TE MANATŪ WAKA
MINISTRY OF TRANSPORT

He whakamahuki i matapaeroa | Long-term Insights Briefing

He aha te pānga mai o ngā waka hautū kore ki runga i ngā rori o Aotearoa | The impact of automated vehicles operating on Aotearoa New Zealand roads

August 2022 | Briefing Paper

UARA
OUR VALUES

WHAKAPAKARI
IMPROVING OUTCOMES

AKO
CAPABILITY DEVELOPMENT

MAHI TAHI
WORKING TOGETHER

RANGATIRATANGA
EMPOWERING
AND LEADING

KAITIAKITANGA
GUARDIANSHIP AND
PROTECTION

WHANAUNGATANGA
COLLABORATION
AND UNITY

MANAAKITANGA
CARING FOR AND
VALUING OTHERS

Kupu Whakataki | Foreword

Te Manatū Waka is the steward of the transport system in Aotearoa.

We help shape the strategic direction and regulatory settings for sea, land, and air-based transport to support wider outcomes, including environmental sustainability, security, and access to services.

There is a lot to consider when we look at our future needs for transport. Our transport network links us with social and economic opportunities, such as healthcare, housing, education, employment, and our natural environment. The safety and accessibility of the transport system also has a direct link to our wellbeing, health, happiness, and prosperity. We know that creating vibrant, liveable towns and cities for our people requires collaboration with other areas such as housing and urban development. To get the best out of transport we need to consider its relationship with the wider environment, both in Aotearoa and as an international connector through trade and tourism.

The transport system in Aotearoa is constantly evolving and must adapt as societal expectations change. We need a transport system that can anticipate and respond to challenges and opportunities in a sustained way. Transport technology has the potential to alleviate some of the long-term challenges we face but it can also be disruptive in the short-term. Technology, in and of itself, will not provide a "silver bullet" to address these challenges. However, engaging early with new technologies will allow us to utilise their benefits and address the potential costs. This includes finding ways to develop policies and a fit-for-purpose regulatory environment that supports the broader outcomes we seek.

The long-term insights briefing (LTIB) allows us to look at the potential impact of automated vehicles (AVs) more closely. We can see examples throughout history of the impact of technology on transport and its ability to significantly disrupt and transform not only the system but society itself. AVs present one of the greatest areas of uncertainty for the future of the transport system. The exact timeframes for fully automated vehicles are still unclear, and the extent to which they will impact our day-to-day life in Aotearoa is unknown. However, New Zealand already has vehicles in its fleet with automated capabilities. The most popular electric vehicle in the country is equipped with some of the most advanced automated features in public use anywhere in the world.

There is already significant global investment in AV technology signalling that, in some form or another, higher levels of automation are coming. We are seeing the development of a range of AVs for transporting goods, such as freight movement from warehouses to stores, or to move people using robotaxis or automated shuttles. Fully automated vehicles are not like the vehicles we currently have on our roads. They will have significant implications for the way we think about and regulate transport.

To understand these implications, we need to have better knowledge around how higher levels of automation will feature on New Zealand roads, including how and where AVs could be operated. We need to understand how AVs might support us to meet our wellbeing and liveability aspirations for the transport system. The LTIB affords us the opportunity to better understand and shape the outcomes we seek with regard to AVs. The aim is to build our understanding of AVs so our future policy options improve individual and community wellbeing as much as broader transport system efficiencies and outcomes.

Te Manatū Waka has welcomed the opportunity to submit its first LTIB and looks forward to ongoing engagement on this important issue.

Bryn Gandy
Acting Secretary for Transport

Ngā ihirangi | Contents

Kōrero Whakataki | Introduction

> **Government agencies have a responsibility to meet the challenges of today and understand and navigate the challenges of tomorrow.**

Long-term insight briefings (LTIB) are future-focused documents that explore emerging challenges and opportunities beyond immediate government work programmes. These are issues that do not often get priority but have important implications for the future of transport and the wellbeing of New Zealanders.

All government agencies are required to develop an LTIB. The briefings are developed independently of Ministers and the subject matter is at the discretion of each ministry's Chief Executive. This allows the briefings to be distanced from current government policy and government agencies' work programmes. By exploring a topic that may have a transformational impact for our transport system, we can better prepare for the challenges it might present.

The focus of this LTIB is on the impact of AVs operating on New Zealand roads. In transport, we are striving to create a system that positively contributes to the wellbeing of New Zealanders and improves the liveability of the spaces we use. Over the next 10-20 years (and beyond), AVs could play a significant role in achieving this. They have the potential to impact regulatory systems, equity, road safety, congestion, emissions, the use of public spaces, economic development, labour markets, the health of New Zealanders and the way we connect with each other. Our role is to consider how AVs might impact these things.

The area of AVs is a broad and complex one, with a high level of uncertainty surrounding their eventual impact. New Zealand already has vehicles on its roads that have automated features that assist the driver, like blind spot monitoring and autonomous emergency braking. This paper focuses on the next level of automation, where vehicles can take over the task of driving for at least a portion of the journey, without the driver needing to pay attention to the road. The paper explores the risks and opportunities associated with these higher levels of vehicle automation, with particular emphasis on the potential impacts these might have on New Zealand achieving its transport outcomes.

New Zealand has not regulated for higher level AVs, and there are none on New Zealand roads. This paper starts from the position that higher level AVs (in some form or another) will eventually be part of the New Zealand vehicle fleet. It does not do this because AVs are "inevitable," but uses this as a hypothesis to test what the impact might be if it was true. The paper asks a series of questions and draws insights from the responses to them. The questions have been posed from two perspectives –people within New Zealand who will engage with AVs in their day-to-day lives, and the wider transport sector. The insights will help inform and align future decisions around AVs across local and central government.

The high level of uncertainty surrounding the impact of AVs means we do not have all the answers to the questions posed, and further work will be required. AV technology is evolving at a rapid pace, and it is doing so within a continuously evolving transport ecosystem. The transport system in Aotearoa that AVs will enter will not be the same transport system we have today. Other transport technologies and innovations will develop in parallel with AV development, along with the demographic make-up of the country, where people live and work, and how they choose to spend their time. All will influence the actual impact of AVs operating on New Zealand roads. This paper will, however, go a long way towards helping government understand where there might be opportunities and risks associated with AVs to shape future policy thinking.

INTRODUCTION

The content in this paper has been informed by workshops attended by experts from academia, industry, and other government agencies. We have engaged with the disability sector, older people, and active mode users to identify their concerns and aspirations for AVs. We have also run focus group sessions around the impact of AVs on transport equity as one of the key considerations in understanding the topic we have chosen. We have drawn insights from these discussions about how AVs might impact New Zealanders, the wider transport sector, and what we might need to work on first. We thank those individuals and groups, including those who submitted feedback during our first and second rounds of consultation, for sharing expertise, concerns, and aspirations around AVs. This input has provided the foundation for our thinking and has helped shape our conclusions. We would especially like to thank Helen Fitt from Lincoln University for peer reviewing this paper and providing us with additional themes and areas for consideration.

> In transport, we are striving to create a system that positively contributes to the wellbeing of New Zealanders and improves the liveability of the spaces we use

Ngā kupu ka whakamahia i te rōanga ake o tēnei pepa | Key terms used throughout this paper

The terminology used to explain automated driving has evolved as quickly as the technology itself. To provide clarity around the terminology used in this paper, a list of key terms is provided below.[1]

We have adopted the term *automated* rather than *autonomous* when referring to driving and vehicles. "Autonomous" suggests systems that have the ability and authority to make decisions independently and self-sufficiently. The most advanced systems that replace human drivers will operate according to algorithms and otherwise obey the commands of users; these systems will not be self-aware or capable of making their own choices.

Advanced Driver Assistance Systems (ADAS) – describes a broad range of electronic safety features that provide warnings to the driver or momentarily undertake control of the vehicle for safety or convenience reasons. Systems include forward collision warning (FCW), lane keeping assistance (LKA), and automatic emergency braking (AEB).

Automated driving – when the automated driving system undertakes the driving task. Automated driving might operate for some of a journey, or the whole journey, depending on the capabilities of the system, the suitability of infrastructure, and constraints on where and when it can safely operate (based on environmental, geographical, and time-of-day restrictions).

Automated Driving System (ADS) – the hardware and software that are collectively capable of performing the entire driving task on a sustained basis. This term is used specifically to describe automated vehicles. ADS uses a combination of sensors, controllers, and onboard computers, and sophisticated software to carry out the driving task.

Automated Vehicle (AV) – this is a vehicle with SAE Levels 3–5 automation (see section two for details on the levels of vehicle automation). It has an automated driving system, which means it can perform the driving task, in at least some circumstances or situations, on a sustained basis without human input. It is distinct from vehicles with automated features that assist the driver (SAE Levels 1–2, e.g., vehicles with technology such as blind-spot monitoring or cruise control).[2]

Car sharing – is a model of car rental where people rent cars for short periods of time, often by the hour.

Driving task – all the real-time operations and functions required to drive a vehicle in traffic, including steering, acceleration and deceleration, object and event detection and response, and manoeuvre planning.

In-service – when a vehicle, supplied to the New Zealand market, is in use on New Zealand roads.

Mixed traffic – when there are vehicles with different levels of automation sharing and moving on same carriageway without any physical segregation between them.

1 SAE Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles – J3016, updated in April 2021

2 This term is no longer used by the Society of Automotive Engineers (SAE) who recommend against using terms that make vehicles, rather than driving, the object of automation (to avoid confusion between the two). It is however still widely used by regulatory agencies, as the vehicle is the subject of regulation. As such it will be used in this paper to refer to SAE Levels 3-5.

KEY TERMS USED THROUGHOUT THIS PAPER

On-road – refers to publicly accessible roadways (including parking areas and private campuses that permit public access) that collectively serve all road users, including cyclists, pedestrians, and users of vehicles with and without driving automation features.

Public Transport (PT) - is a system of transport for use by the general public, typically managed on a schedule, operated on established routes, and that typically imposes a charge/ fee for each trip. A subset of PT is demand-responsive transport (DRT), where PT is provided in areas of low passenger demand where a regular PT service would not be considered financially viable.

Ride-hailing – is when a customer orders a customised ride online, usually via a smartphone application.

Society of Automotive Engineers (SAE) – SAE International is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries. It established the levels of vehicle automation in its technical document J3016. These have been explained in section two.

Transport options – refers to the quantity and quality of accessibility options available to an individual or group, considering their specific needs and abilities. This includes all modes of transportation across air, land, and sea.

Use cases – to understand the varied characteristics of vehicle use, the term “use cases” allow us to identify the different ways vehicles can be used. This includes public and private vehicle use.

He Whakarāpopoto | Executive Summary

Te Manatū Waka Ministry of Transport has chosen to investigate the potential impacts of automated vehicles (AVs) operating on Aotearoa New Zealand roads. These are vehicles that can take over the driving task, even if for only part of the journey.

This topic was chosen as AVs present one of the greatest areas of uncertainty for the future of the transport system. AVs will operate within an already complex land transport system. They have the *potential* to significantly improve transport outcomes and the wellbeing of New Zealanders but could also create challenges for both. This paper has been developed to highlight the opportunities and risks AVs might present in a New Zealand context.

AVs will have wide-ranging impacts for individuals, communities, businesses, and the wider transport sector.

Transport enables and shapes social, economic, and environmental outcomes such as access to healthcare, essential goods and services, work and leisure, engagement with education and training, and contact with friends and whānau. In understanding the impact of AVs on New Zealand, Government will need to consider how AVs may address existing and future challenges across the transport sector and how they support broader transport outcomes for Aotearoa.

AVs have the potential to impact all users of the transport system in Aotearoa. This is regardless of whether New Zealanders purchase, lease, or hire an AV, use a shared AV service (like taxis or ride-hailing), use automated public transport, or interact with an AV in a mixed-use space (as another road user, cyclist, or pedestrian).

New Zealanders come from many different backgrounds, have a range of physical and mental capabilities, and have a variety of transport needs, preferences, and values. AVs may provide benefits for many New Zealanders, depending on where they live and their ability to access available transport options. Those unable to drive may be afforded greater freedoms by AVs. Locations currently underserved by transport options may be able to access more affordable demand-responsive transport options that better meet their needs.

Safety is a primary consideration before AVs will be allowed to operate on New Zealand roads. Individuals and communities will want to know AVs are safe, who is responsible in the event of a collision, and that their personal information is secure. Government has a key role to play in ensuring appropriate vehicle safety standards are in place for higher levels of automation, and that enforcement activities and the penalty regime is reflective of the changing role of the driver.

Businesses could benefit from AVs. They will want to understand how AVs might support their existing business models, and what new industries and opportunities might be created by AVs. Top of mind for businesses will be the regulatory pathway government decides to pursue, including any restrictions and requirements that may be placed on the operation of AVs as a commercial venture. Businesses will want enough information to inform their future investment decisions around AVs, as well as clarity around any changes to vehicle standards and compliance requirements that may influence these decisions. Of equal concern will be where and when long-term investment for supporting infrastructure (digital and physical) will occur, and whether there will be incentives for businesses to invest in AVs in the future.

The wider transport sector will likely face significant disruptions by the introduction of AVs into the vehicle fleet. This includes those businesses (including not-for-profit and iwi

businesses) that want to own and operate AVs as a business or service, want to sell AVs in New Zealand, want to utilise AVs for their own operations or maintain, repair, and test them. Potential changes to vehicle standards, inspection and compliance systems, and the impact on some transport sector jobs will disrupt existing processes and systems across the sector. Government and Industry will need to work closely to understand and respond to this potential disruption.

There are still outstanding questions around when many of these impacts might be felt, if at all. Apart from the timeframes surrounding the technology itself, questions around what government regulation ought to be in place, what supporting infrastructure is required (both physical and digital), and whether realising benefits will be reliant on shared access models are yet to be answered and agreed upon.

Understanding the potential impacts of AVs has allowed us to draw some insights.

New Zealand's Transport Outcomes Framework (TOF) outlines the five outcomes we are seeking to achieve across the transport system in Aotearoa. It is a useful tool to guide policy thinking and decision-making, and to prioritise transport activities and investment. Insights have been grouped under each of the outcomes that outline the opportunities and risks AVs might create. At the centre of the framework is the objective of improving people's wellbeing and the liveability of the places they live in and visit. We have also considered the distributional impacts of AVs both across different groups in society and geographically.

Inclusive access – When thinking about enabling all people to participate in society through access to social and economic opportunities such as work, education, and healthcare:

- AVs will only improve access for many New Zealanders if they are affordable, provide for the needs of different groups across society, and are deployed across both urban and rural areas.
- A predominantly private ownership model for AVs could worsen commuter congestion through increasing urban sprawl (living further away from the central city) and having AVs make return trips to their point of origin with no passengers. Conversely, AVs might reduce the pain of holiday traffic congestion by allowing people to travel overnight to their destination.
- The greatest opportunity for AVs to improve access lies in affordable shared ownership models that supplement or replace existing public transport networks.
- Suitable physical infrastructure will be a key determinant of AVs' impact on access, particularly for those who currently face challenges navigating the built environment. Longer-term, physical, and digital infrastructure will define how AVs are deployed across the country and as part of everyday life.

Healthy and safe people – When thinking about protecting people from transport-related injuries, harmful pollution, and making active travel (such as walking and cycling) an attractive option:

- AVs could significantly reduce the high number of deaths and serious injuries (DSI) on New Zealand roads, but this will depend on how and where they are deployed. A noticeable change in DSI numbers because of AVs is only likely to be seen over the longer term, and alongside other measures to reduce DSI.
- Level 3 technologies present an immediate safety concern for the transport system, with the driver's ability to switch concentration back and forth in a timely manner still relatively untested in a real-world environment. The variety of different Level 3 systems that may be available on the market will likely create additional challenges for drivers.
- The challenges raised by AVs operating in mixed traffic should not be underestimated as we do not fully understand how AVs will be programmed to adhere to local road rules and driver etiquette in New Zealand, and how other road users will react to them on the roads.
- AVs will present greater safety challenges for certain groups, and particularly those with impairments or disabilities who may need additional visual or verbal cues to engage with AVs in mixed-use spaces.
- AVs may have a negative impact on health outcomes if people are substituting active travel for AV trips (due to the increased comfort and convenience they might provide).

Economic prosperity – When thinking about encouraging economic activity via local, regional, and international connections, with efficient movements of people and products:

- AVs could improve the efficiency and productivity of New Zealand businesses by reducing operating costs, increasing flexibility in service delivery, developing new use cases and supporting industries.
- AVs would likely bring significant disruption to the land transport sector through changes to compliance and licensing regimes, vehicle standards, driver licensing, job losses, and new roles as new industries develop.

Environmental sustainability – When thinking about the role transport plays in responding to climate change:

- More vehicles on the roads could lead to poorer environmental outcomes as AVs use up resources through wear and tear across their lifetime. They could also reduce emissions if they take petrol and diesel vehicles off the road and connect more people to public transport services.
- The full life cycle of AVs needs to be considered to assess their environmental impact, particularly as New Zealand currently imports all its vehicles. It is unclear how we will recycle and repurpose AV technology in New Zealand.
- Understanding urban development and land-use will also define the impact of AVs. This will depend on property developers and urban planners incorporating AVs into their designs.

Resilience and security – When thinking about adapting to emerging threats, recovering effectively from disruptive events:

- Software security will become synonymous with safety as more of the driving task is controlled by the software that runs the vehicle and vehicles capture huge amounts of personal information on their users. In some respects, this data may increase the physical security of a vehicle (e.g., through use of biometrics such as voice or fingerprints to activate a vehicle), however software security will be essential to avoid potential cyber attacks from hackers, who may be able to access systems from anywhere in the world.
- The New Zealand AV market will remain reliant on global supply chains to source AVs and the parts required to maintain and repair them. This could bring AVs to a halt if there is no contingency in place to build resilience on New Zealand shores.
- Systems like those being used in aviation and maritime environments may need to be introduced to provide assurance that automated technologies can be safely operated on New Zealand roads.

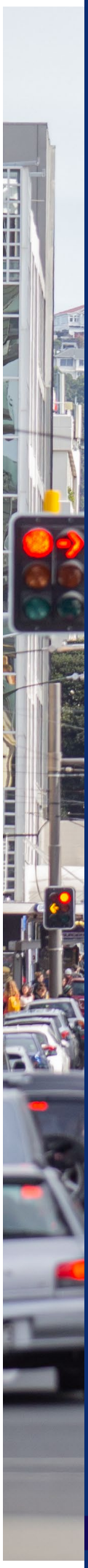
What should happen first?

Government has a choice around how much to invest in proactively preparing for automated vehicles. Compared to many other jurisdictions, New Zealand has taken a relatively 'hands off' approach to date. There are advantages and disadvantages to being an 'early adopter' or a 'fast follower', however, inaction poses significant risks.

At a minimum, we need to ensure that our regulatory system is fit for purpose and holds the right parties to account for risks that are within their control. Our rules, offences, and penalties are designed to influence human drivers, and further work is needed to ensure that our regulatory framework incentivises manufacturers and software developers to take all practicable steps to ensure that the technology they deploy is safe. Without clear liability and responsibility provisions in legislation for AVs, we could see premature deployment of the technology without clarity around the consequences of negligence or misuse. A high level of engagement with regulatory agencies in other countries will be key to progressing this.

If the Government chooses to take a more proactive approach, it could further clarify its goals and objectives for AVs, including considering how AVs could be deployed to meet transport goals in areas such as decarbonisation and equitable access. This would help ensure that the deployment of AVs supports Government's broader outcomes. Scenarios could also be developed to test assumptions and shape the preferred future for Aotearoa. This would require discussions with industry, councils, regional transport bodies, and groups in the community.

A structured research programme and the development of an evidence base could be established across agencies and academic institutes for the use of future AV investment and decision-making. This programme of work could also take a broader focus beyond transport and consider the long-term aspirations Aotearoa strives for including for housing, urban development, social welfare, and investment in innovation at a national level.



Te pūnaha hautū waka o Aotearoa | The transport system in New Zealand

This section provides background and context on the transport system in New Zealand. It also discusses how the Transport Outcomes Framework (which outlines government priorities for the transport system) will be applied to understanding the impact of automated vehicles operating on Aotearoa New Zealand roads.

Transport enables and shapes social, economic, and environmental outcomes such as access to healthcare, essential goods and services, work and leisure, engagement with education and training, and contact with friends and whānau.

The transport system is complex. It includes road, rail, air, and sea movement, and the movement of people and goods, domestically and internationally. The transport system is the cornerstone for many businesses in New Zealand that rely on goods and materials, the transportation of produce from farms to supermarket shelves, and the movement of finished products to retail stores or ports for export. It allows individuals, families, and groups to travel for work and leisure. It allows tradespeople to get to and from job sites, and office workers to commute to and from work. At the international level, the transport system provides access to other countries for work or leisure and brings visitors to New Zealand to support our tourism industry. It allows domestic producers to access export markets and importers to bring in goods for domestic consumption.

The New Zealand transport system includes:

- light and heavy vehicles that move people and products
- physical infrastructure (e.g., airports and seaports, the rail network, roads, and car parks)
- digital infrastructure (e.g., satellite-based navigation infrastructure and aids, travel apps, communications technologies)
- institutions and regulatory systems that influence how the transport system functions and develops (e.g., through their structures, management practices, rules, policies, and funding/investment tools)
- two major domestic airline carriers.

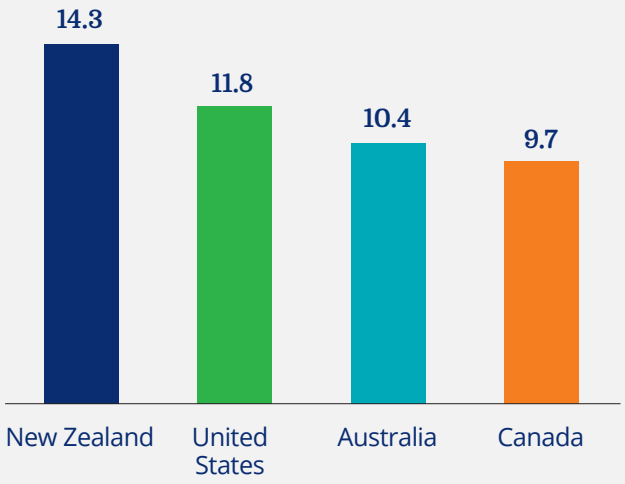
The New Zealand vehicle fleet is predominantly made up of light vehicles (92 percent),[3] with a large proportion of New Zealand's car imports coming from Japan (94.7 percent of the light fleet entering the country in 2020 – note that the country of manufacture can be other than Japan).[4] The light vehicle fleet is old (with an average age of 14.3 years),[5] and approximately half have a crashworthiness rating of one or two stars out of a possible maximum of five. Because of our relatively small market, New Zealand is constrained in terms of the vehicles it can access.

3 Ministry of Transport. (2021). *Te tatauranga rāngai waka a tau 2020 | Annual fleet statistics 2020.* https://www.transport.govt.nz//assets/Uploads/Report/AnnualFleetStatistics.pdf

4 Ministry of Transport. (2020). *The* New Zealand *2020 Vehicle Fleet: Data Spreadsheet.* https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/2020-annual-fleet-statistics

5 Ministry of Transport. (2021). *Te tatauranga rāngai waka a tau 2020 | Annual fleet statistics 2020.* https://www.transport.govt.nz//assets/Uploads/Report/AnnualFleetStatistics.pdf

Average age of light vehicle fleet 2020 (in years)



Public transport (PT) in New Zealand takes several forms. Buses are the most common form, making up most trips in every city that has PT (and often being the only PT mode available). Some parts of the country also have access to ferries and trains; however New Zealand is still growing and, in most places, lacks the population and density to justify rapid transit metros or light rail systems of scale.

Because of our relatively small market, New Zealand is constrained in terms of the vehicles it can access

New Zealand's transport context

Aotearoa is two long skinny islands with terrain ranging from mountainous landscape to low-lying coastal areas and open plains. We experience a range of temperate weather conditions and our roads have tended to hug the coastline and hillsides as many were built along the path of least resistance around geographic obstacles. Our longest stretch of State Highway in a straight line is only 13.7 km long (compared to 1466.6 km in Australia).[6,7] Rural roads make up most of our network (80 percent), with urban roads comprising the remaining 20 percent.[8] We drive on the left-hand side of the road like Australia, the UK and most of Asia, but this is different from 66 percent of the world.[9]

New Zealanders have become highly dependent on cars and have a high rate of car ownership. The development of our built environment to favour a central business district and satellite residential suburbs, and the dispersed nature of our cities and towns across the country, has made it difficult to get around New Zealand without a car.

The chart below shows how, as the population has grown, the number of vehicles per household has also steadily increased over time.[10] Nearly three quarters of New Zealanders commute to work by car, truck, or van, with around half of those travelling to education doing the same.

New Zealand has a high number of deaths and serious injuries (DSI) on its roads every year compared with other countries. In 2019/20 there were 304 deaths and 2224 serious injuries on New Zealand roads.[11] The majority of DSI were on open roads, with approximately 80 percent of deaths involving light vehicles. About half the people who were harmed on our roads did not contribute to the accident. They were harmed by other people's errors in judgement.[12]

6 Waka Kotahi. (n.d.) *State highway frequently asked questions*. https://www.nzta.govt.nz/roads-and-rail/research-and-data/state-highway-frequently-asked-questions/#:~:text=What%20is%20the%20longest%20straight,straight%20section%2013.7km%20long.

7 Wikipedia. (n.d.). *Eyre Highway*. https://en.wikipedia.org/wiki/Eyre_Highway

8 Waka Kotahi. (2021). *The length of urban and rural, sealed and unsealed roads.* https://www.nzta.govt.nz/planning-and-investment/learning-and-resources/transport-data/data-and-tools/

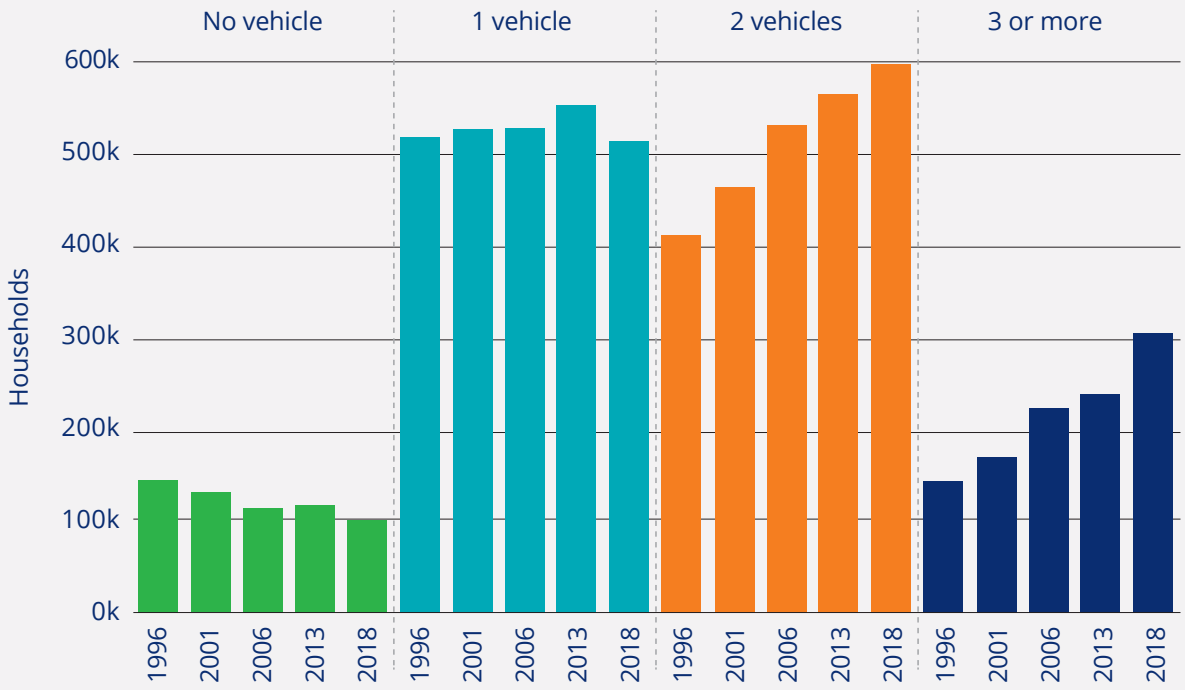
9 McCarthy, N. (2020). *Which Side Of The Road Do You Drive On?* Statista. https://www.statista.com/chart/9261/which-side-of-the-road-do-you-drive-on/#:~:text=The%20bulk%20of%20countries%20that,of%20Ireland%2C%20Malta%20and%20Cyprus

10 Ministry of Transport. (n.d.). *Fleet statistics.* https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/vehicle-ownership-2

11 Ministry of Transport. (n.d.) *Transport Indicators.* https://www.transport.govt.nz/statistics-and-insights/transport-indicators/sheet/healthy-and-safe-people

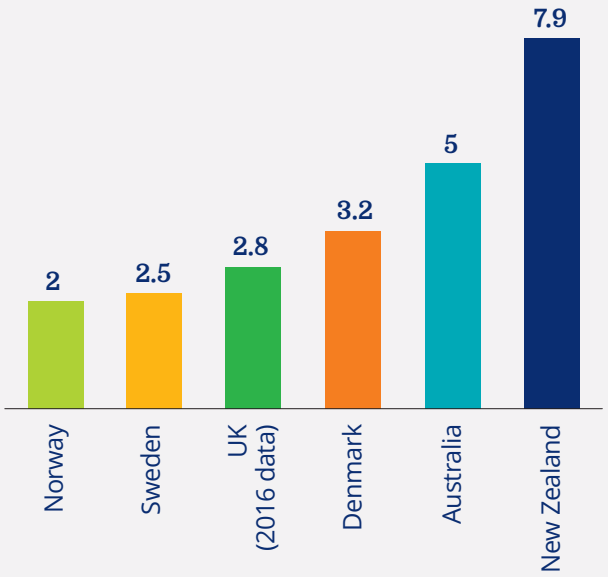
12 Ministry of Transport. (2019). *Road to Zero* New Zealand's *Road Safety Strategy 2020-2030.* https://www.transport.govt.nz//assets/Uploads/Report/Road-to-Zero-strategy_final.pdf

RD036 – Households with access to motor vehicles



Source: 1996, 2001, 2006, 2013, 2018 Census, StatsNZ

Road fatalities per 100,000 population 2017 (or latest available figures)



Each of these deaths and serious injuries has a wide-reaching impact beyond the immediate family. The chart on the following page illustrates the plateauing of safety gains on Aotearoa New Zealand's roads, with the level of DSI remaining largely stagnant for a decade.[13]

Approximately 90 percent of all road deaths are attributable to human error.[14] Almost one third of road deaths involve a driver with drugs (either recreational or prescription drugs that can impair driving) in their system.[15] Driver distraction is an increasing safety issue due to the increase in handheld devices and more touch screens available in vehicles. In 2020, there were 24 deaths and 111 people seriously injured on New Zealand roads because of "diverted attention".[16]

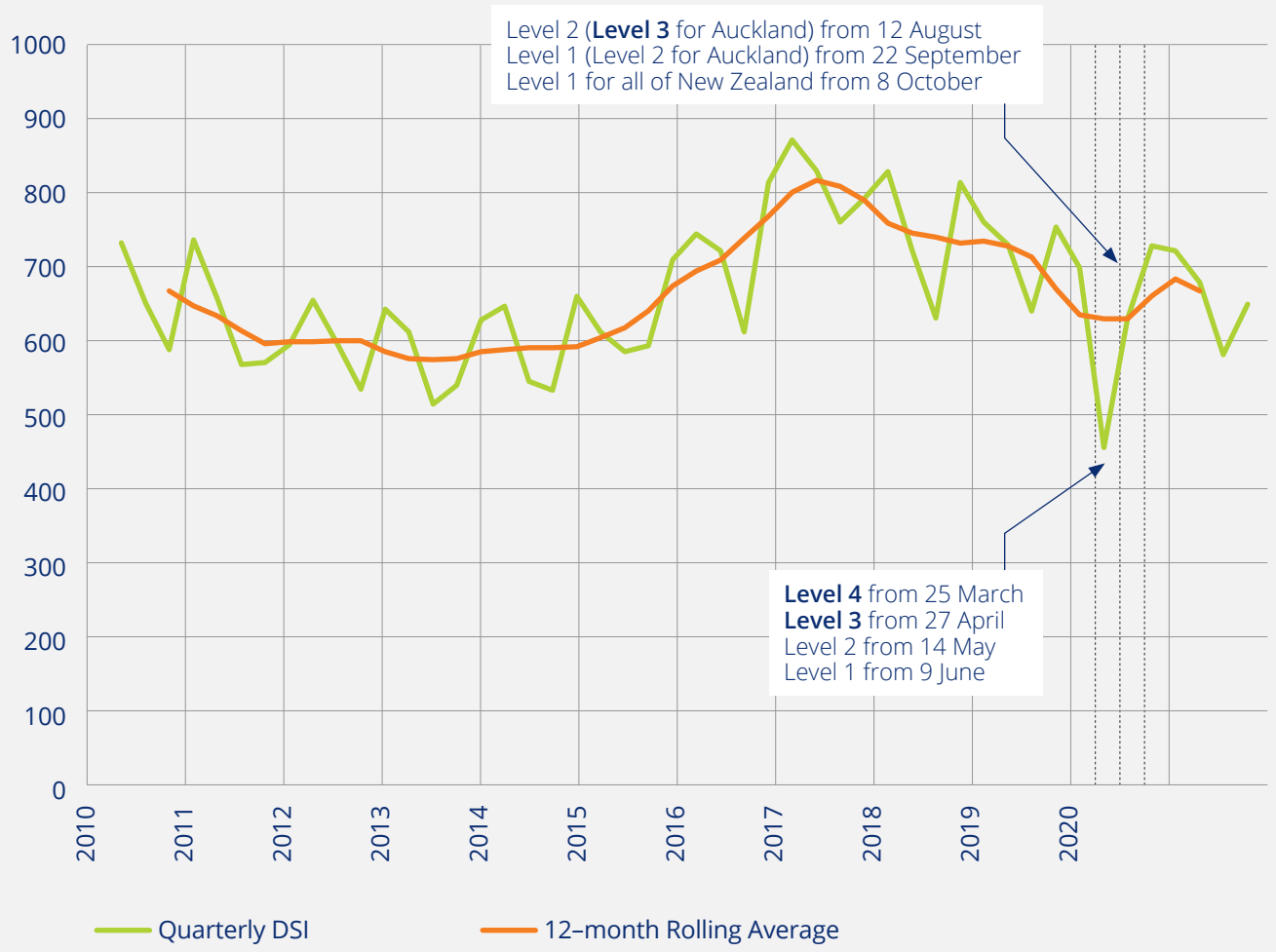
13 Ministry of Transport. (2020). *Road to Zero Annual Monitoring Report.* https://www.transport.govt.nz//assets/Uploads/MOT-3833-Road-to-Zero_Annual-Monitoring-Report-2020_FA4_WEB.pdf

14 NHTSA. (2017). *2016 Fatal Motor Vehicle Crashes: Overview.* https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456

15 This figure comes from the Second Reading Speech Land Transport (Drug Driving) Amendment Bill (2021). https://www.parliament.nz/en/pb/hansard-debates/rhr/combined/HansDeb_20210811_20210811_40

16 Ministry of Transport. (2020). *Safety – Annual statistics.* https://www.transport.govt.nz/statistics-and-insights/safety-annual-statistics/sheet/diverted-attention

Quarterly number of deaths and serious injuries 2010–2020



Not only are road deaths and serious injuries damaging to the communities in which they happen, they also carry an economic expense. The total annual economic cost of all vehicle crashes in Aotearoa is around NZ$5 billion.[17]

While New Zealand has a transport technology sector (involved in component parts of vehicles and related systems) we have no vehicle manufacturing sector so are reliant on sourcing vehicles from other countries. Across all imported goods and services, vehicles are our second largest import. While the uptake of electric vehicles has been increasing in recent years (in part due to policy initiatives like the clean car discount, but also the rising availability of EV technology globally), in 2020 EVs made up 9.5 percent of newly registered light vehicles.[18] The policy choices we make in Aotearoa will go some way in shaping the types of vehicles that enter our market, along with changing customer preferences and international supply and demand.

Legislation does not prohibit the use of AVs on New Zealand roads, provided they comply with all other vehicle certification standards. This is because there is no requirement to have a driver in the vehicle.

17 Ministry of Transport. (n.d.). *Social cost of road crashes and injuries 2020 update.* https://www.transport.govt.nz/about-us/news/social-cost-of-road-crashes-and-injuries-2020-update/#:~:text=The%20total%20social%20cost%20of,NZ%20Police%2C%20hospitals%20and%20ACC.

18 Ministry of Transport. (2020). *Fleet statistics.* https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/light-motor-vehicle-registrations/

The evolution of the transport system

The transport system includes our domestic and international environment and the linkages between the transport sector and other sectors. The operation of this system is influenced by a range of factors, including politics, government, councils, urban planning, commerce, and human behaviour.

The transport system in Aotearoa is constantly evolving in response to diverse influences, including the needs and wants of its population, and the transport outcomes it is seeking to achieve. In recent decades, we have seen different road and corridor types developed to support active travel (such as cycle lanes), and transit lanes developed to address emissions and congestion. More recently, we have seen new technologies on our streets and sidewalks, including e-scooters and e-bikes. There are now approximately 15,000 shared e-scooters operated by eight companies across ten territorial authorities in New Zealand and e-bike ownership has been rapidly increasing, offering alternative transport options to users.

There are also more non-traditional players operating in the transport system in New Zealand. These companies supplement existing transport modes and business models and are developing new options for mobility and demand responsive transport. Along with e-scooter providers like Flamingo and Beam, there are ride-hailing companies like Uber and car sharing companies like Cityhop and Mevo. Ohmio is a New Zealand based company and New Zealand's first and only road-based AV operator. They are developing automated shuttles as 'last mile' transport options to connect people to transit hubs and provide alternative transport options within urban areas.

Internationally, there are emerging automated transport options that could arrive in New Zealand. For example, the use of small automated robots and e-bikes for urban goods delivery is growing. In the maritime environment, testing and trialling large automated cargo ships is underway. In the aerospace environment, the use of drones for small goods delivery is increasing along with research and development into passenger travel by drone.

The transport system we know now is likely to be very different in twenty years' time. The choices we make now will determine what that future might look like in New Zealand. The Transport Outcomes Framework was developed to support decision-makers to make informed choices.

The transport system we know now is likely to be very different in twenty years' time. The choices we make now will determine what that future might look like in New Zealand.

The Transport Outcomes Framework as our lens

The Transport Outcomes Framework (TOF) sets out five key outcomes for the transport system in New Zealand (shown below). The TOF helps us to understand and prioritise transport's many areas of influence across society and the economy, and to be more explicit about the trade-offs between the outcomes that we are trying to achieve for individuals, groups, businesses, and government. At the centre of the framework is the objective of improving people's wellbeing and the liveability of the places where they live, work and visit.

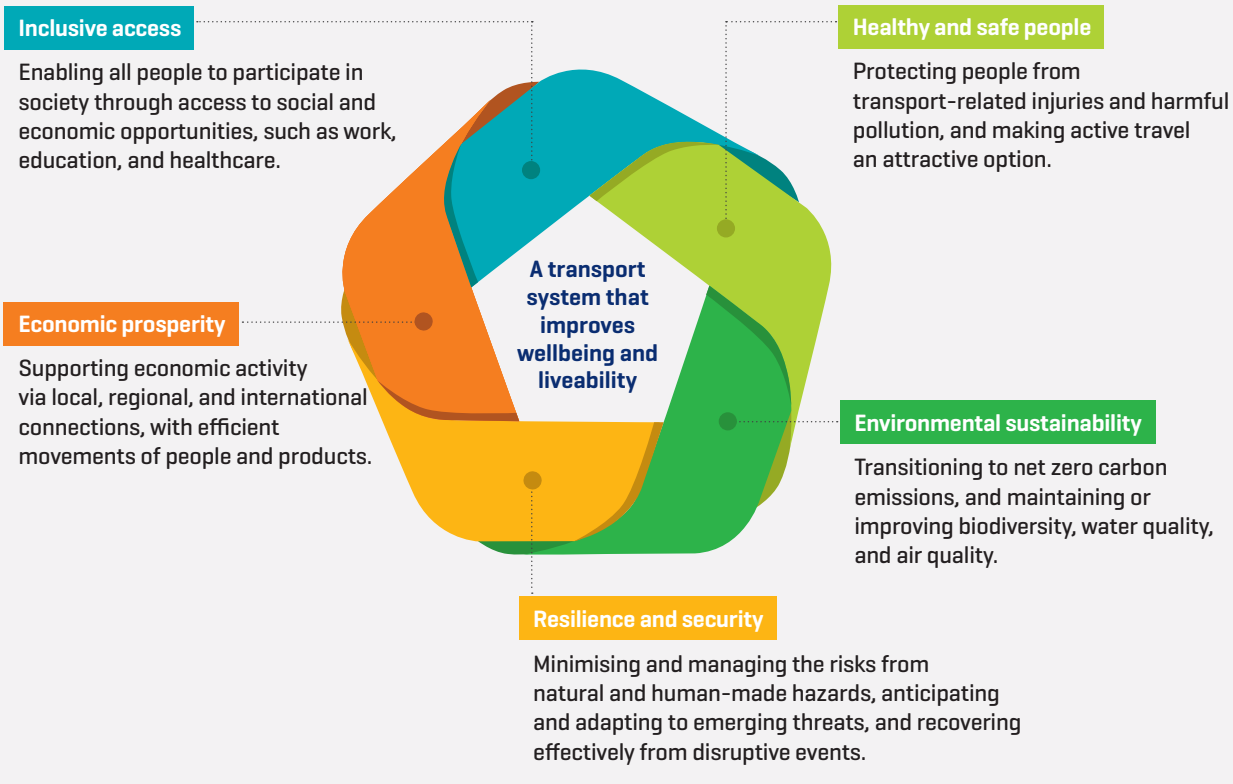
It has been designed to be enduring and used across the transport sector. The TOF is closely aligned with the Treasury's Living Standards Framework, which looks at the drivers of wellbeing and considers the broader impacts of policy advice in a systematic and evidenced way.[19]

The TOF is pictured below.

We will be using the five outcomes identified in the TOF to help us understand the impact of AVs operating on New Zealand roads. We will assess whether AVs have the potential to contribute to each outcome (and under what circumstances), or whether they may create challenges or barriers to its achievement. The outcomes are defined below:

Inclusive access is about enabling all people to participate in society through access to social and economic opportunities, such as work, education, and healthcare. Accessibility is shaped by a range of factors including location and distance (i.e., how far people need to travel to access what they need/want), personal and community capabilities (including mental, physical, and financial abilities), the range of travel options available, and time (i.e., how long it takes to travel by each option). Access is high when people can access many social and economic needs and opportunities within a short amount of time and at an affordable cost.

The purpose of the transport system is to improve people's wellbeing, and the liveability of places. It does this by contributing to five key outcomes, summarised in the diagram below.



19 The Treasury. (2021). *Our Living Standards Framework.* https://www.treasury.govt.nz/information-and-services/nz-economy/higher-living-standards/our-living-standards-framework

We are interested in understanding who will benefit from AVs, in what ways, where, and whether they will only benefit a few or serve many different individuals and groups with differing needs. We are also interested in understanding if benefits will accrue for those who live in certain locations or only for those who can afford it.

Healthy and safe people is about protecting people from transport-related injuries, harmful pollution and making active travel an attractive option. The transport system can benefit or harm people's health, depending on how it is designed, developed, and used. New Zealand's transport system, particularly its land transport system, needs to be much safer in the future.

There are significant opportunities for transport to play a more positive role in supporting physical and mental wellbeing. Providing people with attractive options to incorporate physically active travel into their daily lives could bring significant personal and public health benefits. Safe and attractive walking and cycling infrastructure needs to be widely available.

We are interested in understanding whether AVs can play a role in protecting people from transport-related injuries and harmful pollution. We are also interested in whether AVs will contribute to poorer health outcomes or increase the risk for death or serious injury on our roads. It is also important to consider the potential unequal distribution of benefits from AVs.

Economic prosperity is about encouraging economic activity via local, regional, and international connections, with efficient movements of people and products. Transport supports economic activity by connecting businesses with their workers, customers, suppliers, and other businesses. This enables each community and region of New Zealand to take advantage of its unique strengths and resources.

We are interested in understanding how AVs might support businesses and economic activity. We also need to understand how AVs might disrupt current business models and any negative impacts they might have on particular sectors or on economic activity as a whole.

Environmental sustainability acknowledges that the transport sector has a particularly important role to play in responding to climate change. Transport is responsible for 39 percent of New Zealand's total domestic carbon dioxide (CO_2) emissions, and 17 percent of gross emissions.[20] There are many opportunities to reduce and avoid transport emissions while also benefiting health, access, and economic prosperity.

Along with transitioning to net zero carbon emissions, environmental sustainability in transport is about maintaining or improving biodiversity, water quality, and air quality. This outcome recognises that people and places will only be able to prosper in the long term if the living systems that our society, economy, and wellbeing depend on are sustained in a healthy condition.

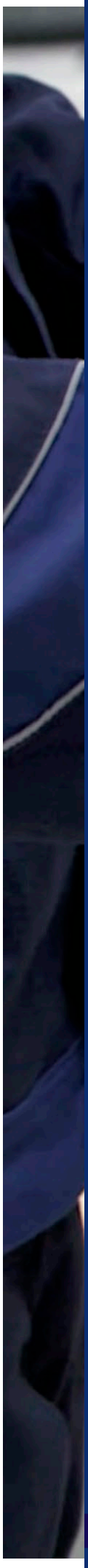
We are interested in understanding how AVs might help us meet carbon emissions targets and improve biodiversity, water quality, and air quality. We are also interested in understanding if AVs will make it harder for us to reach these targets.

Resilience and security is about minimising and managing the risks from natural and human-made hazards, anticipating and adapting to emerging threats, and recovering effectively from disruptive events. It is also about the resilience of the transport network in times of crisis (including pandemics like COVID-19). A well-functioning transport system is vital for restoring communities and business activity after the emergency phase is over.

The increasing prevalence of technology in our vehicles and systems is expected to create increased risks to the resilience of the transport system, while also providing new means to anticipate and rapidly respond to threats. The security of the transport system (both digitally, in terms of cybersecurity, and in the physical space) needs to be maintained to guard against intentional harm to people, infrastructure, the environment, and our economic prosperity.

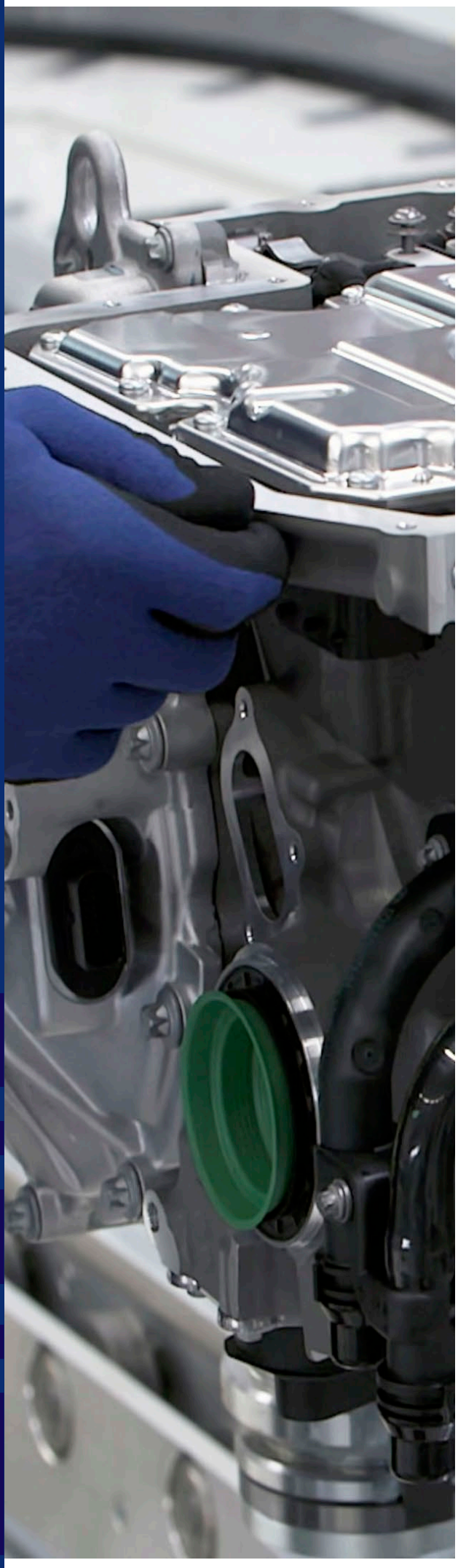
We are interested in understanding the level of risk AVs will pose to the resilience and security of the transport system. We are also interested in understanding what would need to be done to create assurance that this risk can be managed.

20 Ministry for the Environment. (2022). *Aotearoa New Zealand's first emissions reduction plan: Chapter 10 Transport.* https://environment.govt.nz/publications/aotearoa-new-zealands-first-emissions-reduction-plan/transport/



Te whanaketanga o ngā hangarau i roto i ngā kaupapa Hautū waka | The evolution of technology in transport

This section focusses on the role of technology and automation in transport. It discusses technology as an enabler and the growth of automation in the transport system. It concludes with a discussion on the emergence of automated vehicles across the global vehicle manufacturing industry.



> Technology is not inherently good or bad, but its application, and interaction with its environment (built, natural, and human) determines its overall impact.

Technological progress has been an important force behind the dramatic growth in incomes, productivity, and wellbeing over the past 250 years.[21]

Technology can also function as a catalyst for major change by expediting progress beyond incremental improvements that might take too long to meet objectives. This role of technology is particularly critical when we are facing challenges that require systemwide adaptation, such as climate change or a global pandemic.

Technology as an enabler

Technology can be an important enabler to help us reach our transport outcomes. For example, the electrification of our light vehicle fleet to help reach our emissions reduction goals, and improved safety systems in vehicles to contribute to the decline in deaths and serious injuries (DSI) on our roads. For example, from 2015 all new cars, vans, 4-wheel drives, and goods vehicles imported into New Zealand require Electronic Stability Control (ESC). ESC is a crash prevention system that intervenes if a vehicle is about to skid or lose traction.

People and businesses must see the value in technology before they adopt it. The onus here should be on the developer of the technology to demonstrate its value. New technology should be more efficient and effective, including from a cost perspective, especially if it is going to be mandated. Whether a technology delivers benefits to society is also determined by how society chooses to use it.

Technological developments are not without their risks. The risks may be known or unintended, and they may be immediate or delayed. For example, vehicles with internal combustion engines (ICE) enabled greater mobility but caused increased congestion, harmful emissions, road deaths, and serious injuries. Government agencies have a role to play in helping steer the application of technology away from negative outcomes and toward desirable ones. They can do this through shaping regulation and influencing government procurement, land-use planning, and investment decisions.

We must also consider the risk of not adopting new technology. What benefits might we miss out on by not enabling AVs? By not embracing new technology, we are consciously or unconsciously saying that the available options are sufficient in helping us reach desired outcomes. However, the uncertainty surrounding some of the challenges we face, their magnitude, the rate at which we need to address them, and what solutions may arise in the future, means our assumptions need to be clear and considered before we make decisions to adopt new technology.

Automation in the transport system

Rudimentary forms of automation can be traced back to ancient Greece and many of the great economic and social strides from the industrial revolution can be attributed to automation. By removing human labour, things could be done faster, more accurately, in a safer manner, and more cost effectively.

21 New Zealand Productivity Commission. (2019). New Zealand*, technology and productivity – Technological change and the future of work.* https://www.productivity.govt.nz/assets/Documents/740ce1e715/Draft-report-1_NZ-technology-and-productivity-v2.pdf

Automation is already well developed in aviation and rail. The first aircraft autopilot was developed in 1912, permitting the aircraft to fly straight and level on a compass course without a pilot's attention, greatly reducing the pilot's mental load. Automated trains allow operators to run more trains on a single line because they are more efficient and can guarantee the necessary precision. A range of systems and processes underpin automation for rail and aviation, as well as legislation and regulation.

Risk tolerance has largely guided how and when automation has been used in the transport sector. The successful integration of automated features into other transport modes relied on factors that revolve around the overall risk tolerance of those sectors. For example, the aviation sector has set their risk threshold at one catastrophic failure for every billion flight hours. A commercial airliner is typically operated for about 75,000 hours over its lifetime.[22] Pilots are also still required onboard even though some technology, such as autopilot, has been available and proven for decades.

The road environment is substantially different to that of rail and aviation. Aviation and maritime environments do not have the volume of other operators and vehicles in the same space, making journey planning much easier and minimising opportunities for collision. Risks surrounding the use of automation are managed because ships and aircraft are supported by well-established systems, processes, and crews of highly skilled individuals that back-up software and algorithms. Aviation also has a "no blame" culture designed to encourage knowledge-building over singling out individuals, affording pilots the confidence to use automated technologies.

Understanding the risk tolerance for road transport will be a key factor in determining the future for AVs in New Zealand. Road transport presents a more "cluttered" and complex environment for automated systems to navigate. AVs will likely introduce new points of vulnerability into the system as they require additional or new digital and physical infrastructure to operate safely, such as those used in aviation and maritime environments.

The development of automated vehicles (AVs)

Research and development for AVs is a multi billion-dollar global industry. Investment comes from major automotive companies such as Nissan, Toyota, and Honda. There is also investment from non-traditional sources that include technology giants such as Facebook, Apple, Amazon, Microsoft, and Google, and start-up ventures that can offer the necessary expertise and capital for AV development. The various industry players are approaching the AV industry as a long-term economic investment opportunity and are operating across country borders with a focus on being the first to deploy AVs at a commercial scale.

Internationally, manufacturers are testing and trialling vehicles with varying degrees of automation. At the most advanced stages of AV development, Level 4 driverless taxi services are operating in pilot areas with fare paying customers, and some countries have enacted legislation to allow the operation of Level 3 AVs on public roads. Policy makers in some countries, such as Japan, are thinking specifically about how AVs can help address growing social concerns, like providing mobility to an ageing population. Other countries are focused on the opportunities AVs might present for job creation, innovation, and economic growth.

22 Rutherford, D. (2021). *A NEW CLIMATE OF AIRCRAFT SAFETY.* The International Council on Clean Transportation. https://theicct.org/a-new-climate-of-aircraft-safety/

On-road AV use cases

AVs can be used for transporting both people and goods and may replace or complement parts of the existing transport system

People transport

Automated shuttles

Could support the existing public transport network by transporting small groups of people along fixed and planned routes to their final destinations after a public transport journey.

Carrying 8-20 people, typically limited to about 30 km/h and suitable for indoor as well as outdoor use, these shuttles are successfully emerging in many closed areas, such as university campuses, office parks, airports, industrial parks and hospitals.

Automated buses

Could replace existing bus fleets to increase the reliability and frequency of bus services, allow for easier on demand services and reduce costs by removing the need for a human driver.

Automated buses can vary in size – to suit the requirements of the city, town, or community – and the complexity of the environment. Automated buses are currently in use in some parts of the world, although many still feature a designated safety person onboard to reduce passenger concerns.

Robotaxis

Could provide cheaper ride-hailing due to their anticipated intensive use, and lower maintenance and running costs, including no driver to pay.

They may provide improved mobility for older people, young, and disabled users, and communities with few mobility options. Robotaxis have recently started being used commercially in places like China and parts of the United States.

Goods transport

Last mile goods delivery

For example, from a store to a house

Middle mile goods delivery

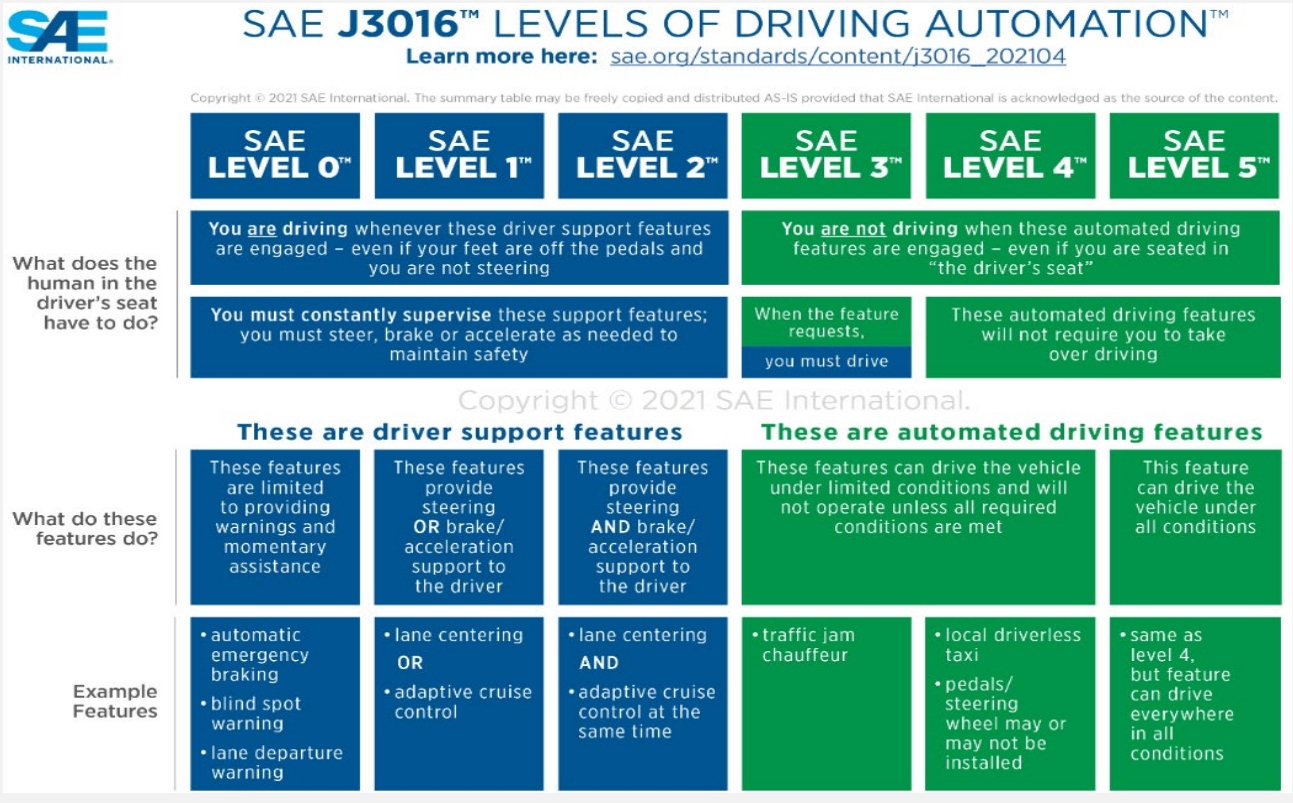
Hub-to-hub, for example, from a warehouse to a store

Automated goods delivery may be faster, cheaper, and able to operate with greater flexibility than current delivery systems that rely on a driver. Last mile goods delivery via AV may help satisfy high public demand for contactless delivery, and demand for last mile delivery that has arisen with the increasing popularity of e-commerce.

The final incremental technological developments necessary for the safe operation of higher levels of automation is particularly challenging, despite the recent increase in patents for AV technology. In New Zealand, Ohmio is the first AV company to test and trial an automated shuttle with members of the public. The shuttle trials have been limited to simple environments, such as the Christchurch airport and botanic gardens, but the company has been able to expand overseas and is now trialling its shuttles on public roads in South Korea.

There are established frameworks that define the levels of automation for manufacturers, investors, and regulators. The industry-standard is the *Society of Automotive Engineers (SAE) levels of driving automation.* The SAE framework describes six levels of automation from a technical perspective where Level 0 is no automation, Levels 1 and 2 provide some assistance to the driving task and Levels 3-5 allow the vehicle to operate independently of the driver, in given situations. The framework can be seen below. There are also dedicated UN working parties developing global standards for AV deployment and use.

> "Taking the first few meters from the base station to the summit seems easy. But the closer you come to the goal, the thinner the air around you becomes, the more strength is required for each further step, and the more complex become the challenges you have to resolve."
>
> **Michael Hafner**
> Head of automated driving at Mercedes-Benz research and development



This paper is concerned with Levels 3-5 (the green section in the SAE framework).

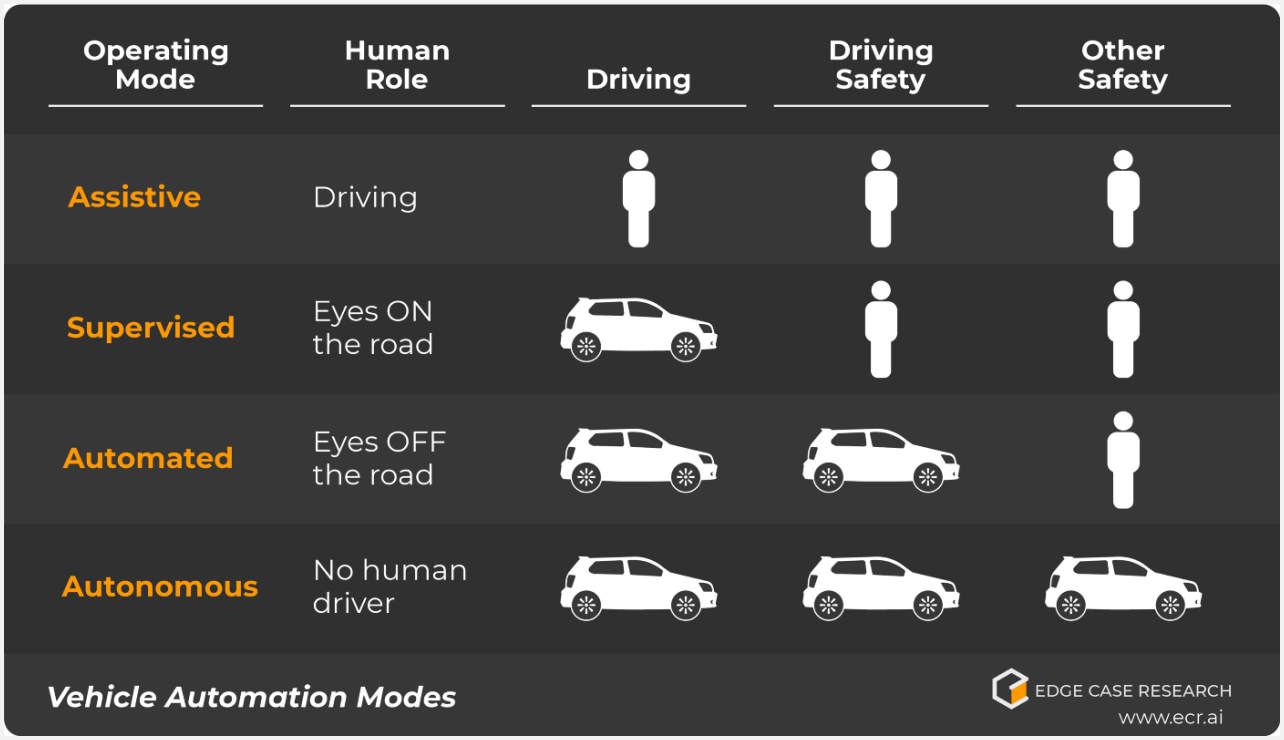
SAE Level 3 is known as *Conditional Driving Automation* and marks the point at which the vehicle can perform all aspects of the driving task without the human driver needing to monitor the driving environment. The driver must however be alert and ready to take back control when the system requests them to intervene.

SAE Level 4 is known as *High Driving Automation* and is where the vehicle undertakes all aspects of the driving task, within a defined geographic location. The user is not required to monitor the driving environment or take control of the vehicle at any point. This is the primary difference between Level 4 and Level 3 AVs.

SAE Level 5 is known as *Full Driving Automation* and is where all aspects of the driving task and monitoring of the driving environment are undertaken by the vehicle itself, under all conditions. There are no design-based weather, time-of-day, or geographical restrictions on where and when the vehicle can operate. This is the primary difference between Level 5 and Level 4 AVs.

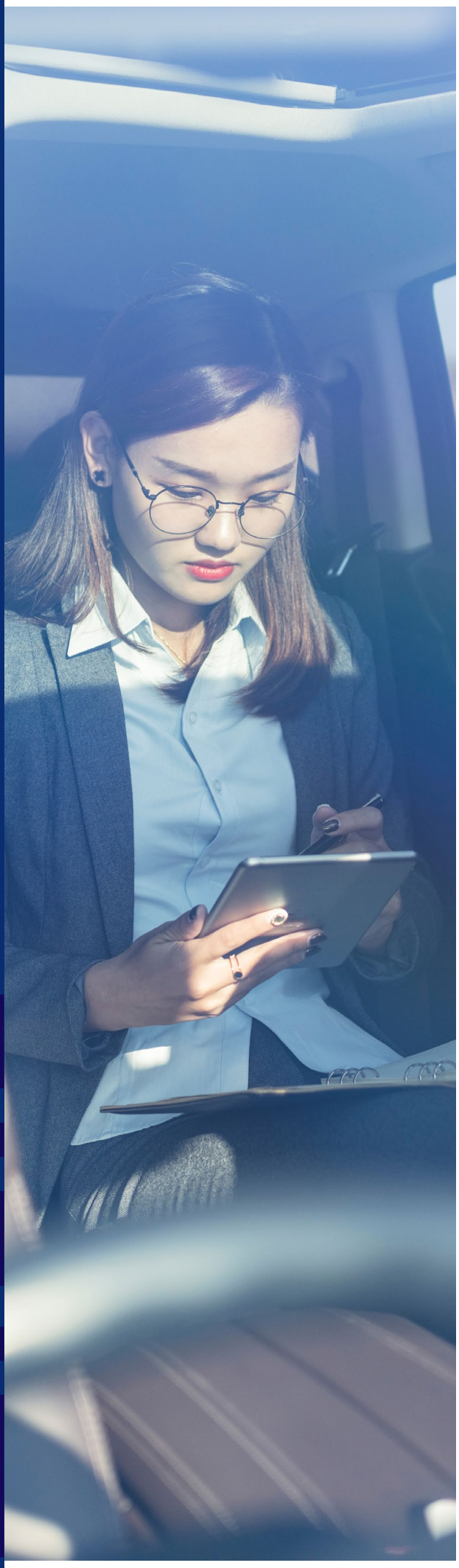
The SAE framework was developed by engineers. It is useful because it is widely recognised internationally and creates consistency in the language used by manufacturers around the world. However, it does not cover the full range of roles and responsibilities a human may have under each level. For example, the responsibility for securing children's seatbelts and for securing a trailer and its load. To make good policy we need to understand better how people fit into the equation.

Other frameworks, which work alongside the SAE levels of driving automation, can provide a valuable contribution to policy thinking. One example is the Edge Case Research framework below that clearly delineates the role of humans in both driving the vehicle and managing the safety of the vehicle and its occupants. Like the SAE framework, the human can only take their eyes off the road and ignore the driving task at the *Automated and Autonomous* levels when the ADS is in operation (Level 3 and above in the SAE framework). However, the Edge Case Research framework makes it clear that humans are still responsible for vehicle and passenger safety at the *Automated* level, even when the system is in operation. The value of this approach is it makes it explicit that there are other roles people play, even when a vehicle is driving itself.



He tirotiro ki te pānga mai o ngā waka Hautū kore | The potential impact of AVs

This section looks at the potential opportunities and risks of AVs and scrutinises their impact on New Zealanders and the nation's transport sector by identifying key questions they may want answers to. Questions have been drawn from discussions with academics, industry experts, councils, the disability sector, and other Government agencies.



> Internationally there is hype around promised opportunities and benefits from AVs. While commentary outlines potential safety benefits from AVs as well as raising some risks and challenges, the actual impact of AVs is less certain with limited real-world application and experience. Exactly when and where AVs will be operating in New Zealand, and how the public will engage with them adds another dimension of uncertainty to their impending arrival.

A scan of available research (primarily international) provides a high-level understanding of the potential opportunities AVs could bring to the transport system in Aotearoa. However, much of this is speculation driven by industry leaders with a vested interest in the success of AVs. The wider transport sector and academia provide a more balanced view, seeing the potential risks as just as likely as the purported benefits. It is difficult to foresee what the actual outcomes might be.

While the AV literature provides a starting point to consider opportunities and risks, we need to consider these within New Zealand's context and test them against our overarching ambitions for transport in Aotearoa. The Transport Outcomes Framework (TOF) provides a useful lens through which to consider opportunities and risks from the perspective of those who will be impacted.

We identify two key groups who we believe will be impacted by AVs and have structured this section's discussion under each:

New Zealanders – The public in New Zealand who will be the users of AVs and those who will interact with them in shared public spaces. These individuals and groups come from many different backgrounds, have a range of physical and mental capabilities, and have a variety of transport needs. Those visiting or living temporarily in New Zealand are included.

The Transport Sector – This group includes businesses that want to own and operate AVs, want to sell AVs in New Zealand, want to utilise AVs for their business or will inspect, maintain, repair, and test AVs. It also includes the wider technology sector that will innovate in AV development. These groups are operating for profit, social outcomes, or are not-for-profit, and could be domestic or foreign.

There is overlap across these groups, but each has specific goals, drivers, and constraints. The following discussion will work through the key questions that both groups will want answered when considering whether to purchase, use and/or support AVs operating on New Zealand's roads. Both groups will be impacted in different ways, influenced by how government views AVs (while simultaneously being *influencers* themselves through their use and response to the technology) and, subsequently, how government decides to regulate and support AVs.

Questions New Zealanders want answered

Aotearoa New Zealand is a diverse country. Around 70 percent of the population are of European descent, with the remainder being of Māori (16.5 percent), Asian (15 percent), Pasifika (8 percent), or Middle Eastern/Latin American/ African (1.5 percent) descent.

Over one in four (27.4 percent) of those living in New Zealand were born overseas; in Auckland, this figure rises to 41.6 percent. Of all people living in New Zealand, a quarter have lived here for less than five years.[23] International tourists and students also make up a small component of the motoring public in some parts of New Zealand. The multicultural nature of our country has implications for norms and expectations regarding lifestyle, including transport expectations and choice.

As our population continues to grow the demographic makeup will change over time. For example, if current trends continue:

- there will be significant population growth in the "golden triangle" between Hamilton, Auckland, and Tauranga in the coming years
- the ethnic makeup of our population is likely to shift, with those identifying as 'European or Other' estimated to reduce from 70 percent (in 2018) to 64 percent in 2043, while all other ethnic groups will increase their population share. The broad Asian ethnic group will have the largest rise, increasing from 16 percent of the population (in 2018) to 26 percent (or approximately 1 in 4 residents) by 2043[24]
- all regions, cities, and districts will be home to more people aged 65 and over by 2048
- deaths will increase relative to births in almost all locations as the population ages.[25]

AVs will be experienced and perceived differently depending on where people live, what their transport needs are, their cultural values and their ability to use available transport options. Being conscious of the existing diversity of New Zealand and knowing how the population is likely to change over time helps centre our thinking on what is important to New Zealanders now, and what is likely to be important in the future.

Will AVs be safe?

Government and the wider transport sector have a shared responsibility for ensuring the safety of the transport system. This includes regulating what vehicles we allow into the country, setting standards, and developing systems to assess those vehicles upon entry and throughout their lifetime on the road. The safety of AVs is likely to be a primary concern for most New Zealanders, but what is considered "safe" will vary for different individuals and groups of people.

Other road users need to know that AVs will behave in a predictable manner, adhere to the road rules, and will drive more safely than a human driver. Depending on where AVs are eventually allowed to operate, they may interact with light and heavy vehicles, motorcyclists, cyclists, pedestrians and micromobility (e.g., e-scooter) users. As the population grows over the next 30 years, all road users will likely be competing for access to the same space. Consideration will need to be given as to how all road users can operate safely within the space.

Those choosing to use AVs will want to know that the vehicle's systems are safe for them to operate. System failure will likely be top of mind, particularly in the early days of AVs operating on public roads. There have been failures in Level 2 vehicles already on public roads in other countries, resulting in deaths and injuries. The security of the vehicle's systems will also impact the perception of safety. As the vehicle software will be responsible for the dynamic driving task, the risk of malicious hacking and vehicles being taken over remotely will require assurance that software systems are secure.

Pedestrians will want to know that AVs will prioritise their safety in areas where AVs and people interact. Pedestrians may experience challenges with AVs because there is no driver to visually communicate with. Currently, much communication between drivers and pedestrians happens purely via gestures and eye-contact. For example, pedestrians waiting at a pedestrian crossing and drivers waving them across, and people on bikes waiting to turn at intersections.

23 Statistics NZ. (2018). *Census place summaries.* https://www.stats.govt.nz/tools/2018-census-place-summaries/new-zealand

24 Statistics NZ (2021). *Population projected to become more ethnically diverse.* https://www.stats.govt.nz/news/population-projected-to-become-more-ethnically-diverse

25 Statistics NZ (2021). *Subnational population projections: 2018(base)–2048.* https://www.stats.govt.nz/information-releases/subnational-population-projections-2018base2048

This presents additional anxiety for pedestrians interacting with AVs, as well as cyclists and other road users.

Some groups in society already face more transport related challenges than others. People with impairments or disabilities will face additional safety challenges if their needs are not met. Visually impaired people already face challenges from the low noise emitted by electric vehicles. New Zealand will need to address this issue, since most Level 4 and 5 AVs built are electric.[26] Similarly, those with hearing impairments will need clear visual signals from the environment and vehicles. AVs will also need to provide all people, but particularly those with physical or mental impairments, adequate warning of their intentions. This will become more important over the next 30 years as our population ages.

Perceived safety will be a key determinant of whether people support the use of AVs on New Zealand roads and choose to use them. AVs will need to be at least as safe as a human driver, but the threshold may need to be much higher to get widespread public acceptance. The impact of a single death because of an AV is anticipated to have a far greater impact on public trust than hundreds of deaths under current settings. This perception may change over time as AVs become more commonplace, but, in the early days of deployment, it will shape people's views around AV safety.

Demonstrating AVs are safe is the responsibility of manufacturers and those who bring AVs to market. While regulators have a role in setting and justifying the standards for safety, it will be up to manufacturers to convince the public that AVs are safe. This will be complicated with the potential for misinformation around AV safety.

Ethics and AVs: The trolley problem

Public acceptance of AVs will be a key factor in their uptake in Aotearoa. Among the uncertainties around AVs are ethical concerns. One example often used is the 'trolley-problem'. The trolley problem is a thought experiment where an onlooker is faced with a moral dilemma: to divert an oncoming trolley to save five people in immediate danger of being hit with the loss of one life (standing where the trolley is diverted to), or to let the trolley run its course. The term is often used more loosely about any choice that seemingly is a trade-off between what is "good" and what sacrifices are "acceptable" (if at all) to achieve it.

In the context of AVs, ethical dilemma presents as though, if an accident were to occur, the AV will be faced with a choice. A hypothetical scenario often described is whether an AV will be able to make a "morally acceptable choice" between colliding between two different people. For example, choosing between hitting a young child versus an older person or risking the vehicle occupant's safety. This line of thinking implies that human intuition will always lead to a "morally acceptable" decision compared with how an AV would respond given the same (highly unlikely) scenario.

However, AVs will not be sentient, rather, will likely be programmed to do what is necessary to protect the driver, and this does not differ greatly from how a human driver would likely respond given the same life-threatening scenario and making a split-second decision. Rather than trying to address the trolley-problem, more emphasis needs to be placed on the underlying concerns presented by this fictional case; how will AVs be programmed and what inherent biases might be embedded into their development? To mitigate longer-term inequitable outcomes, more attention is required in the early phases of AV development to ensure that biases are not coded into their software. The public and regulators will likely need demonstrable assurance that measures to reduce bias have been taken by manufacturers. To assist with building trust and assurance, certification processes may require AVs to meet certain ethical standards.

26 The EU and US have established regulations to require electric vehicles to have devices attached that make the same amount of noise as an ICE vehicle. New Zealand has not instituted similar regulations yet.

Who is responsible if the vehicle crashes?

Consideration is needed around who will be liable for damages in the event of a crash if the vehicle's software (the ADS) was driving the vehicle at the time of the collision. Other countries have already started developing legislation to answer the liability question. In Australia, a separate entity is being designated through legislation and will be held responsible for liability purposes when the ADS is in operation. This ensures there is a single entity held culpable for all aspects of a vehicle's systems, as opposed to having to engage with individual component manufacturers or importers to determine the origin of the fault that led to an accident. In most cases the responsible entity will be the manufacturer of the vehicle.

New Zealand will need to decide how it wishes to regulate liability before AVs operate on our roads. Without clear liability and responsibility provisions in legislation for AVs (Levels 3-5), we could see premature deployment of the technology without clarity around the consequences of negligence or misuse. This is likely to exacerbate public and business distrust in, and unwillingness to engage with AVs.

Establishing the concept of a single responsible entity would enable Waka Kotahi, as the regulator, to set conditions before granting approval to deploy AVs on New Zealand roads. Further work would be needed to determine which conditions would need to be met, but this could include requirements such as ensuring that data is recorded and made available to investigators in the event of an accident, and requirements related to cybersecurity.

AV safety goes beyond just the operation of the vehicle itself.

Even at Levels 4 and 5, AV users will retain some responsibility for the safety of their passengers and other road users. As well as not misusing automated technologies or tampering with the vehicle's software systems, users will still need to ensure things like passengers are wearing seatbelts, trailers are securely fastened, and vehicles are not overloaded. These responsibilities need to be clearly established, along with the penalties for not discharging them.

Will my personal information be secure?

Individuals and companies will want assurance that the information collected by AVs remains private. Individuals will want to know that their personal information cannot be accessed without permission, either by companies who may consider using it or selling it, or by hackers who may also use it for personal gain. Companies will want to know that their commercial information remains secure to maintain their competitive advantage.

AVs will collect origin and destination information, travel patterns, and potentially evidence of offences (like speeding). They will have audio microphones that may capture all conversations even if not directly engaging the ADS (the Amazon Echo Dot does this now), and voice activation in vehicles may lead to concerns around speech being recorded. The vehicle's cameras will be continuously recording and storing this information in the vehicle's Event Data Recorder. Information may also be collected on those interacting with the AV who may not have given consent for it to be collected.

The Privacy Act 2020 outlines a framework for protecting an individual's right to privacy of personal information, including the right of an individual to access their personal information, while recognising that other rights and interests may at times need to be considered. It also gives effect to internationally recognised privacy obligations and standards in relation to the privacy of personal information, including OECD Guidelines, the International Covenant on Civil and Political Rights, and the European GDPR. Questions remain around who owns the vehicle's data and how individuals can be assured their data is not being misused.

The transport network could be improved by using the data AVs collect. Access to data on near misses and AV disengagements, peak travel times, traffic bottlenecks and vehicle kilometres travelled (VKT) is useful to improve the efficiency of the transport network by reducing congestion and improving traffic flow. In the freight sector this could be used to support and inform logistics systems. This data could support/inform future revenue collection for the transport system.

Real-time access to vehicle data by enforcement agencies would also facilitate investigations into incidents and help to monitor compliance

requirements for vehicle owners (e.g., updating vehicle software systems). At present a search warrant is required, creating delays in accessing data recorder information and using up court time. If this is seen as a significant benefit for enforcement agencies, consideration should be given to how this information can be easily (and legally) obtained.

Will AVs benefit me and my community?

The AV benefits presented to people depend on individual and community circumstances. The affordability of AVs for private use, and the affordability, accessibility, and availability of shared AV services (those available to the public), will vary between people and result in a range of experiences across the population.

The use of AVs for goods delivery would likely offer flow-on benefits to all consumers by increasing market competition and improving service delivery. Reduced driver costs and associated constraints (like mandated rest times) could also result in cheaper transport services, greater flexibility in service delivery (through more on-demand models) and better network coverage. New Zealand already faces driver shortages across the PT sector, resulting in frequent delayed and cancelled services. There are similar driver shortage challenges in the freight sector that AVs are suited to address, potentially also reducing the cost of goods to consumers.

For those who can afford to own or lease a Level 4 or 5 AV, there are a number of personal benefits. AVs will provide added comfort and convenience, particularly on longer journeys. This could facilitate people living further away from their place of work or travelling with greater flexibility in their leisure time (e.g., sleeping en-route to a holiday destination overnight). Commuters may also avoid paying for parking if their AV can return to their point of origin once it has dropped them off. It is not clear whether the law would change to allow children under the age of fourteen to travel unaccompanied in AVs. If this is the case, then AVs might be able to support parents sending their children to and from school and to extra-curricular activities as well. While all these benefits could accrue to individual AV owners, there are implications for other parts of the transport system and transport outcomes (for example, increased urban sprawl and congestion in some locations).

Shared AV services would provide benefits for a wide range of individuals and communities. Shared transport is directly linked with community connectedness for Māori for example. Shared transport for Māori is empowered by the principles of kawa (cultural practices) and tikanga (cultural principles).[27] Shared mobility presents an opportunity for kaumātua (older people) who live across the region to be together and kōrero (converse). In many cases travelling together is a way to reflect family togetherness and emphasise the importance of the collective. Shared community vans also help many Māori communities to reduce transport costs. The responsibility, however, often falls to an individual to obtain their licence and assume the role of the designated driver for their whole whānau or community. Shared AV services could reduce the reliance on individuals, and potentially provide the same service at a more affordable cost than vehicle ownership.

Other groups in Aotearoa, such as Pasifika people and many people of Asian decent also place great importance on community and family, with inter-generational living arrangements not being uncommon. Rising pressure on housing affordability is also forcing more people and families to live in shared spaces thus increasing the demand for transport solutions that are affordable and practical, such as shared transport options.

AVs could provide benefit to people who cannot drive or do not have a licence. Older people who have had their independence reduced through losing their driver licence (because of deteriorating eyesight, hearing, cognition and/or physical mobility) or who experience driving anxiety, could access more transport options. At present, a significant number of older people are reliant on friends and family to travel. Disabled people are less likely than non-disabled people to find it easy or very easy to access key public facilities. Across New Zealand, disabled people make fewer trips than others and often the trips are longer due to the need for an accessible route. To support these groups, AVs will need to be designed for easy access in and out for those with mobility constraints, particularly where

27 The Royal Society of New Zealand. (2018). *Shared mobility in a Māori community.* https://ourarchive.otago.ac.nz/bitstream/handle/10523/8040/Shared%20mobility%20in%20a%20Maori%20community.pdf?sequence=1&isAllowed=y

human assistance is otherwise relied upon. The vehicles might also need to have voice activation for those with visual impairments, and a clear heads-up display with detailed information for those who are hearing impaired.

Public transport could be supplemented with AVs. Many older people view PT as unreliable, and it does not always suit their needs. This is primarily because of the way the PT system is designed, a heavy reliance on driver availability, and the way urban development has historically centred on the private car. Without relying on human drivers, AV shuttle services could provide more affordable, reliable, and frequent transport to and from the places older people need to access (e.g., visiting friends, the supermarket, clubs, parks, the hospital, pharmacies etc) and increase independence.

AVs could also provide a safe transport alternative for those who currently experience discrimination within the transport system. Transport options are not always designed with women or the rainbow community in mind (e.g., not feel safe travelling at night on public transport). If AVs provide a more affordable option than existing ride-hailing or taxi services, they could provide a safer alternative for more people, particularly if services are on-demand and provide door-to-door pick-up and drop-off. Conversely, removing the human driver may, in some instances, make these groups even more vulnerable and expose them to risk that was not otherwise present when another human could monitor and respond to threatening situations.

Realising the personal and community benefits of AVs and minimising the potential risks will depend on how they are deployed and where. If shared AV services are not available across all locations, particularly in city fringe and rural areas (where there has typically been less access to PT, ride-hailing, and shared vehicle options than in urban areas), then these communities could miss out on the benefits of AVs. Similarly, some groups might not realise the benefits of AVs if the vehicles are not designed for all users to easily engage with, including those with disabilities and impairments.[28] The risk here is that AVs could create greater division between different groups in society.

Growing reliance on technology to access transport services could also lead to exclusion by people who are not digitally proficient, do not have access to, or cannot afford the technology in the first place. Access to new transport options (like ride-hailing and car sharing) typically requires a smartphone as well as a bank account and not all New Zealanders have both. The digital divide may also be greater in the disabled community, lower-income households, and among older people. With online access to services growing, there is a risk that some New Zealanders could miss out on the benefits of AV services. To avoid this, access to AVs needs to suit all potential users.

What will the user experience be like with no driver?

Drivers providing services to the public often have additional roles beyond just the driving task. Drivers may help customers with their luggage or groceries, help them get in and out of the vehicle, provide information about a destination or the journey, and provide someone to converse or interact with. This may impact certain groups more than others (disabled people, visitors, and older persons in particular).

Having someone on board PT services also provides customers with assurance that there is someone present if anything goes wrong or someone requires emergency assistance. This role may need to change, at least during the early days of AV deployment, even if it is to provide assurance and help new users navigate the AV system and process. Certain sectors may also still need someone on board to deliver their services (like tourism operators), and PT operators may still require a "conductor" to ensure fares are being paid (like trains in some cities at present).

28 Twenty four percent of New Zealanders have some form of impairment. Statistics NZ. (2014). *Disability survey: 2013.* (https://www.stats.govt.nz/information-releases/disability-survey-2013)

Questions the transport sector wants answered

The New Zealand transport sector employs 108,000 people (4 percent of the country's workforce) and contributes 4.8 percent of New Zealand's GDP.[29] Road transport is facing driver shortages in key industries – particularly PT and goods delivery (due to increasing demand for goods from population growth and e-commerce). Labour issues, like network strikes, can cause disruption further increasing unreliability in some areas. In other parts of the system, there has been growth in the number of drivers, with the ride-hailing sector creating more jobs.

The road transport sector is much broader than those who drive vehicles. Mechanics, engineers, vehicle inspectors, driver licence instructors, regulators, law enforcement professionals, and many others support the operation of vehicles on the road, the surrounding infrastructure and compliance systems. Compliance services include everything from pre-arrival checks before vehicles enter the fleet, on-road assessments while vehicles are in-service, and post-use disposal (i.e., scrappage). As an example of the size of the compliance element of the transport sector, there are around 3200 Warrants of Fitness (WoF) agents in New Zealand and more than six million WoFs are registered each year.[30]

As New Zealand does not have an established vehicle manufacturing industry, it relies entirely on international imports to receive vehicles. A large portion of vehicles entering the fleet are second-hand, making pre-arrival checks particularly important. Several appointed inspection organisations are based in Japan, due to the large number of vehicles imported from there.[31] There will need to be enough lead time provided to these organisations around changes to regulations.

As in the previous section, if we are to understand the potential impact of AVs on businesses operating in the transport sector, we need to start by considering the key questions businesses will want answered. This discussion has been tailored to the transport sector for the sake of brevity, but AVs will have impacts on other sectors and businesses as well.

How might AVs benefit New Zealand businesses?

Businesses that already provide passenger and goods delivery services could benefit from the deployment of AVs, particularly Level 4 and 5 AVs. For passenger services, this may include increasing their catchment area for passengers, operating services for longer (with no driver meal breaks and only stopping to recharge vehicles) and operating seven days a week. For goods delivery services, this could include opportunities to invest in smaller vehicles that run more frequently, smartly (the removal of a driver could allow for more flexible deployment with vehicles being more responsive and adaptive to traffic flow and being able to operate 24/7), with a wider distribution area, and potentially cheaper services for customers (primarily because competition could increase with more players in the market and there are no driver costs).

Without drivers, there could be opportunities to grow the ride-hailing and car sharing industry in New Zealand. Individuals providing ride-hailing services could run multiple vehicles on the network if no driver is required in the vehicle. The market could expand for car sharing companies who would be able to provide vehicles for those people who do not have a licence, have physical or mental impairments that previously prevented them from using the service, and overseas visitors not comfortable driving on New Zealand roads.

Other businesses may want to utilise AVs through third party services. This includes companies that want to use AVs for just-in-time delivery, but do not want to own or lease the vehicles themselves (either to avoid the overhead, or due to the infrequency of use). An example might be supermarkets contracting an AV delivery service for rural deliveries.

New Zealand has numerous innovative businesses and research institutions creating world class vehicle, fleet, and freight technologies, with a proven track-record of development, testing, and evaluation of a wide variety of new transport solutions. The deployment of AVs in New Zealand would support innovation and growth in this area. We already have Ohmio operating in Christchurch,

29 Ministry of Business, Innovation and Employment. (2020). *Transport fact sheet.* https://www.mbie.govt.nz/assets/transport-factsheet.pdf

30 Waka Kotahi. (n.d.). *Warrant of Fitness.* https://www.nzta.govt.nz/vehicles/warrants-and-certificates/warrant-of-fitness/

31 Waka Kotahi. (2021). *Waka Kotahi NZ Transport Agency appoints border inspection organisations.* https://www.nzta.govt.nz/media-releases/waka-kotahi-nz-transport-agency-appoints-border-inspection-organisations/

with the potential to deploy AV shuttles across New Zealand.

Consideration will need to be given to what new legal requirements might be needed for each business model. For example, a revised form of small passenger licence might be required for commercial entities wishing to operate commercial fleets of robotaxis. Restrictions might include where different AVs can operate (for example, larger AV delivery trucks might have restrictions imposed on them around operating in densely populated urban areas), the hours they can operate, or the loads they are allowed to carry (for delivery services). It might also include specific requirements when operating in mixed traffic and with other road users (like cyclists).

How will the regulations for AVs affect my business?

Whatever changes are required, business owners will want regulatory certainty around potential restrictions and requirements placed on AVs operating on New Zealand's public roads. Employers have many responsibilities, including responsibility for ensuring their drivers have the appropriate driver licence class, comply with the conditions of that licence, complete logbooks accurately and fully, and are not fatigued or affected by alcohol or drugs.[32] These obligations will change dramatically when there is no driver – they may reduce under certain conditions, but they may also increase under others. For example, large, automated trucks carrying dangerous goods may have more restrictions placed on them than those with drivers currently. And tourist buses operating on rural roads may have more stringent requirements around passenger safety.

Businesses will want a regulatory environment that supports their business models and has the necessary safeguards and protections built in to protect their ongoing profitability. They will want clarity around insurance rules and regulations, as well as around responsibilities and liability should something go wrong with an ADS. Insurance, for example, will ultimately depend on how insurance providers choose to calculate risk in an ever-changing environment (particularly one with mixed traffic). Businesses will want to know how these risk calculations have been made and what they can do to mitigate high insurance premiums.

Whatever changes to legislation are considered, businesses will want enough lead time to make changes to their business models to remain compliant and avoid added costs. This includes changes to inspection requirements for vehicles entering the country, in-service testing, regulatory conformance while vehicles are in-service (e.g., WoF, CoF), and evolving driver licensing requirements. For example, vehicle inspection organisations will want to know their role in ensuring the safe operation of AVs as standards evolve. In the future, there will be greater consideration of vehicle software (as well as hardware).

Will there be Government funding or incentives to support AV deployment?

Businesses in the road transport sector will consider the total compliance and operating costs associated with using AVs before deciding whether to invest in them. There may be elements of wellbeing and inclusivity in their approach, but their key driver is usually to make money and remain viable. If government wants businesses to deliver specific use cases that support transport outcomes, but that impact on business profitability, businesses may demand funding or other incentives such as the Low Emission Vehicles Contestable Fund (LEVCF) established to support the uptake of low-emissions vehicles.

Businesses will want to know what use cases will be supported through funding mechanisms. This requires government to better understand the use cases that will help it to achieve its transport outcomes. This cannot be obtained from looking solely at international experiences and will differ across New Zealand based on regional transport challenges and existing strategic transport plans.

Businesses will also want opportunities to test and trial new technologies before investing. Funding and partnerships with local and central government could support opportunities to pilot AV technologies that positively contribute to transport outcomes. This requires a clear and seamless process to test and trial AVs in New Zealand. Testing regimes will need to incorporate consideration of the shared responsibilities for roading infrastructure across councils, road controlling authorities, and Waka Kotahi.

32 Employment New Zealand. (n.d.). *Vehicles.* https://www.employment.govt.nz/workplace-policies/work-equipment-and-clothing/vehicles/

Will there be supporting infrastructure for AVs (both digital and physical)?

Prior to deploying AVs, the transport sector will want to know that AVs can operate within the existing infrastructure (for example, road marking, road signs, and roading quality). In the future, changes may be required to intersection design, pedestrian crossing facilities, school drop-off zones, or even residential layouts to improve the safety of pedestrians and other road users. These are changes that are unlikely to be needed in the next five to ten years, but are critical to how the built environment will support the safe interaction between AVs and people over the longer term.

To get the full benefits from AVs, we need to consider digital infrastructure as well as physical infrastructure. Our digital infrastructure is currently poor in some parts of the country, particularly in suburban or rural areas, where a significant portion of our population lives. Many businesses may choose to not operate AVs in these locations if digital infrastructure is not available. Vehicle to infrastructure (V2I) connectivity will be particularly important to communicate with AVs that require remote operation or assistance. If there is a desire to use the information collected by AVs to improve the flow of the traffic network in real-time, continuous, and reliable digital connectivity will be essential.

As physical infrastructure tends to have a long life, often 50 to 100 years, making informed decisions about what we need in the future is important. Conversely, most digital infrastructure is short-lived and needs constant upgrading and replacing to stay relevant. The capital and operational costs of infrastructure development, clarity around how much of the responsibility for infrastructure investment will fall to government, and how to work with private businesses, will need to be established up-front if businesses are to invest. It is likely that modifying some existing infrastructure could be expensive, but equally there may be solutions that can be implemented at far less cost (e.g., AV-friendly lane markings are likely to be cost effective now). Where central and local government invests will inform business decisions. Infrastructure for AVs will likely benefit the overall transport network by providing greater connectivity and better road conditions (e.g., more consistent signage and road surfaces or markings).

Automated AND connected?

Regardless of whether a vehicle is automated or not, investing in 'invisible infrastructures' of digital connectivity, data, and institutional capacity, is useful in providing connectivity to communications networks and infrastructure, and improving the overall efficiency of the transport network.

Some of the biggest international players currently developing AVs including Tesla, Alphabet – a division of Google's Waymo, and General Motors' Cruise, are designing their vehicles to not rely on undisrupted internet connection when operating.

While better connectivity will likely improve the efficiency of the transport network, it will not necessarily be a prerequisite for all AVs. When investing in AV infrastructure, focus should initially be on providing adequate connectivity to communications networks and infrastructure on key roads and ensuring availability of HD maps for key sections of the road network.

As these 'invisible infrastructures' are often privately operated, government's role will be more about providing leadership and regulatory stewardship than implementation. Improvements to network connectivity are valuable regardless of the future of AVs, but materially improve the ability of AVs to operate on the road network.

How might AVs disrupt existing inspection and compliance systems?

AVs could disrupt the way the transport system operates and could impact systems, processes, and people.

All vehicles must comply with New Zealand's standards for entry into the country and must meet vehicle certification standards and regularly pass inspections that ensure ongoing roadworthiness. These standards and inspections will need to be reconsidered for Level 4 and 5 AVs.

The standards are based around the physical hardware of the vehicle. New Zealand legislation is already struggling to approve AV shuttles because they need so many exemptions for mandatory features like windscreen wipers. In addition, AVs are likely to depend on an array of hardware

components that have not traditionally been a part of our testing and compliance regime, including electronics, sensors, and computer systems. This includes understanding that vehicles from different countries may have different systems, potentially requiring less prescriptive and more performance-based standards in the future. It also means that standards will need to evolve quickly to reduce the burden on an already strained exemption-based process.

Clarity around vehicle standards for AVs will impact on businesses that want to sell AVs in New Zealand to private users or companies. This includes vehicle manufacturers, importers, and retail dealerships. It includes new vehicles and second-hand vehicles being sold to the public and private companies. It includes all types of vehicles, across all levels of automation. They will want to know the regulatory compliance regime for automated vehicles as well as any tariffs or incentives for specific vehicles.

While operating on New Zealand roads, Warrants of Fitness (WoF) and Certificates of Fitness (CoF) are key processes in ensuring vehicles are safe. These mechanisms ensure vehicles are legally compliant and that they meet minimum roadworthy requirements. Vehicle inspection organisations that provide these services may need to modify how they inspect vehicles with higher levels of automation, with an increasing emphasis on the software systems and sensor suites in the vehicle. Calibrating vehicles in New Zealand is already seen as a growing area of vehicle safety. Changes to these processes could be costly and require new skills.

A new driver licensing regime may also be required. A New Zealand photo driver licence verifies who you are, the vehicles you are qualified to drive and any conditions you are required to meet when driving. The licence provides the user with legal permission to drive on New Zealand roads. The licence class, shown on the licence, identifies the types of vehicles an individual can drive. This is based on the user's knowledge and competency using those vehicles. For AVs, a similar requirement could be needed to ensure users can operate Level 3 vehicles safely and competently.

Users of Level 3 vehicles may require additional knowledge to ensure they know how and when they may be required to take back control of the driving task from the ADS. Knowledge of the specific automated features of the vehicle and what they do may also be required, resulting in a change to driver training programmes. Recently conducted research on the awareness of drivers using Level 2 ADAS vehicles (currently operating on New Zealand roads) revealed a lack of understanding by some around their responsibilities while ADAS features were engaged.[33] Around one-third did not believe they were responsible for monitoring the vehicle's driving functions for the entire time that the system was engaged. The level of knowledge on different ADAS featured was also highly variable, for example 73 percent could correctly identify what BSM (Blind Spot Monitoring) did, and only17 percent correctly identified ACC (Adaptive Cruise Control). If not properly regulated for, the operation of Level 3 vehicles will present significant risks to road users and pedestrians. It is also unclear that, even when a user is equipped with full knowledge of the safe operation of a Level 3 vehicle, that they can adequately handle the mental load of switching at short notice between a monitoring task and active driving.

At Level 5, there may not be any requirement to have a licence to operate the vehicle. Variations in the way to engage and use the ADS across different makes and models could mean that vehicle users may still need to be tested on their knowledge of a vehicle's systems, especially when renting or leasing vehicles. The driver will still have obligations to make sure occupants are wearing seatbelts, that their vehicles meet safety standards, and loads are secured. Those operating AVs as a passenger or goods delivery service may also face new licensing requirements that account for changes to liability.

There will still be a need for a physical driving test and knowledge assessment of the road rules for those operating a Level 0-3 vehicle. This could be required for another 20 years given the long lead times to transition New Zealand's vehicle fleet. A separate licence may potentially be required for those wishing to only drive a non-AV.

33 Waka Kotahi. (2021). *Research Report 685 Consumer awareness, understanding, and use of advanced driver-assistance systems currently available in vehicles on* New Zealand *roads.* https://nzta.govt.nz/resources/research/reports/685

How might transport sector jobs be impacted by AVs?

At Levels 4 and 5, automated driving will remove the need for a human driver to be in control of the driving task. This will result in job losses in some industries. In 2018 (the latest available census data), New Zealand had 45,960 delivery drivers (from courier to heavy trucks), 8,874 bus drivers, and 8,721 taxi/ride-hailing drivers. While many of the driving roles in these industries will become obsolete, certain sectors will have ongoing requirements to have a human presence onboard, even if in a different capacity.

There will also be other opportunities for drivers to transition to new roles. New industries will develop, and new skills will be required to assess AVs entering the country and support AVs while in-service (including maintenance and mechanic work and logistics and packing roles). The question here will be whether the workforce can (and wants to) transition into these roles. We need to ensure this doesn't exacerbate income inequality. How this transition is managed and who takes responsibility for upskilling and retraining people for new vocations (and associated costs), and ultimately the appetite and willingness for change, is uncertain. Working with universities, technical institutes and polytechnics, and wānanga and those operating across the transport sector to transition the industry to new skills will be key to a successful transition.

How might AVs impact road policing and enforcement?

The existing penalty regime for non-compliance while operating a motor vehicle is based around the driver in the vehicle. The removal of the driver will require a redesign of the penalty regime and enforcement powers of authorities like the Police. Existing laws might need adapting, such as driving hours, mobile phone use while driving, give way rules, and speed limits when operating AVs in certain areas. This will have implications for police training. Enforcement agencies will need to keep current with technology developments to understand whether drivers are operating vehicles safely and complying with current traffic laws.

There will also be an increasing need to identify the level of automation for each vehicle operating on the road. As the number of AVs increases, enforcement agencies will need to be able to identify those vehicles on the road with ADS and know when that system is in operation. This will be particularly important during the period where AVs operate in mixed traffic to facilitate enforcement agencies intervening where the systems are being misused. This may require special markings on the vehicle to indicate the level of automation and the legal requirements of the driver. This will be less of an issue if AVs predominantly operate in segregated lanes or are physically distinct from other vehicles (like small, automated shuttles).

How could AVs impact achieving transport goals?

As well as understanding how the wider transport sector might be impacted by AVs, it is important to know how AVs might impact the longer-term objectives for the transport system.

The transport system faces significant challenges around road safety, congestion, emissions and shifting people to more sustainable transport options. We need to understand whether AVs are likely to help address any of these challenges, exacerbate them, or create new challenges.

Could AVs help reduce deaths and serious injuries (DSI) on our roads?

AVs could provide a solution to address deaths and serious injuries (DSI). Level 4 and 5 AVs would remove a significant proportion of DSI given approximately 90 percent of all road deaths are the result of human error (alcohol, drugs, excessive speed, driver fatigue and driver distraction). Improving road safety will, however, be heavily dependent on where AVs are deployed in relation to where crashes currently occur. This includes the circumstances of the crash (e.g., at intersections) as well as the types of vehicles predominantly involved in crashes.

We know that most road crashes occur on the open road, so AV deployment in cities will have little overall impact on DSI. Equally, we know most crashes involve light vehicles, so if AVs are primarily deployed as heavy trucks there will be minimal impact on road safety.

Certain groups in society experience disproportionate road harm compared with others. Young people, older people, Māori, and people walking, cycling, and motorcycling

are all over-represented in road harm. Traffic mortality rates are estimated at between 60 and 200 percent higher for Māori compared to non-Māori.[34] Novice drivers are also more commonly involved in road crashes because of inexperience and higher levels of risk-taking behaviour. These groups also tend to drive older, lower-spec vehicles, so would not be the primary beneficiaries of AVs, at least until prices are affordable.

Could AVs help reduce congestion and emissions?

Transport in New Zealand faces growing emissions and congestion challenges as the population grows and continues to have high rates of vehicle ownership. While there are programmes to reduce emissions (including through reducing our reliance on cars and adopting low-emission vehicles and fuels), the turnover of the vehicle fleet is slow. To reduce congestion, New Zealand needs to move more people and goods with less vehicles. Along with more active travel and use of other modes like micromobility, this requires a significant shift to shared vehicle ownership models and increased uptake of PT.

Shifting people to a shared vehicle ownership model is difficult. New Zealand has a strong car culture, with many New Zealanders owning one or more vehicles. In 2020, New Zealanders owned 0.8 light passenger vehicles per person, ranking us in the top 5 globally for vehicles per capita.[35] Vehicle ownership can also be viewed as a rite of passage in New Zealand and is the only real transport option in many locations. Although car-sharing and ride-hailing are becoming more popular, they have not caused a major cultural shift in car ownership patterns.

Central and local government are focussing on shifting people to PT. AVs could help. Initially, smaller automated shuttles might provide last mile connectivity to major transport hubs (like bus terminals and train stations). In the medium term, small on-demand automated buses could provide on-demand transport options in city fringe communities. Over the longer term, as technology matures and supporting infrastructure is created, larger buses could connect cities and rural areas.

There are obvious cost challenges with this model, but the removal of driver costs and restrictions (such as mandatory rest breaks), and the reduced expenses associated with smaller vehicles (potentially 3D-printed in the future), could help meet some of the additional costs.

If AVs are electric, then they have the potential to support current government objectives to reduce emissions through decarbonising the vehicle fleet. However, regardless of whether the AVs are electric, they still require resources to manufacture and be disposed of in an environmentally sustainable way and, when in-service, their tyres release particulates that contribute microplastic pollutants into both our air and oceans.

Could AVs impact existing transport mode shift goals?

The current focus on encouraging active travel could be circumvented by AVs. New Zealand already faces an obesity epidemic, with the third highest rates in the OECD and particularly high levels among Māori and Pasifika people and those living in socially deprived areas.

AVs could create a more sedentary lifestyle for many, particularly if the vehicles are more comfortable, convenient, and cost-effective. If AVs provide a more attractive last mile alternative to active modes or incentivise taking a vehicle for short trips (as it can return home immediately afterwards), then they could have a detrimental impact on the general health and wellbeing of New Zealanders. In some parts of the country, private vehicles are the preferred mode of travel, even for trips under 2 kilometres (around a third of all car trips in main centres are less than 2 kilometres).[36] AVs could exacerbate this trend through making short trips more convenient and comfortable.

Privately owned and leased AVs could inadvertently encourage a movement away from PT. Private vehicles offer freedom and flexibility, particularly in places where PT or ride-hailing services are unavailable, or walking/cycling is not feasible.[37] If car ownership patterns continue along the current trajectory, AVs could make

34 Waka Kotahi. (2021). *HE PŪRONGO WHAKAHAUMARU HUARAHI MŌ NGĀ IWI MĀORI Māori road safety outcomes.* https://www.nzta.govt.nz/assets/resources/maori-road-safety-outcomes-report/maori-road-safety-outcomes-full-report.pdf

35 Wikipedia. (n.d.). *List of countries by vehicles per capita.* https://en.wikipedia.org/wiki/List_of_countries_by_vehicles_per_capita

36 Waka Kotahi. (2022). *Benchmarking Sustainable Urban Mobility.* https://nzta.govt.nz/assets/resources/sustainable-urban-mobility-benchmarking/sustainable-urban-mobility-benchmarking-report.pdf

37 Ministry of Transport. (n.d.). *Household Travel Survey.* https://www.transport.govt.nz/statistics-and-insights/household-travel/

using a car more appealing than PT. Some of the appeal of PT is not having to pay attention during the journey, allowing passengers to undertake other activities (like reading a book or watching a show online). AVs could encourage mode shift away from PT if they are viewed as providing similar benefits, with the addition of improved flexibility, privacy, and comfort. This shift will not be available to everyone but may reduce ridership in certain areas and suburbs and, at the very least, make it more difficult to convince New Zealanders to use PT.

A shift to privately owned AVs might lead to an increase in urban sprawl and congestion. If travel time is no longer seen as "wasted" time, people may be willing to travel longer and further. Additionally, growing housing affordability issues in Aotearoa may reinforce some people's decision to live further outside urban areas, and with all Level 4 and 5 AVs likely to be electric, fuel costs will be less of a concern. More travel could result in increased congestion, especially if AV trips have the potential of doubling the distance travelled if vehicles return to their point of origin at the end of every trip.

A "flexible and adaptive" regulatory system?

Regulators can employ a range of approaches from ones that tightly prescribe the requirements and actions that regulated parties must follow, to more flexible approaches that give regulated parties more choice around how they comply.

Both ends of the regulatory spectrum have their merits and flaws. Prescriptive regulatory systems (where more explicit or exhaustive rules and legislation clearly articulate what is permitted) can provide certainty for regulated parties giving them confidence when making decisions or choosing to invest. However, prescriptive systems can also quickly become outdated (and be cumbersome to change), onerous and costly to comply with, or end up missing their objectives. Dated regulation can stifle or slow innovation, with society missing out on benefits.

Conversely, flexible regulation that allows regulated parties to choose how they comply can reduce compliance costs because those parties have incentive to seek the lowest cost method. More flexible types of approaches are often called "performance-based" or "outcome-based" schemes. In such schemes, government establishes the 'what' i.e., the overall objective, such as "safety," and allows the regulated parties to choose the 'how' i.e., the way in which they will deliver that objective. This approach affords more freedom to parties to innovate or adopt new technology because a specific set of rules or actions does not constrain them.

However, there can be drawbacks to a more open regulatory approach, including increased complexity, uncertainty, costs for regulators, as well as greater exposure to risk.

Finding a balance between prescriptive and flexible regulation comes down to a careful analysis of the associated risks, costs, and benefits to an approach. In a complex world, several regulatory approaches may be required. For example, regulatory approaches may vary at the regional level so that they are appropriate to the location, or might be tailored to the different needs, and risk-profiles of particular use cases. The level of regulation might also take a phased approach over time that adapts accordingly as technology matures. A regulatory sandbox approach (where regulation is effectively "trialled" for a fixed period or within specified parameters) is another means to create a balance between the tension of risk but also prospect of reward from new technology.

If the benefits presented by new technology, such as AVs, are deemed worth pursuing, then the rapid pace of technological change and uncertainty around the exact scale of adoption and ways in which AVs will be used in the real-world lends itself a more flexible regulatory regime. Regulators will likely otherwise struggle to keep up with developments or miss opportunities that only eventuate once technology is given the chance to interact with its environment.

What are the immediate risks to the transport system?

Vehicles operating in mixed traffic

There will be a long period of mixed traffic on New Zealand roads where AVs and non-AVs will occupy the same road space. The slow vehicle fleet turnover combined with the high number of vehicles on New Zealand roads per capita means it is likely that when AVs enter the fleet, they will operate in a mixed traffic environment for an extended time. This will be at least twenty years but could be closer to thirty for some makes and models.

AVs operating in mixed traffic present several safety challenges for New Zealanders. These will be determined by both the unpredictability of human behaviour and the vehicle's software being able to navigate the cultural nuances of driving on New Zealand roads. As AVs should be programmed to obey the traffic laws and (effectively) drive more safely than a human, the interaction between the AV and other road users is likely to be most problematic. This complicates assessing the risks posed by AVs operating in mixed traffic. We should consider how the operation of AVs on public roads in mixed traffic might compromise road safety in the short term.

Level 3 vehicles will introduce new risks to the transport system

At Level 3, AVs require the driving task to be switched between the vehicle's software system (the ADS) and the human driver. While the ADS is in operation the driver does not need to pay attention to the road. They must, however, be ready to assume control of the vehicle when asked to do so. This can occur at any time during the journey. This presents a series of new safety risks to the transport system that we have not had before. Thought will need to be given to how realistic it is that a human could safely retake control in a timely manner in an emergency.

There are questions around whether drivers can switch their focus back and forth (potentially at quite short notice) from watching a movie on their phone (or a similar activity) to assuming responsibility for the driving task again. This may occur multiple times during a journey, and could also increase the stress placed on drivers, continually waiting for the message to take back control. There may also be increased risk-taking by drivers due to an over-reliance on and trust in the technology. We are already seeing this with Level 2 ADAS. A further consideration is needed around whether reducing the role of the driver could result in the atrophy of driving ability over time.

At Level 3, drivers still need to meet the same conditions as a driver of a non-automated vehicle i.e., holding a valid driver licence, ensuring that they are not impaired (e.g., not under the influence of alcohol or drugs), wearing a seatbelt, and meeting the conditions of their licence (such as wearing glasses to drive). This raises questions around whether the New Zealanders' "she'll be right" culture could result in more people being willing to operate a Level 3 vehicle while not meeting these safety conditions.

Level 3 AVs also have implications for existing laws, such as not being able to use your mobile phone while driving. Consideration is needed around whether New Zealand should allow Level 3 vehicles on its roads given the potential risks versus benefits.

A growing reliance on vehicle software systems introduces new safety risks

AVs will be reliant on the vehicle systems software to undertake the dynamic driving task (DDT). The security of AV software systems will become synonymous with their safety. The risk to safety includes the possibility that software systems could be tampered with or fail. Systems could also be hacked remotely from any location geographically and could impact an entire fleet of vehicles. Hackers could either take control of the vehicle or shut down the network entirely (potentially for ransom). Vehicle hacking may become very lucrative as the number of AVs increase on the roads. There have already been claims of remote vehicle hacking overseas.[38]

There will be growing concerns around whether different generations of AVs remain secure throughout their lifetime. There needs to be consideration around how often systems should be calibrated and replaced. Software systems may not continue to be supported if the company goes out of business, and hardware systems will also age and need to be replaced.

While cyber-security standards are being

38 Farland, M. (2022). *Teen's Tesla hack shows how vulnerable third-party apps may make cars.* CNN Business. https://edition.cnn.com/2022/02/02/cars/tesla-teen-hack/index.html

developed at the international level (particularly for manufacturers to adhere to), this will remain an ongoing risk as new vehicle systems are developed and deployed. Different manufacturers will likely have different security standards and pose different cybersecurity risks when entering the New Zealand fleet. New Zealand will need to agree the standard it wants across the vehicle fleet and impose it on all vehicle imports – new and used.

Increasingly, vehicle software is being updated through over-the-air (OTA) updates.[39] Software updates are an integral part of ensuring vehicle systems are operating effectively as they contain important feature enhancements and crucial security patches. OTA updates allow manufacturers to send an update to all the users at once without the need for vehicles to physically go to a service centre.

OTA updates introduce risks to the transport system. If critical safety updates are not made, or defective software is uploaded, this may compromise the vehicle's systems and will potentially create a system-wide failure for all the vehicles on the road running the same software. Some vehicles will also be able to be upgraded to higher levels of autonomy through OTA updates at little to no warning.

At present, regulators and users have little visibility over when software updates occur and what additional functionality they provide.

Edge-cases: AVs need to be programmed to learn

For AVs to be versatile and responsive in their environment, programming is necessary to ensure the vehicles can safely navigate and learn from various unexpected and dangerous situations. These so-called edge-cases can be manmade, such as road cones to divert traffic in a temporary traffic management response for an event, or stem from natural hazards like flooding, slips or an emergency response to an incident. Natural hazards are a particularly pertinent issue for a nation that sits on volatile, earthquake-prone land.

It is near impossible to predict every possible edge-case so instead, AVs need to be able to adapt and constantly improve as they encounter new obstacles. This can be done through machine learning. Simulating some known edge-cases under controlled conditions may help AV software build up a repository of experiences before full deployment (as edge-cases in the real-world are often rare and a vehicle may not get much exposure to them). However, testing cannot cover all potential cases, and some will only ever arise in the real-world. As such, edge-cases will always present some level of risk to AVs and this risk, regardless of testing and overseas experience, is unlikely to ever resolve entirely. Edge-cases are unpredictable by nature so new examples may appear with little to no warning (e.g., with the arrival of new vehicle modes on the road).

However, it is worth considering that while humans may be able to navigate some edge-cases with greater ease than AVs, the reverse may be true in other scenarios (especially if the AV is pre-programmed to leverage off a collective database from other AVs).

Beyond ensuring that AV technology itself is capable of continuously updating, responding to, and learning from (and then sharing this learning) edge-case scenarios, support systems can be developed to provide fallback options in emergency cases where the AV is unable to safely navigate out of a situation. For example, some AV companies are hiring people to remotely monitor their vehicles for offsite intervention should anything unexpected happen on the road. This is one approach that could be considered in New Zealand too.

A learning and sharing culture among people will also be important to ensure the safety of AVs when presented with edge-cases. These individuals may be on the scene (e.g., first-responders and the operator of the vehicle itself) or investigating after the fact (e.g., Police, regulators, or the manufacturer responsible for the vehicle software who may hold critical data). All those involved will need to work together to ensure the right safeguards are put in place to minimise or mitigate future similar incidents.

39 The wireless delivery of new software, firmware, or other data to computer systems in the same way that smartphones receive updates.

Currently, many Level 2 vehicles on New Zealand roads already have all the hardware required to be upgraded, through OTA software updates, to Level 3 and beyond. In New Zealand, there are currently no legislative barriers to this occurring. Manufacturers may provide this information, but unless it is received and understood by the vehicle user, there remains a safety risk. Consideration is needed as to whether certain updates should be mandatory before the vehicle is used, versus those that only alter comfort or auxiliary systems. Questions also need to be asked around what happens if an update is not performed by the user and a system malfunction leads to a collision. This will have liability implications.

What are the other unknowns around AVs?

Will people want to use AVs?

It is still not a given that New Zealanders will want to use AVs. While there will always be a sector of the population who want to use new technology (early adopters), unless the technology can be shown to benefit people's lives, there will be many who chose not to. For AVs, trust in the technology plays a key role in its acceptance. People will probably want to experience the technology firsthand to understand how easy it is to use and how it can benefit them and their community (i.e., the tangible difference to their lives). For many, it will clearly provide additional mobility options to engage in social or economic opportunities. Others will assess the value AVs provide over and above existing transport options. Potential adopters will also want to know that the technology (and the companies behind it) are socially responsible and aligned with their values. Until there are some demonstration projects available for people to engage with, it is challenging to know how much support there will be for widespread AV deployment.

When will they get here and what they will look like?

The timing around when higher level AVs might arrive in New Zealand and what they look like is uncertain. Some use cases, like urban freight or PT, could change very quickly, while privately owned Level 4 and 5 vehicles may be some way off. New Zealand may be seen as an easy test market for new vehicle capabilities due to our legal settings and the Accident Compensation Corporation Scheme, so there is a possibility we could see some form of AVs soon. However, New Zealand also experiences a lag in vehicle technology because we import all our vehicles. This means we do not often get the latest vehicle technologies until 4-6 years after they have been deployed overseas. AV technology presents a different challenge as vehicle software systems can be upgraded OTA, potentially changing the capability of the vehicle. This means the rate of technological change could be much faster with the roll out of more software-based technologies, making the lag considerably shorter over the next 10 years.

We will still need to import the vehicles from manufacturers and supply chains will influence how quickly this occurs for AVs. If we follow the same pattern as EVs, we will see an incremental increase over a longer period of time. The types of vehicles entering the country will be impacted by these supply chains, but also driven by regulatory settings, compliance regimes, and consumer demand.

The types of vehicles we know are being developed for different use cases today could change significantly in 15 years with increasing levels of automation in both aviation and maritime sectors (for example, automated amphibian vehicles crossing Auckland Harbour).

Where will the AVs come from?

AVs may arrive in Aotearoa from a broader range of vehicle markets in the future. With the potential for vehicles to have no steering wheel (at Level 4 and 5), there will be no specific left- or right-hand drive models. This opens New Zealand to more markets and manufacturers from which to source vehicles. Increasing supply and vehicle options might require greater resourcing and expertise in government to be clear on criteria for entry and to ensure vehicles are compliant when they arrive.

Certain types of AVs could be built here. Ohmio already builds its Level 4 shuttles in Aotearoa and can 3D print most components. With the greater prevalence of technologies like 3D printing, building more AVs in New Zealand could become a reality. If Aotearoa develops an AV manufacturing sector (like we have done with rockets and Rocket Lab), the options available to consumers could increase significantly, as well as the number of people who can access them (if reduced importation and compliance costs lower their price).

How might councils need to adapt to changes AVs might bring with them?

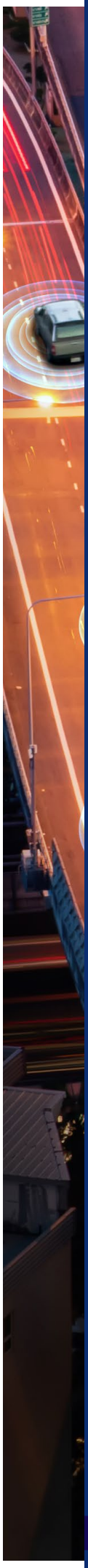
Alongside regulatory change, council revenue generating mechanisms may also need to change. Two of the key mechanisms local government agencies use to obtain revenue from transport are parking fees and parking infringements. This includes curbside parking and airport parking (for some councils). This revenue supports the operation of local government, and in some locations, it is a substantial contribution to local government budgets. Revenue generated through parking also reduces the amount of revenue needing to be raised through other mechanisms, such as rates.

Level 5 vehicles might not need parking at all. Automated goods delivery vehicles will undoubtably return to base or their next delivery drop-off or collection point after each delivery. Level 5 vehicles dropping off passengers could (theoretically) also return to their point of origin after they have dropped off their passenger(s). They could also drive around empty until their passenger is ready to be collected instead of paying parking costs (much more likely when the distance is large, or the reason for making the journey is a short appointment). Each option, however, results in more vehicle kilometres travelled than is necessary, leading to increased congestion on our roads. On a large scale, this would have a significant impact on the operation, and environmental sustainability of the transport network. A loading zone or taxi stand approach for shared AVs could help alleviate this concern.

There may need to be consideration of alternative approaches to raising revenue from parking, as well as addressing the "empty vehicle" challenge. For example, vehicles could be "taxed" based on their occupancy, with infringements targeted at vehicles travelling with no passengers or goods onboard. There will need to be consideration around how infringement fees could be collected to ensure that the administrative burden and cost of this type of system does not outweigh its benefits.

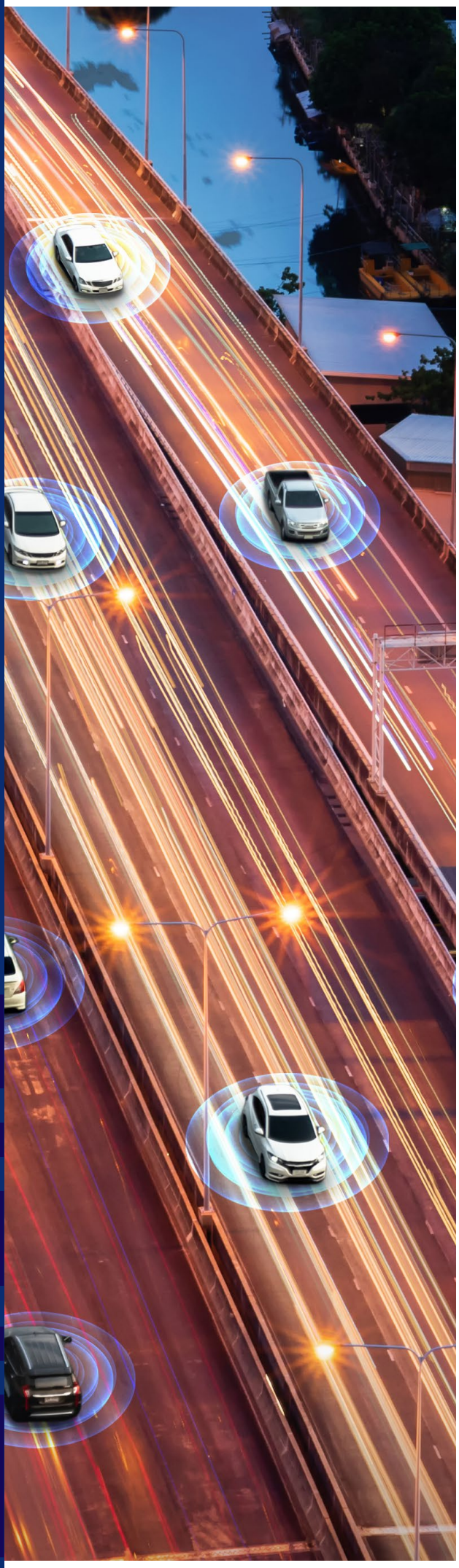
Vehicles could also be "taxed" based on the distance they travel. This is similar to the current Road User Charges (RUC) approach for vehicles that do not use a fuel source that is taxed at the point of sale (such as diesel fuelled vehicles). Zone charging could also be looked at so that using an AV within its home suburb costs less than when it drives outside that area. A levy could also be imposed on fast charging infrastructure to assist local government with revenue generation. However, taxing solutions may go amiss with those who can afford to pay the price in the name of convenience.

There are also opportunities to better use parking spaces. Parking spaces could be converted into multi-use lanes for cyclists and micromobility devices. This would have some positive impact on active travel goals and would remove micromobility devices from footpaths for a better pedestrian experience. Designated drop-off points for shared AVs could be scattered across cities to provide convenient pick-up and drop-off points. This also frees up room for other uses, such as greener spaces, seating, retail and hospitality space, and more room for housing.



He whakarāpopoto | Summary insights

This section consolidates the discussion from previous sections in the paper into a series of insights. The section is structured around the five transport outcomes, with each insight clarifying the “risks to address” or “opportunities to pursue”. Under each outcome, we have assessed what this means for future transport policy development.



Inclusive access

> "Enabling all people to participate in society through access to social and economic opportunities, such as work, education, and healthcare"

Insight: AVs might not improve access in an unregulated market environment

We cannot rely solely on the free market to provide transport options that improve access for all people, both in terms of private ownership and accessing shared services. AVs will be no different in this respect. Businesses will seek to deploy AVs in locations where they can make a profit. Without any incentive to deploy more widely (and support areas that are currently underserved by transport) it is highly unlikely all New Zealanders will have access to the benefits of AVs.

The types of AVs deployed, and the services offered, will be driven by consumer demand. In some locations in New Zealand there will not be the population density nor income levels to encourage private enterprise to supply shared AVs for that population. Remote rural areas are an obvious example where fewer transport options are provided by the private sector, but ride-hailing and e-scooter offerings have also been lacking in some city fringe suburbs too. These suburbs are also likely to be areas that are currently underserved with adequate PT options, and where the cost of private vehicle ownership causes hardship for many.

Automated technologies may exacerbate current inequities. Those who can afford to access the technology (through owning, leasing, or hiring) will reap the benefits, but we know that certain members of society are disproportionately negatively impacted by the transport system. Household spending on transport has been growing significantly for those in the lower quintile of earners. For this group, the cost of transport now comprises more than 25 percent of overall living expenses.[40] Accessing shared AVs will likely require a smartphone (or similar digital device in the future). There will be sectors of the population that cannot afford a smartphone, or the data plan needed to access the necessary app to engage with AVs. Some also do not have bank accounts from which to pay for online services. There will also be people who are not digitally proficient and cannot use the technology (even if they can afford it). If alternative methods are not readily available for users to engage with AVs, some groups will be excluded from using them.

For many, a key challenge to improving mobility, and access to opportunities is centred on affordability. Even for those who can afford AVs and the supporting technology, access could still be limited by what the market provides. If the market primarily supports able-bodied people with no physical or mental impairments, part of the population could be excluded from having their access to social and economic opportunities improved. Twenty-four percent of New Zealanders have some form of impairment, many of these impacting their ability to use transport options. There are current inequities with transport options for many of the people in these groups now. AVs have the potential to improve access, but only if the market caters to broad needs.

Insight: a predominantly private ownership model for AVs could increase commuter congestion

If the ownership model for AVs ends up being predominantly private and not shared, AVs may only exacerbate existing congestion challenges for commuters. For example, increasingly people are living where housing is more affordable on the outskirts of main centres where they have long commute times by private vehicle. It will become even more palatable to commute between these cities in the future if the ADS will do all the driving. If most of these AVs are single occupancy (like many cars are in cities like Auckland and Wellington), this will compound congestion in our main centres.

40 Ministry of Transport. (n.d.). *Transport Indicators.* https://www.transport.govt.nz/statistics-and-insights/transport-indicators/inclusive-access/

Level 5 AVs could be programmed to return to the owner's residence after the vehicle has dropped them off, and then return at the end of the day to collect them. While this would reduce the need for parking in urban areas, it effectively doubles the number of kilometres travelled each day, half of which involve no occupant in the vehicle. While this is a worst-case scenario, even AVs travelling short distances with no occupants creates an unnecessary increase in congestion and impacts on wear and tear on roads and infrastructure, and increases the release of particulates from tyres.

Level 5 AVs could also contribute to urban sprawl as they will allow some to live further away from their place of work when the commute distance is less of a concern if the ADS is undertaking the driving function for the duration of the journey. Living further away will be even more attractive for office workers who may be able to work in their vehicle during their commute, with the possibility that the time spent doing so can be attributed to their workday.

The choice of some to live further out of the city, and travel for longer on the road, directly impacts the travel journeys of other road users. Those with relatively high elasticity in their transport choices (i.e., those who can switch between various options freely) come at the direct expense of those who do not have this flexibility. Any increase in congestion will be most felt by those who are unable to afford a Level 5 AV and/or do not have the option to work from home by virtue of their job. For example, retail workers, cleaners, and hospitality workers all need to be physically located at their place of employment. They often live some distance from their jobs and many already have long commutes. AVs could increase this burden and negatively impact on the health and wellbeing of those with few options.

Beyond commuting, AVs could help reduce congestion through providing greater flexibility for people travelling for leisure. Congestion created during holiday periods could be reduced if people choose to travel overnight to their destination, as all passengers can sleep throughout the journey. While travelling outside of peak periods is an option now, the reduced burden of driving under less-than-ideal conditions (in the dark and while tired) could help stagger traffic during peak periods.

Insight: the greatest opportunity for AVs to improve access lies in affordable shared access models

Private ownership models are unlikely to improve access for the vast majority. In general, an affordable shared access model is preferred across the transport system, for all vehicles, as it helps address many of the detrimental impacts that arise from private car ownership (such as increased congestion, pollution, and urban sprawl). AVs provide the added advantage that they can be flexible and cater for those working shift work, people living in remote areas, and those unable to drive because of mobility issues or impairments. Shared AVs should also be more cost effective, providing a viable alternative to car ownership.

Across Aotearoa, there are large parts of the transport network where transport options are limited. Some New Zealanders do not have access to any form of PT. Even within the main centres, access to frequent PT services is limited (27.4 percent in Auckland and 14.9 percent in Wellington).[41] AVs provide an opportunity to improve PT access through the deployment of smaller on-demand services that have increased frequency and geographical coverage. Level 4 and 5 AVs also support services like robotaxis and ride-hailing through reduced operating costs for companies no longer having to employ drivers.

Work is underway to review and revise the types of services that can be contracted and funded by Public Transport Authorities (PTAs) to broaden the range of potential passenger transport service types that can be contracted. This would allow PTAs to consider the potential impact of commercial on-demand services on the wider PT network and may support the deployment of services like robotaxis.

Local and central government could accelerate the acceptance and uptake of shared vehicle services through existing regional transport plans. Supporting shared transport offerings from the private sector would help embed the concept of shared vehicle services in communities prior to the arrival of AVs. Incentivising and prioritising shared AVs in procurement processes would also influence the use cases and business models that private companies choose to provide. This will be reliant on understanding where shared AVs can be deployed for the greatest benefit and the investment costs associated with their safe deployment (e.g., new infrastructure).

41 Ministry of Transport. (2020). *Transport Indicators.* https://www.transport.govt.nz/statistics-and-insights/transport-indicators/sheet/inclusive-access

Insight: suitable infrastructure will be a key determinant of AVs' impact on access

Where AVs can operate in the future will be informed by the physical and digital infrastructure available to support their operation. As it stands today, our transport infrastructure varies significantly across the country. There are inconsistencies in road types, road markings, digital connectivity, and signage. These inconsistencies are sometimes within urban areas but are more pronounced between urban and rural parts of the country.

If AVs can only be deployed in already well-serviced parts of the country because the infrastructure is more suitable, this will impact where and who has access to them. Inconsistences in the level and type of infrastructure across the country could also limit where businesses can operate, potentially restricting the benefits of AVs for interregional and long-distance travel.

The expectation that AVs will be able to adapt and operate in any environment in the future is still a concept that is a long way off. Even if AV technology develops exponentially in the next five years, some places might not have the required infrastructure to be suitable for deployment (for example, remote rural communities on the West Coast of the South Island and the East Cape of the North Island). This means people in those locations will not be able to access the social and economic opportunities associated with AVs.

Physical infrastructure also needs to support access for all New Zealanders. We know existing built infrastructure and urban design contributes to current inequities. There will need to be a consistent approach to designing AV infrastructure and deployment across the country to support access for all groups (e.g., similar sounds and visual signals). This includes things like curb heights for mobility impaired populations, signage for hearing impaired and audio signals for the visually impaired.

Transport infrastructure often involves costly, long-term investments that shape our spaces for decades to come. It is also challenging for councils to resource new infrastructure from existing budgets, particularly when a significant portion of funding is dedicated to maintenance activities. If AVs demand changes to current infrastructure, new funding will be required, and this money will need to come from somewhere.

So what?

For AVs to support inclusive access, they need to be affordable, available across the country, and everyone needs to be able to use them. This means AVs will need to be accessible for all groups of people across society, otherwise only some will benefit. Policy needs to include consideration of equity outcomes, including things like deliberate government investment and targeted funding to provide services to underserved areas, and minimum design features in AVs that assist those with impairments or disabilities. It means considering what supporting infrastructure is required to achieve this and what services different groups need. It also means assessing the ownership model for infrastructure (e.g., whether assets are publicly or privately owned) as this will drive investment decisions. The emphasis should be on the application of shared automated PT that addresses current transport inequities.

Policy thinking needs to consider where New Zealanders could benefit most from AV deployment and how funding criteria might support those investment decisions. Government should first look at how to improve transport options in those areas that are currently underserved by PT. Government may also need to consider restricting where businesses can operate AVs, if these service offerings have the potential to negatively impact transport outcomes. Government could clarify desired use cases and outcomes and let the market bid for funding support to deliver those outcomes. This will need to be informed by New Zealand-specific research.

There will always be trade-offs between transport outcomes and system constraints. Investment decisions need to be considered in line with current policy approaches to emissions, mass transit and congestion to ensure AVs are being considered as part of the wider transport system. Visibility of these trade-offs will assist decision-makers to make better investment decisions.

Healthy and safe people

> "Protecting people from transport-related injuries and harmful pollution and making active travel an attractive option."

Insight: AVs could reduce DSI, but this will be over the longer term

AVs have the potential to significantly reduce DSI caused by human error. Many "near misses" also occur on the road every day in New Zealand where death or serious injury is avoided. Some of the main contributors to DSI (alcohol, drugs, excessive speed, driver fatigue, and driver distraction) would be eliminated if more vehicles on New Zealand roads were Level 4 and 5 AVs. This includes both public and private vehicles. If AVs are designed to adhere to the speed limit and traffic rules, programmed to drive more cautiously in poor weather conditions, and, in some cases, take up less space on the road (e.g., smaller goods delivery vehicles), they could create a safer road environment for all road users.

Several variables will influence the overall impact of AVs on road safety. Significant improvements in road safety are dependent on where AVs are deployed in relation to where crashes currently occur. This includes the types of vehicles involved in crashes, as well as the circumstances of the crash (e.g., at intersections). If most road crashes occur on the open road, then AV deployment in cities will have little impact on DSI. Equally, if most crashes involve light vehicles and AVs are primarily deployed as automated shuttles, then AVS will have an inconsequential impact on road safety.

Understanding the characteristics of those drivers most frequently involved in crashes will also help quantify the potential impact of AVs on road safety. For example, novice drivers are more commonly involved in road crashes, (because of inexperience and higher risk-taking behaviour), but they tend to drive older, lower-spec vehicles, so would not be the primary beneficiaries of AVs, at least until the price is affordable. During the initial transition period where AVs will operate in mixed traffic, the impact of AVs on DSI could be limited.

There will also be a long lead time before New Zealand sees Level 4 and 5 vehicles operating *en masse* on public roads. On average it takes around five to six years for the latest ADAS technologies to filter through to the New Zealand car market. As the average age of light passenger vehicles in New Zealand is around 14.3 years, without incentives to shift to AVs, the transition to AVs will be slow.[42] As such, we cannot rely on AVs for road safety improvements in the short term, even if they present the most significant opportunity to do so over the longer term. The Government has a Road to Zero strategy to address DSI on our roads now. It has set an ambitious target of a 40 percent reduction in deaths and serious injuries (DSI), by 2030 (from 2018 levels). There is value in better understanding how AVs could contribute to a reduction in the remaining 60 percent beyond 2030.

Insight: Level 3 technologies present an immediate safety concern for the transport system

The safety benefits of Level 4 and 5 AVs are well understood. Removing human error from the driving task significantly improves the safety of that vehicle on the road. However, before we reach this stage of automation, Level 3 AVs will add another layer of complexity to the driving task. Requiring humans to be willing and able to take back control of the vehicle when requested by the ADS places an entirely new set of demands on the driver. The ability to effectively switch concentration back and forth has not been

42 Ministry of Transport. (2021). *Te tatauranga rāngai waka a tau 2020 | Annual fleet statistics 2020.* https://www.transport.govt.nz/assets/Uploads/Report/AnnualFleetStatistics.pdf

tested in real-world driving environments in New Zealand. While we can learn from the experiences of other countries (who will deploy Level 3 vehicles before New Zealand), we do not know exactly how New Zealand drivers will engage with Level 3 technologies and how cultural norms may feed into attitudes and behaviour towards the technology.

The variety of Level 3 systems that may become available in the market also needs consideration. Each vehicle will likely have a slightly different operating system, with potentially different warnings and signals for the driver to assume control. Driver education on the safe use of Level 3 technologies will be increasingly important as the vehicles become more prevalent on our roads.

New Zealand does not currently have any regulations or guidance around operating Level 3 vehicles on our roads, including where they can operate and who is liable if there is a collision. We can see evidence of misuse and confusion over the role of the driver with existing Level 2 technologies. Restrictions might be needed on where and how AVs are able to operate at Level 3 and at what speeds the ADS can be engaged.

Understanding the level of risk Level 3 AVs pose requires urgent attention. While not yet on New Zealand roads, Level 3 vehicles are being deployed in other jurisdictions, with legislation passed to support their operation.[43] For example, Honda is now selling Level 3 AVs in Japan. Given Japan is our largest second-hand vehicle market, similar vehicles are likely to enter the New Zealand market in the next five years unless we deliberately restrict the use of the technology or regulate for its safe use.

Insight: challenges raised by AVs operating in mixed traffic cannot be underestimated

Providing assurance that AVs will not create safety risks in a mixed traffic environment requires answers to some key questions. We need to understand how AVs will be programmed to obey the traffic laws, and whether this will include deviation from the road rules in certain situations. For example, human drivers often decide when to "break" a road rule to allow traffic to flow (for example, driving up on a footpath to allow an emergency vehicle to pass or letting a driver go first, even when they do not have right of way).

Most human drivers also adhere to social norms like pulling over to let others pass if they are holding up the flow of traffic. If AVs strictly stick to the letter of the law, there could be implications for how traffic flows, and resentment on the road by those who see AVs as a hindrance. As noted above, approximately half the people who are harmed on our roads did not contribute to the accident; they were harmed by other people's errors in judgement. We know that driver impatience, particularly during holiday periods, contributes to road accidents.

Level 3 vehicles may allow the driver to assume control to navigate in uncertain conditions, but there may be no option to do so at Level 4 and 5, or the user may not legally be able to assume control (e.g., if they have been drinking or are not a licensed driver). New Zealand drivers have evolved informal ways of navigating roads through driver etiquette and discretion. It is unclear whether programming AVs with culturally specific driver etiquette will be possible.

43 Including Germany and Japan, who have passed regulations to support the on-road operation of Level 3 vehicles.

Precautions could be put in place, such as separating AVs from other vehicles on the road as well as limiting where and when they can operate. These would be expensive and would potentially restrict who would benefit from AVs. Developments in other transport technologies may impact AV deployment. For example, drone technology (for goods delivery in particular) and automated aviation (for passenger transport) could change the composition of road traffic, including the types of AVs on our roads and when they operate.

Insight: AVs could present greater safety challenges for certain groups

As well as operating in mixed traffic, if AVs operate in mixed use spaces (i.e., with pedestrians), we need to ensure the environment will remain safe for all users. This includes those with different physical abilities or impairments (hearing, visual, or mental impairments), as AVs could present additional challenges for these groups. For example, people who are hearing impaired will need visual cues to assure them that the AV is behaving in a safe way, while those cues will be irrelevant to someone with no sight, who will need audible cues. Communication with pedestrians and other road users that might not speak English or have varied experiences with automated transport could also be challenging.

People's physical and mental abilities change as they age. Mobility, vision, and hearing can all change across a person's lifetime, presenting new challenges when accessing transport options. This could be complicated by AVs where there may be no human driver to communicate with or assist.

AVs could impact vulnerable groups, including women, children, or the rainbow community. Their level of vulnerability can also fluctuate depending on the situation or time of day (e.g., women feeling less safe on PT late at night).

Regardless of how proven the safety of AV technology is, if people do not perceive AVs to be safe then they will be less willing to accept and adopt them. Once proven safe, we need to consider ways to cater for all groups and instil trust in the technology so that people feel confident and capable engaging with it safely.

Insight: AVs may have a negative impact on health outcomes

AVs are not inherently detrimental to people's health. How the technology is deployed, and the way people choose to engage with it, will determine its impact on health and wellbeing. For example, if people directly substitute a private vehicle for a private AV, then we will not see any health improvements, but rather a continuation of the status quo for these individuals. If people are replacing active travel (like walking and cycling) for the convenience of an AV, there will be health implications. We can see evidence from other technology, such as e-scooters, that while a portion of e-scooter trips are replacing car trips, the majority are replacing walking.

New Zealand has a strong culture of car ownership and a high level of car dependency. It is not difficult to imagine this trend continuing with AVs in the fleet if they provide added convenience and comfort. To support better health outcomes, policies need to be clear around which AV use cases might negatively impact health outcomes, and consider whether other initiatives, such as better cycling infrastructure and the availability of shared bikes would provide a comparable alternative with better health outcomes.

So what?

Safety needs to be the priority for AV regulation. It is highly likely that existing regulations, systems, and processes will be insufficient for higher levels of automation. Current laws need to be updated, or new laws created, particularly around who is liable when driving or operating AVs on New Zealand roads. This includes the responsibilities of manufacturers, or other parties that bring AVs to market in New Zealand. Changes to primary legislation, Road Transport Rules, or other policy instruments to support the safe deployment of AVs could be required. Education campaigns and guidance for AV users, other road users and the wider public on what to expect from AVs may also be required.

Internationally, safety issues are being addressed through both legislative and non-legislative mechanisms. Working parties under the United Nations Economic Commission for Europe (UNECE) are developing regulations with a focus on the safe deployment of AVs, including the operation of software systems. Understanding and aligning to international standards should be our starting point.

Specifically in Aotearoa, we need to consider how and where AVs can be deployed safely, given concerns around operating in mixed traffic. This includes consideration of whether segregated lanes and geo-fenced areas are necessary, and how we can educate users and the wider public on the capabilities of different AVs.

The potential for AVs to operate in mixed-use spaces requires policy thinking around how to prioritise these spaces for different groups. For example, will pedestrian movements be prioritised over AVs, and do we need physical barriers to separate the two? Consideration around maximum vehicle speeds in different environments, and what types of AVs should be allowed to operate where also needs to be included in policy thinking.

Level 3 vehicles are likely to arrive on New Zealand roads first. Understanding liability and responsibility requirements at Level 3 should be a priority in the regulatory work programme, as well as developing guidance for drivers on their role as the fallback user. As Level 3 AVs present new complexities to the system, consideration is also needed around enforcement activities, potential changes to existing legislation (e.g., using a cell phone while driving), licencing requirements for companies using Level 3 AVs as part of their business, and partnering with industry deploying Level 3 AVs in New Zealand.

Economic prosperity

> "Supporting economic activity via local, regional, and international connections, with efficient movements of people and products."

Insight: AVs could improve the efficiency and productivity of New Zealand businesses

The removal of a driver from the vehicle opens several possibilities for how businesses operate. Operations could be 24/7, with reduced costs over the medium and long term as driver wages are removed, and new use cases could evolve to support industries outside the transport sector. Resources can also be repurposed to other aspects of the business (like research and development, purchasing better quality vehicles, entering new markets, and increasing market share).

AVs could also increase competition in the transport sector as an individual's private AV could be operated as a business if they desired. For example, you could operate an AV as part of a fleet of shared robotaxis while at work during the day. Businesses will likely emerge that lease and manage people's private AVs for them as more AVs enter the fleet.

Uptake of AVs in the commercial sector could increase the availability of AVs to the public. After these vehicles have been used for commercial purposes, they then enter the second-hand market and are on-sold to members of the public. Commercial applications would also provide opportunities for the public to see AVs in operation and build assurance that they can be operated safely as part of the wider transport network.

Insight: AVs could bring significant disruption to the land transport sector

Disruption will occur across the transport sector as the level of automation in vehicles increases along with the number of AVs on New Zealand roads. This will inevitably result in trade-offs. While job losses may be inevitable in some transport related occupations, there will also be opportunities as new roles are created and new industries develop. There will likely continue to be a role for people within AVs for several use cases at higher levels of automation. Government could partner with industry and local government to understand the challenges in transitioning existing transport sector employees to new roles as well as identifying where capability gaps may develop.

The on-road operation of AVs will require changes to our licensing regime for companies operating and using AVs and potentially for the driver licensing system for those using them. This will require new skills and training programmes across the sector and clarity for industry around evolving requirements and their implications. Different taxation and pricing mechanisms for regional revenue generation may be needed as fuel taxes and parking revenue may reduce over time. Options like taxing vehicle kilometres travelled (VKT) and vehicle occupancy could be explored.

The potential influx of AVs (from various jurisdictions) over the next ten years will require a substantial review of our vehicle and importing standards. The existing process allows vehicles entering the New Zealand fleet a special exemption on a case-by-case basis if they do not fulfil vehicle standards. While this model works in the current environment where vehicle exemptions are the minority, the same system is unlikely to hold when we see increasing numbers of Level 3+ AVs entering the fleet. This may be

managed through changes to transport rules but could also require a change to the regulatory approach, potentially requiring less prescriptive legislation for emerging technologies and a system more focussed on the desired outcomes for transport.

There are also questions around whether drivers should be required to obtain a special licence that demonstrates they are capable and confident operating a Level 3 vehicle (in the same way that drivers who learnt to drive an automatic vehicle were not licensed to drive a manual one).

So what?

AVs will disrupt the way we inspect, maintain, and monitor vehicles on our roads. This disruption will also lead to new opportunities and potentially better business models that benefit consumers. New Zealand will need to review and revise its compliance systems to support these changes. Government should stay current on international developments, especially from our major vehicle markets for Level 3 vehicles to inform these changes. It will also need to keep abreast of new and developing markets for Level 4 and 5 vehicles.

Businesses will most likely require financial support to transition to AVs (in the same way they have needed support to shift to electric vehicles). Government will need to understand where the greatest benefits for AV deployment lie and decide how to support industry to capitalise on these opportunities. While funding is one mechanism, more creative options need to be developed in tandem if we want to speed uptake in those use cases that support desired outcomes.

Environmental sustainability

> "Transitioning to net zero carbon emissions, and maintaining or improving biodiversity, water quality, and air quality."

Insight: more vehicles on the roads could lead to poorer environmental outcomes

AVs will contribute to Government's goals to reduce carbon emissions and improve air quality by virtue of being electric. However, regardless of their fuel type, it takes resources to manufacture vehicles and the vehicles then experience wear and tear throughout their lifetime. AVs will still have a detrimental impact on the environment, even if this is less than ICE vehicles, particularly if they do not lead to a reduction in the overall size of the vehicle fleet (i.e., if private ownership is the predominant ownership model).

AVs have the greatest potential to positively impact emissions through connecting more people to PT hubs (last mile services), and/or replacing existing PT options with ones that are more demand responsive, service a wider number of people and communities, and are provided at a reduced cost. This will take more cars off the road. Shifting people out of private vehicles is challenging though, due to the perception of flexibility and freedom that private vehicles provide and some people being car dependent.

Insight: the full life cycle of AVs needs to be considered

Both the longevity as well as the materials and resources used in the manufacturing of AVs need to be considered to adequately assess their environmental impact. As New Zealand is currently not involved in the manufacturing process itself, our role should be to set clear standards and hold manufacturers accountable for the processes and materials used to develop AVs. Transport sector organisations, academia and New Zealand's growing technology sector can bring significant expertise to these conversations. Working in close partnership with these groups could help minimise the negative environmental impacts of AVs.

Given the emerging nature of AVs, it is unclear how well we will recycle and repurpose AV technology in New Zealand. AVs will require additional components and parts like sensors, cameras, and computer hardware. These may be designed to be replaced rather than repaired, meaning a shorter lifespan for components and unintended consequences such as wasteful disposal. Battery disposal is an additional concern and one that is getting greater visibility with the increasing number of EVs entering the market. There is also the concept of planned obsolescence which may creep into the AV market as it has done with cell phones and other computer electronics.

Insight: understanding urban development and land-use could define the impact of AVs

The built environment shapes the way people engage with transport options, and in turn what transport options are provided in different locations. Housing developers and urban planners should consider how AVs can contribute to the wider outcomes of a community as they design and plan new housing developments. There are already good examples of how this can be achieved, including the current Auranga development in South Auckland.[44]

So what?

To support environmental sustainability goals there needs to be a continued focus on active travel modes (walking and cycling) and shared transport. Policy makers and urban/city planners should centre these as the first choice when considering transport options. Removing vehicles from inner cities should be a priority (AV or not), with infrastructure investment considering how to support shared AVs in the future, including dedicated corridors and connectivity to PT hubs.

We need to mitigate or minimise the environmental challenges from AVs in the future if we are to avoid a graveyard of AVs in thirty years' time. This will require understanding and agreement on what standards New Zealand should accept for the processes and materials AVs are built from, and strategies for refurbishment and reuse of those materials, including batteries. There needs to be clear market obligations for the safe disposal of AVs and obsolete AV (and EV) parts. This should be supported through government levers, including regulation and funding support to repair, repurpose, and reuse materials from AVs at their end of life.

We know a private ownership model will have negative environmental outcomes. Local government bodies are already considering how they can increase passenger trips (and not vehicle trips) in their regions.

44 Auranga. (n.d.). *Integrated Transport Strategy | Auranga*. https://vimeo.com/674612695/52169f52f8

Resilience and security

> "Minimising and managing the risks from natural and human-made hazards, anticipating and adapting to emerging threats, and recovering effectively from disruptive events."

Insight: software security will become synonymous with safety

Security will become synonymous with safety as more of the driving task is controlled by the software that runs the vehicle. While safeguards will be put in place by manufacturers and regulators, vulnerabilities will remain as vehicles are connected to the internet to receive updates and to access third-party apps. Combined with aftermarket modifications to the vehicle systems, this increases the risk that vehicles can be hacked and even controlled remotely for malicious purposes. These threats may come from anywhere in the world and have the potential to impact large portions of, or even the entire fleet (the scale will depend on the type of attack and proportion of the fleet that are AVs).

We will need to decide what OTA software updates will be accepted in Aotearoa. Regulating and enforcing this will be challenging with most AVs being manufactured by multi-national companies overseas. AVs might need to be classified based on "generations" (e.g., first, second, third). This might mean different generations could have different compliance requirements. There could be a requirement to monitor what software each vehicle is running – either through existing compliance processes (e.g. Warrant of Fitness) or through enforcement agencies.

AVs will also capture huge amounts of information about their users and the public (through the vehicle's cameras and audio recording systems). Ensuring the safe storage disposal of such information will be important in building trust in the technology and a critical security component in the deployment of AVs. Who then has access (if any) to the information, and for what purpose, is also crucial to clarify as it could be used as a form of surveillance. The extent to which the public will need to be assured of the security and privacy of their information is unclear. While we can already see complacency arising from how people interact with existing technologies collecting data on them (e.g., automatically updating a smartphone without reading the Terms and Conditions), it is hard to know how this will translate to the way people then interact with, and interpret in-vehicle software systems collecting their information.

Insight: The New Zealand AV market will remain reliant on global supply chains

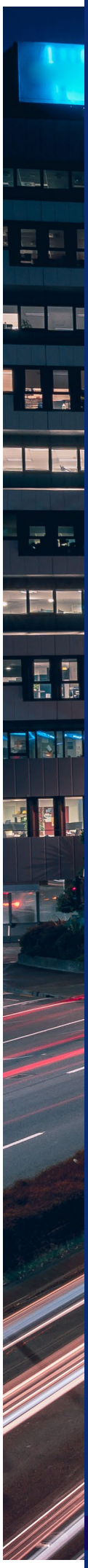
New Zealand could face challenges because of its reliance on global supply chains for AV parts and materials, (e.g., vehicle sensors and batteries). Vehicles will be unable to pass compliance requirements if sensors are not functioning properly and replacement sensors are not available. Vulnerability to international markets is not new in New Zealand but could bring AVs to a halt if there is no contingency to build resilience.

AVs will need a reliable and robust charging network to operate at scale. A greater reliance on the network means that the transport system will be more vulnerable to instances that currently may only impact a small group of vehicles e.g., power outages or adverse weather events that cause digital or physical infrastructure damage.

So what?

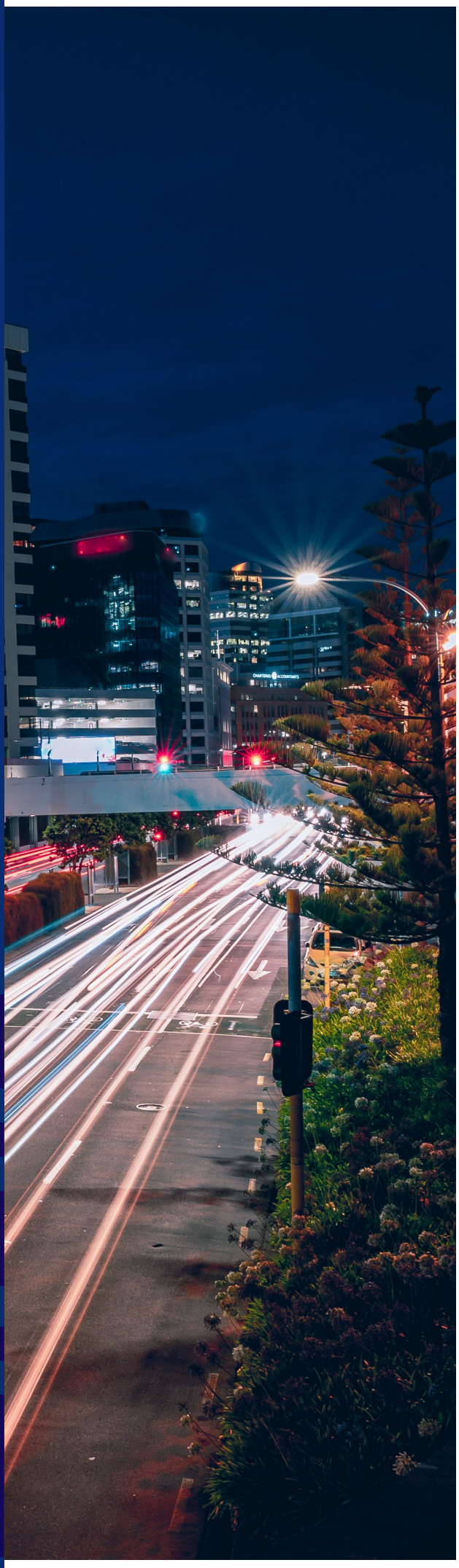
AVs will require robust and tested systems to ensure they are resilient and secure in the face of cyber threats. New Zealand will need a clear national framework for cybersecurity to reduce the points of vulnerability across the network. It will need to develop regulation around third-party apps and aftermarket modifications and the requisite liability if there is a system breach.

In the future, AVs could have security ratings (like safety ratings now) for AV models with differing levels of software encryption. This would assure those who, for example, want to use AVs as an office while commuting to work that their information and network connection is secure. New Zealand should continue to leverage other jurisdictions and international bodies (like the UN), as well as other sectors or industries that have navigated similar issues.



What now?

This section is informed by the discussion in the previous sections and outlines how we might move forward in our regulatory approach for AVs in Aotearoa.



> Aotearoa needs the necessary systems, processes, investment, and regulation in place to ensure the safe introduction of AVs on our roads in a way that supports broader transport outcomes. The direction moving forward will be contingent on resourcing, buy-in from relevant parties, and risk-tolerance, and underpinned by the overarching objectives for AVs on the roads in New Zealand.

The following section illustrates high-level options that the Government could choose to adopt when managing AVs. These options are not intended to set out specific work programmes, but rather show the potential benefits or risks associated with different levels of Government involvement. While each approach is depicted as distinct, in reality, there could be a mixed approach or phasing of approaches over time.

The 'wait and see' approach

A 'light-touch' approach, focused on monitoring developments overseas and ensuring that immediate regulatory issues are addressed. Minimising risk is the key driver rather than capitalising on benefits (although this approach may offer flow-on positive impacts).

Accepting our position as a taker of technology, New Zealand could deliberately maintain a more hands-off approach when preparing for the deployment of AVs on our roads. The focus of any regulatory work would be on monitoring international trends and addressing key gaps as they emerge, particularly those that present material risks to public safety or the integrity of our regulatory system.

Designing our regulation and supporting systems to ensure the safe operation of Level 3 vehicles will be a key priority, as these vehicles present the most immediate safety risks. The liability and responsibility of drivers, vehicle manufacturers and importers at Level 3 needs to be clarified. Fundamental questions around whether humans are capable of safely switching tasks at short notice (from monitor to driver) will also need to be considered.

Keeping on top of international developments and maintaining a high level of engagement with international stakeholders will be key as we will draw heavily on overseas regulatory bodies who are likely to be early movers.

This 'hands off' approach avoids unnecessary investment, ensures resources are being used efficiently, and allows us to learn what works and what doesn't based on experiences in other countries. However, it also creates the risk that New Zealand will be slow to realise the potential benefits of AVs. Avoiding "unnecessary costs" in the short term is not a risk-free approach. It leaves deployment largely to economic forces, where profit is the key driver and vehicles may end up being deployed in a manner inconsistent with the Government's broader goals for the transport system (for example, a proliferation of privately owned vehicles exacerbating urban sprawl).

A balanced, iterative approach

Unsure of the risks and opportunities of AVs, a regulatory sandbox approach could help us explore potential regulatory options before fully enacting them. The emphasis is on getting deployment "right" by thinking more holistically about the longer-term impacts of AVs across broader outcomes.

The Government could take a more active approach to AVs by creating a regulatory sandbox (that sets out certain time or conditional parameters for regulation). This approach acknowledges that the true risks and benefits

of AVs are unclear until proven in the New Zealand context. A regulatory sandbox allows us to explore ways in which AVs may be deployed, while also not locking in a regulatory approach until it has been effectively "tested" in the real world.

A regulatory sandbox approach could help build consumer confidence and test assumptions around use cases. To work effectively there will need to be clarity around the rules and regulations for companies operating Level 4 and 5 AVs. We would refine and amend legislation as new technologies emerge.

To help guide this approach and support the development of an evidence base for future AV investments and decision-making, a structured research programme across agencies and academic institutions could also be established. The feasibility of different use cases to support regional goals should be part of this. It should also take a broader focus than just transport and include health, housing, social welfare, urban development, and investment in innovation at a national level.

Work could also include clarifying the goals and objectives for AVs – including consideration of the current gaps in the transport network, where AVs could be best placed to address these, as well as whether New Zealand wants all levels of AVs operating on our roads. This would require collaboration with industry, councils, regional transport bodies, and groups in the community as well as those from non-traditional transport sectors such as telecommunications and AI.

Considering current constraints and challenges and other transport objectives to encourage active travel, urban development, shared and PT uptake and emissions reduction will be key to this approach. A particular focus is to engage with Māori and agree where AVs could benefit tangata whenua or exacerbate existing transport inequities. This would help set the future aspirations and direction for AVs.

The development of scenarios to better understand the costs, risks, opportunities, and benefits may also help bring clarity around the potential futures of AVs and where they should be deployed on our roads. This will require discussions with industry, councils, regional transport bodies and groups in the community.

This approach emphasises building a strong case for AVs in Aotearoa. While it would allow room to reap potential benefits from AVs more quickly, it also exposes the market to more risk. However, risks would likely be easier to manage under the controlled settings provided by a regulatory sandbox. Businesses and investors may struggle with this model as it can only provide short-term assurance around regulatory settings and makes it harder to plan in the longer term. It also takes a more selective approach that makes the barrier to entry higher if manufacturers cannot clearly demonstrate the benefit of their AVs to the broader transport system (when sometimes the benefit will take years to accrue, beyond what a regulatory sandbox period may capture).

Steering the course and enabling innovation

To capitalise on the potential benefits of AVs more rapidly, the Government could proactively shape regulation and take an active approach to the deployment of AVs. This approach focuses on innovation and getting widespread safety benefits as quickly as possible.

The Government could proactively set out a vision for AVs in Aotearoa and strive to create a regulatory framework that enables innovation. By taking this forward-looking approach, New Zealand could become an early adopter of AV use cases that improve the transport system and solve problems that are otherwise difficult to address with existing options e.g., driver shortages, and a world leader in some niches of AV deployment.

Once goals and objectives are clarified, the Government could actively pursue and attract certain AV use cases that have already been "proven" internationally. The testing and trialling of less proven modes of AVs, where they present potential benefit, could also be actively incentivised. This would require investment (monetary and resourcing) and a change in regulatory focus to be more responsive and adaptive.

To enable AV innovation, the Government would need to proactively invest in the necessary physical and digital infrastructure for AVs. Partnership and support with/for local government could be explored when looking at investment decisions relating to AV deployment so that they better align with broader transport goals e.g., decarbonisation and equitable access.

By taking a proactive approach, New Zealand could more quickly capitalise on the benefits of AVs, however safety will always be at the forefront. The appropriate regulatory frameworks will be necessary to ensure safety and public and private buy-in and trust.

If New Zealand wanted to be a world-leader in AV-related industries, the right skills and investment into the sector would also be necessary to keep pace with international developments. This would not involve a one-off investment, but instead require year-on-year funding to maintain momentum.

Good relationships across government, internationally, and with industry, will be imperative to build the strength of the AV sector in Aotearoa. The Government will need to find ways to make New Zealand's market attractive to international players and incentivise ongoing collaboration. This will require dedicated time and investment to keep building and maintaining relationships.

This approach assumes a return on investment and takes a leap of faith in trusting that AVs will bring worthwhile benefits to the system. A key risk to an open regulatory approach is investing in and deploying use cases that have not undergone rigorous scrutiny as to their appropriateness to the needs of New Zealanders and industry. We may find ourselves with AVs that only add clutter to the transport system or end up being detrimental to overarching transport outcomes. To get the most value out of a more proactive, open approach to AVs, establishing some form of criteria will still be necessary to ensure that the vehicles are fulfilling a genuine need rather than featuring as a gimmick.

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Te Kāwanatanga o Aotearoa
New Zealand Government

Directory

Wellington

Head Office
Te Manatū Waka
3 Queens Wharf
Wellington 6011
PO Box 3175
Wellington 6140
Telephone: +64 4 439 9000
Email: info@transport.govt.nz

www.transport.govt.nz

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