vehicle comprised of the chassis, engine, transmission and steering mechanisms. To the mechanical vehicle, a layer of different technologies has been added to replace the human driver.⁷ This layer is comprised of input technologies,⁸ a processing unit and an output mechanism. An installed series of cameras, laser sensors, motion sensors etc, set to provide the

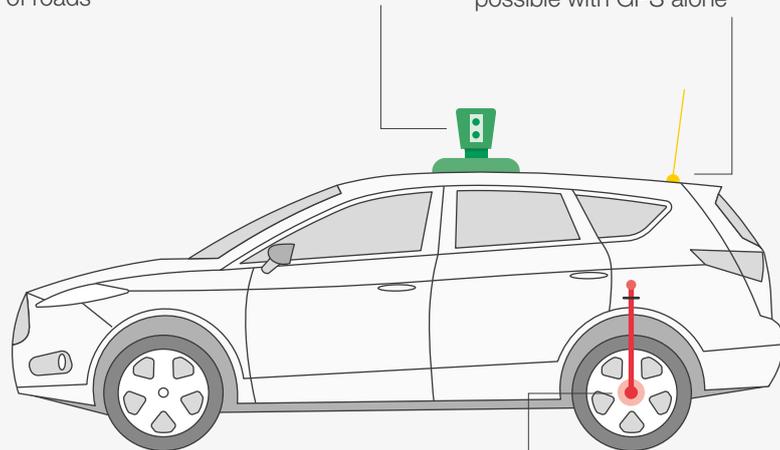
input gathering the required information about the surroundings.

A sophisticated set of algorithms, some created using Artificial Intelligence (hereinafter AI),⁹ acts as the processing unit, deciding what to do with the input provided. This "mind" uses a vast database gathered over a long period of time to deduce in any given situation the preferred action to reach a redetermined desired result. The output is a set of control mechanisms, which steer the car and decide whether to increase or decrease speed etc. All these different technologies of sensors, programming and mechanical processes, work in tandem to provide the result of an autonomous vehicle.

How a self-driving car works

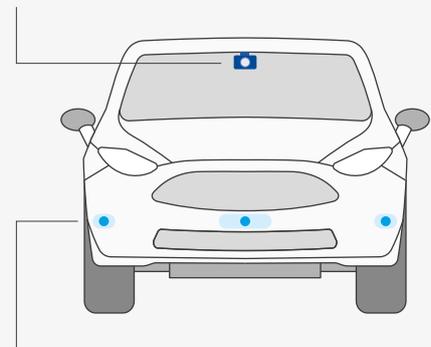
Lidar (light direction and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads

Signals from **GPS (global positioning system)** satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone

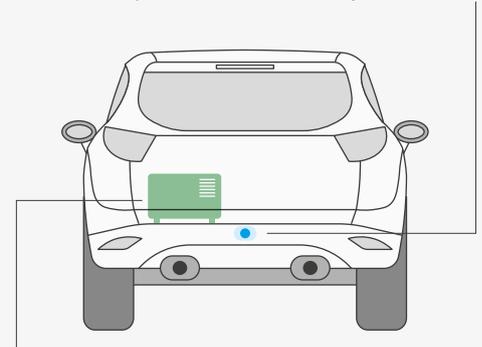


Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as a curbs and other vehicles when parking

Video camera detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road



Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems



The information from all of the sensors is analysed by a **central computer** that manipulates the steering, accelerator and brakes. Its software must understand the rules

Adapted from data provided by The Economist

In general, the process is thus:

When driving along the street, cameras and other sensors will pick up data from the surroundings and pass them on to the algorithms.

The algorithms will then determine where each of the identified objects is heading, and answer questions such as 'is the human going to cross the street', 'is the car going to stop' etc.



The algorithms will try to make sense of the raw data using face-recognition and other types of software. They will distinguish people from cars, and moving objects from stationary objects (where in space the car is).

The next step will be to determine what to do with the interpreted data; to continue forward, stop, go right or left. Algorithms will decide the best course of action, with reference to the basic rules to prevent harm, comply with the law and the ultimate objective of arriving to destination.

AI for autonomous driving

Autonomous vehicles use AI algorithms to replace the different decision-making processes of the human drivers. These sophisticated software codes have two main

tasks; To interpret the data coming in from the sensors thus achieving complete understanding of the surrounding environment; To decide how the vehicle will respond to each situation – considering the different variables, like traffic, streetlights, weather conditions, etc.¹⁰

The unique technological aspect of the autonomous driving algorithms is the use of AI to program some of the tasks which standard human programming cannot complete alone.¹¹ AI is essentially “teaching” a computer to solve

situations without programming each scenario in advance. In this learning process, programmers insert into the machine as much data as possible while attributing value to that data. The program utilizes different methods to discern a pattern from all the data and creates an algorithm which predicts what value will be given to any future data that will be entered.

This means that if programmers insert into the software 100 cases when running a red light leads to something undesirable happening, then the program creates an algorithm that predicts that in the future if you run a red light most probably something undesirable will happen. The more data you enter the machine, the more accurate will it be able to predict future outcomes.

3

Israel's AV policy

Challenges

- Insufficient public transit infrastructure and mass transit systems.
- Increasing population with high density in metropolitan areas while many newly developed areas were planned with insufficient infrastructure for public transit services.
- Heavy reliance on private car usage resulting in high congestion, mainly in metropolitan areas, economic loss and high emissions.
- Motorization rate is comparatively low to OECD countries and expected to keep growing.
- Shortage in transit depots and drivers.

Opportunity

- Making Israel a global hub and a prime location for AV pilots and deployment for AV companies from all over the world.
- Increase automobile electrification and reduce greenhouse emissions and pollution.
- Improve road safety and decrease casualties and economic loss.
- Deploying AVs in Israel in MaaS mode to improve the quality of public transit services and decrease usage of private cars and individual rides.



Strategy

Israel is home to US \$35 billion worth of mobility innovations that are re-shaping the global industry, with over 250 autonomous and connected start-ups.¹² Israel strives to be a global leader in the field of smart transportation and autonomous driving and is making significant steps towards integration of advanced technologies in infrastructure, on demand transportation, connectivity and MaaS.

In a comprehensive report¹³ published in September 2019, MOT shared its vision and goals in the smart transportation field. MOT aims to harness the smart transportation revolution to provide optimal mobility to 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 an emphasis on public and shared transport services.
- Preparing for a transition phase in which novel infrastructure is not yet available and operational and smart transportation solutions will have to focus on efficient use of existing infrastructure.

MOT is currently forming its strategy for the commercial deployment of AVs in Israel. Its goal is 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 transportation 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.¹⁴ These exemptions include, for example, the option to remove hands from the steering wheel or exceeding the speed limit.
- To receive a permit to conduct AV pilots on public roads, a company must receive the approval of two professional committees:
 - **Vehicle Divisions Committee:** Chaired by the Head of Engineering and Standardization Department at the MOT, comprised of representatives from relevant divisions in the Ministry and other relevant governmental agencies in accordance with the technology and type of approval requested.
 - **Advising Committee to the Traffic Controller Officer:** Chaired by Chief Scientist of MOT and comprised of representatives from Infrastructure Division, Vehicle Division, Public Transportation Authority, Police, and the Technion Technological Institution

MOT is currently revising its pilot procedure and considering the establishment of 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) in order to make

the Israeli pilot procedure more accessible to the global AV industry. On August 19th 2020 MOT released a legislation draft, enabling the approval of driverless pilots (or other forms of testing such as having only a controller but no driver on board).

MOT is intending to establish an Advisory Committee, headed by DG MOT with members from Ministry of Justice, Ministry of Finance, Prime Minister's Office, Innovation Authority, Israel Police and two experts in the field from industry/ academy. C4IR Israel is going to take part in the committee's discussions as representatives of the Innovation Authority.

The Advisory Committee shall:

1. Follow up the technological developments and the operation methods in the field of autonomous vehicle around the world;
2. Study the results of the experiments conducted in the field of the operation of an autonomous vehicle, in Israel and worldwide;
3. Collect data from Israel and the world, concerning severe safety events involving autonomous vehicles, analyze their causes and recommend on means to prevent them;
4. Propose the terms and conditions required, in its opinion, for the purpose of approving an autonomous vehicle experiment

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

The Approval Process:

- The AV operator is required to submit an application including a trial portfolio to the Vehicle

Division's 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 on 2019).¹⁵ The procedure presents a set of rules, terms and milestones required for the approval of trial vehicles conducting pilots on public roads in Israel.

- To perform AV pilots an exemption from Transportation Ordinance and Regulations is required. In this case, the Vehicle Division's 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 the Israeli Traffic Ordinance and Regulations.

Safety

- Israel is extremely focused on the safe deployment of AVs. All trial vehicles must go through a rigid safety assessment evaluation by the technical service/type approval authority, which includes:
 - Assessment of the functional and operational safety for the automated system design.
 - Functionality tests.
 - System failure tests.
- As of today, the Ministry requires the presence of a safety driver in the vehicle. According to the Ministry, so far there has been only one safety event with no damage to property or bodily injury.
- Currently, MOT is collaborating with the Technion-Israeli Institute of Technology, to develop a safety scenarios simulator that will ensure AVs safety prior to operating on public roads. So far, the Ministry has collected 42

safety scenarios tailored to Israeli environment and infrastructure in order to test the simulator.

AV Deployment Status

- There are currently 3 companies performing AV pilots on public roads in Israel: Intel's Mobileye, GM and Yandex.
- On December 2017, MOT launched an innovative testing centre operated by Ayalon Highways Co Ltd. The testing centre enables the examination of AV technology in a natural yet sterile environment by using closed sections of Ayalon Highway and other roads. Mobileye, General Motors, Innoviz, Argus Cyber Security, Nexar Ltd and others have all tested their technological solutions in the centre. The Ministry is planning to expand the current testing centre and to establish and operate a large and modern centre in a permanent location.
- On December 2017, Russian multinational technology company Yandex NV announced it had obtained permission to conduct test 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 receiving regulatory approval.
- The Ministry of Transportation is collaborating with Israeli Innovation Authority to support pilot programs for Israeli technology companies in the field of smart transportation. The participating companies are receiving financial support of between 20%-50% of the approved Pilot's expenditures. An exceptional support rate of 75% of approved R&D expenditures is awarded to programs with potential for exceptional impact on streamlining and improving transportation in Israel. This incentive program supports amongst other things the piloting and implementation of autonomous driving technologies.

4

National and state AV policy comparative review

4.1 National and state AV policy summary

This section reviews the development of AV policy in jurisdictions that are relatively resembles that of Israel: Singapore, UK, Australia, California and Arizona.

4.1.1 Singapore’s AV policy

Challenges

- 5.7 million people (and an ever-increasing population) on a mere 700 sq. m of land, resulting in 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 likely 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

Singapore Land and Transport Authority (LTA), an executing body of the Singapore Ministry of Transportation, is coordinating the government’s work on AVs by regulating pilots 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.¹⁶

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 the extension of the sandbox.

In 2017, the Singapore Ministry of Transport introduced an AVs Rules (‘AV Rules’) for prospective trials and use of AVs. The AV Rules and broader legislation framework enable the LTA to create

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 reaches adequate safety and security levels in an urban setting.

- 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 30 years of history and 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.¹⁷ Its members include renowned international experts, academics and industry representatives. The committee emphasized constant discourse and feedback from the industry.
- To support the vision and work of CARTS, the LTA signed a memorandum of understanding with Singapore's lead R&D agency A*STAR¹⁸ 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 in 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 concern. In 2019, the LTA published Technical Reference 68 for AVs (TR68) to guide the industry in the development and deployment of fully automated vehicles. The standards are divided into the 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 & 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 safety driver that has 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).¹⁹ The plan emphasizes public transport as well as shuttles and dynamic (on-demand) routes, including robo-taxis. Varying products available in different places and at various times of day are other key planning considerations.

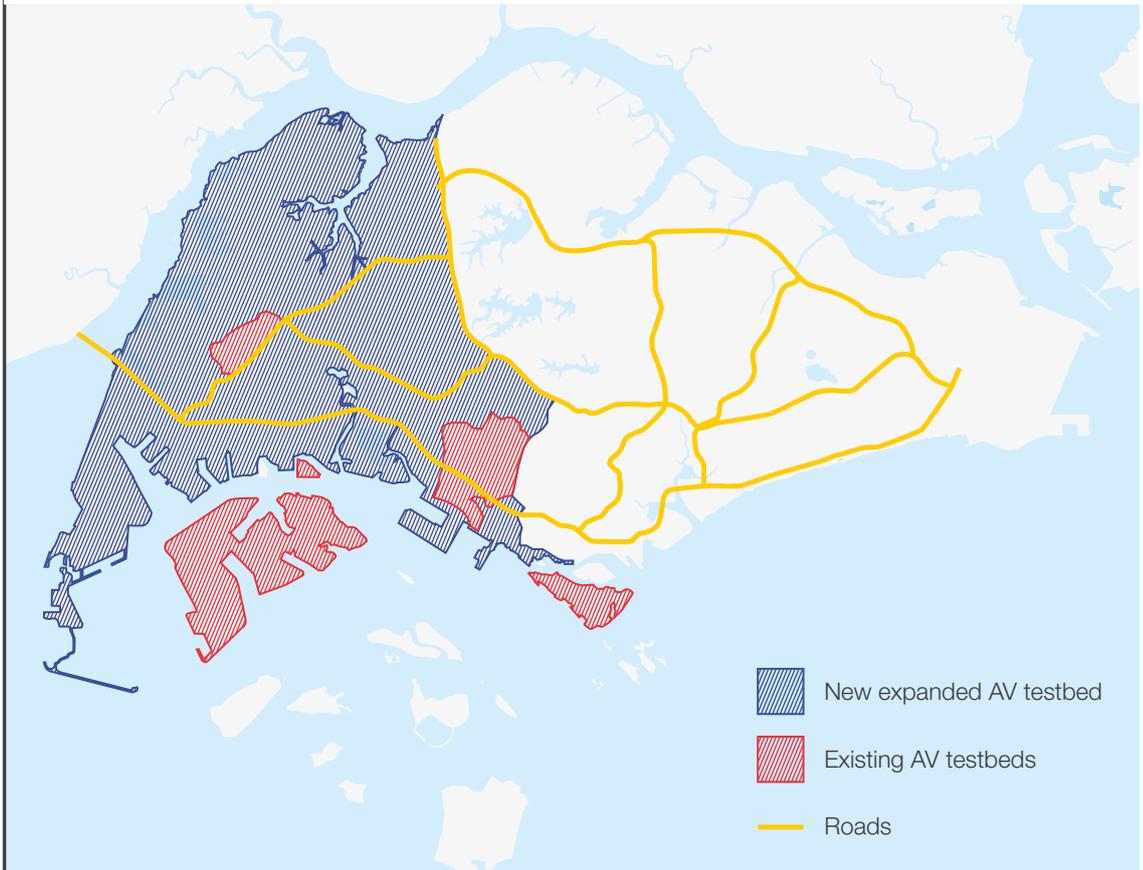
Infrastructure

- Due to its small size, Singapore is not planning to allocate dedicated lanes to AVs but to mix them in with regular traffic on high occupancy vehicle lanes and public transportation 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 km of road 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 1).

FIGURE 1: Singapore's AV Testing Area



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 Vehicles Rules, 2017 (January 2020 update)²⁰

	Trial	Use
Definitions	Road trial of an AV or AV technology	Road-use of an AV-, including a permission to operate a service -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: <ul style="list-style-type: none"> - Types of AV and AV technology - Number of vehicles - Nature of modifications for trials - Safety documentation - Objectives - AV system <p style="text-align: right;"><i>No additional requirements</i></p>	

	Trial	Use
Authorization	<p>Fees: \$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:</p> <ul style="list-style-type: none"> - 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	<p>The authority will give 14 days' written notice of any modifications.</p> <p>The modification date will be as stated regardless of any objections raised.</p>	
Extension	<p>Six months' notice is required by the requestee.</p> <p>The period of extension is not specified (or limited).</p> <p>Flexible and open policy regarding extension, tailored to company needs.</p>	
Cancellation/ suspension	<p>Cancellation or suspension may apply:</p> <ul style="list-style-type: none"> - 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 fit. <p>The ability to appeal exists but the authority rules until otherwise decided.</p>	
Liability/ insurance	<p>Liability insurance must always be in place and enforced, including during use or trials.</p> <p>The insurer must be registered in Singapore.</p> <p>A fine, limited to \$2,000, applies if no Singapore registered liability insurance is in place.</p> <p>If insurance according to the above cannot be obtained, a deposit of \$1.5 million can be paid to the authority to be used as needed in case of related death, bodily injury and/or property damage (if used, the deposit must be replaced to meet the required amount within 14 days).</p>	
Maintenance	<p>Ensuring good operating conditions of the AV, ADS and parts always is required.</p>	
Reporting	<p>Data collection:</p> <ul style="list-style-type: none"> - 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 3 years (regardless of the authorization period). <p>The data should include:</p> <ul style="list-style-type: none"> - Date and time stamp - Location (latitude and longitude) in at least 2 Hz frequency 	

	Trial	Use
	<ul style="list-style-type: none"> – 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 <p>Data recording:</p> <ul style="list-style-type: none"> – Data cannot be edited and copies must be provided to the authority. – An editing contravention 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. <p>Incident reporting:</p> <ul style="list-style-type: none"> – 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 The United Kingdom's AV policy

Challenges

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

Opportunities

- To support and promote the safe trialling 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 in order 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 trials on public roads in the UK, the government conducted a detailed legislation review 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),²¹ whilst relying on existing rules and regulations (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, in 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)²² was formed to govern public-sector efforts in support of connected and automated vehicles (CAVs) development. CCAV is part of the Department for Transport and Department for Business, Energy & Industrial Strategy.

In 2018 British Parliament passed the Automated and Electric Vehicles Act 2018²³ 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 some 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 2019²⁴.
- 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^{25,26}.
- 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 Program including PAS 1880 Guidelines for Developing and Assessing Control Systems for Automated Vehicles, and 1881 Assuring Safety for Autonomous Vehicle Trials and Testing.²⁷
- Data must be provided if needed, as well as full compliance in case of an investigation. On 17 July 2020, the BSI has 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 2017.²⁸
- 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 the increased 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 the safety of the system.
- Establish a new safety assurance scheme to authorize autonomous driving systems, to

complement 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, which includes 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

of 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.²⁹
- 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 London³⁰
 - UK Autodrive, Milton Keynes and Coventry (working together as one project)³¹
- 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)³²

Trial ³³	
Definitions	<p>Oversee various AV classes, including pods and shuttles, and a variety of purposes, including goods and passenger mobility</p> <p>NOT for the purpose of testing driver assistance technologies</p>
Engagement	<p>Minimal requirement:</p> <ul style="list-style-type: none"> - 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. <p>Public communication:</p> <ul style="list-style-type: none"> - 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.³⁴
- Adhere to the Freedom of Information Act 2000 (FOIA).³⁵

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 driver
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.

Data recording:

- At a minimum, record data capable of determining who controls the vehicle.
- Record data at a minimum of 10 Hz, including:

<ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> – 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)
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- 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 Australia's AV policy

Challenges

- Technological and institutional development barriers to the deployment of AVs (a 2016 National Transport Commission study identified 700 barriers³⁶).
- 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)³⁷ 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' Committee³⁸) through a partnership with Austroads³⁹ and the Department of Infrastructure, Transport, Regional Development and Communications⁴⁰ (which represents Australia in the UN World Forum for Harmonization of Vehicle Regulations WP.29⁴¹) and territory transport road agencies.⁴²

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, Australia's ministries adopted the "Guidelines for Trials of Automated Vehicles in Australia".⁴³ 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.⁴⁴ 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.⁴⁵

In May 2018, Australia's 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 regulate 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.⁴⁶

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.⁴⁷ 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.⁴⁸
- **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 Review of Guidelines for Trials of Automated Vehicles in Australia” published on May 2020 by the NTC:⁴⁹

- Since National Guidelines for Automated Vehicle Trials were published in 2017 approximately 15 AV trials have taken place in Australia.
- Up to date, there have not yet been trials of large number of AVs in Australia.
- Most trials were shuttle buses in limited operating domains.⁵⁰
- Other technologies that are 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, 2017⁵¹

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	<ul style="list-style-type: none"> – 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	<p>The permit application should:</p> <ul style="list-style-type: none"> – Clarify trial location. – Describe the technology being trialled. – Provide a safety management plan, including anticipated risks and mitigating actions: <ul style="list-style-type: none"> – 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	<p>All trialling organizations must develop a safety management plan to identify and manage key safety risks, including:</p> <ul style="list-style-type: none"> – 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- for the time of writing this paper, all trails in Australia requiring the presence of a safety driver in the vehicle. – Training provided for the driver/ operator. – Whether vehicle identifiers will be used to signal to other road users that the vehicle is autonomous.

Trial

Cancellation/ suspension	<p>If any condition of the exemption or permit is not complied with, the exemption or permit may be suspended or revoked.</p> <p>Penalties may also apply, depending on the state or territory’s enabling legislation or regulations.</p>
Liability/ insurance	<p>Appropriate insurance must be provided to protect against risks included during the trial, such as a state-based insurance scheme.</p>
Reporting	<p>Data recording in case of serious incidents:⁵² 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.</p> <p>Data could include:</p> <ul style="list-style-type: none"> – 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. <p>End-to-end trial report on research outcomes: high-level summary with no requirement for any commercially sensitive information.</p> <p>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.</p> <p>Time frame:</p> <ul style="list-style-type: none"> – The data must be provided within 24 hours of the incident. – A full report including relevant data and information must be provided within 7 days of the incident. <p>Other cases requiring reporting include:</p> <ul style="list-style-type: none"> – Near misses – When a human takes back control of the vehicle – When a public complaint is received regarding the performance of the vehicle. <p>Time frame:</p> <ul style="list-style-type: none"> – On a monthly basis – If requested, within 7 days
Commercial Trials	<p>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.</p>

California's AV policy

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 reductions 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 DMV⁵⁶ 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,⁵⁷ 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 California's regulation were held in 2014, 2015 and 2019.⁵⁸ 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 vehicle⁵⁹ testing and deployment (since 16 December 2019).
- Information for manufacturers testing AVs with a driver
 - The AV Tester Program administered by DMV's 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).⁶⁰
- 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.^{61,62}
 - Two companies has 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.⁶³
- **Permit for public use (passengers' commute)**

In case a permit holder wish to transport members from the public who are not employees, contractors or designees of the manufacturer, manufacturer must apply to California Public Utilities Commission (CPUC), to participate in California's Autonomous Vehicle Passenger Service Pilot. As of June 3, 2020, 7 permit holders that are 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);⁶⁴ archived reports are available to the public upon request.⁶⁵

– **Hearings and workshops**

Hearing and workshops’ video recordings are made available online.⁶⁶

– **Contingency plans**

Law enforcement interaction plan for “first respondent” (law enforcement, fire department, emergency medical personnel) is required for emergency and traffic enforcement situations; such 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
Definitions⁶⁷	Autonomous mode, autonomous test vehicle, dynamic driving task, minimal risk condition, operational design domain, disengagements, testing, deployment, personal information ⁶⁸		
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. ⁶⁹		
Permit application for testing or operating vehicles	<p>The manufacturer must submit Autonomous Vehicle Tester (AVT) Program Application for Manufacturer’s Testing Permit,⁷⁰ including:</p> <ul style="list-style-type: none"> – 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 	<p>The manufacturer must submit the Autonomous Vehicle Form OL 318 Driverless Testing Permit Checklist,⁷¹ including:</p> <ul style="list-style-type: none"> – 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 	<p>The manufacturer must submit the Autonomous Vehicle Form OL 321 Deployment Checklist,⁷² including:</p> <ul style="list-style-type: none"> – 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
	<ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> – 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	<p>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.</p> <p>The test driver must be in immediate physical control or be actively monitoring the vehicle and capable of taking immediate control of the vehicle.</p> <p>The vehicle has a mechanism that is easily accessible to the operator to engage and disengage the autonomous technology.</p> <p>Remote operators have completed enough training programmes.</p> <p>Driverless testing:</p> <ul style="list-style-type: none"> – 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. 	<p>Description of any commonly occurring or restricted conditions (including weather limitations) under which the vehicle is unable to operate</p> <p>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</p> <p>Description of how the vehicle is designed to react when outside its ODD</p> <p>Copy of the manufacturer’s law enforcement interaction plan⁷³</p> <p>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</p>	
Modifications	<ul style="list-style-type: none"> – 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
<p>Cancellation/suspension</p>	<p>Upon 15 days written notice:</p> <p>Any act or omission of the manufacturer or one of its agents, employees, contractors, or designees which the department finds makes the conduct of autonomous vehicle testing on public roads by the manufacturer an unreasonable risk to the public</p> <p>Driverless testing permits additional grounds for suspension:</p> <p>The manufacturer's driverless AVs are operating outside of operational design domain specified in the application submitted pursuant to Section 227.38 of this article.</p> <p>The manufacturer fails to make the disclosures required by subdivision (i) of Section 227.38.</p>		<p>Upon 30 days written notice:</p> <ul style="list-style-type: none"> - The manufacturer has 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 fails 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 fails to comply with any of the provisions of this article related to the deployment of AVs. <p>Immediate suspension</p> <ul style="list-style-type: none"> - If a manufacturer, distributor, or remanufacturer license 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. <p>The manufacturer's vehicles are not safe for the public's operation.</p>

	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. ⁷⁴ 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. ⁷⁵
Reporting	<p>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.</p> <p>Disengagement report: Manufacturers are required to submit an annual report summarizing the disengagements of the technology during testing.⁷⁶</p>		
Disposal or transfer of test vehicles	<ul style="list-style-type: none"> – The transfer of ownership is only possible 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 Nonrepairable Vehicle Certificate⁷⁷ 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 2 years.		
Commercial trials	<p>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.</p> <p>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 California Code of Regulations AVs</p>		

Arizona's AV policy

Challenge

- Public acceptance, regaining public trust after the fatal Uber crash on 18 March leading to a \$10 million lawsuit against the state⁷⁸.
- 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 growth⁷⁹
- Improved transport safety, reduced transportation costs, decreased road congestion and travel time, reduced fuel consumption and increased productivity, according to the Arizona Commerce Authority⁸⁰

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 Ducey's executive order from that year states that all agencies of Arizona should support

the testing and operation of self-driving cars on public roads in Arizona.⁸¹ 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 2016.⁸²

Tactics

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

- First executive order (25 August 2015) encouraging self-driving systems' cross-agency collaboration in support of ADS testing on public roads⁸³
- Second executive order (1 March 2018) leading to:⁸⁴
 - The establishment of the Institute of Automated Mobility⁸⁵ under the Arizona Commerce Authority, a public-private consortium of businesses, higher education institutions and government officials to promote greater collaboration in the AV industry⁸⁶.
 - 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 Arizona⁸⁷.
 - The authorization of fully driverless cars without a person behind the wheel to operate on public roads, and subsequent requirements:⁸⁸
 - 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 protocol⁸⁹
 - 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:

There are over 12 AV companies piloting and operating over 600 automated test vehicles on Arizona's roads.⁹⁰

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

Policy summary

	Trial	Use
<p>Definitions</p>	<p>Automated driving system: The hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational design domain</p> <p>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:</p> <ul style="list-style-type: none"> – 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 <p>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</p> <p>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</p>	
<p>Compliance with federal and state law</p>	<p>All testing or operation, with or without a natural driver, is required to follow all federal laws, Arizona state statutes, Title 28 of the Arizona revised statutes, and all regulations and policies set forth by the Arizona Department of Transportation, in this order.</p>	
<p>Permit application for testing or operating vehicles</p>	<p>Testing/operating (with a driver)</p> <p>Submission of a written statement to the ADOT acknowledging that:</p> <ul style="list-style-type: none"> – 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 	<p>Testing/operating (without a driver)</p> <p>Submission of a written statement to the ADOT acknowledging that:</p> <ul style="list-style-type: none"> – 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 performing 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	<p>The operating entity must provide a law enforcement interaction protocol, including:</p> <ul style="list-style-type: none"> – 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	<ul style="list-style-type: none"> – Documents on file with the MVD must show the vehicle meets the financial responsibility requirements under ARS section 28-4135.⁹¹ – The insurance details of AVs operating on public roads without a driver are made public in Arizona on websites (e.g. Waymo).⁹² 	
Reporting	There are no requirements apart from insurance details and collision reporting collaboration with enforcing entities.	
Disabled vehicles	<p>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:</p> <ul style="list-style-type: none"> – Pursuant to ARS section 28-871, 28-872⁹³ – 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 state-level AV policies outlined in chapter 4.1. The sub-sections listed in Annex C were designed

in response to Israel's proposed regulation principles as articulated in AV Regulation draft 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/ academy			Regulations	Executive Order

For more detailed comparison between the different nations and states, please see Annex C

Synthesis and recommendations

Regulation in all the reviewed nations and states is still nascent and constantly evolving so this paper sought to identify commonalities and highlight distinctions. By synthesizing regulators' decisions from various contexts, we draw initial recommendations that may forward the work of Israel's Ministry of Transportation 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 infancy of the technology and the market benefits of supporting its development. The need to ensure public safety while the technology through road while the technology development progresses through road experimentation, has motivated the introduction of a spectrum of safety requirements. The potential pitfalls of AV commercialisation have also been broadly acknowledged, including sustainability and inclusivity impediments, but only lightly addressed through current regulation. Some of the reviewed regulatory environments advocate for electrification and shared rides in order to mitigate the adverse effects of AVs and plan to introduced related measures in the future.

Short term versus long-term regulatory approaches: All three nations have established dedicated entities to coordinate and lead governmental efforts in creating 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.

Forming regulation through multi-stakeholder consultation and ongoing discourse: Multi-stakeholder 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 adopt a slightly different approach: while Australia's guidelines allow AVs without a human driver or operator, 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 individuals projected to 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 are specific in their reporting requirements, while Singapore is less precise but requires that information on technological malfunctions be reported. California requires collision reporting, miles driven and annual disengagement reporting, 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 from last year. 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, an AV regulation requires a profound change in the perception of driving, enforcement, road safety and privacy. Therefore, it is crucial to engage all relevant governmental agencies as early as possible. While AV policy approaches depend on existing regulatory environments, institutional structures, cultural settings, technological capacities and other unique characteristics, 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 state's mobility goals and improves its overall mobility system. Therefore, investing in a policy framework that includes not only safety considerations but also the implications of AV commercialisation on congestion, multimodality, emissions, access and economic growth is critically important. AVs can shape a better mobility ecosystem, if designed right.

A guide for AV regulation

Define and communicate policy goals.

Form an authoritative body capable of designing an AV policy.

Design pathways for engaging multi-stakeholders, from the public, private, and Civil Society, in a manner that is sustainable and collaborative to all.

Consider bi-directional exchanges of information with the general public, not only for user education and awareness building, but also to account for concerns and various needs of road and mobility users (disadvantaged groups etc.).

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 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 commercialisation.

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.

Acknowledgements

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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 a progressive agile governance for the deployment of AVs in Israel, that improves the state of mobility through consultation with global industry leaders and regulators and other significant stakeholders from around the world.

C4IR Israel autonomous mobility objective is to foster safe growth of autonomous technology and innovation, enhance the governments' mobility goals, and position Israel as a leading player in the field.

Appendix A

Key principles of driverless AV pilots legislation draft

A Title of the proposed law

Traffic Ordinance (Amendment No. 129) (autonomous Vehicle Experiments), 2020

B Objective of the bill, the need for it, main points of its provisions and its effect on existing law

In recent years, the development of an autonomous vehicle has been advancing all over the world, that is - a vehicle capable of traveling on the road, where instead of the driver – there is an autonomous driving system that combines hardware and software components that allow it to control the vehicle. This system operates the driving actions of the vehicle based on data collected by sensors and other means, which are processed with artificial intelligence technology.

The State of Israel is at the forefront of the said development and there are currently a number of companies, both Israeli and foreign, which are conducting trials of autonomous vehicle travels in Israel. In these experiments, the autonomous driving system drives the vehicle but there is an experiment driver therein, whose role is to control the vehicle in the case of an emergency, and within the said framework, there are no passengers in the vehicle. These experiments are conducted in accordance with an approval granted by the National Inspector of Transport, under Regulation 16a of the Transport Regulations, 1961. Pursuant to government resolution No. 2316, dated January 22, 2017, the State of Israel is striving to be amongst the world leading countries in this sector, and this bill is intended for regulating the transition phase from experiments in autonomous vehicles with such a safety driver to experimental drives in autonomous vehicles without a driver at all, even within the framework of transportation of a paid or unpaid passenger, by means of a variety of technological solutions for the operation of autonomous vehicles.

Alongside these experiments, it is proposed to form a legal infrastructure for experiments in less-advanced vehicles, which carry out only a share of the driving tasks by means of autonomous systems, when they have a driver who performs the rest.

This bill is intended to present the principle conception of the Ministry of Transport and Road Safety, with regard to continuing to promote the development of the autonomous vehicle in Israel, while various details continue to be examined.

Essence 1:

It is proposed to authorize the Minister of Transport and Road Safety (Herein: the “Minister”) to regulate by regulations the rules for the execution of autonomous vehicle experiments without a driver and with passengers.

Essence 2:

It is proposed to authorize the National Inspector of Transport to grant an approval for carrying out an experiment in an autonomous vehicle, to any person who is compliant with the terms and conditions set forth in the regulations. The approval shall include the terms and conditions for the execution of the experiment, the terms and conditions for its cessation, and exempts from the applicability of the rules of conduct on the road, which are stipulated in Part B of the Transport Regulations, and which do not apply to an autonomous vehicle, and which are exempted from the vehicle license conditions, to the extent that these are irrelevant.

Essence 3:

It is proposed to establish an advisory committee, headed by the General Director of the Ministry of Transport and Road Safety (Herein: the “Ministry of Transport”), to be comprised of members of the Ministry of Transport, Israel Police, Fuel Substitutes and Smart Transportation Administration, the Innovation Authority, the Ministry of Justice and representatives of the public. The committee shall serve as a center of knowledge in respect of all matters concerning the autonomous vehicle, from Israel and from overseas, on the basis of which it shall prepare reports and advise the Minister on matters concerning autonomous vehicles.

Essence 4:

It is proposed to obligate any entity carrying out autonomous vehicle experiments, to immediately report to the National Inspector of Transport about the occurrence of a severe safety event over the course of conducting the experiment. The Inspector shall be entitled, following the report – to order to cease the experiment or amend its terms and conditions.

Essence 5:

It is proposed to publish for public knowledge information concerning autonomous vehicle experiments.

Essence 6:

Together with the autonomous vehicle that does not require a driver, there are companies that develop vehicles with a lower autonomous level, in which some of the driving tasks are performed using autonomous systems, but they 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 regulate regulations that will enable the National Inspector of Transport to grant a permission to perform experiments on such vehicles, including while transporting passengers.

Explanatory Notes

General This bill proposes a regulation that will enable experiments in an autonomous vehicle, without having a driver in it, and while it is driving passengers. To date, experiments have been conducted in Israel on the operation of autonomous vehicles, in an outline that examines only the very functions of the vehicle under different conditions; the purpose of this proposal is to enable an experiment in an autonomous vehicle, in such a manner that simulates a commercial operation outline, in which – unlike in the existing experiments – there will not be a driver in the vehicle, and there will be passengers, including paid passengers, all which will be carried out on public road and not only in closed compounds.

In respect of Section 1**In respect of Section 9B**

Among the definitions proposed in this bill, it is proposed to define an “Autonomous Driving System”, which is a system that is capable of carrying out all of the driving tasks of the vehicle. There are two types of these systems – high independence driving system, which is a system that is able to carry out the said tasks pursuant to pre-defined terms and conditions, such as – only during day light hours, and a full independence 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, a conditional independence driving system exists, which is a system with the ability to carry out some of the driving actions independently, which – in professional terminology – is called autonomous driving system level 3. According to what is proposed, a vehicle with the said driving system shall not be considered an autonomous vehicle, and the majority of the provisions of the law shall not apply to it.

In respect of Section 9C

It is proposed to authorize the Minister, in consultation with the Advisory Committee, to stipulate by regulations the arrangements for the

approval of experiments in an autonomous vehicle. The proposal prescribe that this is indeed a learning process in the rapidly varying technological world, and that it is mandatory for the law to be able to quickly respond in accordance with the accumulated in experience and the varying knowledge.

The purpose of the Regulations is to ensure road safety and other public interests, including the reduction of road congestion, building trust in the smart traffic technologies and forming 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 experiments by means of a variety of technological developments are enabled.

The regulations to be regulated shall regulate the following:

1. The autonomous vehicle: the technological requirements which the autonomous vehicle and the systems installed therein shall comply with, including the standardization requirements stipulated pursuant to the Traffic Regulations, as well as the standardization requirements from which it will be exempted. These provisions shall be as required by the fact that it is a vehicle operated not by a driver but by an autonomous driving system.
2. The autonomous driving system: this system is the core of the autonomous vehicle. The approval of a vehicle having such a system requires the proof that it is capable of safely driving a vehicle and that it is reliable, and the applicant for an approval for experimenting shall present supporting proofs, including the experiments conducted and a declaration of the manufacturer of the system, the manufacturer of the vehicle and the applicant for an approval for conducting the experiment, including the abilities of the system.
3. Approval of autonomous vehicles experiments: this approval shall be granted to an applicant who will present an experiment plan, and the

operation space and conditions. In addition, the applicant will be required to present abilities for the implementation of the operation plan and control over the autonomous vehicles by means of a control center, data collection infrastructure and datum concerning the activation of autonomous vehicles, and that it is compliant with the cyber and communication standard, as well as any other information that the National Inspector of Transport may require in order to approve the experiment.

4. Obligating the Bearer of Approval for Experimenting an Autonomous Vehicle 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. Obligating the Bearer of Approval for Experimenting an Autonomous Vehicle to deliver information to the National Cyber Security Authority, about any cyber attack event on the autonomous vehicle systems.

In respect of Section 9D

It is proposed to stipulate prohibition on autonomous vehicle experiments without the approval of the National Inspector of Transport; Although it is possible that the operation of an autonomous vehicle without an approval 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 an approval to carry out an experiment in an autonomous vehicle is issued to anyone that is compliant with the regulations stipulated pursuant to Section 9C, and holding an insurance suitable for such an operation.

It is proposed to stipulate the authority of the National Inspector of Transport to stipulate the terms and conditions of the approval, concerning – among others – the following matters:

1. The period of the approval, which shall not exceed 3 years;
2. The maximum number of vehicles to be taking part in the experiment;
3. The obligations imposed on the Bearer of the Approval and the terms and conditions for annulment thereof.

It is suggested to stipulate that the National Inspector of Transport shall be entitled to grant the experiment vehicles exempts from provisions under the Traffic Ordinance, which regulated paid driving, and – by consultation with the Licensing Authority, an exempt from the provision under the Vehicle Licensing Ordinance. In addition, by consultation with a police officer, the National Inspector of Transport shall be entitled to prescribe

in the approval exemptions from the applicability of the provisions in the Traffic Regulations that regulate the behavior on the road. In addition, the National Inspector of Transport shall be entitled to stipulate provisions substituting the exempted provisions, all in order to ensure the safety of all of the users of the road and the participants of the experiment, to reduce the possible 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 the autonomous vehicle within the framework of the experiment, to the extent that no exemption from them is granted.

In respect of Section 9E

It is proposed to grant the National Inspector of Transport authorities that will enable him effective supervision over the autonomous vehicle experiments, including to require a Bearer of an Approval pursuant to this Article, to identify himself; to require a Bearer of an Approval or any other person taking part in the execution of the experiment information and documents required for supervision; to enter the control center of the experiment and any place where operation are taking place within the framework of the experiment, including an immobile vehicle, but no entry to a place used for residence shall be allowed without a court order.

In respect of Section 9F

It is proposed to establish an Advisory committee to accompany the experiments. The head of the Committee shall be the General Director of the Ministry of Transport and Road Safety and the members of the Committee shall be 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 representative thereof, the head of the head of the Traffic Division of the Israel Police or his representative, the Deputy Attorney General (Economic) or his representative, and two experts in the field from the public, 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 the technological developments and the operation methods in the field of autonomous vehicle around the world;
2. Study the results of the experiments conducted in the field of the operation of an autonomous vehicle, in Israel and worldwide;

3. Collect data from Israel and the world, concerning severe safety events involving autonomous vehicles, analyze their causes and recommend on means to prevent them;
4. Propose the terms and conditions required, in its opinion, for the purpose of approving an autonomous vehicle experiment.

It is proposed to obligate the National Inspector of Transport to provide the Advisory Committee with information in its possession concerning severe safety events occurred while operating an autonomous vehicle.

It is proposed to stipulate considerations that the Advisory Committee is required to consider, among which is maintaining safety and providing response to the risks to the body and the property of the road users, preventing disturbance to other economical operations, sharing information, encouraging competition and technological innovation, improving the transport in Israel, and it shall further consider the manner of the response in matters such as cyber defense, insurance and handling emergency events.

In addition, the Committee shall advise the Minister on matters concerning the stipulation of the regulation for regulating experiments in autonomous vehicles. In order to ensure the effectiveness of the advising procedure and preventing it from becoming a barrier in the process, it is proposed to allow the Committee 30 days from the day on which the Minister approached it requesting the said advise, and the Minister is entitled to extend the said period, by another 30 days. In the event that the Committee failed to respond to the request for advise by the expiration of the allotted period pursuant to this section, the Minister shall be entitled to stipulate such provisions without consulting the Committee.

In respect of Section 9G

It is proposed to stipulate that the provisions of any law, including the Torts Law and the Privacy Protection Law shall apply to experiments in an autonomous vehicle.

In respect of Section 9H

It is proposed to obligate the Bearer of Approval for Experimenting to report immediately, and no later than following one working day, to the National Inspector of Transport of any severe safety event. In this respect, it is proposed to adopt the definition of "severe safety event" stipulate in Section 46(29) of the Railways Ordinance [New Version], 1972. Following such a report, the National Inspector of Transport is entitled to order provisions concerning the continuation of the experiment, including its cessation, provided that the Inspector of Transport will not order the cessation of an experiment for a period exceeding 10 days without the Bearer of Approval being given an opportunity to make his claims.

In respect of Section 9I

It is proposed to obligate the Inspector of Transport to publish on the website of the Ministry information concerning approvals of autonomous vehicle experiments given.

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

In respect of Section 9J

It is proposed to authorize the Minister to regulate regulation that will enable experiments in vehicles at lower autonomous level, which require a driver for the purpose of executing some of the driving actions. Since there is a driver in these vehicles, there is no need for the broad arrangement that is proposed in respect of vehicle with higher autonomous level. However, the existing law does not enable the execution of experimenting them on the roads. Therefore, and in order to encourage technological variety, it is proposed to include in the bill authorization to stipulate in the regulations authorities for the issuance of exempts from the existing law in respect of these vehicles, for the purpose of carrying out experiments in them.

In respect of Section 9K

It is proposed to authorize the Minister to stipulate provisions concerning the method for submitting the applications for the approval of an experiment, the obligation of the Bearer of Approval for Experimenting an Autonomous Vehicle to file reports concerning its progress, special event over the course of it, and summarizing it upon expiration of the period.

Appendix B

Analysis of American Autonomous Vehicle Companies' safety reports

To date, 18 companies have completed voluntary safety reports related to the 12 criteria outlined by 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 2.094

<p>Safety system</p>	<p>ADS programmes should follow a robust design and validation process, adopting industry standards such as:</p> <ul style="list-style-type: none"> – 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
<p>Operational design domain (ODD)</p>	<p>ODD should describe and define the specific conditions under which a given ADS or feature is intended to function.</p> <p>Each entity should define and document ODDs using the following minimum information to define each ADS's capability limits/boundaries:</p> <ul style="list-style-type: none"> – Roadway types (interstate, local, etc.) on which the ADS is intended to operate safely – Geographic area (city, mountain, desert, etc.) – Speed range – Environmental conditions (weather, daytime/night-time, etc.) – Other domain constraints
<p>Object and event detection and response (OEDR)</p>	<p>ADS programmes should follow a robust design and validation process, adopting industry standards such as:</p> <ul style="list-style-type: none"> – 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	<p>Fallback is defined as: “a process for transitioning to a minimal risk condition when a problem is encountered, or the ADS cannot operate safely”.</p> <p>Fallback procedures should consider the fact that human drivers may not be following laws or regulations and could be under the influence, drowsy, etc.</p> <p>At later stages, the ADS must be able to fallback into a minimum risk condition (MRC) without the need for human intervention.</p> <p>An MRC will be case dependent but may include automatically bringing the vehicle to a safe stop, preferably outside of a traffic lane.</p>
Validation	<p>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.</p>
Human-machine interface (HMI)	<p>An ADS should be capable at a minimum of conveying information to the human operator or occupant through various indicators that the ADS is:</p> <ul style="list-style-type: none"> – 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	<p>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.</p>
Crashworthiness	<p>Occupant protection systems should be maintained at the intended performance level regardless of whether they are human, or ADS operated.</p> <p>Unoccupied vehicles equipped with the ADS should provide geometric and energy absorption crash compatibility with existing vehicles on the road.</p>
Post-crash behaviour	<p>Entities should establish methods to return ADS to a safe state after becoming involved 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.</p>
Data recording	<p>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.</p> <p>Data should be collected and analysed when associated with 1) fatal or non-fatal personal injury; or 2) damage that requires towing.</p>
Consumer education and training	<p>Consumer education programmes are encouraged to cover topics such as ADSs’ 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.</p> <p>Programmes should include explicit information on what the ADS is capable and not capable of to minimize potential risks from user system abuse or misunderstanding.</p>

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 in order to travel safely past a broken-down vehicle).

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
Safety system				
<p>Waymo employs a multipronged system entitled “Safety by Design”, which is broken down into the following categories:</p> <ul style="list-style-type: none"> – Behavioural safety – Functional safety – Crash safety – Operational safety – Non-collision safety 	<p>Uber utilizes a system engineering approach to ODD selection and characterization along with object and event detection and response (OEDR).</p> <p>Uber’s safety system is based on the following “safety principles”:</p> <ul style="list-style-type: none"> – Proficient – Fail-safe – Continuously improving – Resilient – Trustworthy 	<p>Cruise highlights its use of a variety of system safety engineering tools grouped into the following categories:</p> <ul style="list-style-type: none"> – 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. <p><i>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.</i></p>	<p>Apple states that its ADS design and integration are analysed using an “industry safety analysis method and best practices”.</p> <p>The hazard analysis is based on the planned use case of typical street driving and the assumption that a human driver will be present.</p>	<p>Zoox defines its safety innovation strategy as “Prevent and Protect.” Its report does not include itemized principles like those of the other companies.</p>

Waymo	Uber	GM Cruise	Apple	Zoox
2018 Safety Report ⁹⁵	2018 Safety Report ⁹⁶	2018 Safety Report ⁹⁷	2019 Safety Report ⁹⁸	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 these 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 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 utilizes a strict geofence in which vehicles can comply with outlined traffic laws.

Apple’s report does not include information on the company’s ODD.

The Zoox ODD is 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 describes its OEDR programme as divided into 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 describes its OEDR programme as divided into the following parts:

- **Mapping:** Precise road data that gives the system information about an environment before it receives real-time information
- **Perception:** Perception software that 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 describes its system with 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 breaks down 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	Uber	GM Cruise	Apple	Zoox
2018 Safety Report ⁹⁵	2018 Safety Report ⁹⁶	2018 Safety Report ⁹⁷	2019 Safety Report ⁹⁸	2018 Safety Report ⁹⁹
	<ul style="list-style-type: none"> – 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 <p>The report includes a detailed discussion on the screening and training process for human vehicle operators.</p>		<ul style="list-style-type: none"> – Act: Software that converts the planning component's location and trajectory information into commands for the vehicle's steering, braking and propulsion systems 	<ul style="list-style-type: none"> – Planning: Software that constantly evaluates the vehicle's surroundings and prediction models to plan its future moves – Localization: Software that allows the vehicle to know where it is always, down 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 <p>The report notes that since Zoox manages its own fleet, maps can continuously be updated as cities grow.</p>

Fallback				
<p>The Waymo fallback system relies on the following redundancies:</p> <ul style="list-style-type: none"> – Backup computing – Backup breaking – Backup steering – Backup power systems – Backup collision detection and avoidance system – Redundant inertial measurement systems for vehicle positioning 	<p>The Uber criterion for fallback to a minimum risk condition (MRC) is a type of failure that may result in harm to a person.</p> <p>Fallback is accomplished by portioning safety features to different parts of the system, thoroughly testing components and designing key system redundancies.</p> <p>Uber provides extensive training on procedures to operators in multiple types of system failures</p>	<p>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.</p> <p>Key systems, such as steering and breaking, also have separate and redundant controllers and actuators.</p>	<p>Apple outlines the following policies to ensure "Operational Safety":</p> <ul style="list-style-type: none"> – Daily vehicle checks and meetings with human vehicle operators – The ability of safety drivers to assume control of the vehicle at any time 	<p>The Zoox fallback system utilizes remote operators to "help" the vehicle navigate uncertain scenarios.</p> <p>It includes the use of redundant safety features and to mitigate the risk of hardware failure, a mixed hardware strategy with hardware elements that have unique features to guard against a common failure, including steering, braking and battery and powertrain.</p>

Waymo	Uber	GM Cruise	Apple	Zoox
2018 Safety Report ⁹⁵	2018 Safety Report ⁹⁶	2018 Safety Report ⁹⁷	2019 Safety Report ⁹⁸	2018 Safety Report ⁹⁹

Validation				
<p>Waymo tests on public roads, within closed courses and in simulations that include thousands of real-world scenarios</p> <ul style="list-style-type: none"> – 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 as being among the most common by the NHTSA. 	<p>The Uber report describes processes for software, hardware and on-road testing and reporting systems:</p> <p>Software testing:</p> <ul style="list-style-type: none"> – Map compatibility test – Onboard integration tests – Unit tests – Virtual simulation regression set test – Reaction time metrics test <p>Hardware testing: Simulation involving test scenario development across multiple scenarios including: 1) normal driving scenarios; 2) crash avoidance scenarios; 3) crash situations</p> <p>On-road testing: Reliance on high manufacturing standards and traceability of assembly</p> <p>Reporting system: A robust system for reporting all system faults</p>	<p>GM Cruise validation processes employ both conventional and SOTIF (safety of the intended function) validation processes.</p> <p>Conventional validation processes:</p> <ul style="list-style-type: none"> – 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 <p>SOTIF validation processes:</p> <ul style="list-style-type: none"> – Systematic exposure of the self-driving system to performance requirements of the ODD 	<p>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.</p> <p>All proposed changes are subjected to rigorous and comprehensive simulation testing that evaluates the software against predetermined criteria.</p> <p>After passing simulation testing, the entire system undergoes on-road testing at closed-course proving grounds before being nominated for operation on public roads.</p>	<p>Zoox tests in highly detailed simulations and on the road, making a priority to invest heavily in in-house simulation capabilities.</p> <p>Vehicles are used as tools by the engineering teams to test and validate the sensor suite and autonomous driving software.</p> <p>Zoox focuses on a robust training programme and high standards for all vehicle operators.</p>

Waymo	Uber	GM Cruise	Apple	Zoox
2018 Safety Report ⁹⁵	2018 Safety Report ⁹⁶	2018 Safety Report ⁹⁷	2019 Safety Report ⁹⁸	2018 Safety Report ⁹⁹
		<ul style="list-style-type: none"> – Identifying and iteratively testing driving scenarios and edge cases that challenge the self-driving system – 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 quantitative and qualitative criteria 		

Human-machine interface (HMI)

<p>Waymo’s HMI includes the following features:</p> <ul style="list-style-type: none"> – Display: It 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: It is accessible inside the vehicle or on a mobile app to start the ride. – Pull over button: When engaged, the vehicle will identify the nearest location to safely stop so the rider can exit the vehicle before their original destination. 	<p>Uber has strict policies in place for vehicle operator behaviour.</p> <p>Self-driving vehicles are equipped with a touchscreen that follows the NHTSA’s Human Factors Guidance for Driver-Vehicle Interfaces to minimize distractions.</p> <p>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.</p>	<p>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.).</p> <p>It utilizes GM OnStar Automatic Crash Response, which automatically responds in the event of a crash using OnStar established systems to communicate with first responders.</p> <p>Currently, the ride-hailing app and service is only available to employees.</p>	<p>The Apple HMI includes the following measures:</p> <ul style="list-style-type: none"> – A persistent visual display of the system’s 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 	<p>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”.</p>
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Waymo	Uber	GM Cruise	Apple	Zoox
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2018 Safety Report⁹⁵

2018 Safety Report⁹⁶

2018 Safety Report⁹⁷

2019 Safety Report⁹⁸

2018 Safety Report⁹⁹

- **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.

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

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, that drive 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	Uber	GM Cruise	Apple	Zoox
<p>2018 Safety Report⁹⁵</p> <ul style="list-style-type: none"> – 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 	<p>2018 Safety Report⁹⁶</p>	<p>2018 Safety Report⁹⁷</p>	<p>2019 Safety Report⁹⁸</p>	<p>2018 Safety Report⁹⁹</p>
Crashworthiness				
<p>Waymo utilizes vehicles that are compliant with FMVSS.</p> <p>Waymo’s current vehicle is the 2017 Chrysler Pacifica Hybrid Minivan.</p>	<p>The crashworthiness of the base vehicle is defined by the vehicle structure, occupant restraint systems and other factors.</p> <p>The self-driving system works with the base system to be geometrically compatible with standard vehicles on the road.</p> <p>Uber’s current testing uses the Volvo XC90.</p>	<p>GM Cruise analysed the car to account for new systems and included the following additions:</p> <ul style="list-style-type: none"> – 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 <p>Currently, the GM Cruise ADS is mounted on the Chevrolet Bolt base.</p>	<p>Apple uses test vehicles certified to the FMVSS and has “top crashworthiness ratings in consumer crash tests”.</p>	<p>Zoox uses a testing fleet that meets the FMVSS.</p> <p>Currently, Zoox’s testing fleet includes the Prius C and Toyota Highlander.</p>
Post-crash behaviour				
<p>Waymo software can detect when it has been involved in a collision and will notify the Waymo operations centre automatically.</p> <p>Post-crash procedures involve interacting with law enforcement/first responders and riders via trained crash specialists.</p>	<p>In the event of a crash, the base Volvo platform of the Uber ADS performs safety actions depending on the type of collision:</p> <ul style="list-style-type: none"> – Passive safety features activation (airbags, etc.) – Post-impact braking 	<p>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.</p>	<p>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.</p>	<p>The Zoox report does not outline exact 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).</p>

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
<p>Vehicles are tested for safety after they return to the road.</p>	<ul style="list-style-type: none"> – High-voltage battery disconnection – Hazard lights illumination – Emergency services notification <p>Uber’s human operators remain post-crash to provide reasonable assistance to the involved parties, law enforcement officers, etc.</p>		<p>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.</p>	
Data recording				
<p>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.</p>	<p>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.</p> <p>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’s guidance.</p>	<p>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.</p> <p>The data recording system is designed to keep data intact even in a crash. In addition to crash data, the vehicle records info on vehicle performance during normal driving and avoided crashes.</p>	<p>Apple does not indicate specific data recording practices but notes extensive data collection and analysis, particularly as it relates to post-crash data.</p>	<p>Zoox data collection continues when a vehicle is involved in a crash.</p> <p>Data is stored securely on vehicles as well as backed up at operation centres.</p>
Consumer education and training				
<p>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.</p>	<p>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.</p> <p>Uber plans to create a self-driving safety and responsibility advisory board</p>	<p>Upon the launch of the GM Cruise mobile app, in-vehicle touchscreens and other user interfaces will provide “helpful information and safety reminders”.</p> <p>At the launch, GM plans to publish consumer information about what to expect when using the service to obtain rides.</p>	<p>Apple states it “stand[s] ready to be a resource on current and future technological, regulatory and public policy matters”.</p>	<p>Zoox provides the following educational resources for law enforcement and first responders:</p> <ul style="list-style-type: none"> – Immersive educational information – Operational training exercises – A vehicle disengagement guide

Waymo	Uber	GM Cruise	Apple	Zoox
2018 Safety Report ⁹⁵	2018 Safety Report ⁹⁶	2018 Safety Report ⁹⁷	2019 Safety Report ⁹⁸	2018 Safety Report ⁹⁹

State and local laws

<p>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.</p>	<p>Uber uses base vehicles certified by FMVSS.</p> <p>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.</p>	<p>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.</p> <p>The programme is designed to comply with local and state laws in each AVs 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 the ADS technology.</p>	<p>Apple reports that: “we vigilantly adhere to relevant regulations and requirements”.</p>	<p>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”.</p>
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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 (i) malfunctions of the AV or ADS; (ii) 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 complete stop, upon experiencing a failure of the vehicles 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: a crash involving a trial vehicle or a contravention 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				
<ul style="list-style-type: none"> – 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) 	<p>Safety cases shared with the regulator and general public, including:</p> <ul style="list-style-type: none"> – Trial information – Driver and operator training – Law compliance – Points of contact with related agencies – Safety plans 	<p>First supply for commercial deployment: Self-certification, including risk anticipation and responses incorporating:</p> <ul style="list-style-type: none"> – 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 	<p>The manufacturer must submit the Autonomous Vehicle Form including:</p> <ul style="list-style-type: none"> – Copy of Articles of Incorporation – Description of the ODD and how the vehicle reacts once outside the ODD – restricting 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 	<p>Written statement acknowledging that:</p> <ul style="list-style-type: none"> – The vehicle is equipped with an ADS that follows all federal law and all Arizona State's 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	<ul style="list-style-type: none"> – 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				
<p>Conditions may apply, relating to:</p> <ul style="list-style-type: none"> – 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. 	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				
<p>Modifications to permits by the authority may occur, with notice, either in response to a trial or non-compliance, or due to a ruling of the authority.</p> <p>n/a</p>	n/a	n/a	n/a	n/a
			Manufacturer can make modifications to permit by submitting a new form and a fee of \$70	
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 controlled environment is being done prior to trailing.	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 personnel permitted to drive	n/a	n/a	List personnel permitted to drive	

Singapore	UK	Australia	USA – California	USA – Arizona
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 is issued an Autonomous Vehicle Testing Program Test Vehicle Operator Permit. Training program to safety drivers and remote operators is required.	Safety driver/ remote operator depending on the type of permit 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 license, must be an employee, contractor or designee of the manufacturer, completion of manufacturers training program 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, wasn't convicted 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 users' 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 licensing.	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 a certification that the vehicle meets appropriate and applicable current industry standards to help defend against, detect, and respond to cyber-attacks.	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 a 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. If over 3 years old (4 years in Northern Ireland), the vehicle must have a valid MOT certificate.	The vehicle should: 1) be capable of complying with road rules; 2) have on-road behavioural competency; and 3) verify road conditions as part of the ADS safety self-certification process. n/a	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 applicable laws. – 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.

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. Some data must be recorded at a minimum 2 Hz frequency (speed, location).	n/a Data must be recorded at a minimum 10 Hz.	Data recordings should be kept for 7 days; data should be reported within 24 hours of an incident. n/a	To receive deployment permit manufacturer should equip the vehicle with a data recorder. 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)	<ul style="list-style-type: none"> – 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.	n/a	n/a	
Speed	Speed	n/a	n/a	
Sensor data	Sensor data of other road users	Sensor information	n/a	
n/a	<ul style="list-style-type: none"> – Steering command and activation. – Braking command and activation. 	n/a	n/a	
n/a	<ul style="list-style-type: none"> – 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	<ul style="list-style-type: none"> – 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 3 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 the above specifications).			

Singapore	UK	Australia	USA – California	USA – Arizona
Event reporting				
<p>Of any:</p> <ul style="list-style-type: none"> - Malfunction of the AV or ADS. - Incidents involving personal injury or property damage. 	<p>In case of an accident, data recorded 30 second before and 15 seconds after the incident at a recommended minimum frequency of 50 Hz.</p>	<p>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.</p> <p>Time frame:</p> <ul style="list-style-type: none"> - The data must be provided within 24 hours of the incident. - A full report including relevant data and information must be provided within 7 days of the incident. <p>Other cases requiring reporting include:</p> <ul style="list-style-type: none"> - Near misses - When a human takes back control of the vehicle - When a public complaint is received regarding the performance of the vehicle. <p>Time frame:</p> <ul style="list-style-type: none"> - On a monthly basis - If requested, within 7 days. <p>Data recording in case of serious incidents: 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.</p> <p>Data could include:</p> <ul style="list-style-type: none"> - Identity of the vehicle operator at the time of the incident. 	<p>Collisions- Bodily injury or damage to property- within 10 days after the collision.</p> <p>Disengagements- annual report including total number of miles driven.</p>	

AV liability requirements and legal aspects

Singapore	UK	Australia	USA – California	USA – Arizona
Insurance				
<p>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.</p> <p>The insurer must be registered in Singapore.</p>	<p>According to existing 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.</p> <p>n/a</p>	<p>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 MALL to favour a national approach led by the Board of Treasurers, primarily by:</p> <ul style="list-style-type: none"> – Reviewing insurers’ mechanisms to recover their claim costs. – Creating provisions enabling people involved in an AV crash to access MALL schemes. – Considering data access for MALL insurers to assess liability and next stage in-service safety work. <p>The insurer must have a corporate presence in Australia.</p>	<ul style="list-style-type: none"> – According to existing vehicle insurance requirements; – Surety bond in the amount of \$5M. – Certificate of self-insurance- with audited financial statements reflecting a new worth of not less than \$5M. 	<p>According to existing vehicle insurance requirements.</p>
Criminal Liability				
n/a	<p>A new system of sanctions to replace some criminal offences for AVs has been proposed but not yet introduced as a policy.</p>	<p>A new system of sanctions to replace some criminal offences for AVs has been proposed but not yet introduced as a policy.</p>	n/a	n/a

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