Ministry of Transport
TE MANATŪ WAKA

Autonomous Vehicles

Background paper three

Trends and Considerations

The Ministry of Transport has started a work programme looking at challenges and opportunities Autonomous Vehicles (AVs) present to the transport system in New Zealand. This paper outlines some of the key global trends influencing the development and deployment of AVs. It is not an exhaustive list, but a starting point for discussions on the implications of these trends for New Zealand.

Introduction

Autonomous Vehicles (AVs) are an emerging technology in the land transport system. They will affect how people and goods move, as well as the demands on physical infrastructure (such as roads and car parks) and digital infrastructure (such as satellite-based navigation and communications technologies).

There is a significant work underway globally to develop fully autonomous vehicles that can be deployed on public roads. The anticipated benefits are perceived to outweigh the potential risks, with improvements in safety, comfort and accessibility all expected to result from a shift to greater levels of autonomy.

New Zealand is a technology taker. We import vehicles from four different right-hand drive markets. Global trends in auto-manufacturing, as well as international approaches to vehicle regulation, all influence the vehicles coming into New Zealand's fleet.

To stay abreast of international developments, we have identified some of the main trends that could influence the deployment of AVs in New Zealand. A trend can be described as a general direction in which something is developing or changing. It is evidence-based, and shows a trajectory of change in one direction, often as an increase in interest, investment or effort. We identified these trends using the PESTLE framework[1] to ensure we had considered all of the external influences on AV development and deployment.

This paper highlights seven trends and provides a summary of the evidence that supports them. It also highlights several broader considerations that could also influence the development and deployment timeframes and pathway for AVs. These trends and considerations have been developed from our review of international literature. We want this paper to provoke discussion on the implications of these trends and considerations for New Zealand (if any).

[1] PESTLE stands for Political, Economic, Social, Technological, Legal and Environmental

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The New Zealand context

The New Zealand context will significantly influence the approach we might take to AV deployment.

New Zealand has 11,000km of state highways and 83,000km of local roads. Approximately 72% of the vehicle fleet is defined as 'light passenger', 20% as commercial and 6% are heavy trucks.

Road transport makes up over 90% of total transport greenhouse gas emissions, with 70% of road transport emissions from light vehicles. Electric vehicles (EVs) comprise less than 3% of light vehicle registrations. The New Zealand Government has declared a climate emergency and set a target of net-zero emissions by 2050.

New Zealand is in the top 10 countries for vehicle ownership per capita, and around 83% of household trips are made by private car and nearly 90% of known distance travelled to work is travelled as a driver.

Around 84% of our 5 million New Zealanders live in urban areas and life expectancy is increasing. The cost of transport makes up a significant portion of New Zealander's weekly spend, with this being higher for people living on the outskirts of cities and in rural areas. New Zealand is facing growing concerns around affordable housing.

Around 350 people die in road crashes each year and thousands are injured.

New Zealand has a Transport Outcomes Framework[2] centred on the wellbeing of New Zealanders and the liveability of places. This is a useful lens when thinking about what New Zealand's approach to AV deployment should be.

[2] Transport Outcomes Framework | Ministry of Transport

Trends

Trend 1 – Greater collaboration and partnerships

In recent years, there has been a significant increase in the rate of collaborations between automakers (horizontal integration), and between automakers and the other businesses that contribute to the production of AVs, such as software companies (vertical integration). Collaboration helps individual companies to increase their potential market share and beat their competitors in deploying finished products to market.

There are several benefits to partnerships and collaborations. Firstly, partnerships help companies accelerate their development pathway, and/or achieve all-important scale to develop their products for market. Different companies bring with them different skills and assets to leverage off, reducing the costs of developing all the necessary capabilities in-house. Secondly, the arrangement creates flexibility. The benefit of flexible arrangements like these is that a company can leave the partnership or collaboration when it is no longer profitable or advantageous, or further leverage the partnership by joining with other companies to increase their combined market influence.

These strategies also help companies to spread the risks associated with investment. This includes the cost of the vehicle itself, the vehicle's eyes (lidar, radar and cameras) the vehicle's brain (hardware and software) and the services that will eventually enable the vehicle to be deployed (for example, ride-hailing software and services). There are also benefits for all companies involved in having each of these components developed together.

Strategic collaboration is occurring more-and-more, and it is occurring across international borders. For example, Honda and Softbank (a Japanese telecommunications and technology conglomerate) invested approximately NZD3.8 billion and NZD3.2 billion, respectively, into Cruise, a US self-driving vehicle company. Toyota is cooperating on AVs with ride-hailing service companies such as Didi Chuxing and Pony.ai in China; Jaguar formed a partnership with Waymo in 2018; Toyota partnered with Uber in the same year; and Fiat Chrysler Automobiles partnered with Voyage in 2020.

Large tech giants, like Microsoft, are also investing in, and partnering with, automotive companies. Microsoft has invested in Cruise and General Motors (GM), which will now use Microsoft's cloud computing platform Azure to help them scale and commercialise their fleet of AVs. In February 2021, Apple announced they had approached Nissan to work on an AV project. Apple have also been in discussion with Hyundai to develop 'the Apple car'.

Trend 2 – Increasing mergers and acquisitions

As well as greater collaboration across the sector working on autonomous technology, there is an increasing emphasis on mergers and acquisitions within the sectors. The anticipated future profits in the AV market is driving the trend. The estimate for the value of the global AV market is anywhere between USD $2 trillion and USD $3 trillion by 2030.

Mergers and acquisitions provide additional certainty over collaboration and partnerships and allow a company to control more of its supply chain by owning it. Mergers and acquisitions also ensure that intellectual property is held within a single organisation. For companies with large cash reserves, buying up the capability they need from outside significantly speeds up the development pathway. It also allows companies that have not traditionally worked in the automotive sector to upskill and become completive quickly. This trend is expected to increase AV production scale and, as a result, make autonomous driving technology more affordable over time.

Traditional automakers see the increasing demand for autonomous driving technology in cars by consumers and understand the potential profitability in autonomous vehicle fleets. To reduce costs and bring innovation and expertise in-house, traditional automotive manufacturers are acquiring AV technology start-ups. For example, in 2016, General Motors acquired Cruise for an undisclosed amount, although media reports have placed the number "north of $500 million". In addition, Toyota acquired Jaybridge Robotics in 2016, Delphi acquired NuTonomy in 2017 (around $400 million), and Ford acquired Argo AI in 2019.

The trend is not limited to traditional automotive manufacturers. Amazon acquired Zoox in 2014, Intel acquired Mobileye in 2017, and Samsung acquired Harman in 2017. Start-up Nuro also acquired AV trucking company Ike in 2020, and notably, U.S. self-driving company Aurora acquired Uber’s troubled self-driving unit in 2020.

In addition, leading automakers are expanding their in-house vehicle software development capability through dedicated internal software engineering teams. This has led to the “poaching” of talent across companies. For example, Uber acquired 40 robotics engineers from the prestigious National Robotics Engineering Centre at Carnegie Mellon University in 2015. Aurora hired its CEO Chris Urmson from Alphabet Inc.’s self-driving project; its co-founder Sterling Anderson previously led the team that developed Autopilot for Tesla Inc., and its Chief Technology Officer Drew Bagnell is a robotics professor at Carnegie Mellon University.

Trend 3 – Increased availability of venture capital

Emerging technology is an attractive option for venture capital. Despite the Covid-19 pandemic, AV manufacturers, both established and start-ups, were able to raise billions of dollars through venture capital sources last year to support the development of AVs. In 2019, Uber raised $1 billion in investments to fuel its autonomous driving efforts ($333 million from SoftBank and $667 million from Toyota and Denso). At that stage, its self-driving unit ATG was valued at USD $7.25 billion. Despite the capital injection, Uber sold its Advanced Technologies Group to Aurora in 2020 but retained a 26% stake.

Funding for AV companies reached a new peak in 2020, reaching $7.3 billion. Waymo alone raised over USD $3 billion in 2020 and Oxbotica has recently raised $47 million, with significant investment by Beyond Petroleum (BP). Globally, autonomous truck and freight companies raised more capital than the capital raised for autonomous passenger vehicles in 2020.

The AV development ecosystem is maturing, as investors have identified tech leaders and are investing heavily in these firms. The average deal size rose to $104 million from $89 million in 2019.[3] Tech giants like Amazon, Google, Apple and Microsoft all invested billions of dollars in AVs over 2020. Amazon's acquisition of Zoox, and strategic investment in Aurora, illustrate the increased interest that tech giants are showing in AVs. But the investments also reveal a pattern of diversification in investment across a portfolio of mobility and transport interests, including electric vehicles, on-demand delivery, mobility-as-a-service (MaaS) and auto insurance.

Asian technology 'giants' Samsung, Huawei and Tata Elxsi are also investing heavily in AVs, alongside other mobility areas of interest. Huawei is working with auto manufacturers (like Audi and GAC Group) with the goal of launching AVs in the early 2020s. Its aim is to provide the communications technologies needed to make low-cost AVs widely available for purchase.

[3] State Of Mobility: Investment & Sector Trends To Watch (cbinsights.com)

Trend 4 – Increased focus on artificial intelligence and machine learning

Artificial intelligence (AI), including machine learning and cloud computing, are increasingly seen as essential for higher levels of automation. AVs will create enormous amounts of data based on millions of images and experiences that are centralised on a common database. This will require significant and ever-evolving computational power to analyse data and make timely decisions. Computer systems will also need to identify and quickly respond to a number of unique situations to operate in fully autonomous mode.

Increasingly AI, specifically the subfields of Machine Learning that are Deep Learning and Reinforcement Learning, is seen as the most effective way to achieve fully autonomous driving. Companies like Microsoft, Nvidia and Baidu are leading the development in this space. Microsoft is building a connected vehicle cloud on top of its connected vehicle platform, allowing automakers to deploy self-driving tech in vehicles at scale. Chinese company Baidu opened two AI research labs in Silicon Valley, and in August 2020 launched Apollo Computing Unit (ACU) capable of handling vast amounts of radar and camera data.

AI can recognise and respond to any situation better and faster than a human driver. It will make decisions around vehicle route planning, departure times based on traffic volumes, and optimal speed based on weather conditions. Through centralised, modern, and updatable AI in the vehicle's brain, automakers will be able to update the software over-the-air and implement new business models that can increase the value of the vehicle over time.

Supporting more use of AI and machine learning, is the growing acceptance and pursuit of "simulation" as a valid method of testing how vehicles might operate in the real world. Simulation avoids having to road test vehicles for millions of miles and allows the testing of "edge" cases (the unique situations mentioned above). This is particularly important as different driving environments will present unique "hazards". Additionally, every jurisdiction has slightly different road rules and infrastructure, such as road markings and signage. Testing potential scenarios using virtual simulations can accelerate development and save time on testing failed solutions, with big implications for costs savings.

Trend 5 – Increased international regulation around vehicle software systems

The automotive sector is undergoing a transformation with the digitalisation of in-car systems. These systems are necessary to deliver vehicle automation, connectivity and shared mobility. Today, cars contain up to 150 electronic control units and about 100 million lines of software code (four times more than a fighter jet). This is projected to rise to 300 million lines of code by 2030.[4] This transformation is resulting in an emerging and integrated industry which differs greatly from the conventional auto industry in technical development, application and management.

As software systems increasingly undertake more of the driving task, international regulations are shifting towards managing the risks this might present. The United Nations World Forum for Harmonization of Vehicle Regulations (Working Party 29) is a permanent working party focussed on the harmonization of vehicle regulations across member states. The benefits of such harmonized regulations include road safety, environmental protection and access to trade.

Working Party 29 has recently produced three regulations focused on AVs. For example, Regulation No. 157 Automated Lane Keeping System (ALKS) is designed to establish uniform provisions concerning the approval of vehicles with ALKS and includes prescriptive conditions for where and when vehicles can operate with ALKS. The regulation also includes general requirements for the safety of the system for handing over the driving task between the human driver and the vehicle's automated ALKS system. These prescriptions set a high bar for AV development, and set strict limits for the operation of ALKS. For example, ALKS cannot operate above 60km/h.

The significance of this shift in regulatory focus resulted in the establishment of a UN working party focussed on Automated/Autonomous and Connected Vehicles (GRVA) in June 2018. GRVA's mandate is to ensure that the development of regulations can keep with the pace of the technologies and industries, meet the demand of future type approval and management, and guarantee the safety and security of automated/autonomous connected vehicles.

The trend is being driven out of safety concerns by regulators and by industry wanting assurance that there will be standardisation across the international markets they sell their vehicles in. It is possible, however, that we are seeing a level of "over-regulation" to mitigate the uncertainty and potential risks associated with new technologies, including cybersecurity and data privacy concerns.

[4] UN Regulations on Cybersecurity and Software Updates to pave the way for mass roll out of connected vehicles | UNECE

Trend 6 – Increased frequency and severity of extreme weather events

Climate change increases the frequency, unpredictability, and severity of extreme weather events, such as snowstorms, hurricanes and floods.[5] The annual cost of repairing land transport networks damaged by weather-related events has more than quadrupled over the past decade as a result.[6]

> *"It's a very noticeable blind spot. Deploying autonomous vehicles in bad conditions is not really tackled, or really talked about"*
>
> Alexander Wang, CEO of Scale AI

Adverse weather conditions are challenging AV development for several reasons. The sensors operating on AVs are affected by inclement weather, resulting in poorer performance, or the inability to undertake certain functions altogether. Snow and rain can obscure and confuse sensors, hide markings on the road, and make a car perform unexpectedly.

Adverse weather may also increase the demands on machine learning, pushing the limits of computer algorithms, and impacting higher levels of automation. AI may become more critical for AVs to navigate extreme weather conditions as all AVs so far use sensors to navigate in adverse weather.

Considerations about climate change and increased extreme weather may mean that fully autonomous vehicles will take longer to develop and bring to market than previously thought.

[5] Global Warming of 1.5 ºC — (ipcc.ch)
[6] View of Funding Climate Change Adaptation (victoria.ac.nz)

Trend 7 – Increased shift away from fossil fuels in transport

The climate change agendas of a number of countries are seeing a growing shift away from fossil fuels. For transport, this means shift to low (or zero) emissions fuels and an increased emphasis on the electrification of the vehicle fleet. The global electric vehicles market is expected to reach 32% of total market share for new car sales by 2030, up from approximately 3% currently.[7] Some companies, like Ford, have set ambitious targets of only producing zero-emissions capable vehicles (hybrid or electric) from 2024.

Jurisdictions, such as California, Canada and Norway, are leading the move to ban new fossil fuel cars to meet ambitious greenhouse gas reduction targets as stipulated by the Paris Climate Accord. These hard targets are pushing automobile manufacturers to phase out fossil fuel car production in favour of electric vehicles. The urgency for automotive manufacturers to switch to electric and other energy sources may cannibalise or re-direct investment from developing AV technology to EV technology. Potential reprioritisation of R&D spend may further delay deployment of autonomous fleets in favour of electric fleets during the transition over the next 8 – 10 years.

Governments around the world are prioritising investment in, and adoption of, electric vehicles and associated technological and infrastructure improvements. Supportive government policies are being tailored to support market transition to EVs, as the social, economic and environmental benefits are clear. Subsidies, incentives, and funded infrastructure to support EVs are common internationally. Fully autonomous vehicles will be electric, so the pathway to their wide scale deployment may be more reliant on their electric capacities, rather than their autonomous functions, at least in the short term. A recent study shows the vast majority of Tesla owners bought the car because of its perceived superiority in the market for electric vehicles, rather than any considerations of its well marketed self driving capabilities.[8]

[7] Electric vehicle trends | Deloitte Insights

[8] Escalent | Would Tesla Be Better Off Without Elon Musk? Some Electric Vehicle Shoppers Think So

Further Considerations

With most emerging and disruptive technologies, there are interdependencies between social, technological and regulatory environments which influence, and at times dictate, the commerciality and ubiquity of the technology. Some further considerations we have identified are:

Public acceptance is a significant variable for success

Public trust in new vehicle technologies is growing, but slowly. It will have a significant impact on deployment timeframes and uses of AVs. As more and more new vehicles enter the fleet with ADAS technologies, users are slowly becoming more aware and comfortable with the role they can play in the driving task. Many AV companies are working on initiatives that will further build public trust in AVs, such as building haptics and warning signals into the vehicle to indicate when it intends to undertake certain manoeuvres. Companies are also using testing and trialling as an opportunity to build social licence through increasing the visibility of AVs for other road users, as well as voluntarily disclosing vehicle disengagement reports[9] and the number of miles travelled by vehicles in the testing and trialling phase.

Consumer preferences are evolving

People are increasingly conscious of the impact their transport choices have on the environment and, in particular, on the reduction of Co2 emissions. Consumer choices are being influenced by the carbon footprint of the goods they purchase and the services they use. AVs are likely to benefit from this shift in consumer preferences because they are also electric and, if they are connected to each other and surrounding infrastructure, AVs can contribute to more efficient transport networks. This may increase consumer demand for AVs in both the new and second-hand vehicle market in the future.

Consumers need information and education

Public trust can, however, be eroded as quickly as it is gained if incidents occur, and the general public rely solely on the media and internet bloggers for their information. As higher levels of autonomy begin to be deployed overseas, the New Zealand public may also rely on international evidence before “buying-in” to the technology being deployed in New Zealand. As the various forms and levels of AVs become available for public consumption, the need for education about how to use, and not use, the technology will become paramount.

Consumers will also need a good understanding of the benefits and risks that AVs present for them and other road users. Education campaigns are already a focus for many countries,

[9] This is records how often the vehicle disengages itself from autonomous mode during tests.

starting with a focus on level 2 Advanced Driver Assistance Systems (ADAS). Vehicle manufacturers, vendors, importers and regulators all have a role to play in ensuring that drivers of AVs have the information they need to operate the technology safely.

App-based ride-hailing services are here to stay

Transportation and mobility have been one of the most heavily disrupted industries since the rise of the "sharing economy". The growth in the sharing economy, and in particular on-demand transport and ride-hailing services, has seen the growth in their prevalence over the past few years. The rapid rise in revenue of sharing economy platforms such as Uber and Lyft show growth in this area (prior to COVID-19). Technology has driven this change, with smartphone apps providing the platforms to deliver these new transport services. Consumers have become more comfortable and more willing to share their information through these platforms, to reap the benefits of cheaper on-demand transport. This has in-turn shifted the expectations of consumers around their transport options and the level of service they expect to receive. Already, the top AV companies are becoming synonymous with ride-share, such as Cruise and Waymo. Their challenge will be to create a point-of-difference in the future "robotaxi" industry to gain market share (an area e-scooters have struggled with).

The technological development pathway remains challenging

The process of creating safe, secure autonomous vehicles continues to cost more, and take longer, than forecasters once believed. All new technologies develop under hugely uncertain conditions and have unpredictable results. The development trajectory of AVs will not be linear. Development will continue to be hampered by technological hurdles and constraints. We have already seen some companies reduce their focus on level 3 autonomy, due to the technical challenges of transitioning control back and forth between the system and driver. Many companies have shifted their focus and capital to advancing level 2 technologies as a result, or to focus entirely on level 4 and 5 autonomy. Some prominent companies, like Uber, have even withdrawn from the AV development market altogether.

There will be ongoing regulatory challenges

AVs need appropriate regulation and will not be able to operate unless each market's legal framework can keep pace with international developments. As with technology, the regulatory hurdles to on-road deployment of fully autonomous vehicles are more challenging that first anticipated. Regulatory development at the international level is focussed on standardisation and safety across autonomous technology, including data privacy, ethics and cybersecurity. However, jointly developing regulations within bodies like the UN is a slow process, is risk averse, and is setting a very high bar.

While nations work on standardising regulations, states are developing their own regulatory frameworks to support development and innovation. These frameworks are, however, being developed in a piecemeal way, with the resultant “patchwork” regulation needing to be reconciled with international standards sometime in the future. Meanwhile, manufacturers are developing vehicles to meet these patchwork regulations.