Australian Government

Department of Infrastructure, Regional Development and Cities

Automated Mass Transit

Submission to the House of Representative Standing Committee on Infrastructure, Transport and Cities

Department of Infrastructure, Regional Development and Cities

December 2018

1. Executive Summary

The Department of Infrastructure, Regional Development and Cities (the Department) welcomes the Committee's inquiry into the use of automation and new energy sources in road and rail mass transit. For the purposes of this submission, mass transit is defined as shared, publicly accessible urban passenger transport services (BITRE, 2014a).

Developments in technology are converging and driving change in the transport sector – including connected and automated vehicles, alternative fuelled vehicles and automated rail systems. The pace of change is likely to accelerate, with potentially profound impacts.

Our growing passenger task

Australia's domestic passenger task continues to grow, with our increasing population one of the key drivers. Congestion is an increasing issue in Australia's largest cities, costing around $25 billion per year, rising to as much as $37 billion per year by 2030 (BITRE, 2015). Congestion is also associated with an array of social costs.

1.21 million Australians use some form of public transport as part of their journey to work and an increasing number of Australians use multiple transport modes. Mass transit provides an integral element of our growing cities' transport networks and can offer advantages over other transport modes because of its capacity to move large numbers of people quickly and efficiently.

Developments in transport technology – their application and potential in Australia

Rapid advances have been made in automated vehicle technology over the past decade, driven by substantial investment from industry, with trials of this technology now underway across Australia. Vehicle manufacturers are investing in alternative fuelled vehicles, including both electric and hydrogen-powered vehicles.

The use of automated vehicles for ride-sharing or ride-hailing, for automated on-road mass transit services, and for the provision of 'last-mile' connectivity, could deliver benefits such as significantly improved safety outcomes, greater efficiency and reduced congestion, better access to transport services for those unable to drive, as well as more liveable urban and regional communities.

On-road automation is not without challenges. Research and trials have made it clear that deploying automation on a crowded, mixed-user road system is a complex engineering and transport planning challenge. If unmanaged, vehicle automation could also have unintended consequences associated with increased convenience of travel and the inducement of additional demand. Governments are working closely with industry and the research and development community to address these challenges and realise the potential of road automation technology.

Automated rail systems, on the other hand, are a mature technology, with increasing uptake in Australia, offering a significant opportunity to enhance the mass transit capability in the more immediate future. A step-change will occur in Australia's urban rail systems over coming years with the completion of Stage 1 of Sydney Metro, Australia's first fully automated passenger railway, anticipated for the second quarter of 2019. Automation in rail allows operators to optimise services by shortening following distances and reducing stoppages, increase the reliability of services, create safer and more accessible services, improve energy performance and reduce operating costs.

Role of the Australian Government and other bodies

In the 2018-19 Budget, the Government announced a $24.5 billion pipeline of major projects and new initiatives as part of its overall 10-year $75 billion investment in transport infrastructure. The majority of investment is through the Infrastructure Investment Program, which supports road and rail projects in both regional areas and urban centres.

The Government is also investing in the 10-year $10 billion National Rail Program, under the Infrastructure Investment Program. The National Rail Program is a major, long-term commitment to invest in passenger rail networks in our big cities, as well as between our cities and their surrounding regional centres.

The Government supports the deployment of automated rail systems in Australia through collaboration with state and territory governments and the rail industry to facilitate interoperability and compatibility, and through the work of the Government-owned Australian Rail Track Corporation.

Through its Smart Cities Plan and City Deals, the Government is playing an important role in delivering more liveable and connected cities. Working with local stakeholders, the Government is supporting place-based planning and investment, and exploring how best to integrate smart technologies into our cities.

The Government is working closely with state and territory governments, the National Transport Commission and Austroads as well as through the Transport and Infrastructure Council to support the safe and early deployment of automated vehicles in Australia. This work is supported by the Government's announcement in October 2018 of its decision to invest $9.7 million to advance work to prepare Australia for automated vehicles and other transport innovations, including through establishing the Office of Future Transport Technology within the Department.

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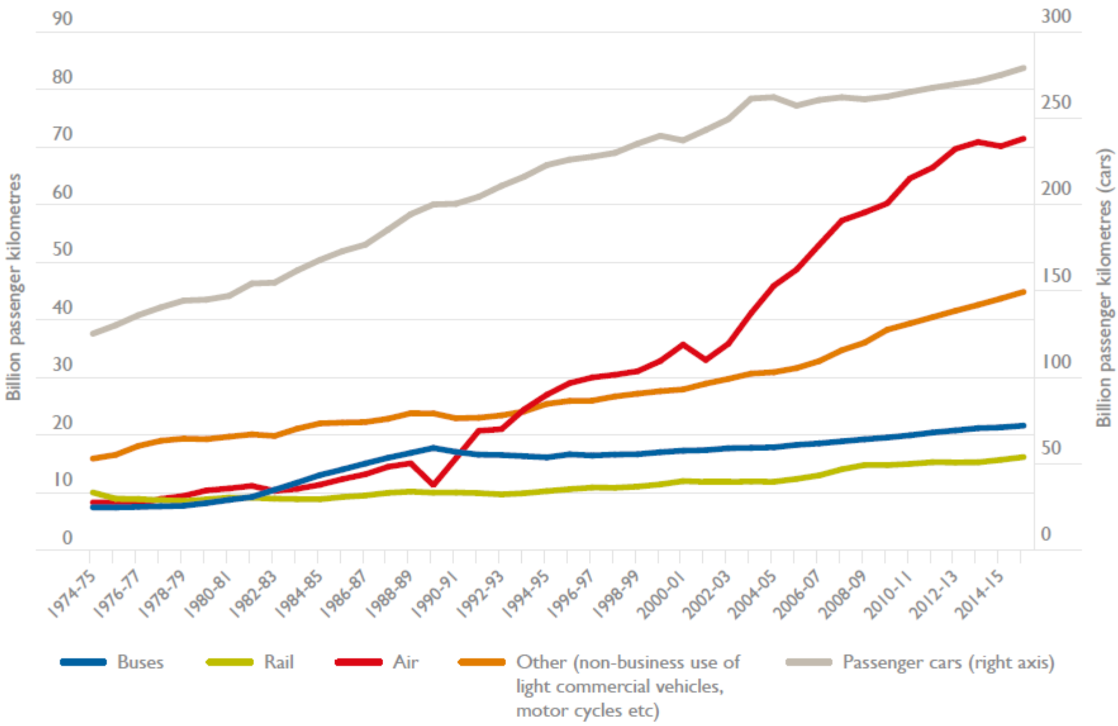
2. Moving people in Australian cities

Our transport system connects Australians with employment, services, commerce, education, family and community. Australia's domestic passenger task (Figure 1) continues to grow, with our increasing population one of the drivers. In our capital cities in 2016-17, Australians travelled 168 billion kilometres by passenger vehicle, 19 billion kilometres by commercial vehicle, 14 billion kilometres by rail, 7 billion kilometres by bus, 1 billion kilometres by motorcycle and 0.18 billion kilometres by ferry (BITRE, unpublished).[1]

Figure 1: Total Australian domestic passenger task, by mode of transport



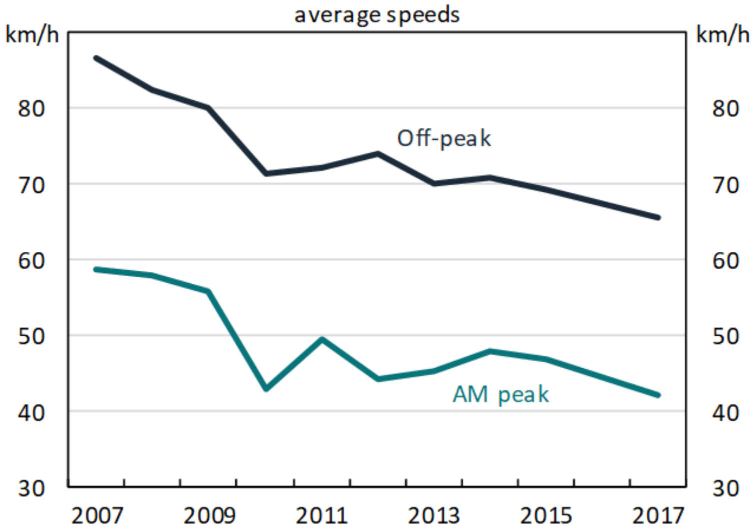
Source: Bureau of Infrastructure, Transport and Regional Economics, 2017.

[1] Current, provisional estimates for forthcoming publication. Total rail passenger kilometres includes both heavy and light rail passenger kilometres. Total bus passenger kilometre values includes both urban passenger transport (UPT) bus values and private bus usage. The UPT bus values refer solely to public route buses, whereas private bus values include private bus usage such as by charter buses.

2.1 Congestion

Congestion is a growing issue in Australia's largest cities, where travel times have increased and average speeds have decreased. Morning peak hour vehicle travel in Sydney takes 65 per cent longer than off-peak (TomTom, 2016). Over the last 10 years, the average time taken for a 30 kilometre peak hour trip in Melbourne has increased from 31 to 43 minutes, with similar outcomes in other major cities (Houston Kemp-HERE 2017). Average travel speed on metropolitan freeways has significantly declined over the past decade; average speeds on Melbourne inner-region freeways are depicted in Figure 2.

Figure 2: Melbourne inner-region freeway speeds



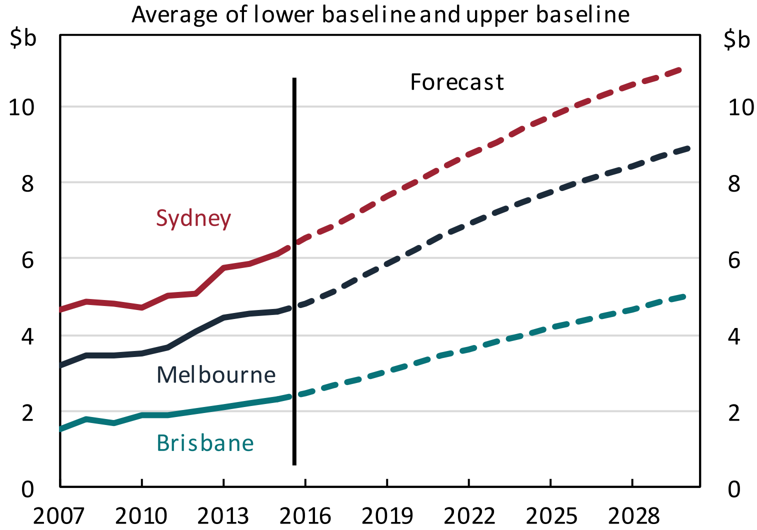
Source: Houston Kemp-HERE, 2017.

Extended commutes caused by congestion have economic, social and environmental costs. For example:

- delays to freight and business travel put pressure on our supply chains and increase the cost of goods and services;
- commutes of 45 minutes or longer have a significant negative impact on overall life satisfaction (BITRE, 2016a);
- 81 per cent of commuters experience travel stress and 41 per cent believe traffic negatively impacts their health (BITRE, 2016a);
- spending more time in a vehicle each day is associated with higher Body Mass Index (BMI), waist circumference and cardio-metabolic risk (Sugiyama et al., 2016);
- extra time spent idling in a vehicle may increase fuel costs (BITRE, 2015);
- congestion leads to poorer air quality, as vehicles under congested conditions emit higher rates of noxious pollutants than those in more freely flowing conditions (BITRE, 2015); and
- congestion increases the unpredictability of travel time – the more congestion anticipated, the earlier a person has to depart to provide assurance of on-time arrival.

BITRE estimates the cost of congestion in our capital cities at $25 billion in 2017-18, rising to as much as $37 billion per year by 2030 (BITRE, 2015). The forecast impact on Australia's three largest cities is depicted in Figure 3.

Figure 3: Congestion costs in major cities



Source: Bureau of Infrastructure, Transport and Regional Economics, 2015.

2.2 Role of mass transit

Around 9 million people commute to work on the average weekday in Australia, travelling an average of 16.5 kilometres to do so (ABS, 2018b). While mass transit plays a growing role, private vehicles remain the most common way Australians get to work, with 79 per cent of the working population commuting via car, as either a driver or passenger (Figure 4). 1.21 million Australians use some form of public transport as part of their journey to work and an increasing number of Australians use multiple transport modes (BITRE, 2017a).

Figure 4: How Australians travel to work[2]

Year	Public transport only	Public transport & other	Car (driver)	Car (non-driver)	Truck	Taxi	Motor-cycle	Bicycle	Walk	Total
1986	10.04%	na	68.96%	10.10%	na	0.53%	1.53%	1.67%	6.59%	5,168,325
1991	8.58%	3.01%	69.79%	9.33%	na	0.38%	1.07%	1.54%	6.30%	5,333,026
1996	7.73%	3.07%	72.77%	8.76%	na	0.41%	0.87%	1.23%	5.17%	6,074,248
2001	7.72%	3.35%	72.26%	7.70%	2.01%	0.32%	0.72%	1.17%	4.75%	6,664,846
2006	8.12%	2.90%	72.88%	7.19%	1.62%	0.30%	0.82%	1.22%	4.95%	7,413,788
2011	8.99%	3.50%	72.95%	6.47%	1.26%	0.27%	0.77%	1.25%	4.54%	8,306,012
2016	9.88%	3.71%	73.66%	5.49%	0.96%	0.22%	0.96%	1.21%	4.15%	8,924,223

Source: adapted from Bureau of Infrastructure, Transport and Regional Economics, 2017.

As Australia's population grows, mass transit has an increasingly important role, including in ensuring our cities function effectively. Mass transit can offer advantages over other transport modes because of its capacity to move large numbers of people quickly and efficiently.

In a global context, mass transit networks:

- help cities to manage population growth;
- contribute to reducing congestion on road networks;
- provide more efficient movement of people than car-based commuting, reducing fuel use and emissions;
- shape and support economic growth and long-term land use planning;
- deliver national and local economic benefits, including from agglomeration and connectivity;
- connect people to housing, jobs, education and services; and
- connect orbital cities with their bigger urban neighbours.

In recognition of the vital role our public transport systems will play in successfully managing projected growth in our population and ensuring our cities are great places to live and work, the Australian Government has established a $10 billion National Rail Program, announced in the 2017-18 Budget, focusing on supporting transformational urban passenger rail initiatives and regional rail links into our cities. More information about the Government's work to invest in and support mass transit is provided in section 6 of this submission.

[2] na: not available. Yearly figures may not add up to 100 per cent due to rounding.

3. Automated and electric vehicle technologies

3.1 Automated vehicles

An automated road vehicle ('automated vehicle') is defined as a vehicle that does not require a human driver for at least part of the driving task (NTC, 2016). This definition encompasses a wide range of capabilities, from systems that automate a single aspect of the driving task (e.g. adaptive cruise control which controls acceleration and deceleration), to future systems that may be responsible for all elements of the driving task at all times. This submission avoids terms that may refer to some or all of these capabilities, including 'autonomous', 'self-driving' and 'driverless' in the context of on-road vehicles.

Vehicles with moderately sophisticated automation features are already commercially available in Australia. This includes innovative features such as self-parking, traffic jam assist and lane keep assist. In these examples, the system is capable of simultaneously controlling steering, acceleration and braking under the supervision of the driver. Vehicles with higher levels of automation are already in use in closed, off-road environments, such as mining sites, enclosed tracks and private property.

Many major vehicle manufacturers and several large technology companies are developing vehicles with higher levels of automation, including vehicles that are designed to require no human control. It is uncertain when vehicles with higher levels of automation will become available:

- Some manufacturers expect to offer **conditionally automated vehicles** by 2020. These will undertake all necessary driving functions under certain conditions, but may need to hand back control to a human driver in certain conditions or places.
- Most experts expect **highly automated vehicles** to become available in some markets between 2020 and 2030. These will not require human intervention when performing some types of driving.
- Designing **fully automated vehicles**, where the automated system is in control at all times and in all road environments, is a much more complex engineering problem. It is not known if or when these vehicles might become commercially available.

For more information about the levels of automation and the technology enabling automated driving, see **Appendix A**.

Early deployments of automated vehicles may have significant restrictions as to the geographic areas or road conditions in which they are able to operate (e.g. only on well-maintained highways, or only in low-speed urban areas).

Like other vehicle technologies, it will take time for automated driving technology to penetrate throughout the vehicle fleet. For example, modelling commissioned by the Queensland Department of Transport and Main Roads suggests that saturation of highly automated vehicles in the Australian fleet could occur roughly between 2050 and 2060 (TransPosition, 2016).

Penetration models generally assume that take-up will be similar to that of other automotive technologies. It is possible that this assumption will not hold in the future, particularly if other developments have a disruptive effect on business models in the automotive sector. For example, wider use of car and ride-sharing business models at the expense of private vehicle ownership could increase vehicle utilisation and lead to faster fleet renewal. Policy and regulatory settings can also affect penetration rates, as could social acceptance, costs and other factors.

3.1.1 Trials of automated vehicles

Trials of automated vehicles are now underway across Australia. They have an important role in public awareness and support acceptance of the automated vehicle technology. Trials of automated shuttle buses, with potential applications for mass transit, are common. The learnings from these are informing approaches to policy, regulation, investment and road operations to support automated vehicles. These trials are supported by the *Guidelines for Trials of Automated Vehicles*,[3] which create nationally consistent guidance for the safe trialling of these vehicles in Australia. A map of trials of automated vehicles planned or underway in Australia is available from Austroads.[4]

[3] Available from: https://www.ntc.gov.au/Media/Reports/(00F4B0A0-55E9-17E7-BF15-D70F4725A938).pdf
[4] Available from: http://www.austroads.com.au/drivers-vehicles/connected-and-automated-vehicles/trials

RAC WA 'Intellibus' automated electric shuttle bus trial

The Royal Automobile Club of Western Australia is trialling a highly automated shuttle bus in South Perth on a public road with regular traffic. While the 'Intellibus' is capable of driving without a human present to take control, a 'chauffeur' is present on the vehicle at all times during the trial to ensure safe operations and to take manual control if necessary.

The shuttle travels at low speeds (below its top speed of 45 km/h) and uses a variety of sensors including GNSS, LiDAR and cameras. The vehicle is clearly marked as an automated vehicle to assist other road users who may need to interact with it.

In its first year of operation, 4,100 members of the public participated in the Intellibus trial and almost 1,900 completed a post-participation survey. 84 per cent of survey respondents rated their experience on the Intellibus as 'extremely positive.' 98 per cent of respondents indicated that automated vehicles are a viable transport option for the future. 91 per cent believed that automated vehicles would benefit the young, ageing and mobility impaired (RAC WA, 2018).

In November 2017, the Australian Government announced the outcomes of the first round of its $50 million Smart Cities and Suburbs Program. Through the Program, $980,000 has been made available to extend the Intellibus trial for a further two years, with $490,000 being provided through a RAC WA co-contribution.

Image courtesy of the Royal Automobile Club of Western Australia

3.1.2 Public attitudes to automated vehicles

A 2014 survey of 500 Australians by the University of Michigan (Schoettle and Sivak, 2014) found:

- A majority (61 per cent) of Australians were aware of 'self-driving' vehicles, with a similar number having a positive general opinion.
- 67 per cent of Australian respondents expressed an interest in having automated vehicle technology and 25 per cent stated they were willing to pay more than $3,000 for highly automated capability. Around 30 per cent of respondents would be unwilling to pay anything extra for an automated vehicle.
- A majority of respondents expected better safety, cost of insurance, fuel consumption and environmental outcomes (but not shorter travel times or reduced congestion).
- A majority were 'moderately' or 'very' concerned about some aspects of automated driving technology, including:
  - system failures (including safety and security);
  - riding a vehicle with no driver controls;
  - automation of commercial vehicles and public transport;
  - legal liability;
  - automated vehicles getting 'confused';
  - unoccupied trips by automated vehicles;
  - interactions between automated vehicles and vulnerable road users; and
  - data privacy.
- A significant percentage would watch the road even when not required (43.4 per cent) or would not ride in an automated vehicle (21.2 per cent).

These findings are largely consistent with a more recent survey of 5,263 Australians conducted by the Australian and New Zealand Driverless Vehicle Initiative (ADVI, 2017).

Social acceptance of automated vehicles is closely correlated with exposure to the technology. Most Australians do not yet have direct experience of more highly automated vehicles on public roads. It is possible public attitudes will evolve quickly with direct experience from further trials and gradual increases in automated technology into the vehicle fleet. Trials and real world deployments will also provide an opportunity for both governments and industry to communicate with the public about how their concerns are being addressed, and adjust approaches in response to feedback.

The concerns highlighted by attitudinal surveys are aligned with key policy and regulatory reform priorities of Australian governments. The Government is working closely both with industry and state and territory governments, the National Transport Commission and Austroads to undertake this work. The roles and responsibilities of the Government and other bodies in this work are set out in detail in section 6 of this submission.

3.2 Electric and other alternative fuelled vehicles

Alternative fuelled vehicles, such as electric or hydrogen fuel cell vehicles, are one of several technologies that will have a profound impact on Australia's future transport system and infrastructure needs. An alternative fuelled vehicle can be defined as one of the following:

- **Pure or battery electric vehicles (BEV)** – are fully electric vehicles, meaning they are only powered by electricity and do not have a petrol engine, fuel tank or exhaust pipe. These vehicles are also known as plug-in electric vehicles as they use an external electrical charging outlet to charge the battery. They can also recharge their batteries through a process called 'regenerative braking'. This is where the electric motor helps to slow the vehicle and uses some of the energy normally converted to heat by the brakes to charge the battery.
- **Plug-in hybrid electric vehicles (PHEV)** – are powered by both electricity and either petrol or diesel. PHEVs can recharge the battery through both regenerative braking and 'plugging-in' to an external electrical charging outlet. The conventional combustion engine extends the range of the car by recharging the battery as it gets low.
- **Hybrid vehicles** – are powered by both electricity and either petrol or diesel. Hybrid vehicles can also recharge by using the electrical energy generated by the vehicles' regenerative braking.
- **Hydrogen fuel cell vehicles** – convert hydrogen fuel into energy. The hydrogen fuel cell vehicle generates electricity through an electrochemical reaction with hydrogen gas and oxygen, which produces electricity and powers the electric motors that drive the car.

3.3 Convergence of automated and alternative fuelled vehicles

The convergence of technology trends such as electric, automated and connected vehicles has the potential to transform the automotive industry. Automated vehicles are not necessarily electric; however, most automated vehicles being developed are either electric or hybrid vehicles. McKinsey & Company (2016) has noted the likely convergence in the development of electric vehicles and automated vehicles in the next decade.

Digital technologies and changing consumer preferences around vehicle ownership are giving rise to a unique convergence between automated driving, electrification and connectivity.
See **Appendix C** for discussion of vehicle and infrastructure connectivity as a complementary development to automated and alternative fuelled vehicles.

4. New mobility models and mass transit

4.1 Automated vehicle deployment models

Automated vehicles may become available through different business models:

- **private ownership** – the user of the vehicle owns the vehicle;
- **ride-hailing** – the user of the vehicle hails a ride from an on-demand fleet service, similar to current taxi services;
- **ride-sharing –** multiple, independent users share a third-party-owned vehicle to travel to the same or nearby destinations, similar to carpooling and services such as UberPool; or
- **a mix thereof**.

Both the ride-hailing and ride-sharing models of automated vehicle deployment have the potential to improve mobility in the community, particularly in Australia's densely populated urban areas.

Expectations that automated vehicles may be deployed in an on-demand, shared-use model, such as ride-hailing or ride-sharing, are supported by the recent shift towards shared mobility services and a reduction in uptake of driver licences in Australia, particularly amongst young people (NRMA, 2017).

Examples of this shift include the emergence of ride-hailing, ride-sharing, car-sharing and bike-sharing. These new business models enable the more efficient, distributed use of transport assets. Today, privately-owned vehicles are in use approximately 5 per cent of the time (Morgan Stanley, 2017). A shared-use model for automated vehicles would likely enable the more efficient use of vehicle assets, significantly reducing the size of our overall vehicle fleet.

Vehicle manufacturers and technology firms such as General Motors, Ford, and Google's Waymo have signalled their intention to deploy automated vehicles through a fleet of shared vehicles, enabling possible ride-hailing and ride-sharing services.

Automated vehicle technology will likely not replace existing infrastructure, such as light and heavy rail, but rather serve to achieve greater efficiency, more convenience for the public, and a further blending of the definitions of public and private transport (Deloitte University Press, 2016). The availability of on-demand access to shared automated vehicles is likely to further global trends towards reduced dependence on private vehicle ownership and normalise public transport use for more people.

Automated vehicles deployed in a shared-use model may be a cost-effective complement to public transport. In October 2018, Infrastructure Victoria released a report advising the Victorian Government on matters related to automated and zero emissions vehicles. The report explored a series of scenarios for the deployment of automated and zero emission vehicles and the impact of those scenarios on both transport networks and infrastructure needs. In each of those scenarios, public transport usage was forecast to increase.

Infrastructure Victoria (2018) observes that high-capacity public transport services will remain more cost-efficient than automated vehicles in urban areas at peak times. Infrastructure Victoria notes:

> *The impact of the ownership model on public transport demand is also likely to be sensitive to the fare structure associated with on-demand vehicles. A subscription-based fare is likely to result in more moderate growth in public transport demand, due to the lower perceived cost of using on-demand vehicles.*

BCG (2016) forecasts that automated vehicles will remain more expensive than public transport on a per-passenger, per-kilometre basis except where three or more passengers share an automated vehicle. Modelling developed by KPMG for Infrastructure Victoria forecasts the average user cost of a ride-hailed automated electric vehicle in Victoria to be $0.24 per-kilometre, compared with $0.56 per-kilometre for a non-automated, petrol or diesel-powered vehicle (KPMG, 2018).

4.2 Automation and on-road mass transit services

Potential benefits of vehicle automation for on-road mass transit services include:

Safety

- ensuring safer travel through being equipped with collision avoidance technologies; and
- reducing personal safety risks, such as walking through unlit areas, by offering more convenient on-demand first and last mile transit options.

Efficiency

- making existing services more cost-efficient for operators and passengers;
- making new services more financially viable; and
- reducing the need for investment in new services and infrastructure through network efficiency gains.

Accessibility

- providing for new services in areas not linked by public transport and in areas of low patronage, particularly in regional centres;
- providing increased accessibility to existing services by providing more convenient first and last mile transit; and
- enabling greater mobility for people who may not currently be able to drive, such as people with a disability and older people.

4.2.1 Safety benefits

Automated vehicle technology has significant potential to reduce the impact of the large number of road crash fatalities and serious injuries on Australian roads every year. In 2017, 1,224 people were killed in road crashes in Australia (BITRE, 2018). The cost of road crashes to society has been estimated to be $27 billion annually, or 1.8 per cent of GDP (based on a willingness-to-pay methodology of valuing human life) (Transport and Infrastructure Council, 2016 and BITRE, 2014b).

International research indicates that human error may be a factor in more than 90 per cent of crashes, and that road user distraction or inattention is a contributory factor in around 10-30 per cent of road crashes (Singh, 2015; TRL, TNO and Rapp Trans, 2015). This does not necessarily mean the driver is the sole cause of the crash; however, it does indicate that human error may be the predominant factor in most road crashes.

If automated technology reduces or eliminates human errors, as is generally expected, then benefits for road safety may be substantial. The expected safety benefits of automated vehicles extend to other vulnerable road users, such as pedestrians and cyclists, as vehicles with higher levels of automation will be able to detect their presence and take evasive action automatically (Somers and Weeratunga, 2015).

However, it should be noted that the effect of higher levels of vehicle automation on road safety remains untested at a large scale and may not be immediate or linear (ITF, 2015). Importantly, the expectation of near zero fatalities with highly automated vehicles may not be realistic, including for the duration of a mixed fleet (Sivak and Schoettle, 2015) (ETSC, 2016). More trials and real-world experiences are required to understand the safety impacts of higher levels of automated driving.

Real world data is already available on the safety impacts of lower levels of automation. For example, Electronic Stability Control has been observed to reduce crashes by typically 20 per cent (Thomas, 2014 and BITRE, 2014b).

Complexities may also arise from how automated and non-automated vehicles co-exist with potentially different driving behaviours. Interactions between automated vehicles and vulnerable road users (primarily pedestrians and cyclists) pose potential risks, with scope for automated vehicles to fail to detect or accurately predict the behaviour of vulnerable road users.

4.2.2 Efficiency benefits

Cost reduction

Recent research in the United States has assessed that purchase of automated large-size mass transit buses will attract an US$80,000 cost premium over equivalent conventionally driven buses. That research concluded that, based on that forecast of capital cost, the adoption of fully automated technology across one transport operator’s fleet would reduce combined capital and operating costs over a 12-year life-cycle by US$3.18 million, or US$265,000 per annum (Quarles and Kockelman, 2018).

The automated shuttle bus trials currently underway in Australia are demonstrating the longer term potential of highly and fully automated driving systems. Partially automated buses, which are likely to be available sooner, may also benefit bus drivers, operators and passengers. Lutin and Kornhauser (2014) showed that the safety benefits of implementing collision avoidance technologies in the New Jersey Transit Bus Fleet outweighed the costs under almost all scenarios. According to one study, 65 per cent of bus-related claims made to one mass transit insurance risk pool could have been prevented through uptake of currently available automation technology (Spears et al., 2017).

The Bus Industry Confederation notes that labour costs account for half of total costs associated with urban bus services, observing that at-scale mass transit services may become less expensive to operate, extending services in areas that are currently under-serviced (BIC, 2017). BIC also observes however that the role of bus drivers extends beyond the driving task and their roles may not be directly replaceable by technology.

On-demand transport

Public transport is moving away from a means of simply commuting along fixed routes. A convergence between automated driving technology and emerging data and connectivity-driven technologies may support more cost-efficient, on-demand on-road mass transit services. On-demand services would offer flexible routing and timing to better meet commercial and passenger needs. New business models and digital platforms, such as Mobility-as-a-Service (MaaS) are likely to provide real-time information about demand to transport operators, enabling the more efficient provision of services.

NSW On-Demand Public Transport Pilot Program

Governments across Australia are already trialling how new technology may enable on-demand services. The New South Wales Government is currently trialling an on demand bus service which breaks from the traditional fixed timetable model for mass transit delivery. On-demand services allows people to book a vehicle via an online app or over the phone, representing a shift away from the concept of fixed transport routes.

The pilot program commenced in late 2016, and has been rolled out in locations such as Eastern Suburbs, Manly, Northern Beaches, Woy Woy and the Illawarra. Over 150,000 customer trips have been undertaken up to the end of September 2018.

The cost of on-demand services through the pilot program is comparable to a one-way bus ticket and it allows people to access public transport when and where they need it, enhancing the existing public transport network. This trial is an example of how smart planning and applying technology in an innovative way to transform existing services can not only make delivering transport more efficient for operators but also provide better services for the community.

On-demand services using small or medium size automated buses with lower operating costs could significantly improve service coverage, including in both urban and regional centres. This type of automated transport could be cost competitive with regional rail links or traditional bus services, or could fill last-mile service gaps, as detailed below.

Mobility-as-a-Service

Mobility-as-a-Service (MaaS) combines public and private transport options in a single app, providing an integrated origin to destination journey, 'handling payment and bookings through the same platform and providing dynamic route-planning information to users (KPMG, 2017).

New business models such as these could accelerate long-term trends away from car ownership, and impact on travel patterns and infrastructure use. If this model matures in Australia, it could provide an incentive for travellers to move away from private vehicle ownership and make increased use of automated vehicles and public transport as part of a new, flexible approach to travel.

Our cities need to be well connected and integrated to support changing consumer expectations of rapid, just-in-time and distributed mobility. Australia, with its high concentration of urban populations and long, narrow linkages between them, is well placed to take full advantage of the efficiencies services like MaaS bring.

4.2.3 Accessibility benefits

Increased accessibility of transit services is likely to be particularly valuable in regional Australia. Road crashes disproportionately impact regional Australians; 65 per cent of road fatalities occur in regional, rural and remote Australia (BITRE, 2017c).[5] Available evidence suggests that human factors, such as distraction and alcohol, are the primary causes of these crashes (Siskind et. al, 2011). Given that automation could reduce or remove the human element of driving, the potential to reduce crash rates is significant – particularly in regional Australia.

The emergence of automated vehicles also provides potential for older Australians and people with a disability to continue to engage and participate in the community. In 2015, there were an estimated 3.5 million Australians aged 65 and over, representing one in seven people (15.1 per cent). Older people may have mobility challenges and as a result, they are less likely to be able to own a private vehicle or be able to drive.

As automated vehicles become more sophisticated over time, it is likely that there will be a reduced or removed expectation that the occupant will need to be ready to take control of the vehicle if required. Highly automated vehicles will enable older people to continue to visit the doctor, do their shopping and participate in the community (Siorokos, 2016).

[5] Of the 1296 fatalities in 2016: 458 fatalities were in major cities; 428 fatalities were in inner regional areas; 290 fatalities were in outer regional areas; 49 fatalities were in remote areas; and 70 fatalities were in very remote areas (as defined by the Australian Statistical Geography Standard).

Renmark regional automated electric shuttle trial

In November 2018, the South Australian Government approved a two-year trial of an EasyMile EZ10 automated shuttle in the regional community of Renmark. The trial will focus on testing the value of automated shuttle services in providing mobility for older people in regional Australia.

The automated shuttle will connect passengers at 15-minute intervals to a route along the Renmark riverfront, to the Renmark Club, aged care villages, swimming pool, library and to the shopping precinct. The Renmark Paringa Council expects the trial will complement existing regional bus and local transport services. The trial is also anticipated to involve upskilling local businesses to provide operational and maintenance support to the vehicle. The trial is expected to commence in the first quarter of 2019.

The EasyMile EZ10 shuttle used in the trial is capable of transporting up to 14 people and is capable of a speed of 40 km/h. The vehicle is expected to operate at 20-25 km/h during the trial. The EZ10 is a battery electric vehicle with an operating range of up to 14 hours.

Similar trials in regional centres are planned in Coffs Harbour and Armidale, New South Wales.

In 2015, almost one in five Australians reported living with a disability (18.3 per cent or 4.3 million people). 34 per cent of people with a disability report difficulties using public transport, with 14.7 per cent of people with a disability reporting inability to use any form of public transport (ABS, 2016).

Highly automated vehicles could mitigate these challenges by providing more convenient access to alternative transport options for people with a disability. Infrastructure Victoria (2018) has estimated that the economic benefit of increased transport accessibility created by the use of automated vehicles to be $3.5 billion per year in today's terms. Trials of automated vehicles are increasingly considering the potential of automated technology to provide people with new mobility options.

Olli and Matilda: accessible last-mile transport

In January 2019, Local Motors and SAGE Automation will commence a trial of 'Olli' – an automated electric shuttle bus – and 'Matilda' – an accessible, connected smart transit hub – in Holdfast Bay, South Australia. The trial is supported by the South Australian Government's Future Mobility Lab Fund.

Olli can carry eight seat-belted passengers, up to four standing passengers, and an on-board steward. Olli is a low-speed urban vehicle that will travel on 10-minute trips between Moseley Square and Broadway Kiosk. For the purposes of the trial, a Matilda smart transit hub will be positioned proximate to Moseley Square Tram Terminus in Glenelg in order to demonstrate the role of automated shuttle buses in providing a last-mile connection.

Users can book a ride on Olli using an interactive screen in the Matilda smart transit hub or via an online booking website that has been built for the pilot. Matilda is capable of communicating with vehicles, ride-share services, networked transport systems and the internet in order to provide passengers with access to different mobility options. Both Olli and Matilda are capable of responding to users' questions. Matilda is designed to be accessible for people with physical, hearing, vision or cognitive impairments.

Images courtesy of SAGE Automation and Local Motors

4.2.4 First and last mile transport

The 'last-mile problem' in transport is the challenge of moving people between a transport hub – such as a bus stop or train station – and their final destination. This 'last-mile' is often disproportionately inconvenient when compared to other parts of the journey and may have a negative impact on public transport patronage – frequently it is too far to walk, too close to drive (and find parking). The same phenomenon exists for the 'first-mile' – connecting people from their origin point to a transport hub.

Mass transit users are increasingly using ride-hailing and bike-sharing services for the first and last mile of their journey. According to L.E.K. (2018), 15 per cent of Uber rides in Western Sydney are to or from train stations, with this figure reaching 25 per cent in some cities in the United States.

Small and medium size automated vehicles could provide more cost-efficient and convenient first and last mile services to and from public transport hubs, or connect people to and from regional heavy rail services. Trials of automated vehicles are increasingly testing this proposition by deploying automated shuttle buses on fixed routes between mass transit hubs and key origin/destination points.

Flinders Express automated shuttle trial

The Flinders Express, or FLEX, is a five-year public trial of an automated electric shuttle bus at Flinders University's Tonsley campus, which commenced in June 2018. The trial involves a NAVYA Arma vehicle, which is capable of transporting up to 15 passengers.

The first stage of the trial is providing a last-mile service from Clovelly Park Train Station to Tonsley's Main Assembly Building, connecting to bus stops on the main South Road and businesses within the Tonsley precinct. Flinders University expects to expand the trial route to include Flinders Medical Centre, its Bedford Park campus and onto arterial roads in the Bedford Park area. Similar trials of automated electric shuttles are underway at other university campuses, such as LaTrobe University and the University of Melbourne.

The FLEX shuttle has now carried over 1,600 passengers. Pre- and post-ride surveys of FLEX passengers highlight the role of trials in supporting social acceptance and uptake, with riders expressing increased belief in the possible mobility, congestion and safety benefits of automated vehicles (RAA SA, 2018).

Image courtesy of Flinders University

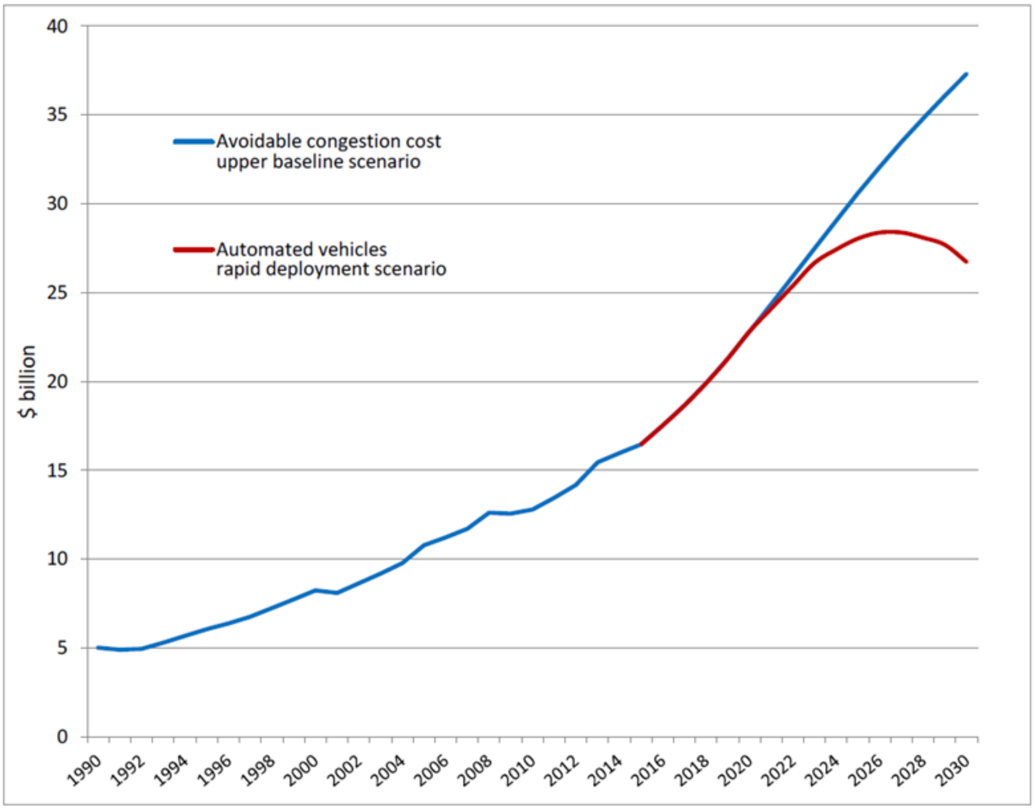
4.3 Automated vehicles and congestion

Automated vehicles have the potential to reduce congestion and improve the efficiency and productivity of Australia's transport networks by:

- increasing average traffic speeds and safely reducing following distances (headway) between vehicles;
- optimising driving behaviours and routes, especially for trips involving multiple passengers with varying origin-destination needs;
- providing increased reliability of travel times;
- reducing stoppages and delays from traffic incidents;
- encouraging the use of public transport through low-cost, on-demand first and last mile connections; and
- facilitating more efficient movement of freight (see **Appendix C**).

Modelling by BITRE indicates that under a fast penetration scenario, in which highly automated vehicles account for up to 30 per cent of urban vehicle-kilometres of travel, aggregate avoidable congestion costs on the Australian road network could fall from around $37 billion to around $27 billion in 2030 (BITRE, 2015).

Figure 5: Potential impact of automated vehicles on congestion costs in Australian cities



Source: Bureau of Infrastructure, Transport and Regional Economics, 2015.

Ensuring automated vehicles are deployed in a manner that reduces congestion will require careful management. Increasing the comfort of in-vehicle journeys and reclaiming commuting time for leisure, work or sleep in highly or fully automated vehicles is an important priority for commuters and hence for vehicle manufacturers. However, this could reduce the perceived cost of travel time and provide an incentive for longer commutes, with a flow-on impact for land use planning and infrastructure provision (SGS, 2018).

According to KPMG (2018), the automated vehicle deployment model has an impact on total vehicle kilometres. The primary cause of the differing impacts of deployment models is the tendency of private-ownership deployment to lead to additional 'empty running' – automated vehicles travelling unoccupied (Monero, et al., 2018). KPMG (2018) modelling indicates that:

- in a base case scenario – without the deployment of any form of more sophisticated vehicle automation technology than already available today – Victorians will travel 166.958 million kilometres in personal vehicles each day in 2046;
- in a fleet-wide, shared-ownership automated vehicle deployment scenario, this would increase to 179.642 million kilometres each day in 2046 (an increase of 7.6 per cent over the base case); and
- in a fleet-wide, private-ownership automated vehicle deployment scenario, this would increase to 192.014 million kilometres each day in 2046 (an increase of 15 per cent over the base case).

This assessment is consistent with modelling by Monero et al. (2018), which concluded that total vehicle kilometres would increase 8 per cent under a shared-ownership model over a base case scenario. While the impact of total vehicle kilometres is unlikely to outweigh the significant network efficiency benefits in terms of net congestion impact, it is critical that all governments work together to ensure the right policy settings are in place to mitigate risks.

4.4 Alternative fuelled vehicles in mass transit

According to Bloomberg New Energy Finance (2018), there were approximately 386,000 electric buses on the road globally in 2017. The vast majority of these, over 382,000, were based in China. Bloomberg New Energy Finance estimates that 1.2 million electric buses will be based in China in 2025, accounting for 95 per cent of the global electric bus market. Bloomberg New Energy Finance also estimates that in 2025, Europe will have the second largest electric bus fleet, comprising of approximately 11,000 electric buses.

Trials of hydrogen fuel cell buses are underway in cities around the world. According to the CSIRO, there are approximately 90 hydrogen fuel cell buses on the road in Europe. In October 2018, the European Commission announced the H2BusEurope program, which will introduce 600 hydrogen fuel cell buses. Denmark will receive 200 hydrogen fuel cell buses by 2020, while the remaining 400 hydrogen fuel cell buses will be based in the United Kingdom and Latvia.

The deployment of public mass transit vehicles in Australia is primarily the responsibility of state and territory government, and many state and territory jurisdictions are trialling or purchasing alternative fuelled mass transit vehicles for their fleets.

5. Automation and new energy sources in rail mass transit

5.1 State of technological development

Train automation refers to the process by which responsibility for operational management of a train transfers from the driver to the train control system. There are various Grades of Automation (GoA), defined according to which basic functions of train operation are the responsibility of the automated rail system (see **Appendix B**).

The key elements for automated rail systems are (UITP, 2011):

- **Automatic Train Protection (ATP)** is a system designed to avoid collisions, and help prevent red signal overrunning and exceeding of speed limits by applying brakes automatically. A line equipped with ATP corresponds (at least) to a GoA1.
- **Automatic Train Operation (ATO)** insures partial or complete automatic train piloting and driverless functionalities. The ATO system performs all functions of the driver, except for door closing. The driver only needs to close the doors, and if the way is clear, the train will automatically proceed to the next station. This corresponds to a GoA2. Many newer systems are completely computer controlled, while still electing to maintain a driver or a train attendant of some kind to mitigate risks associated with failures or emergencies. This corresponds to a GoA3.
- **Automatic Train Control (ATC)** automatically performs normal signaller operations such as route setting and train regulation. The ATO and the ATC systems work together to maintain a train within a defined tolerance of its timetable. The combined system will marginally adjust operating parameters, such as the ratio of power to cost when moving and station dwell time, in order to bring the train back to the timetable slot defined for it. There is no driver, and no staff assigned to accompany the train, corresponding to a GoA4. This Grade of Automation is also referred to as Unattended Train Operation (UTO).

New sources of energy have the potential to make rail services more affordable and reduce their carbon footprint. The Rail Manufacturing Cooperative Research Centre was established in 2015 with an Australian Government investment of $31 million. One of the Centre's research areas is Power and Propulsion, which aims to deliver energy cost efficiency and improved competitive performance in advanced manufacturing. There are a number of current projects underway in this area including:

- new lithium-ion batteries with high energy and long service life; and
- high-energy supercapacitor development.

These technologies could have significant potential applications in both light and heavy rail rolling stock.

5.2 Role of automation in catering for increased mass transit demand

Within dense urban environments where new rail lines can have high upfront capital costs, technological advances and increased automation have the potential to improve the efficiency, capacity and utilisation of existing networks to help cater for expected growth in patronage and attract more people onto rail through customer focused initiatives.

The ways in which automated transport can transform the use of mass transit infrastructure include:

- **more trains, more often** – automated rail systems allow operators to optimise the running of trains, increasing the average speed of the system, shortening headways[6] and reducing dwell time[7] in stations;
- **greater reliability** – driverless technology and advances in communication and control systems increase resilience by allowing dynamic, real time management of the network in the face of disruptions and enabling operators to allocate trains in response to sudden surges in demand. Automated, independent lines also help to improve the reliability of overall networks through untangling networks and better geographically containing network-wide delays;
- **safety and accessibility** – automated rail systems offer safer operations than conventional railways by reducing the human-risk factors and increasing reliability (UITP, 2011). Upgrading to a more modern system design also brings a number of added safety and accessibility benefits. For example, newer metro systems can be built to facilitate level access between platform and train, and platform screen doors can prevent passengers tripping or falling onto the tracks;
- **personalised journeys** – technologies, including automation, create opportunities to provide customers with real time information and facilitate the use of public transport through on-demand first and last mile connections.
- **improved energy performance** – acceleration and deceleration patterns of automated rail are adjustable to reduce energy consumption and maximise energy recovery, therefore significantly reducing energy costs; and
- **reduced operational costs** – communications-based train control systems allow for the removal of traditional trackside infrastructure, such as track circuits and colour signals, and the associated costs of maintenance.

[6] The average interval between trains.
[7] The time a train is stationary at a scheduled stop – typically whilst boarding or deboarding passengers.

Automated rail systems can be safer and more secure

Automated rail systems offer safer operations by reducing the human-risk factors, with well-designed systems proving more reliable than conventional railways (UITP, 2011). Upgrading to a more modern system design also brings a number of added safety and security functions.

As a step towards greater automation, Automatic Train Protection (ATP) is increasingly being rolled out across Australian rail networks. In NSW, for example, ATP is being rolled out across the Sydney Trains and NSW TrainLink electrified network. ATP monitors a train's speed, distance and direction and prevents the authorised line speed being breached due to driver error or if a driver becomes incapacitated (TfNSW, 2018).

Metro rail systems are often closed systems with access restricted to the automated vehicles and controlled access to other types of trains, road vehicles and pedestrians. This element of system design is linked to safety outcomes.

5.3 International context

In the rail sector, automated transport is a proven technology, giving rail a head start over other land transport modes. Fully automated, driverless rail networks have been in operation for over 30 years, with the most advanced rail technology available today allowing for unattended train operation with no staff on board. As of May 2018, there were 63 fully automated operational metro rail lines in 42 cities in 19 countries across the world, including major cities such as London, Paris, Lille and Singapore. The total line length of fully automated metros reached the milestone of 1,000km in 2018. Over the period 2015-17, ten new metro lines designed to run with fully automated operation entered in service in ten cities (UITP, 2018).

Automated train technology continues to grow at a rapid rate. Current forecasts, based on confirmed projects, indicate that by 2025, there will be over 2,300 kilometres of driverless metro lines in operation worldwide (UITP, 2016).

5.4 Automated rail in Australia

The past decade has seen significant advances made in the technology used on urban and freight railways in Australia, including network expansion, signalling and train control system replacement, new rolling stock and increased services. Likewise, future development of Australia's rail systems will be driven in part by investments in new technology (AECOM, 2018).

Sydney, Melbourne, Brisbane and Perth, in particular, have large changes planned for their rail networks, including the introduction of new lines involving major tunnelling projects (AECOM, 2018). New communications-based train control (CBTC) systems are also being adopted. These are well specified, integrated high-performance signalling systems that use telecommunication systems between trains and track equipment to provide traffic management and infrastructure control, providing 'moving block' technology (AECOM, 2018).

Metropolitan railways or ‘metro rail’ systems are generally defined as urban transport systems with high capacity and high frequency of service. Metros are independent from other traffic, road and pedestrians (UITP, 2009). Where metro systems are being developed in Australia, bespoke CBTC systems are being commissioned which are tailored to localised conditions but based on international experience and expertise.

Across Australia’s cities, and even within networks, demand and service requirements can differ significantly. Individual state governments must consider both the operational requirements and the costs of fully automated operations, such as managing shared traffic and ensuring security from incursions, to determine the most appropriate technological upgrades. To date, fully automated driverless systems deployed internationally have been mainly on purpose-built, closed networks.

European Train Control System (ETCS) is a form of technology being considered for rail systems in Brisbane, Adelaide and the wider Sydney suburban network. In addition to significantly improving utilisation through more tightly controlled headways between trains, the advantage of ETCS is that it is designed to allow for interoperability between different levels of train control and offers six staggered stages of technological progression ranging from modest Automatic Train Protection (ATP) enhancements overlaid on conventional signalling to the full implementation of automatic train control functionality (this technology is still in early development).

Australia’s urban rail systems will undertake a step-change over the coming years with the completion of Stage 1 of Sydney Metro – the NSW Government’s $8.3 billion Sydney Metro Northwest railway. Sydney Metro is an automated mass transit solution that will bring congestion busting and city-shaping benefits to Sydney, transform urban centres, and boost economic productivity by improving employment and education opportunities.

Sydney Metro Northwest

Sydney Metro Northwest is Australia’s first fully automated railway and will open in the city’s northwest in the second quarter of 2019. Services will be turn up and go, with trains running every four minutes (15 trains per hour) during peak times from 2019. The new automated metro service will reduce congestion and passenger wait times as well as greatly improve connectivity and liveability. In the long-term, Sydney Metro Northwest will be able to move 40,000 passengers per hour per direction, almost double the existing network’s performance.

Sydney Metro City and Southwest

Stage 2 of the Sydney Metro project will extend Sydney Metro Northwest from Chatswood in the northwest, under Sydney Harbour, through new CBD stations to Bankstown in the south west.

Sydney Metro City and Southwest is expected to cost the NSW Government between $11.5 billion and $12.5 billion, with services expected to start in 2024.

Sydney Metro West

Sydney Metro West will be Sydney's second automated mass transit railway line, connecting the CBD with Greater Parramatta. Announced by the NSW Government in November 2016, detailed planning is underway, with the project expected to be delivered in the second half of the 2020s.

Sydney Metro Western Sydney Airport

Sydney Metro will also deliver Sydney Metro Western Sydney Airport (SMWSA), a joint commitment by the Australian and NSW governments through the Western Sydney City Deal. The project will provide the transport spine for Western Sydney. It will connect strategic centres (including the airport), drive investment in new housing and local jobs, and improve the liveability of Western Sydney. Detailed planning is underway, with a joint objective of delivery in 2026. Planning will consider options for this railway line to be automated, just like the other Sydney Metro projects.

Safety and Security Standards on the Sydney Metro Northwest project

Safety and security considerations are central design features of the Sydney Metro Northwest project. This rail system will be fully automated with no train attendants present. The vehicles will be driverless, with controllers monitoring the entire system from an Operations Control Centre.

The Sydney Metro Northwest trains are being designed, built and operated to the highest safety standards, with more than 300 Australian and international safety standards stipulated in the operations contract for the trains and the associated equipment. High levels of security will prevent trespasser access, such as platform screen doors that keep people and objects away from the tracks and allow trains to enter and depart stations faster. Obstruction detectors will prevent trains departing stations if any door is not fully closed. An intrusion detection system will be a feature on Sydney Metro Northwest, designed to identify and report any track encroachments along the route.

Source: Sydney Metro

5.4.1 Light rail and trackless trams

Across Australia's largest cities, a mix of rail technologies have been deployed, including suburban heavy rail, metro rail and light rail. Light rail currently operates in Melbourne, Adelaide, Sydney and the Gold Coast. A light rail line is also under construction in Canberra. Melbourne has the largest light rail network in the world with 250km of track. As light rail in Australia generally interacts with road traffic and pedestrians, it is less suitable for driverless automation than heavy rail. However modern light rail systems are expected to increasingly adopt automation technologies that improve network safety and navigation.

Recent technological developments in road-based mass transit options include trackless trams. Trackless tram technology varies, but generally involves a tram-style vehicle with rubber tyres that runs on markings on the road surface with the capacity for high levels of automation. Advantages of trackless trams, compared with traditional light rail, is that they can be significantly cheaper to deploy due to lower upfront infrastructure costs and much lower impact on the community during the construction process.

6. Role and responsibilities of Australian Governments and other entities

The Department is responsible for designing and implementing the Australian Government's infrastructure, transport, regional development, cities and territories policies, programs, and regulations. The Department works with other Commonwealth agencies, the Transport and Infrastructure Council, state and territory governments, and other bodies, to invest in new infrastructure and put the right transport policy settings in place, including through the development and deployment of new transport technology.

6.1 Infrastructure Investment Program

In the 2018-19 Budget, the Australian Government announced a $24.5 billion pipeline of major projects and new initiatives as part of its overall 10-year $75 billion investment in transport infrastructure. Most of the activities will be delivered through the Infrastructure Investment Program that supports road and rail projects nationally, in regional areas and urban centres, from major projects like WestConnex in Sydney and the Melbourne Airport Rail Link to targeted sub-programs that improve safety and productivity.

Investments in technology solutions to address capacity on new and existing infrastructure are already being made. The $105 million Bruce Highway (Managed Motorways – Gateway Motorway to Caboolture) upgrade will improve capacity and reduce congestion and travel times by installing an electronic freeway management system including variable speed limit signs; entry ramp signalling; CCTVs; digital message signs providing live updates on traffic conditions and delays; and signs advising drivers of lane and speed restrictions.

The Government's *Principles for Innovative Financing*[8] set out its goals for investment in Australia's land transport infrastructure, and provides a framework for how projects are selected and innovative funding and financing decisions are considered. One such principle is that transport proposals are assessed against the extent to which technology solutions are used to optimise the capacity of existing and new infrastructure.

[8] See: https://investment.infrastructure.gov.au/about/funding_and_finance/principles_for_innovative_financing.aspx

6.2 National Rail Program

In the 2017-18 Budget, the Government established the 10-year $10 billion National Rail Program, under the Infrastructure Investment Program. The National Rail Program is a major, long-term commitment to invest in passenger rail networks in our big cities, and between our cities and their surrounding regional centres. The National Rail Program is designed to help make our cities more liveable and efficient as they grow, reduce the burden on our roads, provide more reliable transport networks and support our efforts to decentralise our economy and grow regional Australia.

In the 2018-19 Budget, the Government committed $4.9 billion to projects under the National Rail Program. Projects include:

- up to $2.5 billion (to a total of up to $5 billion) towards a Melbourne Airport Rail Link;
- $1.1 billion to develop further stages of the METRONET in Perth;
- $475 million to construct a line in the Monash Precinct in Melbourne;
- $390 million to upgrade the Beerburrum to Nambour line in Queensland;
- $225 million to duplicate and electrify the Frankston to Baxter line in Melbourne;
- $220 million to complete the electrification of the Gawler line in Adelaide; and
- $50 million towards a business case for the Western Sydney Airport North South Rail Link, as part of the Western Sydney City Deal.

6.3 Smart Cities and City Deals

Building better transport links using existing technologies must also be supplemented by a view to the future of transport to ensure they meet the needs of tomorrow. Opportunities such as demand-responsive transport, automation, new fuels and connected cities can enhance governments' investment in fixed infrastructure by increasing efficiency, enhancing the user-experience, improving the environment or reducing cost.

The Government's *Smart Cities Plan*[9] articulates a vision for our cities, ensuring they meet their full potential. A key component of this plan is connecting our cities – internally and with each other – through innovative, effective and efficient transport solutions.

One way this objective is being achieved is through the Government's City Deals. City Deals are an important mechanism for developing place-based planning and investment by taking a negotiated and customised approach across the whole of government for a particular city or region. They are developed by working with local and state or territory governments and other stakeholders to harness local knowledge and produce a unified deal that addresses local priorities.

City Deals recognise that cities will approach the challenges and opportunities of a growing population in different ways – with the biggest cities looking to manage the impact of rapid growth and others looking to attract more people. They therefore focus on leveraging each city's unique

[9] See: https://infrastructure.gov.au/cities/smart-cities/plan/index.aspx

strengths and responding to their specific needs, including the opportunities for building better transport links.

Deals are already in place in Townsville, Launceston, Western Sydney and Darwin, with more currently being negotiated. In conjunction with state, territory and local governments, these deals are already enhancing mass transit by investigating demand responsive transport solutions, delivering a heavy rail 'backbone' to Western Sydney and redesigning transport networks to better meet demand.

Automated vehicles and connected cities present great opportunities to redesign our cities to better cater for the needs of local communities. Through the Government's $50 million Smart Cities and Suburbs Program, local governments are already exploring how best to integrate smart technologies into their cities.

6.4 Automated vehicles

In October 2018, the Deputy Prime Minister and Minister for Infrastructure, Transport and Regional Development announced the Australian Government would invest $9.7 million to further support work to prepare Australia for automated vehicles and other transport innovations.[10] This investment includes establishing a new Office of Future Transport Technology within the Department. The Office is responsible for leading and coordinating Australian Government work to prepare Australia for emerging transport technology, including:

- leading policy development within the Infrastructure, Transport, Regional Development and Cities portfolios on automated vehicles and Cooperative Intelligent Transport Systems, including with regard to infrastructure readiness, vehicle safety, network impacts, accessibility and disability standards, and future implications for urban and regional Australia;
- collaborating with other Australian Government agencies on cross-portfolio issues, which include cyber security, critical infrastructure resilience, consumer and competition issues, future workforce and skills needs;
- working with states and territories to support the Transport and Infrastructure Council through implementation of the *National Policy Framework for Land Transport Technology*;
- engaging with state and territory and international colleagues to ensure consistency of domestic and international approaches;
- enabling industry innovation by identifying options to remove regulatory barriers where appropriate and supporting research, trials, investment and commercialisation; and
- consulting with the community to understand expectations and communicate opportunities.

[10] See: https://minister.infrastructure.gov.au/mccormack/releases/2018/october/mm178_2018.aspx

The Government is investing in and enabling transport technology trials by partnering with industry, state and territory governments and academia. The Government has made a $55 million investment in the iMove Cooperative Research Centre (CRC). This investment is matched by $179 million of cash and in-kind support from industry and academic institutions.

The iMove CRC brings together government, industry and academia for applied research into new mobility technology, including connected and automated vehicles. Key research priorities for the iMove CRC include intelligent transport systems and infrastructure, end-to-end freight solutions, and enhanced personal mobility. This work includes piloting emerging transport technologies and researching new business models and systems.

In October 2018, the Government signed a Memorandum of Understanding (MOU) with the US State of Michigan – a long-standing global centre of automotive industry innovation. Once fully operationalised, the MOU is expected to encourage collaboration between Australian industry and researchers and their Michigan counterparts, and support Australian industry involvement in the international automotive technology supply chain. Australia has joined the United Kingdom and the Netherlands in signing an MOU on automotive development with Michigan.

The Department has worked closely with the Australian Trade Commission (Austrade) on the development of an industry capability report, detailing Australian capability and investment opportunities in the future transport and mobility sector.[11] The report highlights that the Australian future transport and mobility sector is expected to generate more than $16 billion in revenue by 2025 (Austrade, 2018).

6.5 Automated rail

6.5.1 Australia's current regulatory framework

Advice from the National Transport Commission (NTC) indicates that there are unlikely to be regulatory barriers to the introduction of automated rail in Australia:

> *…there are unlikely to be regulatory barriers to the introduction of more automated trains in Australia because the rail sector has adopted an accreditation model based on operators satisfying the relevant regulator that they have the competency and capacity to manage the identified tasks.* (NTC, 2016)

The NTC further concluded that no further analysis of barriers to automated rail is required in Australia at this time.

State and territory governments have primary responsibility for managing rail operations and are responsible for rail safety laws. These laws have now been harmonised across jurisdictions through the adoption of the Rail Safety National Law (RSNL). The RSNL establishes the Office of

[11] To view the report, see: https://www.austrade.gov.au/future-transport/

the National Rail Safety Regulator (ONRSR) as the body responsible for rail safety regulation in Australia.

Under the co-regulatory framework, it is the rail industry's role to provide evidence that their system and technology is safe under national rail regulations, with ONRSR providing the overarching regulatory framework and accreditation process. This approach allows for different types and sizes of operations and for industry innovation.

The Rail Industry Safety and Standards Board (RISSB) is an industry owned and operated body that receives funding from the Australian Government, state and territory governments, and the rail industry. RISSB develops and manages national rail industry standards, rules, codes of practice and guidelines. Nationally harmonised operational and management standards improve safety, efficiency and productivity. In developing its standards, RISSB, similar to the ONRSR, focusses on outcomes and performance rather than prescriptive rules.

While current regulations are not thought to be hindering rail automation at this time, there may be opportunities to support the interoperability of automated train technology, including sharing datasets. For example, the release of NSW transport data has seen the private development of multiple transport apps to assist with trip scheduling, booking and alerts.[12]

6.5.2 Working towards interoperability

The adoption of various rail technology systems in Australia may over time potentially lead to inefficiencies in how the Australian rail network operates. In 2016, the NTC concluded that:

> *There may be operational challenges related to establishing a safety case for automated trains that are operating on shared systems and interact with other types of trains.*
>
> *These could be addressed, in part, through the development of international and national standards. However, under the accreditation model, these challenges are the responsibility of rail operators to identify and manage and are not regulatory barriers* (NTC, 2016).

While jurisdictions have primary responsibility for rail network management and investment in train control systems, the Australian Government is working with state and territory governments and the rail industry to facilitate interoperability and compatibility where possible.

[12] See: http://www.transportnsw.info/en/travelling-with-us/keep-updated/apps.page

National Rail Plan

The Transport and Infrastructure Senior Officials' Committee has agreed to create a National Rail Plan, which will focus the efforts of all governments and industry towards addressing the challenges facing the rail industry in Australia. A number of reform priorities relating to technology and innovation, rail data and standards and network interoperability, have been identified, but are yet to be finalised. The work program is expected to be endorsed in 2019 and include activities to facilitate a consistent approach for government and industry to collaborate on developing and implementing rail technology and standards in Australia.

Automated Freight Systems

The Australian Government-owned Australian Rail Track Corporation is continuing to develop its Advanced Train Management System – a new technology specifically designed for and by the Corporation. It uses digital GPS navigation and broadband communications to locate and route freight trains in real time. While an automated system, it is not intended to become fully driverless.

The system, jointly delivered by the Corporation and Lockheed Martin Australia, will allow enhanced safety, greater efficiency and increased capacity of rail infrastructure. Once fully developed, the technology will be capable of broader application both in Australia and internationally. The Corporation is currently deploying the system on trains operating between Port Augusta and Whyalla in South Australia. The technology is expected to be fully implemented on this section of track by September 2019. Monitored use trials, undertaken as part of the implementation of the system, have been ongoing since 2016 and have demonstrated the reliability of the technology on real rail traffic.

6.6 Transport and Infrastructure Council

The COAG Transport and Infrastructure Council (the Council) brings together Commonwealth, State, Territory and New Zealand ministers with responsibility for transport and infrastructure issues, as well as the Australian Local Government Association. The Council plays a key role in delivering national reforms to improve the efficiency and productivity of Australia's infrastructure and transport systems, and ensuring these systems drive economic growth, increase employment opportunities, support social connectivity and enhance quality of life.

In August 2016, the Council agreed to the *National Policy Framework for Land Transport Technology*.[13] The framework takes a principles-based approach to facilitate the efficient, effective and consistent implementation and uptake of transport technology across Australia. The framework outlines the following four roles for government:

- **Policy leadership –** providing a clear, nationally coordinated approach across different levels of government, being responsive to changes in the technological environment
- **Enabling** – ensuring that the private sector is able to bring beneficial new technology to market
- **Supportive regulatory environment –** ensuring that community expectations of safety, security and privacy are appropriately considered in new technology deployments
- **Investment** – investing in research, development and real-world trials that benefit the entire transport network customer base or provide a sound basis for government decision-making (including collaboration with the private sector).

The framework is underpinned by a three-year action plan, which identifies national, short and medium term priorities, with a particular focus on connected and automated vehicles. A future iteration of the action plan is expected to be considered by the Council in 2019 and is anticipated to include actions to support alternative fuelled vehicles, amongst other matters.

At the November 2018 Council meeting, members discussed the opportunities and benefits for Australia from a coordinated national approach to encourage the introduction of low and zero emission vehicles, particularly electric vehicles. Council agreed the Transport and Infrastructure Senior Officials' Committee would develop a program of work to address the barriers and challenges impeding the uptake of these vehicles for Council consideration in the first half of 2019.

6.6.1 National Transport Commission

The National Transport Commission (NTC) is an independent advisory body to the Transport and Infrastructure Council on national land transport reforms. In November 2016, the Council agreed a work program for the Commission to consider options for regulatory reform to support automated vehicles. This work complements and builds on the principles and actions established in the framework. It is designed to ensure conditionally automated vehicles can operate safely and legally on our roads by 2020.

The NTC is working closely with the Australian Government and state and territory governments to progress the work program, which includes:

- clarifying how current regulatory concepts of vehicle control apply to automated vehicles;
- working towards reforms that will enable an automated driving system (rather than a person) to legally control a vehicle;
- ensuring a legal entity is identified as responsible for driving performance when an automated driving system is in use;

[13] The National Policy Framework for Land Transport Technology is available at: http://transportinfrastructurecouncil.gov.au/publications/files/National_Policy_Framework_for_Land_Transport_Technology.pdf

- reviewing compulsory third-party and injury insurance schemes to identify any barriers to accessing compensation for any person injured by a crash involving an automated vehicle;
- creating national enforcement guidelines to assist police in enforcing road traffic laws in relation to automated vehicles;
- establishing nationally consistent guidelines for trials of automated vehicles;
- considering options for the management of government access to data produced by automated vehicles and Cooperative Intelligent Transport Systems; and
- developing a national performance-based safety assurance regime, to ensure the safe operation of automated vehicles on Australian roads.[14]

6.6.2 Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies. It provides evidence-based policy and guidance on the design, construction and management of the road network and associated infrastructure. The deployment of automated vehicles is a strategic priority for Austroads. It has established a Connected and Automated Vehicle Program addressing operational and technical frameworks for connected and automated vehicles.[15]

6.7 Commonwealth cross-portfolio work

There is a range of other work occurring across the Government, which will support the deployment of increasingly automated transport systems. This work includes, for example:

- allocating radiofrequency spectrum for train control systems and Intelligent Transport Systems in road networks;
- enhanced satellite positioning systems, which will enable more accurate positioning of vehicles and trains; and
- enhanced cyber security approaches for connected and automated vehicles.

[14] More information is available from the NTC website at: https://www.ntc.gov.au/roads/technology/automated-vehicles-in-australia/
[15] For more information about the Austroads Connected and Automated Vehicle Program, see: https://austroads.com.au/drivers-and-vehicles/connected-and-automated-vehicles

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Appendix A: Levels of vehicle automation and associated technologies

SAE Levels of Vehicle Automation

The extent to which a vehicle is automated, and in particular, whether a human is required to monitor the road environment and/or be ready to take back control, has significant implications for the social, policy and regulatory impacts.

Authorities in Europe, the United States and Australia have adopted the Society of Automotive Engineers' (SAE) International Standard J3016 as a common language for describing the capabilities of an automated vehicle. The SAE standard has six levels of driving automation from no automation (Level 0) to full automation (Level 5). Classification of automated vehicles (illustrated in Figure A1) is based on whether the system:

- manages steering, acceleration and braking on a sustained basis;
- requires a human driver to monitor the driving environment and respond as needed;
- can operate without handing over control ('falling back') to a human driver; and
- can operate in all situations ('driving modes').

On this basis, SAE has defined the following levels of automation:

- **No automation (SAE Level 0)** — human driver undertakes all aspects of the driving task.
- **Driver assistance (SAE Level 1)** — in some circumstances the system is capable of *either* steering *or* acceleration/deceleration (including braking), with the expectation that the human driver performs all remaining aspects of the driving task.
- **Partial automation (SAE Level 2)** — in some circumstances the system is capable of *both* steering and acceleration/deceleration. The human driver must monitor the driving environment and respond as needed.
- **Conditional automation (SAE Level 3)** — Level 2, but when the system is operating in automated mode the human driver is not required to monitor the driving environment. The human driver must respond to requests from the driving system to intervene.
- **Highly automated (SAE Level 4) —** Level 3, but no human monitoring or intervention is required when the system is operating in automated mode**.**
- **Fully automated (SAE Level 5)** — automated system in control all of the time, and in all road environments.

Appendix A: Levels of vehicle automation and associated technologies

***Figure A1: SAE Standard J3016*[1]**

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Vehicle manufacturers may choose to allow a human driver to take back control from the automated driving system, even where the system is capable of driving without intervention (i.e. SAE Levels 4 and 5).

Technologies enabling automated driving

Automated road vehicles will use a range of different technologies in the process of sensing the road environment, planning movements and executing the desired course of action.[2] The specific technologies used will have implications for how governments manage and maintain the road network in the future, and whether governments will need to support deployment with new digital infrastructure (e.g. accurate satellite positioning or mapping services).

Technologies used by automated vehicles include:

- **Radar** (long, medium and short range) — currently used in applications such as adaptive cruise control and autonomous emergency braking.
- **Cameras** — currently used for applications such as lane keep assist (relies on visible lane markings).[3]
- **Ultrasound** — a short range sensor currently used in parking assist functions.
- **Secure wireless communications** — can be used to share information between vehicles and with roadside infrastructure (illustrated in Figure A2). When used with automation this can enable

[2] For information, see http://www.itf-oecd.org/automated-and-autonomous-driving
[3] For information, see https://mycardoeswhat.org/safety-features/lane-keeping-assist/

applications such as platooning, where several vehicles follow each other at a short distance, relying on wireless communications to coordinate braking, acceleration and other driving behaviours.

- **LiDAR** (**li**ght **d**etection **a**nd **r**anging) — detects objects based on reflections from short laser pulses and can operate in 360 degrees around the vehicle. A LiDAR device is visible on the roof of the vehicle in Figure A3.
- **High resolution maps** — several manufacturers are developing systems that rely on comparing sensor data with high-resolution maps of the road environment collected in advance.
- **Global Navigation Satellite Systems** (GNSS) — such as the Global Positioning System (GPS) available in Australia, are widely used for high-level navigation. In the Northern Hemisphere high accuracy, high integrity GNSS services are available that are suitable for safety-critical functions.
- **Driver sensing systems** — actively monitor the cognitive state of the driver to mitigate fatigue and distraction. These systems assist with assessing whether the driver is sufficiently attentive to the road environment and prepared to take control of the vehicle if required in conditionally and highly automated vehicles.
- **Advanced computer science techniques** — such as machine learning, a type of artificial intelligence where the system improves based on prior experiences. Artificial intelligence could help solve difficult problems such as dealing with different right-of-way rules and behavioural norms around vehicle–vehicle and vehicle–pedestrian interactions in different countries.

Figure A2: Roadside infrastructure for vehicle-to-infrastructure communications

Image courtesy of Cohda Wireless

Figure A3*: Waymo highly automated test vehicle (formerly the Google self-driving car project)*

Source: Waymo.com

Grades of Rail Automation

Train automation refers to the process by which responsibility for operational management of a train transfers from the driver to the train control system. There are various Grades of Automation (GoA), defined according to which basic functions of train operation are the responsibility of the automated rail system.

For example, a Grade of Automation 1 (GoA1) corresponds to 'on-sight operation', where a human driver is responsible for normal operations, with the automated system only intervening to avoid a crash. Grade of Automation 4 (GoA4) refers to a system in which vehicles operate fully automatically without any operating staff on board, which would generally occur within a closed network system (UITP, 2011).

Figure B1: Grades of Automation

Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of Disruption
GoA 1	ATP with driver	Driver	Driver	Driver	Driver
GoA 2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
GoA 3	Driverless	Automatic	Automatic	Train attendant	Train attendant
GoA 4	UTO	Automatic	Automatic	Automatic	Automatic

ATP - Automatic Train Protection
ATO - Automatic Train Operation

Source: UITP (Union Internationale des Transports Publics), International Association of Public Transport)

Appendix C: Complementary developments

Developments in connectivity and freight technology are likely to be important factors for our future mass transit system. Vehicle connectivity is an important enabling technology for automated vehicles. Enabling vehicles to communicate with each other, and with roadside infrastructure, can support the performance of automated driving systems.

Intelligent transport systems

Australia is a mature user of intelligent transport systems, whereby information and communications technologies are applied in the field of road transport, including road-side infrastructure, vehicles and users. These systems enable road users and road operators to receive real-time information about the road environment for safety and network efficiency purposes.

These systems may indirectly benefit on-road mass transit services by reducing network congestion and increasing efficiency, or directly benefit these services through applications such as vehicle prioritisation.

Examples of intelligent transport systems in use in Australia include:

- **high occupancy vehicle prioritisation –** providing traffic signal priority to buses and other vehicles;
- **ramp metering** – facilitating higher speeds and throughput on freeways by using signals on entrances to control access and to smooth traffic flows;
- **variable speed limits** – varying speed limits in response to congestion levels on freeways;
- **traffic signal coordination** – coordinating signals in response to live traffic conditions; and
- **variable message boards** – improving efficiency by providing drivers with real-time congestion, weather and incident information.

Intelligent transport systems can broadly improve road capacity and road safety and reduce congestion, with most applications generating high indicative benefit-cost ratios (BITRE, 2017b).

Cooperative intelligent transport systems

The application of communications technology in a manner that brings together vehicles, roadside infrastructure (like traffic lights and signs) and networks in cooperative ecosystem is known as Cooperative Intelligent Transport Systems (C-ITS). C-ITS applications enable drivers and their vehicles to receive real-time information about upcoming hazards and traffic signals, working cooperatively to achieve safety and mobility outcomes.

Forms of C-ITS communications include:

- **vehicle-to-vehicle communications (V2V)** – enabling applications like cooperative cruise control, vehicle platooning and cooperative collision avoidance;
- **vehicle-to-infrastructure communications (V2I)** – enabling applications like red light violation alerts, road works warnings, and emergency and heavy vehicle priority traffic light signals; and
- **vehicle-to-anything communications (V2X)** – enabling communication with other road users, such as to a pedestrian or cyclist, or to other network hubs and devices.

C-ITS applications is likely to create opportunities to improve safety and efficiency of Australia's road network. The deployment of C-ITS infrastructure in urban corridors has been assessed to have an indicative benefit-cost ratio of 3 (BITRE, 2017b).

Mass transit vehicles and other road users receiving real-time safety information, including advanced warning of potential crashes, could have an important role in reducing the number of road crash fatalities and injuries that occur in Australia every year. Research from the United States indicates that up to 80 per cent of crashes that do not involve drink- or drug-driving could be mitigated by new connected vehicle technology (U.S. Department of Transportation, 2014). Australian research indicates that collision warnings alone could prevent 25-35 per cent of serious crashes (Austroads, 2011).

Uptake of C-ITS technology could also create more efficient mass transit. Communication between vehicles could enable cooperative cruise control, increasing road capacity and mitigating congestion by reducing following distances between vehicles at speed. Communication between vehicles and infrastructure could reduce stoppages and delays at intersections, resulting in less congestion and better fuel efficiency (U.S. Department of Transportation, 2014).

Freight sector reform and technology uptake

Both the freight and passenger tasks often rely on the same road and rail infrastructure, particularly in Australia's cities. As a result, widespread deployment of both road and rail automated mass transit are likely to improve national freight productivity and safety outcomes, especially if they relieve passenger driven congestion around major economic hubs like ports and airports.

By potentially inducing a shift in commuters to public transport, road automated mass transit could have a direct benefit on freight efficiency, by freeing up road capacity to meet the forecast freight growth, and an indirect benefit on road safety outcomes due to the lessened chance of accidents with freight vehicles (crash analysis shows that most casualty crashes involving heavy trucks also involve another vehicle and that 43 per cent of all fatal crashes involving heavy rigid trucks occur in major cities (BITRE, 2016b).

Rail automated mass transit systems have mostly occurred on purpose-build, closed networks, which have a single operator and infrastructure owner performing a single task in isolation from other rail operations. These systems will provide a solution to the current issue of competing freight and passenger priorities on shared rail networks, which impacts on the delivery of reliable and timely rail transport in cities.

However, new infrastructure alone will not be able to meet the increased demand for freight in cities, particularly as experience has shown that increasing capacity leads to an increased propensity for people to use the infrastructure.

Appendix C: Complementary developments

NSW Freight Signal Prioritisation Trial

In June 2018, Transport for New South Wales commenced a trial of connected vehicle technology enabling participating heavy vehicles to receive a priority green light signal. The technology was installed at over 100 intersections in Sydney on key freight corridors, including sections of Pennant Hills Road, Parramatta Road and King Georges Road.

Vehicles and traffic lights were fitted with wireless Dedicated Short Range Communications transceivers, which allow the detection of participating heavy vehicles on approach. Priority signaling for heavy vehicles has the potential to reduce heavy vehicle fuel consumption and emissions, as well as reducing congestion experienced by all road users caused by extended heavy vehicle braking and acceleration patterns.

New energy sources used to power passenger mass transit vehicles can also be used to power freight vehicles, particularly heavy road vehicles. As such, the environmental and community benefits of adopting new energy sources will also be applicable to freight. However, similar to passenger mass transit, uptake will vary depending on the turnover in freight vehicle fleets.

National Freight and Supply Chain Strategy

The Australian Government is working with states, territories and local governments to develop a *National Freight and Supply Chain Strategy* (the Strategy) for consideration by the COAG Transport and Infrastructure Council in 2019.

The Strategy will set an agenda for collaborative and integrated government action with industry engagement on freight and supply chains over the next 20 years. Importantly, the Strategy will support supply chain efficiency by guiding government and industry planning and decisions that have freight implications, including in relation to the development and adoption of productivity and safety-enhancing freight technologies and improving coordination of the passenger and freight task.