Ministry of Transport
TE MANATŪ WAKA

Autonomous Vehicles

Background paper one

Use Cases

The Ministry of Transport has started a work programme looking at the challenges and opportunities Autonomous Vehicles (AVs) present to the transport system in New Zealand. This paper outlines several ways AVs might be introduced. Exploring these “use cases” will contribute to our understanding of how AVs might affect the transport system and transport outcomes.

Introduction

Autonomous driving technology will have a profound impact on our everyday lives. The automation of different elements of the dynamic driving task (DDT) has the potential to change the way in which we think about moving both people and goods. A number of different use cases have emerged over the past decade, as vehicle manufacturers and technology companies all compete to bring the first commercially viable fully autonomous vehicles (AV) to market. Each use case comes with significant hurdles to full deployment. Yet, when fully realised, each could address a traditional transportation problem and drastically reduce costs. They could also produce outcomes counter to our objectives.

For simplicity, the way in which AVs could be used can be divided into two categories: people transport, and goods transport. This is not the only way to segment them, but it provides a useful framework for understanding how AVs might be used, and the different challenges associated with various uses.

- **People transport** is moving people from point to point. It can include commuting to work, going to the supermarket, visiting friends, going to the movies, etc. It includes both personal vehicles, shared transport and public transport.
- **Goods transport** is moving goods from point-to-point. It includes short, medium and long-haul journeys, within regions and between regions.

This paper discusses six different use cases for the on-road deployment of AVs and their development pathways. The paper focuses on what benefits AVs may provide and where we are seeing them deployed internationally. For each, we should consider how the use case might support transport outcomes in New Zealand, as well as the challenges each might bring.

Please note, we have not included *truck platooning* as we see this use case as having a low likelihood in New Zealand given our geography (at least in the short to medium term). Long-haul autonomous trucking is a real possibility but is likely to be further delayed than other applications we might see first. It has also been left out of the discussion for the meantime.

Contents

What are autonomous vehicles?

Autonomous vehicles (AVs) use technology to partially or entirely replace the human driver in navigating a vehicle from an origin to a destination. AVs are also known as driverless cars or self-driving cars.

Autonomous driving is achieved through the Automated Driving Systems (ADS). These systems assess the environment around them and select a course of action to achieve a set of tasks or objectives. To varying degrees, AVs rely on radar, light detection and ranging (LIDAR), cameras, complex algorithms, machine learning systems, and powerful processors to monitor the position of nearby vehicles, to detect traffic lights, read road signs, track other vehicles and look for animals and pedestrians.

The ADS allows AVs to undertake the driving function, known as the Dynamic Driving Task (DDT). This task includes all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic. 'On-road' refers to driving on publicly accessible roadways that serve vehicles of all classes, as well as motorcyclists and cyclists.

AV technology has the potential to trigger significant transformation across the transport system. Trials of AVs are underway around the world (including in New Zealand), and opinions vary on when fully autonomous vehicles will be widely available.

Levels of driving automation

Over the last decade, we have seen increasing levels of driving automation in the vehicles arriving in New Zealand. On-board vehicle technology has progressed beyond on-board computers, or providing warnings when systems are not operating as designed. We now see Advanced Driver Assistance Systems (ADAS) that provide sophisticated support to the driver, such as lane-change assist, electronic stability control, and autonomous braking. New Zealand can expect to see an exponential growth in such features, especially as global companies strive to be the first to trial and deploy fully autonomous vehicles on public roads.

To understand the levels of driving automation, New Zealand has adopted the Society of Automotive Engineers' (SAE) International Standard J3016 as its framework. This framework describes vehicles from SAE level zero (no automation) to SAE level 5 (full vehicle autonomy).

The SAE Levels of Driving Automation make a clear distinction between driver support features at levels 0-2, where the driver in the vehicle is deemed to be driving the vehicle at all times, and automated driving features at levels 3-5, where there are times when the driver is not deemed to be driving the vehicle.

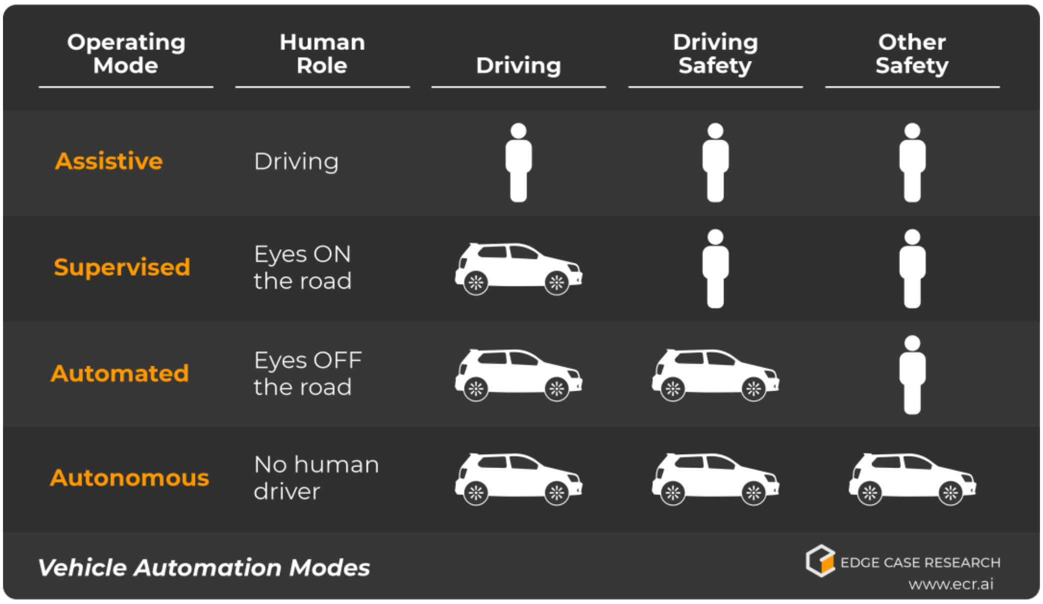
The key difference between vehicles operating at level 4 and level 5 is the conditions within which the driving function can be fully automated. Level 4 vehicles can only operate in fully autonomous mode under certain conditions, whereas level 5 vehicles can operate autonomously under all conditions.

The complete SAE framework is shown in appendix A, along with descriptions of each of the six levels.

An alternative to the SAE levels[1]

An alternative to the SAE levels was proposed in 2021 by an independent group called Edge Case Research. The premise is that the SAE levels are primarily based on an engineering view rather than the perspective of a person driving the car. They saw value in a different categorisation approach that emphasises the role and responsibility of the driver at different levels of automation. The alternative is not a replacement for the SAE levels, but rather a complementary tool for public discussions of the technology that emphasises the practical aspects of the driver's role.

The diagram below sets out the roles and responsibilities under this alternative framework.



This framework clearly delineates the role of the human and the system at each level. The human can only take their eyes off the road and ignore the driving task at the Automated and Autonomous levels. Up to this level, they must keep their eyes on the road and are fully responsible for driving safety. The framework also introduces a new element into the

[1] A User's Guide to Vehicle Automation Modes | Edge Case Research | Medium

discussion, the humans role in ensuring other elements of safety (e.g. children having seatbelts on, trailers being securely fastened to the towbar, etc).

This alternative framework avoids the confusion around what functions constitute level 2, 2+ and 3, which is currently being debated internationally. It may also be a more useful framework when developing policy as it focusses on the role of the human first and foremost.

Levels of automation on New Zealand Roads

Many modern vehicles have partially automated features that assist the driver with speed or steering control, such as lane-keep assist or adaptive cruise control.

There are no level 4 or 5 vehicles operating on New Zealand public roads. Christchurch Airport has a fully autonomous shuttle for public use in restricted areas. The autonomous 20-person shuttle runs along a pre-programmed route, without the need for a driver.

There is a great deal of uncertainty around when level 4 and 5 vehicles might be ready to deploy on public roads i.e. are commercially available and have passed the necessary safety testing requirements. Manufacturers and technology companies are focussed on safety, and this makes them cautious about delivering products to market before they are ready.

Given current technology development (and barring any significant technological breakthroughs over the next few years), it is unlikely that level 4 vehicles will be operating on public roads before 2025 in New Zealand, and highly unlikely that level 5 vehicles will be operating before 2030. What is more likely are increased requests to test vehicles in confined areas, with more complex terrain, eventually building up to testing and trialling on defined public roads. Establishing the frameworks and processes for these trials, especially to ensure public safety, requires work on our regulatory settings and on existing compliance and exemption processes.

People transport use cases

One: Last mile mobility: low speed autonomous shuttles

The ‘first and last-mile’ is a term that describes the beginning and end of an individual’s transport journey. For example, after traveling on public transport, we need to walk, or take a second mode of travel to reach our final destination. This can be a contributing factor when deciding not to use public transport. The industry is tackling this problem with a fleet of electric, autonomous shuttles that transport small groups of people along fixed and planned routes to their final destination.

These low-speed autonomous shuttles are often upright, boxy, 8-20 person vehicles that are symmetrical so they never need to do a U-turn to change direction. They have a small footprint, all-round vision, large doors, are quiet, zero-emissions, and can even go indoors and around university campuses. They are primarily intended for intensive urban use, and their speeds are limited, typically to around 30kmph.

Fixed-route autonomous shuttles are successfully emerging in many closed areas, such as university campuses, office parks, airports, industrial parks and hospitals.

Perceived benefits of automation

Autonomous shuttles could be an effective way of seamlessly connecting people with mass public transport systems. This could provide a number of potential benefits, from empowering those without transport options and those with disabilities, to filling gaps in the transportation network and replacing underutilised vehicles (such as school buses and private cars), reducing both congestion and cost. Shuttles are a particularly good option where frequency is valued, but passenger volumes do not justify full-sized buses. Many of these benefits could encourage people to use private vehicles less.

Current examples

There are a number of start-up companies developing and testing fixed-route AVs globally. In 2017, **Ohmio** partnered with Christchurch International Airport Limited on New Zealand’s first fully autonomous vehicle trial. In February 2020 members of the public were able to ride around the Christchurch Botanic Gardens in Ohmio’s driverless shuttle. Ohmio wants its shuttles to be a first and last mile mode of transport to large bus stations or ferry terminals. Recently, Ohmio has partnered with the Paerata Rise housing development in Auckland to eventually deliver on-demand autonomous transport to residents via a smart phone app.

Two French start up companies, **EasyMile** and **Navya**, are among the leaders internationally, and both have done nearly 100 global tests, trials, and revenue-producing deployments. NAVYA was founded in 2014. It launched its first autonomous shuttle in 2015. Capable of carrying 15 passengers, the company's shuttle is designed for a low-speed environment where there is a high frequency of travel.

EasyMile was also founded in 2014. It has more than 250 projects deployed in 27 different countries. EasyMile's shuttle has driven along routes in a variety of venues close to public transport, including a shopping plaza, an office complex, a hospital and a university. As well as selling autonomous shuttles, EasyMile also licenses its in-house autonomous driving software to other companies.

In China, **Baidu** and **Yutong** are both developing autonomous buses. Baidu has developed an autonomous minibus in partnership with Chinese vehicle manufacturer King Long who designs and manufactures the vehicle. Yutong has focused on manufacturing electric buses, and showcased their pure electric shuttle in March 2019 during a forum in Hainan, China, transporting attendees at the conference venue.

The autonomous shuttle is 5 meters long and has 8 seats. It is equipped with a set of sensors including 3 lidars, radars, cameras and ultrasonics and can go up to 40km/h in a closed environment.

Voyage, a company providing shuttle service to retirement communities, is taking a different starting point. “The beginning of Voyage was very much informed by finding a customer first and working backward to figure out what technology those folks needed,” said Oliver Cameron, co-founder and chief executive of Voyage. “I think all too often in self-driving cars, you start with technology,” he said. “That’s crazy.”

May Mobility will start with low-speed electric shuttles with a maximum speed of 25 miles per hour. This approach makes it easier to overcome regulatory hurdles while building business relationships and operational experience. May Mobility will potentially develop a different type of vehicle with expanded capabilities, but only after learning what type of self-driving vehicle is best for users.

Two: Middle mile mobility: autonomous buses

In addition to smaller autonomous shuttles supporting existing public transport options, autonomous busses could replace larger existing bus fleets with autonomous bus services, linking users from transport hubs to their final destination. Bus sizes can be varied depending on the requirements of the community, and the complexity of the driving task.

Perceived benefits of automation

Navigating massive vehicles safely through urban areas is challenging, but automating buses has advantages relative to robotaxis, cars and semi-trucks. This is again as a result of fixed routes and relatively low speeds. In addition, if fixed routes are able to be pre-mapped, then there will be built in redundancy to support other navigation systems.

By removing the driver scheduling and related costs, the overall operating performance of an autonomous transit system is expected to improve. It is believed that improved reliability, reduced waiting times, and increased frequency can all be achieved through autonomous mass transit, in combination with autonomous intersection management and mass transit signal priority.

The potential eventual removal of drivers, (research indicates that having on-board transit staff may help improve perceptions of security and increase user acceptance of autonomous buses in the early phases) could see reductions in operating costs as an important potential benefit, with reductions upwards of 50–60%. Reduced operating costs would see fully autonomous electric buses becoming life-cycle cost-competitive with diesel-powered buses faster than just electric buses that are not autonomous.

Better transport outcomes could be realised (such as “inclusive access”) if autonomous buses are also used for demand-responsive transportation (DRT). This is predominantly in areas where a regular bus service is not financially viable, or there are people with special needs, such as people with a disability. DRT provides convenient stops for passengers, reducing travel times and supplying easy connections to main transit lines. The idea is that by accommodating the real needs of passengers, they might choose DRT (in conjunction with connected mass transport) over their private vehicles.

Current examples

The battery-powered Xcelsior AV from **New Flyer** is the first level 4 autonomous transit bus being prepared for service in North America. Developed in partnership with Robotic Research in Maryland, the intention is to start testing as early as 2022 in a program with Connecticut’s Department of Transportation. The 40-foot vehicle, able to carry 80 passengers, is loaded with lidar sensors, cameras and radar for 360-degree, 3D vision in daylight or at night, computers, software and a drive-by-wire system. It is also designed to share information, including route conditions and road hazards, with other buses in the network to keep vehicles moving as efficiently as possible. A human driver will remain at the wheel as a backup for the foreseeable future.

New Flyer

LILEE Systems

LILEE Systems, headquartered in San Jose, California (with offices in Taipei), have received the first permit for self-driving bus commercial services on two designated bus lines in Tainan, the second largest city in southern Taiwan. This will be the first revenue-generating service of autonomous rapid transit (ART) in Taiwan and is supported by central and local governments. In July 2020, LILEE Systems received the autonomous vehicle license plate to run self-driving buses on public streets for two bus lines. Through the ART project, LILEE Systems will support the Tainan City Government to enhance and expand its public transportation network. The Tainan self-driving buses on virtual tracks are centrally managed and controlled from an operations control centre as an added layer of safety.

Three: Ride hailing: robotaxis

Driverless ride-hailing, or robo-taxis, have received the most attention and investment to date. This use case remains the leading target for AV development owing to its large market potential, which is forecast to be counted in trillions of dollars in the future. Initially, robo-taxis will look similar to a regular car, but as the technology develops, they will be designed around passenger comfort and entertainment.

Robotaxis are more complex than last-mile goods delivery, low speed autonomous shuttles, and autonomous buses. They operate in environments with more traffic complexity, including pedestrians, which adds difficulties to the AV software development and testing. This complexity means that robo-taxi deployment will probably happen on a city-by-city basis. Robotaxis are still expected to emerge in the next few years in several countries.

In the United States a significant proportion of AV testing for future robo-taxis takes place in California, where over 60 companies tested in 2018, drove over 2 million miles, and used nearly 500 AVs. China, however, ramped up its AV testing in 2019. By October 2019, the Chinese Government has issued over 200 AV testing permits.

Perceived benefits of automation

There are claims that robotaxis could provide greater mobility options for the elderly, young and disabled users, and those communities that have fewer mobility options. They could also provide greater convenience, efficiency and reliability than existing ride-hailing and ride-sharing options.

Robotaxis are expected to lower the cost of ride-hailing and shared mobility options. This is due to their anticipated intensive use, (some being lent by private owners for part of the day), and lower maintenance and running costs (due to not having to pay a driver).

Current examples

Waymo has been developing AV software longer than anyone else, and subsequently has the most on-road and simulation test miles of any AV company. Waymo is the clear leader in robo-taxis, with its revenue-producing deployment in the Phoenix area. As of December 2019, Waymo has transported 100,000 passengers and currently has 1,500 average monthly users. The number of AVs has increased to around 600, and some of the trips are operated without a safety driver. Waymo has also put in place the production infrastructure to convert tens of thousands of the Hybrid Chrysler Pacifica and the Jaguar I-PACE battery electric vehicle (BEV) into robo-taxis over the next few years.

Four: Individual car ownership

The industry has come to the realisation that level 4 and 5 AVs are much harder to develop, test and deploy than originally anticipated. They are likely to first appear in cities where robotaxis have been deployed for a number of years, as robotaxis test software and develop the machine learning required for the deployment of AVs for personal use.

Deployment of level 4 personal AVs may lag behind robotaxis by around five years. However, level 4 highway driving may be possible in a shorter timeframe, due to the reduced complexity in the driving task. The next step would be to get a personal level 4 autonomous vehicle to drive multiple fixed routes (such as to and from work or school), with an eventual shift to geofenced areas (similar to robotaxis).

It is difficult to forecast when level 5 autonomous vehicles will be available to the general public. This is the ultimate software development and testing complexity for autonomous vehicles. It will require substantial artificial intelligence (AI) and machine learning advancements, as well as suitable regulatory environments and public acceptance.

Perceived benefits of automation

With approximately 90% of road crashes caused by human error, a widespread shift to level 4 and 5 vehicles would greatly improve road user safety.

Personal AV ownership is attractive to users as it provides the opportunity to utilise the driving time (and particularly time commuting to work) for other activities, including working, reading, watching movies or even seeping on long trips. AV owners might also be able to earn income if their vehicle is operated as a robotaxi while they are not using it. There is a high level of uncertainty around how AVs might operate once their owners have been transported to their destination, and whether using them as a robotaxi would occur in practice.

There are also claims that AVs will also reduce congestion, pollution and emissions. However, AVs could also increase traffic congestion (resulting from more travel overall due to enhanced availability and lower costs, along with empty cars travelling the roads when collecting their owners or returning from trips), concerns relating to privacy, security, insurance, and liability, as well as job losses. There is still a high level of uncertainty surrounding the benefits, which will be heavily influenced by the way in which AVs are used, whether they end up being predominantly electric, and where they are deployed.

Current examples of level 2

Currently level 4 & 5 personal AV vehicles are in the testing and trialling phase. Only vehicles with ADAS technologies are available on the commercial market for purchase by the general public. These are providing additional autonomous functionality year-on-year.

Level 2 2019 Audi A8

Goods transport use cases

Five: Last mile goods delivery: store-to-home

Autonomous trucking is starting to emerge from the shadow of the much larger robotaxi industry, especially as the COVID-19 pandemic continues to cast doubt on the efficacy of shared ride-hailing.

Last-mile goods delivery is focused on the final stage of delivery, from a distribution hub to the final delivery destination (often the customer's home).

The goal of last mile delivery logistics is to deliver goods as affordably, quickly and accurately as possible. In many cases, this is a becoming a key point of difference for retailers to deliver competitive customer experiences (same day or instant delivery).

There is a growing focus on last mile logistics, primarily as e-commerce continues to drive demand. Retailers have the challenge of shifting from large-scale shipping to a single location, to delivering a large amount of smaller packages to many destinations. Last mile delivery logistics processes can also have high operational costs. Businesses must optimise their delivery processes, or costs can be prohibitive and result in increased overheads, fewer customers and reduced profits.

The problem with last mile goods delivery is that more stops result in more complex routes, more idle time, and more time on the road**.** It also means a larger fleet of delivery vehicles and more drivers are needed to ship the same number of products as a more conventional retail logistic chain.

Perceived benefits of automation

Last mile delivery is relevant for businesses that deliver products directly to their customers. Many businesses could benefit from autonomous last mile goods delivery. They range from e-retailers and large “brick and mortar” retailers to restaurants, supermarkets, florists, pharmacies, and courier companies.

Small and slow-moving sidewalk AVs are already appearing on many university campuses as fast food delivery agents. The sidewalk AVs are also active in grocery store deliveries, with e-commerce delivery promising to become a major new opportunity.

With the growth in e-commerce, the sheer volume of parcels that now need to be delivered needs a massive fleet of vehicles, currently driven by human drivers. Driverless goods autonomous vehicles could offer large cost savings for both companies and consumers by removing the driver’s salary from the company’s operating costs.

Due to the increase in demand for last mile delivery, there are now third-party on-demand service providers dedicated to running the last mile delivery process for retailers. Known as ‘delivery-as-a-service’ providers, we are starting to see growth in this business model. It’s not a huge shift for the freight industry, that has used fixed term contracts for individual truck owner services for decades.

Consumers are now also taking a greater interest, and understanding of, their carbon footprint. This is beginning to influence the service providers they choose to use. Electric autonomous delivery vehicles will reduce the cost to consumers, whilst being environmentally “friendly”.

The future development of “standardised autonomous frames” (where the vehicle is a basic chassis and different “body-types” can be switched out depending on the task), could significantly reduce downtimes, and improve efficiency, as vehicles are being loaded. Loading could be achieved through automation as well, further reducing the need for human involvement in the delivery process.

Of interest will be the interplay between on-road AVs and drones providing delivery services as well. Amazon, has been planning to use unmanned aerial vehicles or drones to deliver packages up to five pounds in less than 30 minutes, in an effort to deliver a more efficient last mile delivery system, particularly in the e-commerce industry.

Current examples

In China, **Neolix** launched driverless Kentucky Fried Chicken (KFC) 'Chicken mobiles' to continue trading during the Covid-19 lockdown periods. The company used autonomous vehicles connected to 5G networks and QR codes to distribute its product on the streets of Shanghai. These were essentially mobile vending machines, with reduced labour costs and a reduced risk of COVID transmission through autonomous contactless delivery.

The Neolix self-driving cars support Level 4 autonomous driving, which allows it to drive itself and avoid obstacles. It has a mileage of 100km on a single charge and a maximum speed of 50km/h. Probably the most convenient feature is that its battery can be swapped in 30 seconds without any tools needed.

Nuro is another autonomous-vehicle delivery service. Nuro's first-generation robot was custom-built to handle local errands, such as delivering groceries or dry cleaning. Dave Ferguson, co-founder and president of Nuro, said that 43% of the 400 billion personal vehicle trips a year are for running errands. He wants Nuro to reduce those trips.

Six: Middle mile goods delivery: hub-to-hub

While last mile delivery is to your doorstep, *middle mile mobility* refers to hub-to-hub trucking that moves goods between logistics centres that are close to highways. For example, transporting goods from a port to a warehouse or distribution centre, or from a warehouse or distribution centre to brick-and-mortar facilities, such as retail stores. It differs from long-haul autonomous trucking in that it operates within a close proximity to distribution centres and is return-to-base.

Middle mile mobility involves known, repeatable routes that reduce the variabilities of travel. Most of the travel for hub-to-hub trucking is on highways, which is relatively simple for autonomous vehicle software to manage in a safe manner. The first and last miles of hub-to-hub trucking can be done via teleoperation by a remote driver. This “transitional” use case makes middle mile mobility more achievable than programming a vehicle to operate anywhere within a geofenced area.

Perceived benefits of automation

The shortage of truck drivers in New Zealand (and globally) makes trucking a desirable sector for autonomous vehicles. Middle mile is also easier than last mile delivery because it operates between fixed locations, rather than in a wider geofenced area, making the “go-to-market” time faster. Autonomous electric trucking also supports a 24-hour delivery cycle, with trucking companies avoiding peak hour times.

In general, new technologies in trucks also improves their safety above already mandated things like digital log books, automatic braking systems, and lane control.

One factor that has helped autonomous truck start-ups is that they provide goods deliveries during their testing phase. This provides significant revenue during the start-up phase that helps fund the company.

Current examples

Walmart plans to use fully autonomous box trucks to make deliveries in Arkansas starting in 2021.[2] The retailer has been working with a start-up called **Gatik**[3] on a delivery pilot for 18 months. Since early 2020, its trucks have been operating with a safety driver on a two-mile route between a “dark store” (a store that stocks items for fulfilment but isn’t open to the public) and a nearby Neighbourhood Market in Bentonville, Arkansas. In 2021, the two companies plan to drop goods off to customers (at designated pickup points), and remove the safety driver, as well as extending their delivery route to 20 miles.

[2] Walmart will use fully driverless trucks to make deliveries in 2021 - The Verge

[3] Palo Alto-based start-up that makes self-driving box trucks

As well as Walmart, Gatik, is working with Waymo, Cruise, Nuro, Udelv, Baidu, Ford, and Postmates. Gatik has recently partnered with Loblaw, the Canadian retail chain to deploy five Gatik vehicles to move goods between warehouses and stores in the Toronto area.

TuSimple is another leading autonomous truck start-up with operations both in China and the US. It has 50 autonomous vehicle trucks operating in the two countries. It also has 18 customers—including UPS for its testing activities. UPS is also an investor in TuSimple. Starsky Robotics is another autonomous truck start-up planning to deploy hub-to-hub autonomous trucking with teleoperation for the first and last mile.

What has come out of COVID?

A key question is whether COVID-19 has led to any changes in emphasis on different AV use cases, and do we think these will be enduring? The Covid-19 pandemic has fast-tracked the significance of contactless payment and delivery systems. Combined with this, as lockdowns and stay-at-home orders accelerated the shift to online shopping, demand for delivery has skyrocketed. As the public are encouraged to practice social distancing, AV developers have seized the opportunity to market and trial a variety of innovative approaches to delivering a contactless service.

There has also been greater apprehension around sharing vehicles, particularly in countries where the pandemic has taken a large toll on human life. Many AV manufacturers have subsequently been thinking more seriously about autonomous goods delivery post-COVID-19.

Logistics applications for automated driving are in many ways simpler and safer for delivering goods instead of transporting people. As an example, in partnership with the Mayo Clinic and Jacksonville Transportation Authority (JTA) in Florida, Navya and Beep began deploying AVs to transport medical supplies and Covid-19 tests. Similarly, during COVID-19 lockdowns, GM's self-driving subsidiary Cruise started deploying its AVs to make deliveries for food banks in San Francisco. This approach helped the company sidestep restrictions that prevented AV testing during COVID-19 stay-at-home orders. In China, autonomous driving developer Pony.ai launched a driverless delivery service in Irvine, California to help fulfil grocery orders during the COVID-19 lockdown. The company partnered with LA-based e-commerce platform Yamibuy.

Investment in autonomous goods delivery saw a sharp increase in 2020, with ongoing investment in early 2021. This has not reduced investment in other areas of autonomous vehicle development, but it has reinvigorated interest in AV goods delivery, both within companies and as a consideration for regulatory development.

Themes and Insights

The following is some early thinking around the themes beginning to emerge across different AV use-cases.

1. **Optimism of mass deployment in the near-term has been replaced over recent years by the reality that developing AVs for personal use is much harder than originally thought**. AV technology, especially the software that replaces human drivers, is extremely difficult to develop and test. Parts of the industry have subsequently turned to specific and more limited AV use cases where the economic returns are expected to be greatest. This means an increased resurgence in the development of ADAS technologies.

2. **Some use cases may also be easier to deploy than others**. With robotaxis, you need to solve for the entire operational design domain and landscape. While robotaxis have dominated AV use case discussions for many years, the challenges with bringing fleets of level 4 AVs to market has shifted the focus of industry to other, potentially, more viable use cases. Those that operate on fixed routes, for example, or in low-speed environments that have fewer unpredictable movements of either people or other vehicles, may require less testing and have fewer regulatory constraints than those operating on the open road in mixed traffic. Use cases involving goods transport only may also have easier compliance requirements than those carrying passengers.

3. **Driverless trucks will cause major disruption to the freight industry**. Autonomous trucks are likely to change the cost structure, utilisation of trucking and the cost of consumer goods. Middle mile mobility could be the dominant use case, with the majority of freight journeys in New Zealand occurring within regions.

4. **Companies working on deploying commercially viable AVs will need to consider the environments within which the vehicles will operate**, including supporting infrastructure, the availability of capital investment, consumer demand and, of course, if there are favourable regulatory settings.

5. **Over the next nine years, many of the AV use cases described above will be deployed in a number of cities globally.** The speed and acceleration of these deployments will depend on how quickly supportive regulation is put in place, consumer acceptance of the technologies, and which development pathways are most attractive for investment.

Appendix A: SAE levels and descriptions

Figure 1: SAE Levels of Driving Automation

The SAE levels of automation can also be described as partial, conditional, high, and full automation. Table one below outlines these descriptions, as well as the role of the human driver.

Table one: Description of Automation levels

Automation Level	Description
Level 0	No automation
Levels 1 & 2	Also known as 'partially automated', these vehicles have limited automated features that may assist the driver with speed or steering control. Examples include; lane-keep assist or adaptive cruise control, pre-emptive braking, lane centring, parking assist, driver observation & alerts, steering, acceleration, deceleration
Level 3	Also known as 'conditionally automated', these vehicles manage speed and steering control, and are also responsible for monitoring the road environment, requiring the human driver to perform a 'fall back' role. An example is roadway monitoring

Level 4	Also known as 'highly automated', these vehicles are capable of operating in some driving modes, in certain environments, without a human ready to take control. These driving modes may be limited by factors such as speed, weather conditions, or access to high quality digital mapping. An example is a defined shuttle route
Level 5	Also known as 'fully automated', these vehicles are capable of operating in all driving modes and are truly 'driverless'. A human will not be required to take back control of the vehicle, and it may have no steering wheel or pedals. An example is a "robo-taxi"