Deloitte.
Access Economics

Automated and zero emissions vehicles infrastructure advice

Socio-economic impact analysis

July 2018

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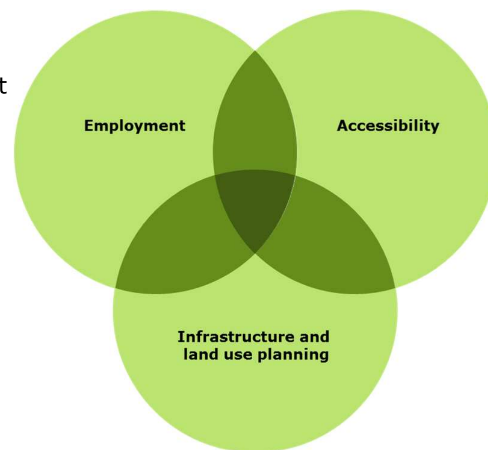
Background

The widespread adoption of zero emission vehicles (ZEVs) and autonomous vehicles (AVs) is likely to be among the most significant technological changes in the upcoming decades. These are emerging technologies, which will not only have significant impacts on travel behaviour and road network operations over the medium to long term, but also will fundamentally change approaches to where Australians live and work, and spend their leisure time.

The technological disruption that is now on the horizon in transport means that now is the right time for governments to consider the impacts of widespread adoption of ZEVs and AVs.

Infrastructure Victoria is, therefore, currently undertaking a suite of projects to consider how ZEVs and AVs could affect Victoria from a number of perspectives, such as transport network, electricity demand, government finances, population locations and how streets 'look and feel'.



One aspect of this work is to consider the socio-economic aspects of ZEVs and AVs – who will benefit, when and where and what economic activity could be spurred or spurned. This report considers these factors in detail:

- Effects on access to services and how these differ for different socio-economic groups;
- Direct consequences of the introduction of ZEVs and AVs on employment and industry structure, and how these impacts flow through the economy; and
- Infrastructure and policy responses that could promote ownership models, technology choices and uptake rates that maximise the benefits of this new technology.

This report measures the access to services, equity and employment outcomes for seven scenarios, including a Base Case (Scenario 7 - Dead End). These scenarios have been developed by Infrastructure Victoria to capture the range of uncertainty around fuel source, ownership structure and autonomy for the future road vehicle fleet. The scenarios in 2046 are listed below:

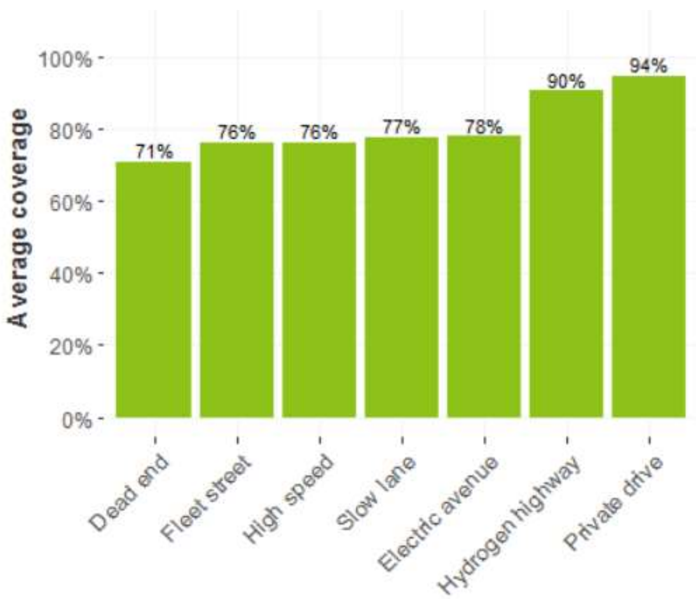
- Scenario 1: Electric Avenue (Non-driverless, private ownership, electric);
- Scenario 2: Private Drive (Driverless, private ownership, electric)
- Scenario 3: Fleet Street (Driverless, shared on-demand services, electric);
- Scenario 4: Hydrogen Highway (Driverless, Private ownership, hydrogen, 2046);
- Scenario 5: Slow Lane (Non-driverless, driverless, shared, on-demand services and private ownership, electric and petrol);
- Scenario 6: High Speed (Driverless, shared on-demand services, electric, 2031); and
- Scenario 7: Dead End (Non-driverless, private ownership, petrol).

Equity and Access to services

Overall, the introduction of ZEVs and AVs has benefits for access to services for all Victorians under all scenarios. The average coverage to critical infrastructure and services across each scenario is shown in Table iChart iFigure i.

It was found that, across the different scenarios, under full adoption in 2046, on a state-wide level, Private Drive had the largest increase in coverage, a 23 percentage point increase in overall coverage. Comparing across scenarios, the increase in access to services under Private Drive and Hydrogen Highway are largest. This is driven by a decrease in out-of-pocket costs and an assumed reduction in the value of travel time (which refers to the cost of time spent on travel). Private Drive is slightly superior to Hydrogen Highway due to the lower perceived out-of-pocket costs for users under Private Drive.

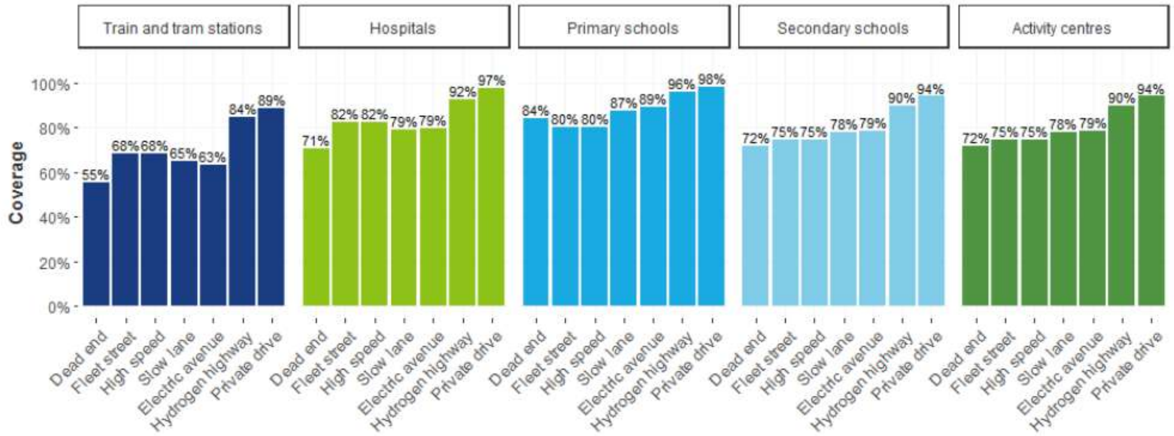
Figure i: Population weighted coverage in 2046 across scenarios



Note: Access to services is measured using the average modelled coverage of the population to each of these services.

Ensuring everyone has access to critical infrastructure is important for improving socio-economic outcomes and equality. Notably, this analysis models large increases in access to services under all scenarios. Figure ii shows a summary state-wide measure of population-weighted coverage in 2046 for a range of critical infrastructure. Coverage to train stations under the various scenarios had the largest improvement due to the low initial coverage. In 2046, Private Drive increased coverage of train stations by 34 percentage points when compared with Dead End. This has important implications for individuals with lower incomes, those living a significant distance from urban areas, and those without a driver’s licence.

Figure ii: Population weighted coverage to critical infrastructure in 2046

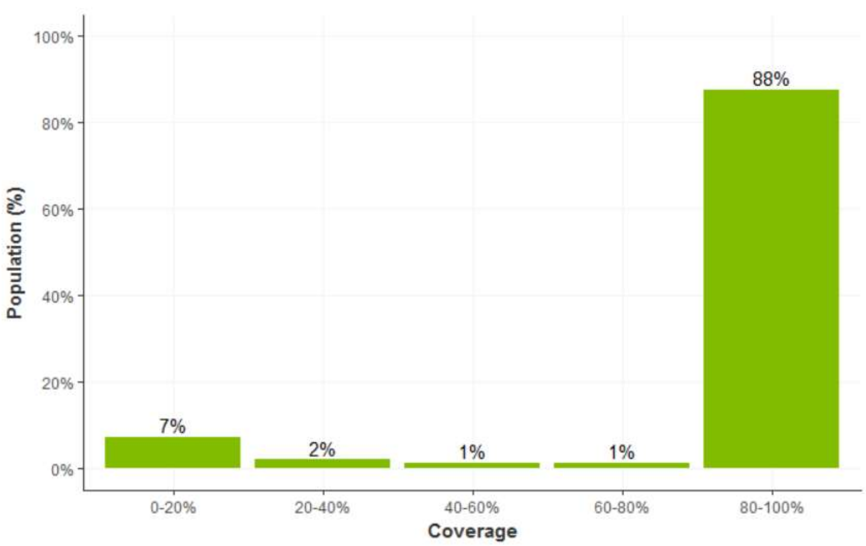


Note: the coverage rates show the percentage of population with access to each service under each scenario

This improvement in coverage for critical infrastructure is correlated to income levels. Regions with lower incomes tend to have the largest improvement in coverage over time across all scenarios, however, this is partially due to lower initial levels of coverage. At present, many high-income SA2 areas already have near 100% coverage and require very little increase in access to services in order to achieve 100% coverage. Many lower and average income regions have low levels of coverage and so the increase in access to services in those areas results in a large change in overall coverage over time.

Even with the full adoption of ZEV and AV technology, there are still regions in Victoria with groups of individuals who have very low levels of access to critical infrastructure.

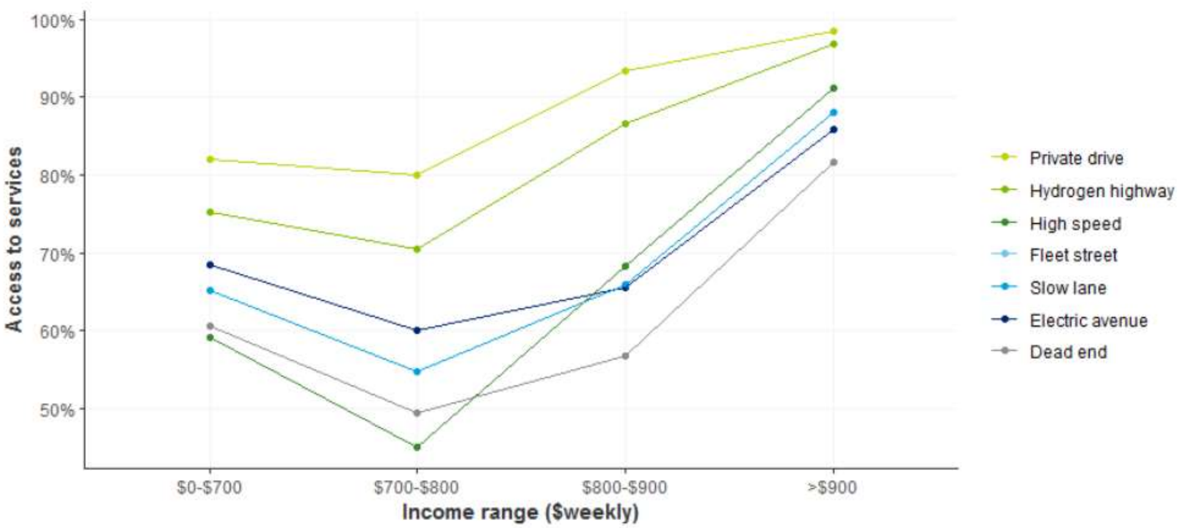
Figure iii: Percentage of Victorians with coverage of activity centres under Private Drive in 2046



For example, Figure iii shows that, under Private Drive in 2046, which generates the largest improvement in coverage, 7% of all Victorians still have very low levels of coverage to activity centres and hence, poor access to services. Other characteristics such as the lack of accessible critical infrastructure or the large size of the region are reasons for the low coverage, even in full adoption. A focus on the characteristics of these specific regions would be needed to create outcomes that are more equitable.

Large improvements in access to services is achieved for most scenarios for those in the lower income ranges, as shown in Figure iv. The only two scenarios that did not result in large improvements were Fleet Street and High Speed. Figure iv shows that, under Fleet Street and High Speed, those in the $0-700 and the $700-800 weekly income ranges had lower access to services compared to Dead End in 2046.

Figure iv: Relationship between average access to services and income range in 2046

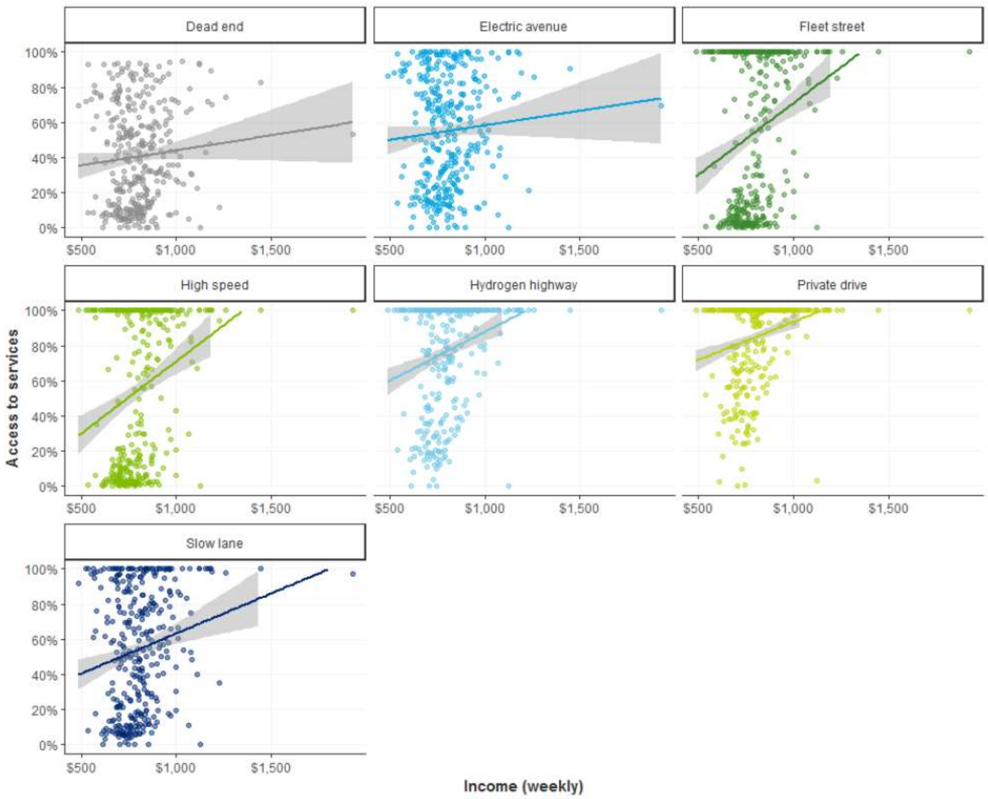


Note: High Speed and Fleet Street have identical access to services in 2046, such that the High Speed and Fleet Street data points perfectly overlap.

With respect to the relationship between income and access to services in particular, most scenarios increase access to services in 2031 and 2046 regardless of income group. Overall, for weekly incomes above $700, income is positively related to access to services. Private Drive equalised access to services the most between income groups, as it had the largest increase in overall access to services in the income group with the lowest initial coverage.

After removing areas with high current levels of access to critical infrastructure, there is a clear relationship between income and access, as shown in Figure v. In this figure, a steeper line indicates a larger relationship between income and access to services. Fleet Street and High Speed had the largest relationship between access to services and income, followed in order of reducing strength, by Hydrogen Highway, Slow Lane and Private Drive.

Figure v: Scatter plot of income and access to services in 2046



From a regression, under Fleet Street and High Speed, the overall access to services is anticipated to increase by more than 8% for every $100 increase in the average weekly income. While in the regression, under Private Drive, for every $100 increase in the average weekly income the overall access to services is anticipated to increase by 4%. This suggests that, even with full adoption in 2046, income is still associated with access to services. This is likely caused by higher levels of initial coverage for higher income areas which are further enhanced by the increased mobility offered by ZEVs and AVs.

In the regression, Fleet Street and High Speed had the largest relationship between income and access to services relative to the other scenarios as they increased access to services to a moderate extent.

In the regression, in Dead End, after removing the areas with high levels of access to services, there is no large relationship between income and access to services. As Electric Avenue and Slow Lane do not increase overall access to services by very much when compared to Dead End, similar to Dead End, in the regression, there is still no large relationship between income and access to services in Electric Avenue and Slow Lane.

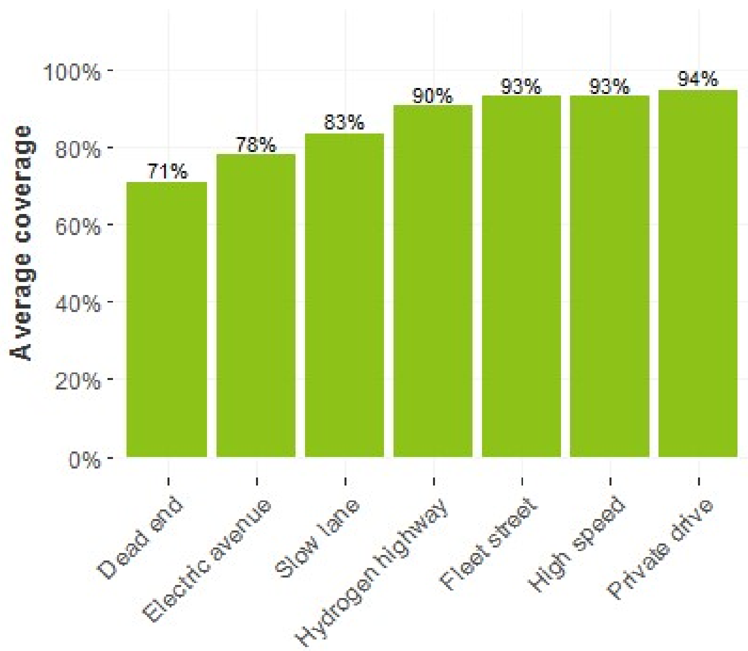
Sensitivity Analysis – subscription

This sensitivity analysis represents an alternative policy option where driverless, shared, on-demand services are accessed on the basis of a subscription service. This subscription based sensitivity analysis has implications for the Fleet Street, Slow Lane and High Speed scenarios.

The critical change in assumptions for this sensitivity analysis relates to the approach to charging for driverless, shared, on-demand services. Under a subscription approach, both the initial flag fall and ongoing travel costs are lower than in the main results.

Under this sensitivity analysis, there are significant improvements in accessibility on a geographic and population basis compared to the main results, this can be seen in Figure vi where outcomes for coverage levels for Fleet Street and High Speed are only just below those for Private Drive and are superior to Electric Avenue and Hydrogen Highway.

Figure vi: Population weighted coverage in 2046 across scenarios – sensitivity analysis

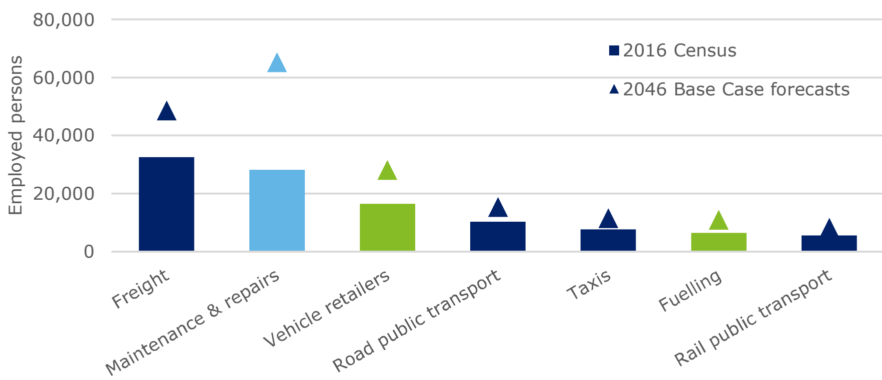


Further, comparing the results of the sensitivity analysis to the main results indicates that a subscription based approach to driverless, shared, on-demand services has significant benefits in terms of reducing inequality as well as boosting access overall. For example, in the main results there is a very strong relationship between income and access to services under Fleet Street in 2046. In particular, those in the $700-$800 income a week range have levels of access to services roughly half that of those in the >$900 a week income range, within the sensitivity analysis this differential falls considerably.

Employment risks and opportunities

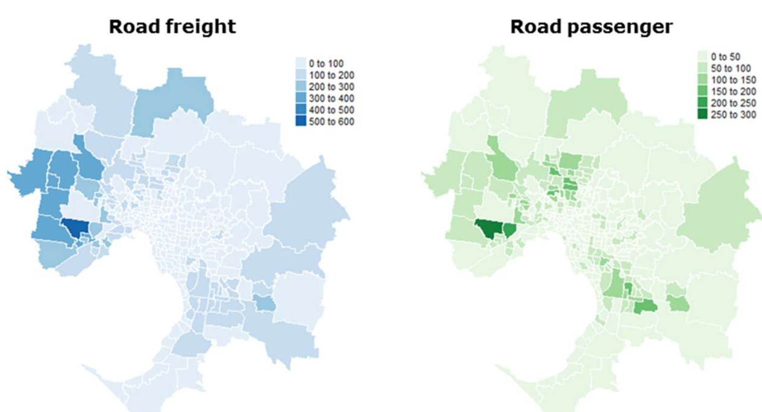
Transport and motor vehicles are fundamental components of the Victorian and Australian economies. The transport industry in Victoria is responsible for 113,000 jobs, or one in every 25 employed persons. A transition to ZEVs and AVs is likely to have a large impact on many of these workers, in particular freight and truck drivers, public transport operators, and taxi and hire car drivers. Other at-risk workers are likely to be in the maintenance and repairs, fuelling and vehicle retail sectors. Employment in these sectors is shown in Chart ii.

Chart ii: Employment forecasts for relevant sectors (Victoria, 2016-2046)



Not only do these key sectors represent a significant number of Victorian workers, but also these workers are more likely to be concentrated in the northern and western Greater Melbourne regions as indicated in Figure vii. Current employment patterns reveal that truck drivers are more likely to reside in Melbourne's west. Taxi operators are also more likely to reside in these western regions. Notably, employment in the Transport industry is predominately within Greater Melbourne, with fewer workers for the rest of Victoria and less clear employment patterns (i.e. no strong clustering of employment in regional areas).

Figure vii: Distribution of transport employment (Greater Melbourne, 2016)



Source: ABS Census 2016. Note: 'Road passenger' includes taxis and hire cars, and road public transport.

By 2046, Victoria is expected to be home to over 5 million workers, including 188,000 workers in what are deemed the most at-risk sectors, including:[1]

- 48,600 in freight;
- 65,200 in vehicle maintenance and repairs;
- 28,000 in vehicle retail;
- 15,300 in road public transport;
- 11,500 in taxis and hire cars;
- 10,900 in fuelling; and
- 8,100 in rail public transport.

While this represents a large potential number of workers, it is a relatively small overall share of the Victorian economy, representing 3.7% of total jobs.

The adoption of ZEVs and AVs is expected to have large impacts on the workforce and therefore would significantly affect the baseline forecasts described above. At a high level, these workforce effects can be described by four forces:

1. Autonomous technology removing the need for human drivers;
2. Autonomous technology prompting a change in ownership structures from private-to-fleet operators;
3. Autonomous technology changing the way people commute and use public transport; and
4. Electric vehicle technology and engines displacing traditional combustion engines.

The links between each force to the primary or 'most direct' employment impacts are summarised in Table ii, noting that they are all interrelated and likely to affect many industries and workers.

Table ii: Mapping technological changes to employment impacts

Industry:	**Transport**				**Other business services**	**Trade**	
Sector:	**Freight**	**Road PT**	**Taxis**	**Rail PT**	**Maintenance & repairs**	**Fuelling**	**Retailers**
Removing drivers	✓	✓	✓		✓		
Private to fleet					✓		✓
Commuter behaviours		✓		✓	✓		
Electric engines					✓	✓	

[1] Forecasts are for the total 'Transport, Postal and Warehousing' industry. This analysis applies a constant average growth rate to each sector, such that is assumes the relative proportions of each sector remain constant.

After considering how these risks will affect each of these employment categories, it is estimated that, in total, by 2046, up to 180,900 workers will need to find new jobs as a result of the adoption of electric, autonomous, shared fleet vehicles (Fleet Street). At the lower end of the spectrum, 30,200 jobs are at risk from electric ZEVs (Electric Avenue). More detail is provided in Table iii.

Table iii: Aggregated future employment shocks by industry (2046, 2031)

Scenario	Transport	Other business services	Trade	Subtotal
Total employment forecast	*169,524*	*1,046,188*	*937,277*	***2,152,988***
1 Electric Avenue	0	-16,292	-10,931	**-27,224**
2 Private Drive	-89,761	0	-10,931	**-100,693**
3 Fleet Street	-89,761	-52,135	-38,967	**-180,863**
4 Hydrogen Highway	-89,761	20,854	0	**-68,907**
5 Slow Lane	-44,881	-28,023	-19,483	**-92,387**
6 High Speed^	-75,425	-38,397	-33,023	**-146,845**

Note: ^High speed scenario is forecast using 2031 estimates.

These initial shocks to employment will create a range of flow on effects throughout the economy. While the introduction of new technologies displaces many workers and jobs, there are also very likely to be opportunities for the economy to change, grow and create employment in new industries, as these technologies change the way individuals, firms and governments interact.

A Computable General Equilibrium (CGE) model is a useful tool to understand how the economy could react to both these productivity and employment changes. It represents the connections between different sectors in the economy, as well as the behaviour of firms, consumers and government. For significant changes to the economy (such as the introduction of a new technology), a CGE model is able to estimate how sectors of the economy will react and where economic activity is likely to shift.[2]

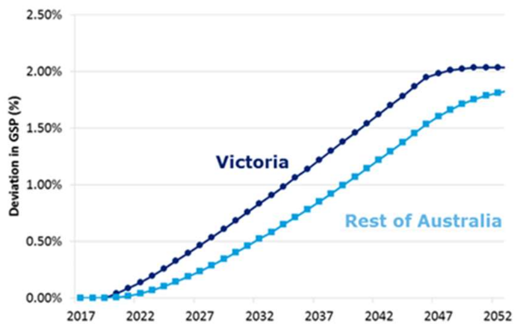
The economic impacts of the productivity improvements related to ZEVs and AVS and the associated 46% decline in transport roles to 2046 can be summarised for Victoria as:[3]

- A direct decline in 72,200 transport roles, which is offset elsewhere in the economy by an increase of 83,700 jobs resulting in an overall increase in employment of 11,500 jobs;

[2] Further detail on the CGE modelling is provided in Section 3.4, while a detailed description of limitations and assumptions is provided in Appendix C.
[3] In order to produce meaningful results, a large and isolated shock is identified for the CGE model. This shock is most appropriate for Private Driver, Fleet Street and Hydrogen Highway scenarios, with similar changes for High Speed and Slow Lane (at faster/slower transitions). See Section 3.4 for a more detailed discussion.

- A $14.9 billion increase (2.0%) in economic output or GSP by 2046, and a similar pattern for consumption, which increases by $6.7 billion (see Chart iii);
- An extensive period of employment transition, particularly among machinery operators and drivers;
- An approximate 100% gain in investment expenditure for road transport, as well as a 5.7% increase for construction; and
- Increasing imports and decreasing exports throughout the economy.

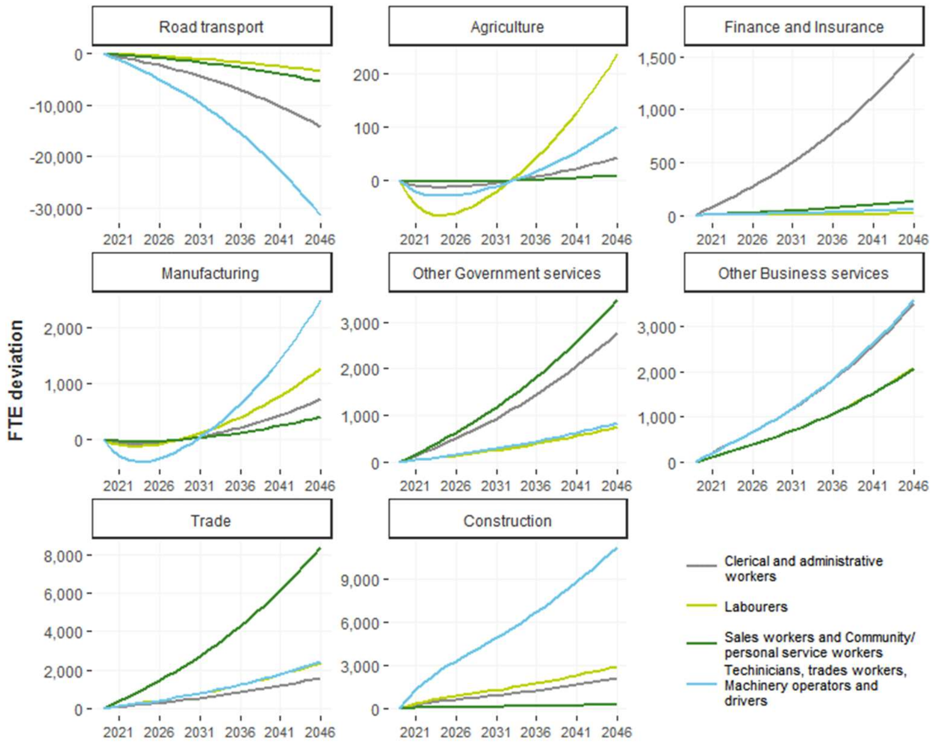
Chart iii: Deviations in economic output from baseline forecasts (shock from 2020)



A large loss of roles for the transport industry is expected. However, this is more than offset by positive employment growth of 83,700, predominately across construction, trade and other business services. Overall, this suggests that the introduction of ZEVs and AVs will be a net benefit for employment in Victoria.

The effects of this shock will differ for workers with different skill sets, as illustrated in Chart iv. The loss of workers in the transport sector is predominately in 'Technicians, trades workers, machinery operators and drivers', who are likely to re-enter employment through construction, manufacturing and other business services.

Chart iv: Change in employment by industry and skill level (Victoria, 2020-2046)



Increasing productivity of capital induces the substitution of labour for capital, as the returns to capital increase. This draws in investment to build the capital stock of the economy. This is clearly identified in the modelling where the almost doubling of capital expenditure for transport was an outcome.

Although outside the scope of the CGE model, the volume of direct capital investment required to support the transition to ZEVs and AVs is potentially significant and could provide employment opportunities for some displaced workers. Additional research indicates that the necessary investment could be in the range of $6 billion under both Electric Avenue and Private Drive, but lower in other scenarios and potentially significantly lower under fleet ownership scenarios.[4]

More broadly, some workers will have the requisite skills in order to transition smoothly from employment in one industry to another. However, others may not have the right skills or may find that these jobs are less geographically accessible.

Government can facilitate these transitions with targeted training and reskilling programs, providing job search services, or prioritising capital works in areas with more displaced workers.

[4] Differences are primarily driven by assumptions on the ratios of vehicles to chargers (more chargers for private ownership scenarios) and the number of vehicles in operation (fewer vehicles for fleet scenarios).

Infrastructure and policy responses

The introduction of ZEVs and AVs will have significant impacts on mobility and access to services, and these impacts will differ by socio-economic groups. Furthermore, there are quite large employment consequences – particularly in terms of transition between industries.

This suggests that there is a role for government to play in helping to manage inequality and socio-economic outcomes where appropriate, and help ease the pains of transition in employment.

A review of current major infrastructure plans shows that the majority of the relevant planning documents either focus on the impact of ZEVs and AVs on transport infrastructure or the impact of transport infrastructure on socio-economic issues, but rarely consider both together. Only Infrastructure Victoria's 30-year strategy addresses the impact of the transition to ZEVs and AVs on transport infrastructure from a socio-economic perspective.

Many of the major projects identified in these plans do not consider the potential impact of ZEVs or AVs. This is true both in terms of how ZEVs and AVs may affect the projects themselves or how the services provided by ZEVs and AVs could augment the desired socio-economic outcomes of the projects.

Overall, in the majority of the current and planned infrastructure projects, there seems to be a gap in analysis of the impact of ZEVs and AVs on infrastructure and policy considered from a socio-economic perspective.

However, in many of these plans, there seems to be an emerging role for integrated transportation, the treatment of transport from a service oriented point of view and a focus on how to best get different modes of transport to work together. This is a positive sign.

Despite the present lack of prominence of ZEVs and AVs in planning documents, government will have an important role in facilitating the introduction and adoption of ZEV and AV technologies.

As there is likely still some time before ZEVs and AVs replace traditional vehicles, this presents an opportunity for governments to use this time to decide on the role that it wants to have in informing and influencing the future of transport.

Policy makers could use these technological advancements as an opportunity to change the way governments in general think about policy and regulation, and how the public sector responds to or pre-empts 'disruption'.

Some key questions for government to consider before defining its role at the intersection of infrastructure, ZEVs and AVs and socio-economics are:

- How best to facilitate the conversation on the role of AVs?
- How the definition of passenger transport will change?
- How to position government to maximise real option values?

Beyond these broad questions, there are areas of infrastructure where governments may wish to intervene to address socio-economic issues.

This analysis has not considered what specific projects could be implemented in specific regions at specific times. However, five focus areas where ZEVs and AVs will intersect with infrastructure and socio-economic considerations has been identified. While these focus areas will require government investment, the nature of this investment will ultimately be determined by how government defines its role in these markets.

These areas have been identified through consultation with Deloitte's global ZEV and AV practitioner network, including consultations with experts from China and Germany, and include:

1. Financial and regulatory support to strategically target charging infrastructure;
2. Considerations of any potentially undesirable impacts of autonomous-only vehicle lanes;
3. Developing and improving intermodal and interchange options and facilities for enabling public transport;
4. Supporting investment to enhance the value proposition in regional areas; and
5. Investing in infrastructure to facilitate communication between AVs and existing transport.

Deloitte Access Economics

1 Introduction

The widespread adoption of zero emission vehicles (ZEVs) and autonomous vehicles (AVs) are likely to be among the most significant technological changes in the upcoming decades. These are emerging technologies, which will not only have significant impacts on travel behaviour and road network operations over the medium to long term, but also will fundamentally change approaches to where Australians live and work and spend their leisure time.

The evolution and increased use of AVs could lead to a range of potential benefits for the community. AVs have the potential to improve safety on roads with more reliable sensors than the human eye, constant attention and very fast reaction times removing the element of human error and fatigue. AVs will also be capable of travelling together and operating at higher speeds, which will improve utilisation of existing roads.

There could also be access to services benefits as road users can travel further and access facilities such as primary and secondary schools, hospitals and places of employment with increased levels of flexibility. This could be particularly true for those who currently can't drive or have limited transport options available.

However, these potential benefits will be a function of the service model used (private ownership or shared use) and the transition path to full AVs (who gets the benefits).

The technological disruption that is now on the horizon in transport means that now is the right time for governments to consider the impacts of widespread adoption of ZEVs and AVs.

Infrastructure Victoria is therefore currently undertaking a suite of projects to consider how ZEVs and AVs could affect Victoria from a number of perspectives, such as transport network, electricity demand, government finances, population locations and how streets 'look and feel'.

One aspect of this work is to consider the socio-economic aspects of ZEVs and AVs – who will benefit, when and where and what economic activity could be spurred or spurned. This report considers these factors in detail.

To analyse the socio-economic impacts of ZEVs and AVs, government must understand what these new technologies can do for citizens in terms of enhancing and improving access to services, and also how different socio-economic groups may react to new technologies. This initial reaction must be overlaid against the direct consequences of the introduction of ZEVs and AVs in terms of changes to employment and industry structure.

Understanding these two socio-economic effects will enable the Victorian government to identify key socio-economic issues and allow for ZEVs and AVs to achieve their potential as safe, efficient, and accessible transport options that improves the economy and sustainability of Victoria.

This report also considers infrastructure and policy responses that could promote ownership models, technology choices, and uptake rates that maximise the benefits of this new technology.

Relationship with other reports

This report is one part of a suite of reports being prepared for Infrastructure Victoria. While a harmonised approach to modelling and assumptions has been taken across these report, some of the assumptions may differ from one stream of research to another. This reflects the high degree of uncertainty in this emerging area of technology.

1.1 Scenarios and periods analysed

This study measures the access to services, equity and employment outcomes for seven scenarios, including a Base Case (Scenario 7 - Dead End). These scenarios have been developed by Infrastructure Victoria to capture the range of uncertainty around fuel source, ownership structure and autonomy for the future road vehicle fleet. The scenarios are listed below:

- Scenario 1: Electric Avenue (Non-driverless, private ownership, electric, 2046)
- Scenario 2: Private Drive (Driverless, private ownership, electric, 2046)
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- Scenario 4: Hydrogen Highway (Driverless, Private ownership, hydrogen, 2046)
- Scenario 5: Slow Lane (Non-driverless, driverless, shared, on-demand services and private ownership, electric and petrol, 2046)
- Scenario 6: High Speed (Driverless, shared on-demand services, electric, 2031) and
- Scenario 7: Dead End (Non-driverless, private ownership, petrol, 2046).

The remainder of this report refers to each scenario by their names. Outcomes are typically compared against the Base Case/Dead End scenario.

For more information on the scenarios, refer to Infrastructure Victoria's report *Advice on Automated and Zero Emissions Vehicles: Infrastructure Future Scenarios* from April 2018.

Each of these scenarios is analysed in both a main set of results and in an additional sensitivity analysis. In the sensitivity analysis, some of the assumptions underlying the operation of driverless, shared, on-demand services have been altered. This sensitivity analysis is referred to with the additional qualifier of 'subscription' as it represents an alternative policy option where shared vehicles are accessed on the basis of a subscription service. This subscription sensitivity analysis has implications for the Fleet Street, Slow Lane and High Speed scenarios. These assumptions are described in greater detail in Section 2.

Turning to timeframes, this study assumes a linear rate of adoption of the new transport technologies (ZEVs and AVs) technologies, starting in 2019. Infrastructure Victoria is generally most interested in outcomes in 2046, once full transition is assumed to have occurred.

All scenarios aside from High Speed assume 100% adoption by the end of 2046. The High Speed scenario assumes 100% adoption by 2031. For the purposes of socio-economic analysis, the transition path itself is of most interest. As a result, the year of 50% overall adoption is modelled and reported for each scenario, in order to assess the socio-economic effects of differential adoption over time. The mobility, access to services and equity outcomes of each scenario was modelled in 2018 (today), 2031 (near 50% adoption) and 2046 (100% adoption).

As the Dead End scenario does not adopt any new technologies, the main drivers of change (travel speeds, out-of-pocket costs and the value of travel time) will remain the same as in 2018. This means that the mobility, access to services and equity outcomes are assumed to be the same for the Dead End scenario in 2018, 2031 and 2046.

1.2 Layout of this report

This report is set out in the following Chapters:

- Chapter 2 considers how the introduction of ZEVs and AVs will affect equity for different sociodemographic groups in terms of their access to critical infrastructure and services.
- Chapter 3 analyses which jobs will be most at risk, provides an accounting for the number of jobs at risk, and models how the economy will respond to this change in jobs.
- Chapter 4 uses the results from the preceding sections to identify a number of focus areas for infrastructure investment and government policy to manage the socio-economic impacts of the widespread adoption of ZEVs and AVs.

2 Equity and access to services

Key findings in this chapter

- The adoption of ZEVs and AVs has benefits for access to services for all Victorians under all scenarios.
- With full adoption in 2046, on a state wide level, Private Drive had the largest increase in average access to services, followed by Hydrogen Highway, Electric Avenue, Slow Lane and then Fleet Street and High Speed.
- The lower the average income of regions today, the larger is the change in access to services over time.
- There are groups of people who live in regions with 0% or very low access to key services, even with full adoption in 2046.
- After removing areas with high current levels of access to critical infrastructure, there is a clear positive relationship, between income and access to services in most scenarios.

This section analyses the mobility, access to services and equity implications of the uptake of ZEVs and AVs.

It is important for policy makers to understand how different socio-economic and demographic groups are likely to respond to the introduction of new vehicle technology and mobility services. There will be a period of transition with some groups of the population benefitting earlier than others do. This section looks at what this means in terms of relative disadvantages in access to different services and opportunities.

An access to services measure based on a generalised transport cost function is used to measure access to service impacts. The section also reviews existing studies to understand possible take-up rates of ZEVs and AVs for different socio-economic groups. The findings from this review are used to inform modelling to gain an understanding of the change in access to critical infrastructure, services and opportunities.

These results are then used to model the impacts of access to services under each of the seven mobility scenarios. This allows for an identification of potential issues in relative disadvantage in access to services between different socio-economic groups.

2.1 Measuring equity and access to services: approach

The following sections set out the approach taken to measure mobility, access to services and equity outcomes for each of the seven scenarios considered in this study.

2.1.1 Defining an access to services indicator

Mobility refers to "the movement of people or goods" (Litman, 2003, p. 23) while access to services refers to "the ability to reach desired goods, services, activities and destinations – collectively 'opportunities'" (Litman, 2003, p. 23). For example, AVs increase the mobility of people by giving both drivers and non-drivers another option of travel and movement. This increase in mobility will result in an increase in the AV users' access to opportunities. In essence, mobility provides a means to achieving access to services, and access to services is the key outcome from an economic value point of view.

The modelling starts by considering how mobility (the distance travelled per trip) is affected but ultimately focuses on outcomes from an access to services perspective.

Deloitte Access Economics created an access to services measure to assess the changes in access to services under different scenarios. The measure provides an indication of the level of access to services and opportunities for residents in Victoria.

In practice, there are four main ways to measure access to services:

1. Infrastructure-based measures – examine access to services from the observed or simulated service level or performance (usually through travel impediment or resistance) of transport infrastructure. This measure is mainly used within transport planning.
2. Location-based measures – examines access to services from the activities available from certain locations (such as the number of jobs available with 30 minutes of travel time from an original point) on a population group level. This measure is mainly used within urban planning and geographical research.
3. Person-based measures – examines access to services from the activities individuals can participate in within a period on an individual level.
4. Utility-based measures – examines access to services from the economic benefits individuals derive from access to activities based on their travel costs (Geurs & van Wee, 2004).

The access to services measure created in this report mainly used the location method, with some elements of the other methods added when appropriate.

The location aspect of access to services was measured for each SA2 in Victoria. It was measured in terms of the percentage of the area enjoying a high level of access to key services of employment, education, healthcare, shopping and recreational activities. Generally, a catchment area was estimated for each critical infrastructure (hospital, primary and secondary schools etc.) in order to measure which areas had access to which critical infrastructure. The types of critical infrastructure used are listed in Table 2.1.

Table 2.1: Critical infrastructure used in this study

Key services	Critical infrastructure used
Public Transport	Train and tram stations
Education	Primary schools and secondary schools
Healthcare	Hospitals
Employment, commercial areas and recreation facilities	Plan Melbourne activity centres and significant urban areas

These activity centres and significant urban areas approximate regions where individuals might travel for employment, commercial activities or to access recreational facilities. For urban areas, activity centres are identified by the Department of Planning of Victoria (2018). The equivalent concept for regional areas is captured by significant urban areas. These significant urban areas are identified by the ABS and refer to dense areas of high population (ABS, 2017). Note that the term 'activity centre' will refer to both these urban activity centres and regional significant urban areas for the remainder of this report.

The utility aspect of access to services was measured using a generalised transport costs method. This generalised cost of travel measures the 'price' individuals are willing to pay for travel to an activity. Generalised transport costs include the monetary and non-monetary costs individuals incur for travel, such as out-of-pocket costs, time costs, parking costs and costs from quality of the trip (Koopmans, Groot, Warffemius, Annema, & Hoogendoorn-Lanser, 2013).

For this study, the coverage of an area with a high level of access to services is defined, as the area within which all trips to critical infrastructure can be undertaken up until the maximum accepted generalised costs an individual is willing to spend to undertake a trip.

For each scenario, first the size of the catchment areas by SA2 at the end state of the scenarios was estimated, i.e., after a complete transition to new vehicle technologies (e.g. 100% uptake of ZEVs in Electric Avenue). The effect of transition over time is then considered in Section 2.1.2.2.

To estimate the size of the catchment areas, the maximum distances people are currently willing to travel for different trip purposes was estimated. This distance was found by first identifying a reasonable average travel time for various trip purposes. The willingness to pay (i.e. the total cost) per trip was then calculated which identifies the average distance travelled per trip using petrol/diesel vehicles (in the Dead End scenario).

To calculate how transport behaviour changes in the scenarios, individuals were assumed willing to pay the same total amount for each type of trip. The distance was then altered to account for new cost assumptions for ZEVs and AVs. This identifies a change in distance travelled per trip.

To calculate the distance travelled per trip in the baseline, the main categories of trip destinations were first identified. Most individuals at some point would travel to one or more of these destinations – public transport, schools, shopping centres, hospitals, areas of employment, commercial areas and areas with recreation facilities. For most people these trips will account for the majority of their travel.

To inform these assumptions on the average accepted trip distances an individual would be willing to accept, actual travel behaviour and strategy documents was reviewed. For example, the 2013 VISTA found the average trip time was 23 minutes in Melbourne (VISTA, 2015) and 17 minutes in regional centres (VISTA, 2015). It is important to note that this average includes travel time from home-to-work – likely to be the longest common trip that most people take. It was found that half of all trips in Melbourne were less than 15 minutes (VISTA, 2015), while half of all trips in regional centres were less than 10 minutes (VISTA, 2015).

The assumptions used in this analysis for travel time tried to reflect the 'average' accepted trip time to each critical infrastructure an individual in both Melbourne and the rest of Victoria would be willing to accept. Due to the uncertain nature of this analysis, estimates that were slightly more conservative were used. Table 2.2 shows the assumptions for average travel time to each critical infrastructure used within this report.

Table 2.2: Average travel time for different trip purposes

Critical infrastructure	**Average travel time (minutes)**
Train and tram station	5
Primary and secondary school	5
Hospital	10
Activity centre	15

The distance individuals would be willing to travel per trip was calculated using the average travel times for each critical infrastructure. The first calculation involved the distance individuals would be willing to travel depending on the purpose of the trip using:

- The Dead End scenario of 100% private non-ZEVs;
- A Marginal Utility of Travel Time (MUTT) factor of 1;
- Vehicle Operating Cost (VOC) of $0.176/km;
- An assumed a value of travel time (which refers to the cost of time spent on travel) of $17.14/hr[5]; and
- An average speed of 30km/hr in urban areas[6] and 75 km/hr in rural areas[7].

[5] Based on the full time adult average weekly total earning of $1,628 in Nov 2017 (ABS, 2018) divided by a 38 hour week multiplied by the private travel time valued at 40% (Australian Transport Assessment and Planning, 2016).
[6] Average of the average speed of arterials roads in the inner (20km/hr) and middle-regions (40km/hr) in Melbourne (Vic Roads, 2015).
[7] Individuals in regional areas are assumed to travel on a mix of roads of 50km/hr and 100km/hr (Vic Roads, 2017) and found the average of 75km/hr. No delay due to congestion was assumed. Previous experience indicates that, even in regional areas, a large proportion of travel is undertaken in built-up areas.

The total cost of the trip was calculated based on the time cost of the individual (using the value of travel time and time of travel) and the VOCs of the vehicle (based on the VOCs and distanced travelled).

The total cost per trip is shown in Table 2.3 for the Dead End scenario split by urban and rural regions. This total cost is predominately the time cost to the individual and the vehicle cost, but also includes incidentals such as parking. The time cost component to the individual is the same in both urban and rural regions. It is assumed that the maximum accepted time cost is the same for individuals to travel to each of the critical infrastructure in both urban and rural regions (as seen in Table 2.2). Parking costs are only included for urban areas.

Table 2.3: Total cost per trip in the Dead End scenario

Costs per trip ($/trip)	Urban	Rural
Train/tram station and primary and secondary school (5 mins)		
Time	1.43	1.43
VOC	0.44	1.10
Parking	3.20	-
Total	5.07	2.53
Hospital (10 mins)		
Time	2.86	2.86
Vehicle	0.88	2.20
Parking	3.20	-
Total	6.94	5.06
Activity centre (15 mins)		
Time	4.28	4.28
Vehicle	1.32	3.30
Parking	3.20	-
Total	8.80	7.58

The difference in total cost between urban and rural trips is largely due to the out-of-pocket costs - the vehicle operating costs, parking costs and flag fall costs. While it is assumed that individuals in the urban and rural regions are willing to travel 5 minutes to reach a train/tram station, as the individual in the rural region is travelling at a faster average speed than the urban individual, the individual in the rural region would travel further in distance in the same amount of time.

As the VOC is measured as a cost over distance, this increase in distance travelled in rural regions results in the higher VOCs per trip in the rural areas compared to the urban areas as seen in Table 2.3. Parking costs are only included for urban scenarios and are the main driver of the higher total cost per trip for urban regions compared to rural regions as seen in Table 2.3.

Using this total cost per trip, individuals are assumed to be willing to spend this same amount for trips of the same purpose under each of the scenarios. The new distance individuals would be willing to travel under the different scenarios was then calculated based on changes in both the value of time, vehicle operating costs, parking costs and flag fall costs. The flag fall cost was only included for scenarios with fleet ownership – Fleet Street, High Speed and Slow Lane.

For each scenario, the time cost per trip was varied based on the average factor of the marginal utility of travel time (MUTT) for each scenario and the distance cost per trip based on the VOCs for each scenario as seen in Table 2.4.

Table 2.4: Assumptions about the out-of-pocket costs and time cost

Scenarios	Out-of-pocket cost			Time cost
	VOC ($/km)	Parking ($/trip)	Flag fall ($/trip)	MUTT (factor)
Dead End	0.176	3.20	0.00	1.0
Electric Avenue	0.050	3.20	0.00	1.0
Private Drive	0.050	0.00	0.00	0.5
Fleet Street & High Speed	0.220	0.00	2.00[8]	0.5
Fleet Street & High Speed – subscription	0.050	0.00	0.50	0.5
Hydrogen Highway	0.176	0.00	0.00	0.5
Slow Lane[9]	0.176 & 0.220	3.20 & 0.00	2.00 & 0.00	0.5

[8] Note that in the transport modelling, there is an additional per minute charge under highly congested conditions. This charge does not apply in this current modelling as congested and free flow conditions are not modelled separately.
[9] In the subscription sensitivity analysis, Slow Lane involves a combination of $0.50 and $0.00 flag fall per trip and a combination VOC of $0.176 and $0.050.

The MUTT measures how much an individual values their travel time. For the purposes of this study, it can be thought of as the opportunity cost of driving. In this study, the MUTT was factored down when autonomous vehicles are available. This lower MUTT reflects the lower value individuals put on their travel time in AVs. While travelling in these AVs, instead of driving individuals can utilise their time in other ways, such as working, resting or participating in other recreational activities (Litman, 2018) and therefore, the time cost of travel is reduced.

For example, in Dead End an individual has a relative MUTT of 1 where in Private Drive an individual has a relative MUTT of 0.5. This means, that in Private Drive, the individual would value the time they spend travelling half a much and hence, it is much less costly (in terms of time) for the individual to travel the same distance in Private Drive than in Dead End. Table 2.4 shows that a lower MUTT was assumed for all the scenarios that have AVs (Private Drive, Fleet Street, High Speed, Hydrogen Highway and Slow Lane). The MUTT value of 0.5 was used in order to be consistent with the transport modelling being undertaken as part of the broader set of projects underway.

If either the MUTT, the VOCs or parking cost is lower than in the Dead End scenario, it would cost the individual less per trip and the individual would be willing to travel a longer distance compared to before, assuming that the individuals are willing to spend this same dollar value for trips of the same purpose.

Table 2.4 shows the out-of-pocket vehicle cost component assumed for each scenario. The assumptions about VOCs and flag fall costs used are consistent with the transport modelling being undertaken as part of the broader set of projects underway. The VOC for Fleet Street used the assumption of the fare being $0.220 per kilometre from the transporting modelling. As the Slow Lane is a mix of the Dead End and Fleet Street, Slow Lane's VOC is an average of $0.176 per kilometre (Dead End) and $0.220 per kilometre (Fleet Street). In a similar sense, for Fleet street, the flag fall cost was assumed to be $2.00 per trip from the transporting modelling and for Slow Lane, the flag fall cost is an average of $0.00 per trip (Dead End) and $2.00 per trip (Fleet Street).

Parking costs of $3.20 were also included in the scenarios with the non-driverless modes, as it is assumed that driverless vehicles do not need to park in the city. After dropping off their users, they can either return home (under the private ownership) or pick up other users (under shared, on demand services). This parking cost was based on reported average parking costs that range from $5.50 per hour for on street parking in the CBD, $3.20 outside of the CBD and $0.80 in all day parking areas (City of Melbourne, 2018).

Using the out-of-pocket cost in Table 2.4, the total distance consumers are willing to travel per trip under the different scenarios in both the urban and rural context was calculated. The results are shown in Table 2.5 and Table 2.6.

Table 2.5: Distance willing to travel per trip (km) in urban regions

	Scenario (urban)					
	Dead End	**Electric Avenue**	**Private Drive**	**Fleet Street & High Speed**	**Hydrogen Highway**	**Slow Lane**
Train/tram station, primary and secondary school	2.50	3.01	15.10	6.07	10.98	3.80
Hospital	5.00	6.01	20.67	9.76	15.03	6.98
Activity centre	7.50	9.02	26.23	13.46	19.07	10.16

For example, in Dead End, individuals in urban regions are willing to travel 2.5 kilometres to reach their nearest train station. The VOC per km of electric vehicles is much lower than the VOC per km of petrol and diesel vehicles as seen in Table 2.4 (comparison of the VOCs of Electric Avenue to Dead End). This reduced cost of travel means that commuters would be willing to travel further. As seen in Table 2.5, in Electric Avenue individuals are willing to travel 3.01 kilometres for a train station, a 0.51 kilometre increase from the current travel distance in Dead End.

While Private Drive has the same VOCs as Electric Avenue, under Private Drive there are no parking costs. Private Drive also reduces the individuals' MUTT and hence, reduces the time cost of travel, which results in individuals willing to travel longer distances in Private Drive when compared to Electric Avenue.

Fleet Street and High Speed have higher VOCs per trip than Private Drive and so users are willing to travel a smaller distance per trip due to this increase in costs. Even though Fleet Street and High Speed's VOCs and flag fall costs are higher than Electric Avenue, for urban regions the parking cost savings in Fleet Street and High Speed outweigh the increased VOCs and flag fall cost, and individuals are willing to travel further per trip in Fleet Street and High Speed when compared with Electric Drive.

Hydrogen Highway has the same VOCs as Dead End with no parking costs and a lower MUTT, and therefore, individuals are willing to travel further than Dead End. As AVs are used in Hydrogen Highway, it has the same MUTT assumptions as Private Drive, Fleet Street and High Speed. Hydrogen Highway has lower VOCs than Fleet Street and High Speed and therefore, users in Hydrogen Highway are willing to travel a larger distance per trip in Hydrogen Highway, due to this decrease in costs, than in Fleet Street and High Speed.

Slow Lane is a mix of the Dead End and Fleet Street and the distance users are willing to travel is between the distance Dead End and Fleet Street.

Overall, due to the differences in out-of-pocket costs and time costs, urban users are willing to travel the largest distance per trip under Private Drive.

This is followed in order of reducing distance, Hydrogen Highway, then Fleet Street and High Speed, then Slow Lane and then Electric Avenue when compared to Dead End.

All rural region scenarios increase the distance individuals are willing to travel compared to Dead End, as seen in Table 2.6. The two differences between the urban and rural scenario are the parking costs and average speed of travel. In the urban regions, the change in VOCs, parking costs and flag fall costs are the main drivers of the total distance consumers are willing to travel per trip between different scenarios. While in the rural regions, as there are no parking costs (Table 2.3), the change in VOCs, flag fall costs and MUTT (Table 2.4) are the only drivers of the total distance consumers are willing to travel per trip between different scenarios.

For example, in Dead End, urban users are willing to travel 2 kilometres to a primary or secondary school while regional users are willing to travel 6 kilometres to a primary or secondary school. This difference is due to the larger budget for travel costs regional users have when compared to urban users. The VOCs for each critical infrastructure is higher in rural regions compared to urban regions, due to the higher average speeds for regional users (Table 2.3).

For the Fleet Street scenario, urban users are willing to travel 6 kilometres to a primary or secondary school in one trip, while regional users are willing to travel around 2 kilometres to a primary or secondary school in one trip. Urban users are willing to travel further using this electric, driverless, shared on-demand vehicle service due to the savings in their out-of-pocket cost. This is because for urban users, the savings in the parking costs outweigh the flag fall cost. Regional users do not initially incur this parking cost and therefore, the flag fall cost actually increases their out-of-pocket cost under Fleet Street, reducing the distance they are willing to travel.

Table 2.6: Distance willing to travel per trip (km) in rural regions

	Scenario (rural)					
	Dead End	**Electric Avenue**	**Private Drive**	**Fleet Street & High Speed**	**Hydrogen Highway**	**Slow Lane**
Train/tram station, primary and secondary school	6.25	9.08	15.39	1.84	10.12	5.97
Hospital	12.50	18.16	30.78	10.66	20.23	13.81
Activity centre	18.75	27.23	46.18	19.48	30.35	21.65

Due to the differences in the out-of-pocket costs and time costs, regional users are willing to travel the largest distance per trip under Private Drive. Followed, in order of reducing distance, by Hydrogen Highway, Electric Avenue, Slow Lane, Dead End and then Fleet Street and High Speed.

Overall, the likely implications for this expanded willingness to travel are:

- Increased access to critical infrastructure that were not accessible before (modelled and discussed in further detail in Section 2.3);
- Increased choice set of transport options (as other forms of transport choices such as ZEVs and AVs become available within the individuals' budget constraint);
- Increased financial savings from a lower out-of-pocket costs (if individuals travel the same distance as before); and
- Increased utility from time savings from lower MUTT (if individuals travel the same distance as before).

These potential outcomes are explored in detail in Section 2.1.2. However, the transition to these outcomes will depend on socio-economic factors, discussed in the following section.

2.1.2 Take-up rates AVs, ZEVs and Shared Ownership models

2.1.2.1 Literature review

To assess if there would be any differences in access to ZEVs and AVs, a range of studies relating to preferences for ZEVs, AVs, dynamic ride sharing (DRS)[10] and car sharing by various socio-economic groups were reviewed.

The studies measure either the individuals' stated or revealed preferences. As these vehicles and technologies have not yet reached mass adoption anywhere, some studies use hypothetical scenarios to capture the individuals' potential for adoption using their stated preferences, while other studies collect data from the actual users of these vehicles to analyse the individuals' real-world revealed preferences for adoption.

From these studies it was found that, in general for ZEVs, those who are most likely to take up electric vehicles (EVs) initially are older, well-educated people with high income and an interest in environmental issues. The characteristics of the individuals who are most likely to first adopt AVs show mixed results depending on the scope of study, however, most studies highlight that AVs would extend the vehicle market to non-driver groups. The individuals who would engage in DRS were on average younger and used public transport more.

Zero emissions vehicles (ZEVs)

Liao, Molin, & van Wee (2017) review various EV adoption studies that use stated preferences. In total, they reviewed 26 studies from various countries. The authors found that the characteristics of the vehicle and the socio-demographic characteristics of the individual had the strongest influence on EV adoption. Attributes of the EV such as low purchase and operating costs, long driving ranges and short charging time are positively associated with an increased preference for EVs.

While the overall socio-demographic factors (of age, income, education level, household composition) are usually found to be a significant factor for EV adoption, the direction of this effect varies from study to study. For example, the authors found that two studies showed a significant positive effect of being male on EV preferences, while another three studies showed a significant negative effect of being male on EV preferences. All studies that included the factor of pro-environmental attitudes found it to have a significant positive effect on EV preferences.

The CSIRO conducted a survey of 2,101 Victorian car owners on their stated preferences towards EV adoption (Gardner, Quezada, & Paevere, 2011). They measured a range of demographic and attitude indicators to characterise the type of individuals more likely to adopt EVs and also identify barriers to uptake. The study found that demographic factors were slightly related to potential EV uptake. Those who have emissions related behaviours (such as solar panels), higher levels of education and younger are more likely to adopt EVs as seen in Chart 2.1.

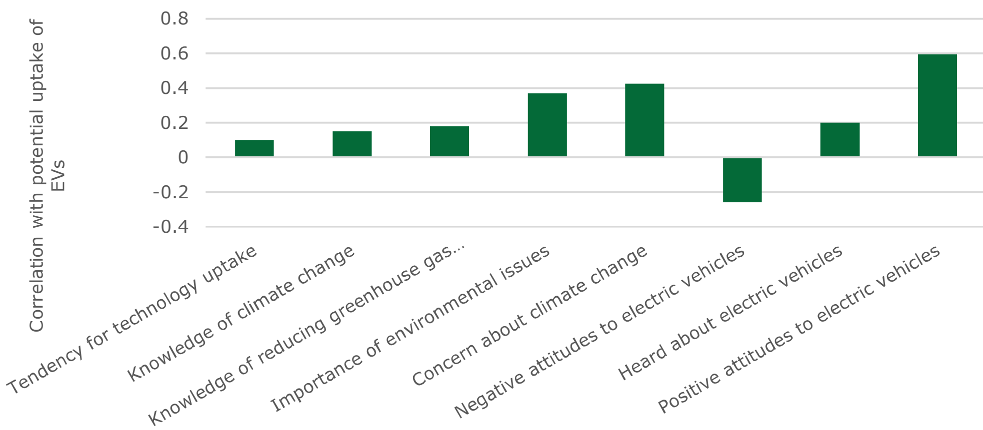
The study found that the individuals' attitudes and beliefs has a more significant effect on uptake of EVs. Those who have positive attitudes to EVs, are concerned about environmental issues and have a tendency to adopt new technology are more likely to adopt EVs as seen in Section 2.1.2.

[10] Dynamic ride sharing (DRS) refers to where rides for individuals are matched on a trip-by-trip basis through an automated process (Hall & Qureshi, 1997).

However, a key limitation of this study as noted by the authors is the self-reported and hypothetical nature aspects of the data. The authors hypothesized that in actual EV adoption, the pragmatic issues of income and need for vehicle replacement might have increased predictive power.

Chart 2.1: Relationship between demographic measures and potential EV uptake (Gardner, Quezada, & Paevere, 2011)

Chart 2.2: Relationship between psychographic measures and potential EV uptake (Gardner, Quezada, & Paevere, 2011)



California is one of the most advanced and competitive EV markets in the world. Major companies often first launch their new EV models in California and it has a relatively advanced EV infrastructure with high amounts of charging stations (ESAA, 2013). A survey sampled 2,039 of California's plug-in electric vehicles (PEVs) owners in 2012. It found that these adopters were on average older (almost 75% were over 45), had higher levels of income (47% had an income of $150,000 compared to the usual 15% of conventional vehicle buyers) and had higher levels of education (52% had a postgraduate degree) (California Center for Sustainable Energy, 2013).

Of all the PEV owners, 94% stilled owned a conventional car. The survey also concluded that the potential to recharge at home was important as 90% of PEV owners lived in a detached home. The study found that biggest motivation for PEV owners was the environmental benefits and energy independence.

Table 2.7: Comparison of Clean Vehicle Rebate Project (CVRP) Consumer Survey Results in 2012 and 2015 (California Center for Sustainable Energy, 2013; California Clean Vehicle Rebate Project, 2016)

Year	2012	2015
Number of vehicles	2,039	91,085
% over 45 years old	75%	62%
% over $150,000 annual income	47%	50%
% with postgraduate degree	52%	49%
% lived in detached home	90%	81%
Main motivation for purchase	Environmental benefits and energy independence	Saving money on fuel costs and environmental benefits

Table 2.7 compares how the household demographics of these PEV owners changed over time. There has been a very large increase in the number of vehicles from 2015. The average age of the owner decreased a little from the increased owners who are 25 to 34 (3% of PEV owners in 2012 compared to 11% in 2015).

However, the age bracket with the highest ownership remains as 45 to 54 year olds (32% in 2012 and 29% in 2015). The demographic proportions for income and education also remain relatively stable. There is a large decrease in the proportion of PEV owners living in a detached home in 2015, which could be due to reduced need for recharging at home from increased public/work-place charging infrastructure. In 2015, while environmental benefits are still a main motivation for PEV owners, the cost savings from fuel cost has become the most important motivation for most PEV owners.

An AECOM report (2011) for the Australian Energy Market Commission also concluded that the early adopter of EVs would be similar to the adopters of the hybrid EVs. These individuals on average are older, have higher levels of income, higher levels of education and above-average technological skills.

Similarly, a Deloitte (2015) report found that EV owners generally have high levels of education, represent the middle or upper class and tend to see themselves as environmentally conscious and tech savvy. The Deloitte (2015) report also found that the first adopters of EVs are very sensitive to government incentives, cost to battery charging and fuel efficiencies.

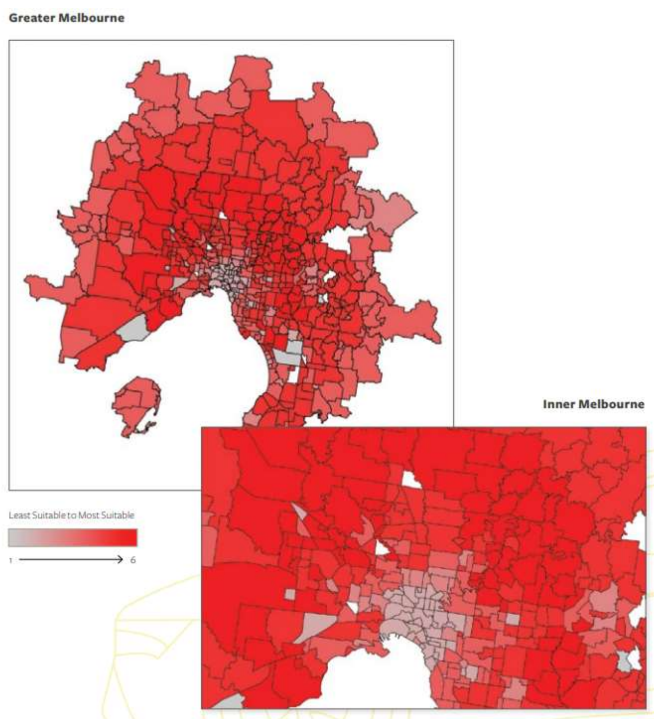
Aside from the socio-economic factors of the individual, other factors such as the overall suitability of the suburbs for EV adoption might result in a differential rate of uptake of EVs. The Energy Supply Association of

Australia (ESAA) conducted a study on the suitability of Australian suburbs for EV adoption (ESAA, 2013). They used factors such as the distance from the CBD, access to garage parking and vehicle ownerships to rate each suburbs' suitability. The study scored suburbs higher for suitability if the suburbs:

- Were closer to the CBD due to the current limitations on the driving range of EV technology;
- Had high proportion of houses with access to garage parking as a proxy for recharging capacity; and
- Had high proportion of households with two or more vehicles as it gives the adopters alternative forms of transport (ESAA, 2013).

Figure 2.1 shows the map of their suitability rating. The study found that within Melbourne, the suburbs of Balwyn North, Derrimut, Greensborough, Ivanhoe East and Point Cook were most suitable for EV adoption.

Figure 2.1: Suitability of suburbs for EV adoption



Source: ESAA 2013

Autonomous vehicles (AVs)

With developments in companies such as Tesla, Waymo (Google's self-driving car) and Uber, AVs are appearing closer to fruition. However, current AV technologies restrain AVs to operating in around 90% of road conditions (Litman, 2018). Litman (2018) also predicts that SAE Level 4-5 AVs will not be commercially available until the 2020s. Subsequently, within this report, only stated preferences are used to model the differential adoption of AVs by different socio-economic groups.

Litman (2018) predicts that AVs will provide mobility independence for non-drivers, such as the elderly, youths, individuals with disabilities and individuals who cannot drive. AVs will directly benefit this group by improving their independence in mobility and likely increasing access to education, employment and certain services. The individuals around this group (such as family, friends and carers) will also indirectly benefit, as they will have reduced chauffeuring responsibilities due to AVs.

Sun et al. (2017) review existing AV studies, summarising aspects of the AVs, their implications for road infrastructure, public attitudes and policy implications, with an emphasis on the Australian context. They find that Australians on average had the highest level of positive opinions regarding AVs when compared to individuals from the US and UK.

The study identifies that AVs will increase mobility for currently disadvantaged non-driver groups, such as the elderly and those with driving impairing disabilities, and that different areas will benefit from different types of AVs. For example, high density urban areas may benefit from high-tech buses capable of platooning, while low density suburbs may benefit more from shared AVs or on-demand public transport feeder services. Concerns regarding AVs range from uncertainty in the competencies of AVs, risk of crashes with non-AV participants, system and data security, and loss of the joy of driving.

Daziano, Sarrias & Leard (2017) estimate the willingness to pay (WTP) for AVs using stated preferences from 1,260 US participants. They find that, on top of the vehicle price, the average household WTP is USD$3,500 for partial automation and USD$4,900 for full automation. Notably, they estimate significant variation in the preferences for automation, with certain groups having a WTP of over USD$10,000. This high WTP group is classified by high levels of education, vehicle ownership, driving long distances and knowledge of the Google car, and are more likely to be early adopters of AVs once they become commercial available.

Preliminary findings from a national survey of public opinions on AVs found that out of 5,263 participants across all of Australia:

- No significant differences between genders on (WTP for AVs;
- Respondents in Victoria were third most willing to pay after South Australia and the ACT;
- A small positive correlation between age and WTP; and
- The majority agreed that AVs would allow mobility for people with impairments or restrictions (40% strongly agreed while 42% somewhat agreed) (Regan, et al., 2017).

A KPMG report (2012) argued that particular groups might be less receptive to AVs. Individuals who are very attached to the driving experience such as car enthusiasts and baby boomers (who might equate cars with personal freedom and identity) would be less likely to adopt AVs. While younger generations less attached to driving and more receptive to new technologies are more likely to be early adopters of AVs.

The Australian and New Zealand Driverless Vehicle Initiative (ADVI) reported that out of 10,000 survey respondents, 39% said they would consider AVs while this figure increased to 62% for younger individuals (O'Connor, et al., 2017). Recently, younger individuals in Australia are less likely to obtain a driver’s licence and seem to be less influenced by the status from vehicle ownership (Sun et al., 2017).

Dynamic ride sharing (DRS) and car sharing

While ride sharing was first introduced in the 1940s in the form of carpooling as a rationing tactic for the war effort, it has been continually used as a cheaper and more environmentally friendly way to travel (Oliphant & Amey, 2010). The development of technology led to DRS, where one time carpooling services can be arranged on short notice.

Wang (2007) used the travel patterns of individuals living in Melbourne and found the characteristics of those who are more likely to adopt DRS have below average income (less than $699 a week), employed in clerical, sales and service industries and used public transport or non-motorised modes for going to work. While 20% of individuals who had higher income or worked as managers and professionals still adopted DRS, Wang explains that this group had cars being offered as salary packages.

An online survey of 435 Australian residents found that the cost, time of travel and waiting time were significant predictors for adoption of DRS (Krueger, Rashidi, & Rose, 2016). They found that shared AVs with DRS were more likely to be adopted by younger individuals, current ride sharing individuals and individuals who use multiple modes of transport.

Instead of ride-sharing, customers can also choose to share ownership and/or access to vehicles. The carpooling market in Europe has been quite substantial for a few decades. Using survey and GPS data from the German *DriveNow* free floating car-sharing service (similar to *GoGet*), Kopp, Gerike & Axhausen (2015) contrasted the core group of DRS users with non-car-sharer (NCS). They found that DRS users using *DriveNow* had a distinct profile, on average:

- Were between 25 and 45 years old;
- Lived in high density urban areas;
- Had above-average incomes (40% of DRS users earned more than €4,000 per month, compared to 24% of NCS);
- Had higher levels of education (70% of DRS users held a university degree or PhD compared to 41% of NCS);
- Were carless (50% of DRS users were carless compared to 16% of NCS); and
- Had better access to public rail-based stations from their home.

The study also found that DRS users reported more trips of shorter distances and used various different modes of transport than compared to NCS.

2.1.2.2 Rate of adoption by different income groups: modelling inputs

To compare the changes in access to services, the likely adoption rate of the vehicles under each of the scenarios over time was modelled.

The literature review found various factors affecting the differential adoption rates of ZEVs, AVs and DRSs by different socio-economic groups (see Section 2.1.2). Overall, it was found that the factors of age, education, income and concern for the environment are significant factors related to preferences for or actual adoption of ZEVs, AVs and car or ride sharing.

When choosing which of these factors to model, the differential uptake age was not appropriate as the effect of age on adoption varied between different studies. For example, the California Centre for Sustainable Energy (2013) found age to be positively correlated with actual adoption of EVs, while CSIRO (2011) age to be negatively correlated with preferences for adoption of EVs. Income was chosen as the major factor in modelling the differential uptake, as it was found to be a positive and significant factor that affects adoption rates in most studies. It should be noted that the opposite was found for DRS, income was found to be negatively correlated with DRS use. However, the positive relationship between income and adoption is consistent under car sharing.

The level of education, level of income and concern for the environment positively influences preference or actual adoption of ZEVs, AVs and car or ride sharing. Concern for the environment was not used due to the subjectivity of this measure and lack of availability of this measure in major data sources.

Income was chosen over education as the major factor for uptake as it captures both the consumer dependent aspects of adoption (preference of high-income individuals), but also partially captures the vehicle dependent aspects (ability of high-income individuals to buy these vehicles). While ZEVs are commercially available, there is still a price premium on ZEVs compared with the current internal combustion engine vehicles (CSIRO, 2011). Therefore, in practice individuals with higher levels of income have a higher probability of being able to actually afford these vehicles compared to lower income individuals.

As the technology for AVs is still not commercially available, there is likely to be an initial price premium when AVs are first introduced. This means that higher income households are more likely to be able to afford these technologies initially. Finally, income and education are generally highly correlated with each other.

Final take up rates were based on broad assumptions provided by IV and assumed a linear take up in the overall population, with take up starting initially in 2019. These assumptions are in line with other work streams being undertaken by IV.

Table 2.8: Five adopter categories by income group

Adopter Classification	Annual Income	Percentage (%)[11]
Group 1: laggards	$1-$15,599	14%
Group 2: late majority	$15,600-$33,799	30%
Group 3: early majority	$33,800-$77,999	37%
Group 4: early adopters	$78,000-$155,999	15%
Group 5: innovators	$156,000 or more	4%

[11] The percentages here do not exactly align with the percentages in Figure b.1 due to limitations in the ABS data used. As the ABS data classifies individuals into different income groups, the income groups used here are a combination of these groups and therefore, this model could not divide individuals into each income group exactly, but only match the percentages in each group as closely as possible.

To simplify the modelling, the full range of ABS income groups were grouped into five categories based on the distribution of the five adopter categories discussed in Box 1, below. Table 2.8 shows the specific classifications, their average annual income and their percentage of the overall population.

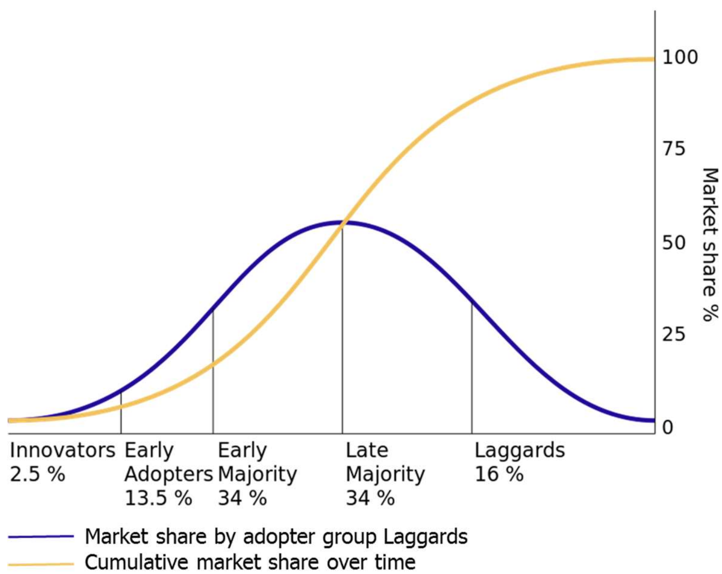
Box 1: Diffusion of Innovation

Diffusion of Innovation

Not everyone will adopt innovation at the same time. In Rogers' Diffusion of Innovation Theory, he defines diffusion as "the process in which an innovation is communicated thorough certain channels over time among the members of a social system" (Rogers, Diffusion of innovations, 2010, p. 34). Rogers classifies the rate individuals adopt an innovation by five adopter categories – the innovators, early adopters, early majority, late majority and laggards as seen in Figure 2.2.

The adopter category can be typically characterised by the willingness to take risks, level of social status, financial liquidity and level of contact/interaction with the source of the innovation. The innovators typically have high levels of these characteristics while the laggards have low levels of these characteristics (Rogers, 1962).

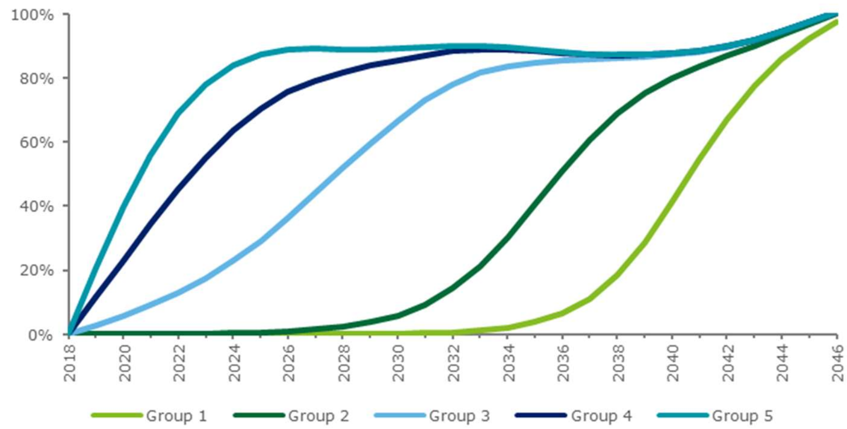
Figure 2.2: Rate of diffusion by categories



Source: Rogers 1962

Different adoption rates were estimated for each adopter group based on the assumption that the high-income groups would adopt the vehicles earlier and at a faster rate than the low-income groups. Chart 2.3 shows the adoption rate for Electric Avenue, Private Drive, Fleet Street, Hydrogen Highway and Dead End over time for the five groups of technology adopters. Table 2.9 shows the take up rates for 2031 and 2046.

Chart 2.3: Take up rate over time for all scenario (aside from High Speed and Slow Lane)



Source: Deloitte Access Economics 2018

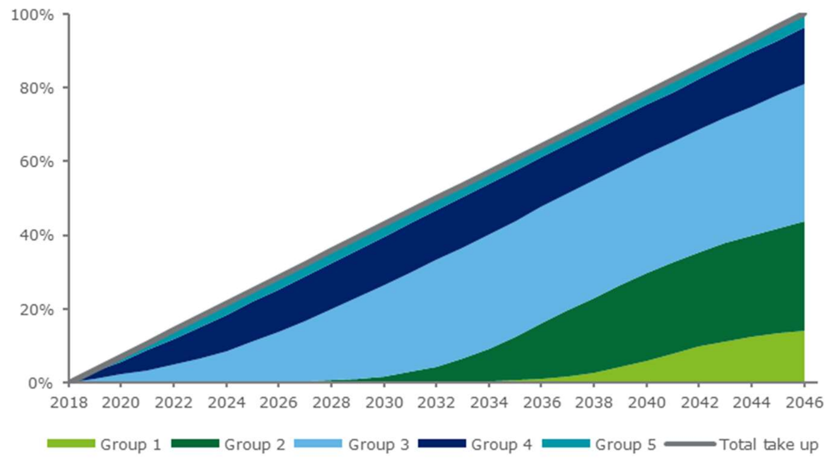
The take up rate for each group over time was fitted by imposing the constraint that the high-income groups would reach 100% adoption at a faster rate than the low-income groups. This can be seen in Table 2.9 where in 2031, nearly 50% of the population has adopted the technology; however, it is distributed unevenly across the different groups as 90% of Group 5 has adopted the technology compared to only 0% of Group 1.

Table 2.9: Take up rates by group for all scenario (aside from High Speed and Slow Lane)

		2031	2046
Total take up		46%	100%
Take up rate within each group	Group 1	0%	100%
	Group 2	9%	100%
	Group 3	73%	100%
	Group 4	87%	100%
	Group 5	90%	100%
Take up rate at the population level	Group 1	0%	14%
	Group 2	3%	30%
	Group 3	27%	37%
	Group 4	13%	15%
	Group 5	3%	4%

The total take up is based on the assumption of a linear take up of the technology over time in the overall population, as shown in Chart 2.4, as well as ensuring that the differing adoption rates within each group always reconciled to the total take up rates at the population level and the total state wide take-up rate.

Chart 2.4: Population level take up of AVs by group for all scenarios (excluding Slow Lane)



Source: Deloitte Access Economics 2018

High Speed used the same approach, but with full adoption reached in 2031 instead of 2046. Slow Lane assumed only 50% adoption by 2046. To reflect the different take up rates by different socio-economic groups, the adopters were not evenly spread across all income groups. Instead, under Slow Lane in 2046, the 50% of adopters of the shared electric AV is made up by 100% of Group 5, 100% of Group 4, 83% of Group 3 and 0% of both Group 2 and 1.

While there are already ZEVs on the road, the technology needed for Level 4 or 5 AVs is currently unavailable. While many vehicle manufacturers have deployed level 1 or 2 vehicles with features such as cruise control and automated parking, most companies are still pilot testing level 3 and 4 AVs (Litman, 2018).

Predictions for timing of availability of level 4/5 AVs varies considerably depending on the source, with IAG (Carsales Network, 2018) predicting that AVs may not be commercially adopted within the Australian market until the 2030s, while Litman (2018) optimistically predicts that they will be available in the 2020s, with a large price premium. However, as a simplifying assumption it is assumed that AVs will be available for adoption in 2019 and will have a linear take up over time.

2.1.2.3 Inequality in adoption of ZEVs and AVs

The literature review revealed that individuals with higher incomes and more education are more likely to adopt ZEVs and AVs, which implies the modelling approach is likely to incorporate an inherent inequality in uptake.

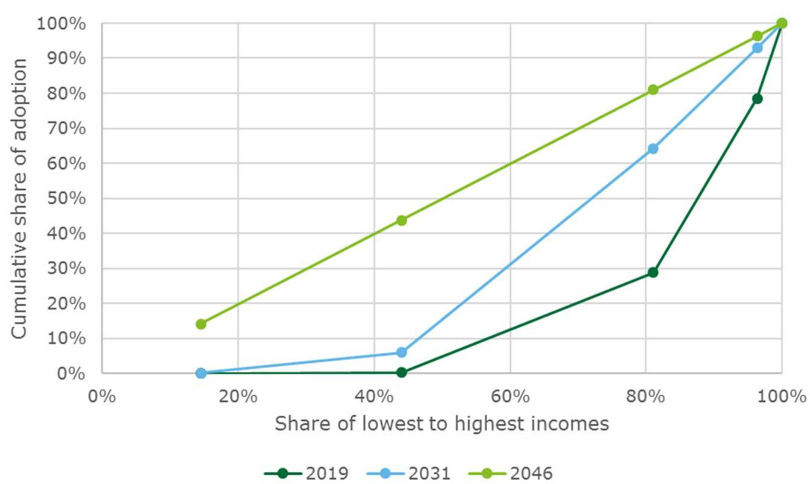
This inequality in outcomes can be summarised using a Lorenz Curve (Figure 2.3), which shows the unequal adoption of this technology over time by different income groups.

By 2046, the modelling shows all individuals with access to ZEVs and AVs, which is represented by the 45-degree line, i.e. perfect equality. This can be contrasted with the period of transition where highly unequal outcomes are seen.

For example, in 2019, the two lowest income groups make up 44% of the population but are modelled to account for 0% of the overall stock of ZEVs and AVS. By 2031, this is slightly improved so that the second lowest income group has some uptake but the lowest income group remains with no uptake.

In these transition years, the top income groups disproportionately account for a larger share of ZEV and AV users. However, this inequality lessens over time, represented by the Lorenz curve approaching the 45-degree line.

Figure 2.3: Lorenz curve of modelled ZEV and EV adoption in Victoria (excluding High Speed and Slow Lane)

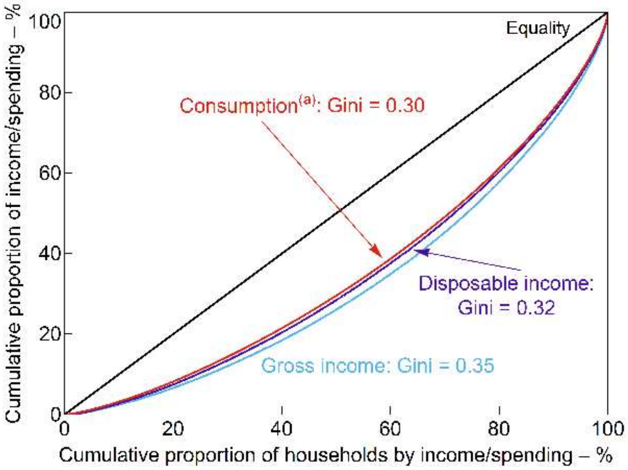


Source: Deloitte Access Economics 2018

Note: due to the low number of income categories used in this analysis a Gini calculation is not likely to provide an accurate estimate.

As a point of comparison, the RBA has calculated Lorenz curves for income in Australia in 2009-10 (Figure 2.4). Notably, these curves are closer to the equality line (compared to the Lorenz curve for ZEVs and AVS), which suggests an expectation for greater inequality in technology uptake and access to services compared to income.

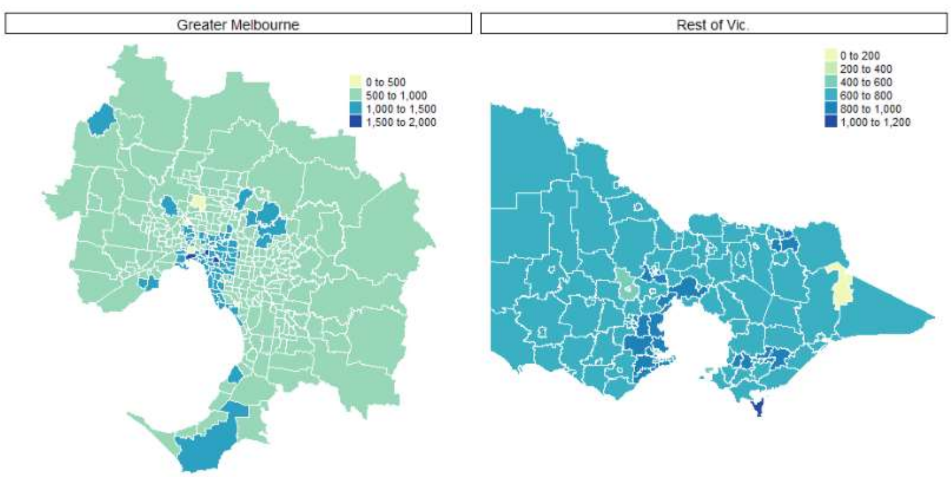
Figure 2.4: Lorenz curve for income in Australia (2009-10)



Source: RBA 2015

Figure 2.5 shows the average weekly income across SA2 regions in Melbourne and the rest of Victoria. Higher income areas are concentrated around the CBD and Greater Melbourne periphery.

Figure 2.5: Average weekly income distribution across Victoria



The implication of this spatial income difference is that, while all areas will reach full adoption by 2046 and enjoy the benefits of ZEVs and AVs, areas with lower incomes are likely to adopt later and subsequently receive the benefits later. This suggests that over the transition period, income inequalities are likely to be intensified.

2.2 Modelling equity and access to services: results

This section provides a summary of the modelling of access to services and how this translates to inequality in outcomes for different socio-economic groups.

The analysis of how access to critical services may change with adoption of ZEVs and AVs is presented in Section 2.2.1. The focus is on access to hospitals, schools and train/tram stations within each SA2, as well as access to activity centres. These activity centres are especially relevant for regional Victoria, where it is assumed that they offer a range of critical services, provide jobs and access to education to the surrounding towns and communities.

An overall measure of access is presented in Section 2.2.1.4, in order to understand inequality in outcomes for different socio-economic groups, including during transition periods.

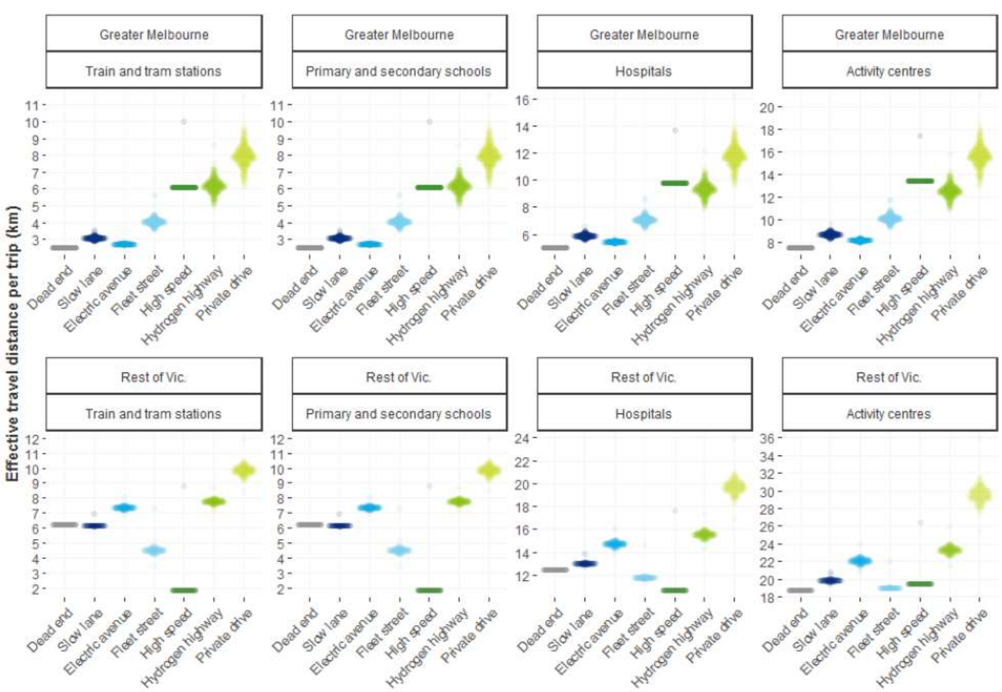
2.2.1 Outcomes in access to services

This section focuses on the first step in measuring equality in outcomes: how access to critical services may change with adoption of ZEVs and AVs.

2.2.1.1 Effective distance travelled by trip purpose and average incomes

The maximum distance that individuals are willing to travel by trip purpose and average incomes (at the SA2 level) in 2031 is shown in Chart 2.5. For all other scenarios (aside from High Speed), 2031 is chosen as a midpoint in the transition to full adoption. High Speed achieves full adoption by 2031.

Chart 2.5: Effective travel distance for trips in 2031



In 2031, as higher income individuals are expected to adopt new vehicle technology earlier than others, there is some variation in acceptable travel distances. This is shown by the vertical spread for each scenario (aside from High Speed). At the top of the spread are SA2s with high levels of income, while at the bottom are SA2s with low levels of income. There is no spread in the effective distances individuals are willing to travel under High Speed in 2031 as all Victorians have transitioned to these new vehicles.

Discrepancy in effective travel distances (i.e., the maximum trip distance individuals are prepared to accept) is expected to be most severe in Greater Melbourne under Private Drive, Hydrogen Highway and Fleet Street. This is led by the take-up of AVs and subsequent reductions in MUTT and out-of-pocket costs of travel.

The reductions in MUTT reflect the assumption that a trip undertaken with a driverless vehicle is more enjoyable compared to a trip with a non-driverless vehicle and hence, the value of travel time is reduced. Higher income groups are more likely to adopt AVs earlier and hence, enjoy lower travel time costs (captured by a lower MUTT) compared to other income groups.

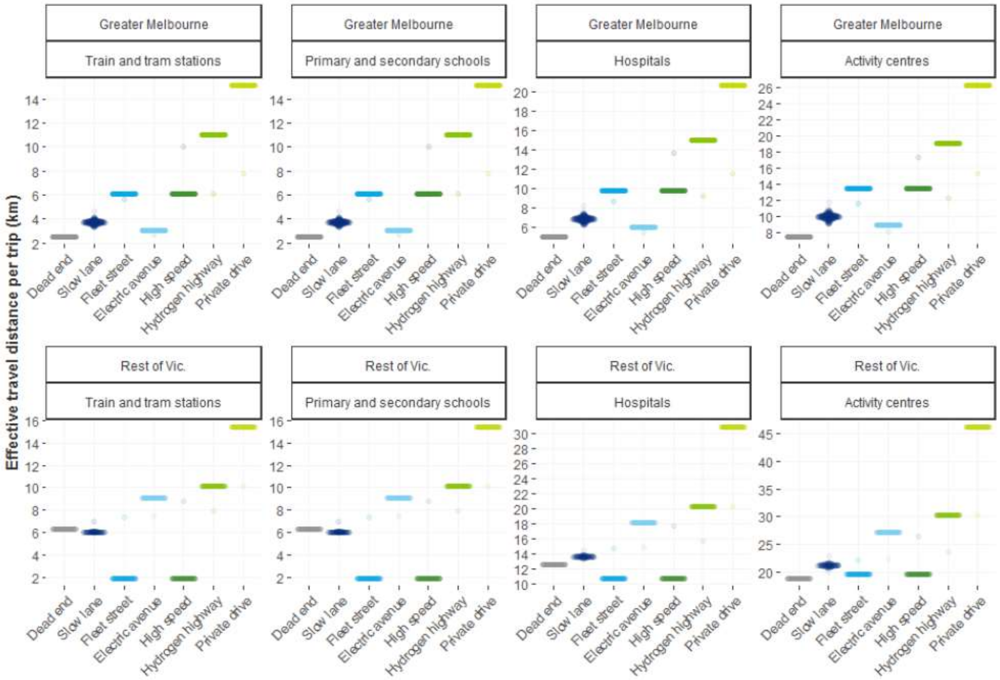
Across regional Victorian areas, the discrepancy in effective travel distances is most severe for Private Drive. Under these scenarios, the savings in the VOCs result in large increases in distances travelled for those with access to the technology. The savings in VOCs in Private Drive reflects the assumption that the operating costs of a private electric AV are less than a non-electric or shared non-driverless vehicle, and hence users are more willing and able to travel further in a single trip. Higher income groups are able to afford the use of acquisition of these vehicles earlier and hence, enjoy lower out-of-pocket travel costs (captured by lower VOCs) compared to other income groups.

There are no discrepancies in effective travel distances under High Speed, as all individuals are assumed to have access to AV fleets and hence enjoy the same level of increase in effective travel distances.

The discrepancy in travel distances seen in 2031 is in contrast to outcomes seen in 2046 (Chart 2.6). By 2046, aside from Slow Lane, the transition to ZEVs and AVs is assumed to have fully occurred and so people living in all SA2s have equal access to new vehicle technologies and experience the benefit of increased travel and access to services. Slow Lane still shows a discrepancy in the effective travel distances as only 50% of the overall population has adopted the technology in 2046.

The overall distances travelled are also greater in 2046 as all residents within each SA2 have access to the vehicle technology, compared to only some portion having access in 2031.

Chart 2.6: Effective travel distance for trips in 2046



Individuals are willing to travel much further due to the low out-of-pocket and time costs per trip under Private Drive. This is shown in Chart 2.6, which reveals significantly higher effective travel distances for users under the Private Drive scenario.

There is considerable variation in effective travel distances across each scenario, which translate to variation in access to critical infrastructure. For example, a well-off SA2 in 2031 is estimated to be willing to travel around 1 kilometre further than a lower income SA2. These effects are further explored in the following section.

2.2.1.2 Change in access to services

This section translates the change in distances travelled into changes in the access of critical services. The location of and distances travelled to critical services are calculated and used to measure how access to these services vary for different socio-economic groups.

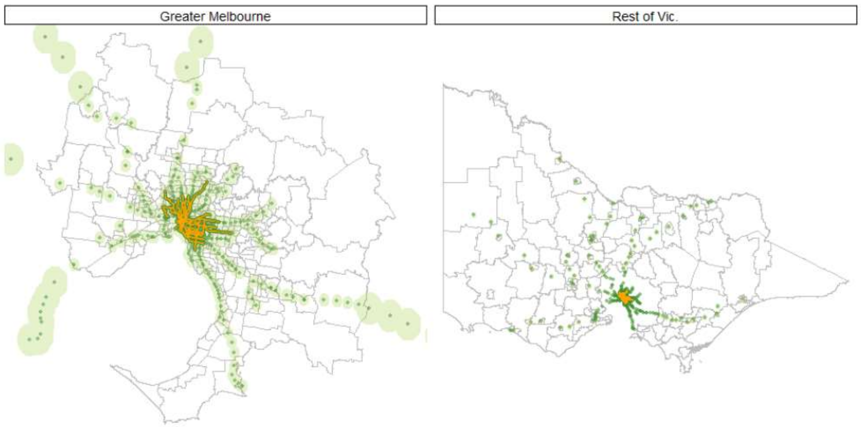
Changes in access to services over time is shown in Figure 2.6. Dark green dots represent train stations, while the orange dots represent tram stations. The green shading then shows the area around each train/tram stop that can be accessed given the modelled costs of available transport. These access to service areas are based on willingness to travel and vary depending on access to different vehicle technologies, which varies by socio-economic group.

While there is currently reasonable coverage for some areas of Greater Melbourne, by 2046, the presence of shared AVs results in more ubiquitous transport coverage in Greater Melbourne due to greatly reduced costs and increased willingness to travel.

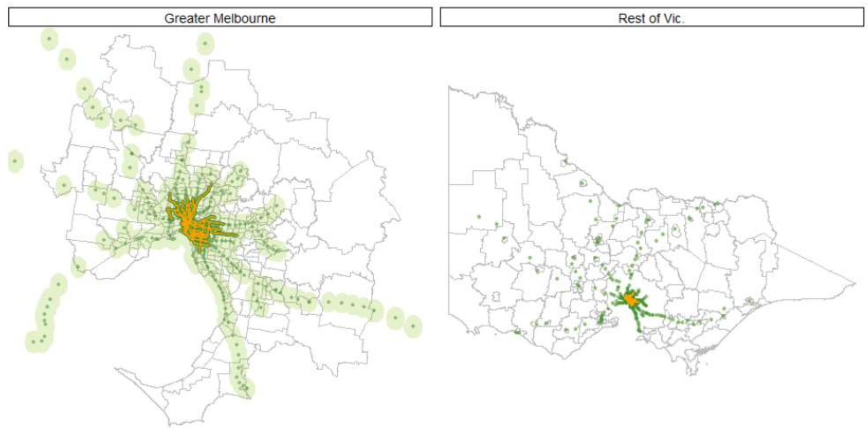
Additional results for multiple types of critical infrastructure, across years and different scenarios are provided in Appendix A. The following section further describes how these catchment zones are translated into access to services and a summary of outcomes is provided at the end of this section.

Figure 2.6: Access to train/tram stations under Fleet Street over time

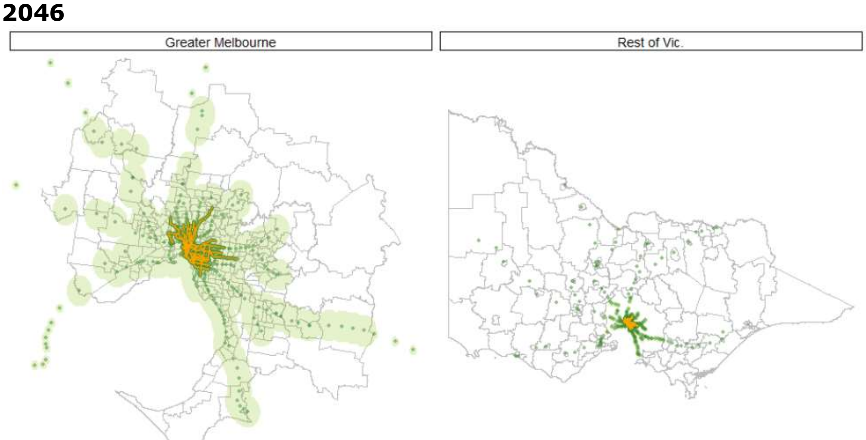
2018



2031



2046



Changes in travel behaviour and catchment areas are likely to vary by different socioeconomic groups and access to ZEVs and AVs. Higher socio-economic areas are more likely to adopt ZEVs and AVs, and hence more quickly expand their catchment areas and access to critical infrastructure.

Varying access to primary schools under Fleet Street modelling is shown in Figure 2.7. These figures show variation in the percentage of the SA2 that has access to a local primary school, using the catchment areas described earlier.

Given the high presence of primary schools, there is already very high levels of access to services in inner Melbourne with most SA2s having coverage of greater than 80% in Dead End. However, on the outskirts of Greater Melbourne, this access to services does decline to be generally in the region of 0-40%. Over time, as ZEVs and AVs are taken up across the city, access to services improves strongly until there is almost 80-100% access to services by 2046.

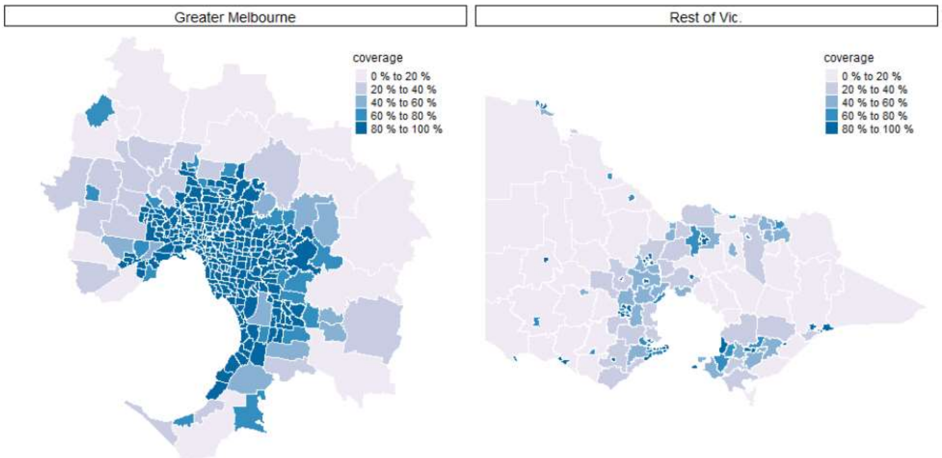
As an example of the type of spatial and socio-economic inequality experienced during the transition, it appears that the outer western suburbs of Melbourne converge faster and closer to full access to services than the outer eastern suburbs do.

Regional areas overall experience reductions in access to services, this is driven by the combination of the significantly lower initial coverage compared to urban areas and the comparatively higher out-of-pocket costs for the shared fleet. The higher out-of-pocket cost is mainly driven by the flag fall cost for each trip.

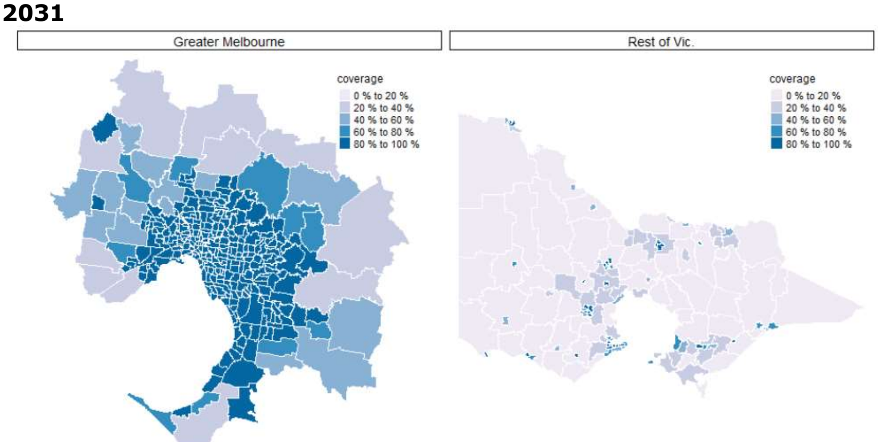
Notably, this modelling focuses on the percentage of land that falls within catchment areas, and does not consider population densities or where individuals reside. This is addressed in the following section.

Figure 2.7: Access to primary schools under Fleet Street over time

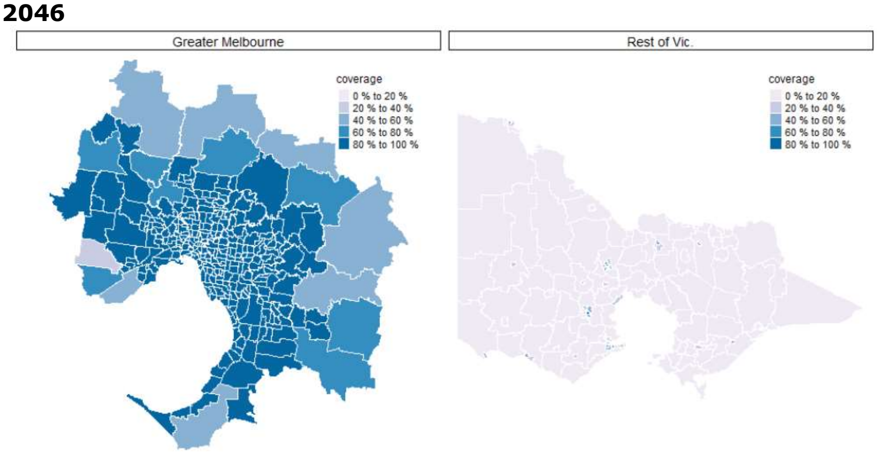
2018



2031



2046



Summary of change in access to services across scenarios

Dead End

Low levels of access to train stations in Greater Melbourne, with coverage being mainly in central Melbourne. Very low levels of access to services in the rest of Victoria due to very low spread of stations in the regional Victoria. High access to services in inner Melbourne due to the amount of hospitals, but low access to services in Greater Melbourne and rest of Victoria. Average access to primary and secondary schools in Greater Melbourne (with high coverage in central Melbourne), low access to primary and secondary schools in the rest of Victoria. Average to high level of access to activity centres in Greater Melbourne but very low access to services in the rest of Victoria due to few activity centre locations.

Electric Avenue

Slight increase in access to train station for some areas in the west and south of Melbourne and west and north of the Victoria by 2046. This is driven by the decrease in VOC of ZEVs, resulting in individuals willing to travel further per trip to access critical infrastructure. Central Melbourne has complete access to hospitals, secondary schools and activity centres in 2031, but the majority of the outer areas in Greater Melbourne do not have high levels of access to services even in 2046. Aside from Melbourne, the rest of Victoria still has low access to hospitals, secondary schools and activity centres in 2046. This suggests either this scenario does not increase users' access to services enough or the location of key services within these areas are too far away.

Private Drive

In 2046, the majority of Greater Melbourne has high coverage aside from some areas in the northeast. Most areas have 80-100% access to hospitals, primary and secondary schools in 2046, aside from some areas located in a few eastern regions of Melbourne. Individuals are willing to travel further per trip due to the decrease in VOC of ZEVs/AVs, the savings in parking costs from AVs and the lower MUTT they have when riding in AVs. Overall, the rest of Victoria has low access to train stations and secondary schools. This is due to the lack of infrastructure and lack of parking costs in regional Victoria. Even though individuals are willing to travel further under this scenario, the lack of train stations in regional Victoria means that individuals living in an area with a train station can benefit from this increased access to train stations. The lack of parking costs in regional Victoria means that these individuals in regional Victoria only benefit from the VOC savings of AVs and lower MUTT from AVs, but they do not benefit from savings in parking costs. There is average access to hospitals and primary schools in the rest of Victoria in 2046. There is very high access to activity centres in Melbourne in 2046, however, there is still overall low access to activity centres in regional Victoria, due to the small number of locations of activity centres.

Fleet Street
Increase in access to train stations, hospitals, primary schools, secondary schools and activity centres in some outer regions in Melbourne by 2046. Individuals in urban areas are willing to travel further due to savings in parking costs from shared AVs. Due to the combination of higher VOCs but a lower MUTT for users of these shared AVs. The access to services of individuals does not increase very much in the rest of Victoria, in the cases of access to train stations, hospitals, primary schools and secondary schools access to services actually decreases compared to Dead End. There is a large difference between access to services in Melbourne and the rest of Victoria under Fleet Street. This is due to the combination of the large savings in parking costs that individuals in Melbourne experience and the large cost of flag fall fees under this scenario. For example, there is near complete access to primary schools in Melbourne in 2046, but low levels of access to primary schools in the rest of Victoria in 2046.

Hydrogen Highway
Due to the similar MUTT, but much lower VOC, Hydrogen Highway results in a relatively higher level of access to key services in the Melbourne and the rest of Victoria. There is an increase in access to train stations, hospitals, primary schools, secondary schools and activity centres in some outer regions in Melbourne by 2046. There is still low access to services in the rest of Victoria to train stations, hospitals, primary school and secondary schools and activity centres in 2046. There is still a difference between access to services in Melbourne and the rest of Victoria as individuals in Melbourne will experience savings in parking costs (and are willing to travel further under Hydrogen Highway) while those in the rest of Victoria do not. In Hydrogen Highway, the difference between access to services in Melbourne and the rest of Victoria is smaller than in Fleet Street, especially for the rest of Victoria, as individuals are willing to travel further per trip due to the low out-of-pocket costs under Hydrogen Highway when compared to Fleet Street.

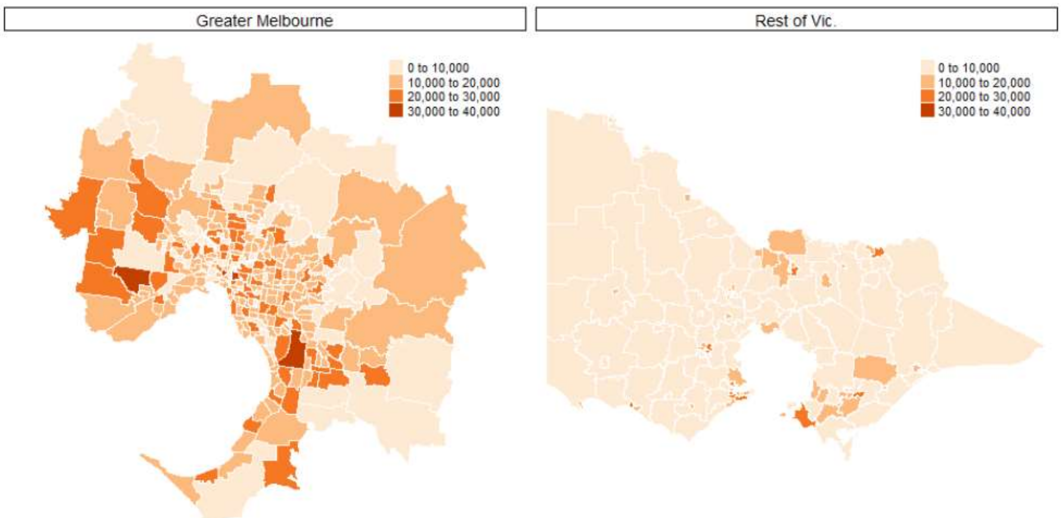
High Speed
Same trend as Fleet Street, however it is achieved in 2031 instead of 2046.

Slow lane
As the Slow Lane has a mix of costs from Fleet Street and Dead End, the results under this scenario for access to services varies. There is low to medium access to trains stations, hospitals, primary schools, secondary schools and activity centres in Melbourne in 2046, with higher levels in locations in inner Melbourne. The access to trains stations, hospitals, primary schools, secondary schools and activity centres in the rest of Victoria in 2046 remains very similar to Dead End.

2.2.1.3 Change in access to services by population covered

This section focuses on the percentage of population within each SA2 area with access to services. This 'population-weighted' analysis is particularly important when considering many areas of regional Victoria that may have very large areas and/or uneven population distributions (see Figure 2.8).

Figure 2.8: Population in SA2 regions across Victoria

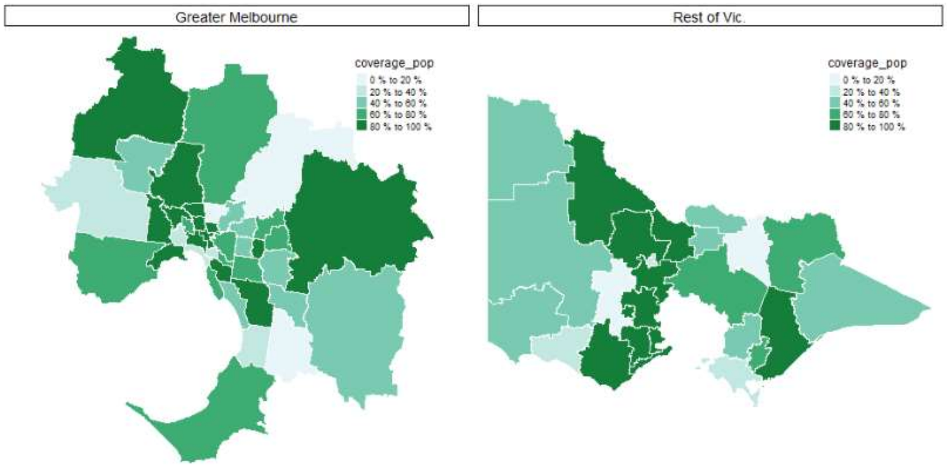


Many regional areas with low population levels are unlikely to be able to support some of the services of interest in this report. Consequently, the analysis is conducted at a larger SA3 level using a weighted access to services by population for each SA3 within a given SA3.

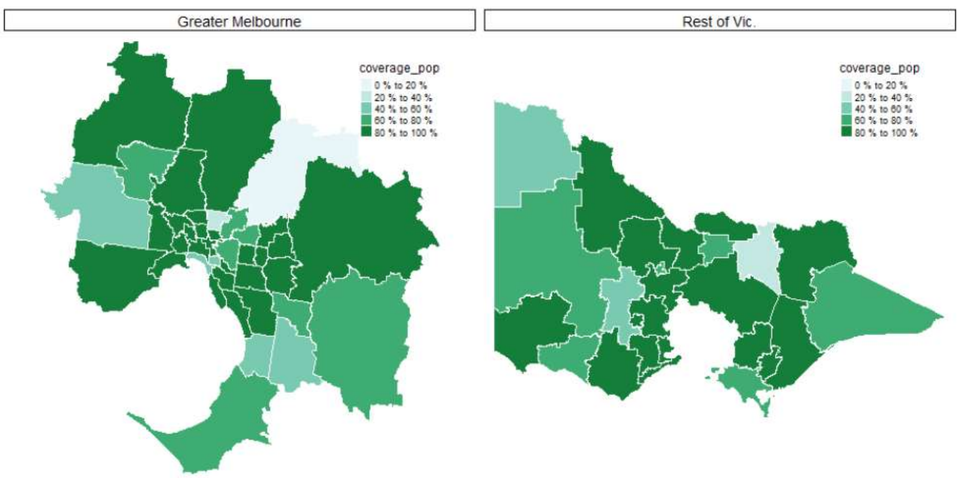
An example of this aggregated measure is shown in Figure 2.9 for access to hospitals under Private Drive. The figures suggest a greater increase in access to services, as compared to the previous land-only coverage measure. This suggests that there is a greater increase in access to services in more heavily populated areas. Further details and results are provided in Appendix A.

Figure 2.9: Population access to hospitals under Private Drive over time

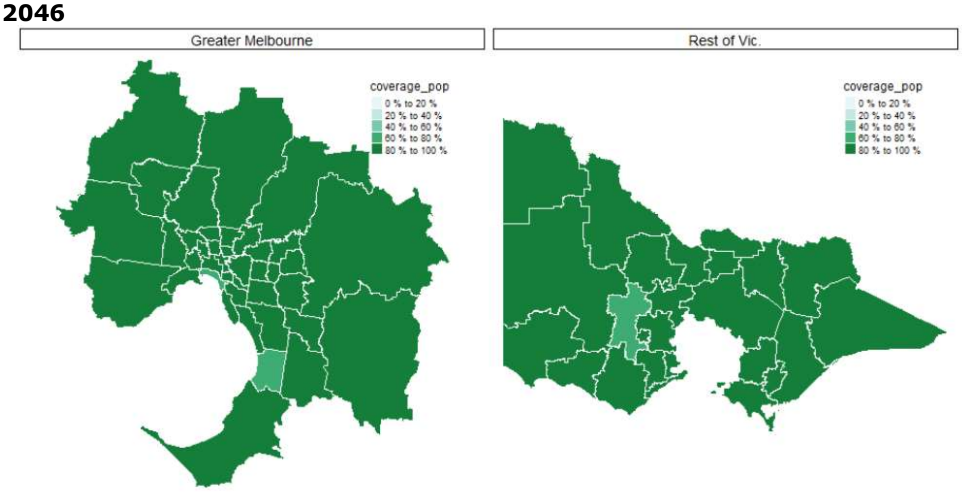
2018



2031



2046



Summary of change in access to services (population weighted) across scenarios

Dead End
High percentage of regions in the north-west and east of Greater Melbourne have access to train stations and secondary schools. The access varies for the south and west of Greater Melbourne. The rest of Victoria has medium levels of access to train stations and secondary schools, with less coverage in the western and eastern regions of Victoria. There is a high coverage of the population with access to primary schools in both Melbourne and Victoria. There is a varying amount of coverage of the population to hospitals and activity centres in the rest of Victoria, with high coverage being in certain central regions.

Electric Avenue
A small increase in the percentage of population with access to train stations, hospitals, secondary schools and activity centres in some areas with originally low coverage in both Greater Melbourne and the rest of Victoria. This is driven by the decrease in VOC of ZEVs, resulting in individuals willing to travel further per trip to access critical infrastructure. However, there are still many areas in both Melbourne and the rest of Victoria with quite low coverage even in 100% adoption in 2046.

Private Drive
The majority of the population has very high levels of access to the key services in Melbourne and the rest of Victoria by 2046. Individuals are willing to travel further per trip due to the decrease in VOC of ZEVs/AVs, the savings in parking costs from AVs and the lower MUTT from riding in AVs. However, there still exist a few areas with very low coverage in 2046. For example, due to the low level of activity centres in specific areas, there are populations near central Melbourne and regional areas on the periphery of Greater Melbourne that have 0-20% coverage of activity centres.

Fleet Street
Coverage of the population with access to train stations, hospitals, secondary schools and activity centres is very different across the regions in both Melbourne and the rest of Victoria. Regions in the north and east of Melbourne have increased access to services, while some regions in Melbourne actually see decreased access to services. There is a similar trend for the rest of Victoria, where regions close to Greater Melbourne experience an increased coverage of the population, and some specific regions (with either low levels of services or low levels of population) experience decreased coverage of the population.

Hydrogen Highway
There is a moderate increase in the coverage of the population with access to train stations, hospitals, secondary schools and activity centres in the low access areas in Melbourne and the rest of Victoria by 2046. As Hydrogen Highway has much lower out-of-pocket costs than Fleet Street, individuals are willing to travel further under Hydrogen Highway due to these cost savings. A few specific regions in Melbourne and the eastern and western regions of Victoria still has low to moderate coverage of the population with access to the key services.

High Speed
Same trend as Fleet Street, however it is achieved in 2031 instead of 2046.

Slow lane
As the Slow Lane has a mix of costs from Fleet Street and Dead End, the results under this scenario for access to services varies. There are slight increases or decreases in the coverage of population with access to key services. Even after these changes, the percentage of the population that has access to train stations, hospitals, secondary schools and activity centres still vastly varies across different areas in Melbourne and the rest of Victoria.

2.2.1.4 Overall findings on access to services

Under each of the scenarios, the adoption of the ZEVs and AVs increased effective distances travelled. This increase in distance travelled translated in improved access to various critical services, including train/tram stations, hospitals, primary and secondary schools and activity centres.

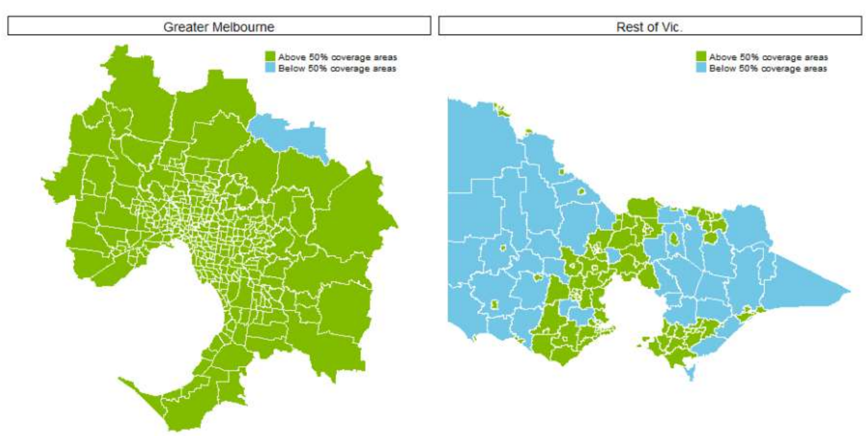
By 2046, Private Drive had the largest increase in access to services, followed by Hydrogen Highway, then Electric Avenue, Slow Lane and then Fleet Street (same increase as High Speed).

During the transition process, the increase in access to services differs by socio-economic background and between regions. As higher income individuals are expected to adopt these new technologies earlier and at a faster rate, they are the first group to benefit from the increased access to services.

Geographically, faster improvements in access were observed in the western areas of both Greater Melbourne and regional Victoria, compared to the eastern areas. Using the population coverage, the greatest improvements in access to services was observed in high population areas.

While there is an overall improvement in both geographical and population coverage, even after full adoption is achieved in 2046, there remain regions with low access to critical infrastructure, even under Private drive, which resulted in the largest overall increase in access (see Figure 2.10). These areas are predominately larger regions and are characterised by being further away from areas of dense population.

Figure 2.10: Areas of high and low overall access to critical infrastructure in 2046 under Private Drive



2.2.2 Inequality in outcomes

This section analyses the relationship between changes in access to services (as discussed in the previous section) to income levels. This provides a view of how differential adoption of ZEV and AV technologies may lead to inequality during transition.

2.2.2.1 Overall increase in access to services at the state level

Before considering inequality in outcomes during transition, an important point to note is that the introduction of ZEVs and AVs has benefits for access to services overall – regardless of income group.

The overall benefits of the introduction of ZEVs and AVs can be seen in Chart 2.7 and Chart 2.8, which show a summary measure of population weighted coverage in 2031 and 2046 at the state level. Coverage is first calculated by taking the proportion of the catchment area around each critical infrastructure (e.g. a train station) for each SA2.

As there are many small SA2s in the Melbourne metropolitan area with high population densities, a simple average of coverage areas across SA2s is likely to over-weight areas with higher population densities. Therefore, the coverage is weighted by population before taking the average of SA2 coverages.

Chart 2.7: Population weighted coverage in 2031

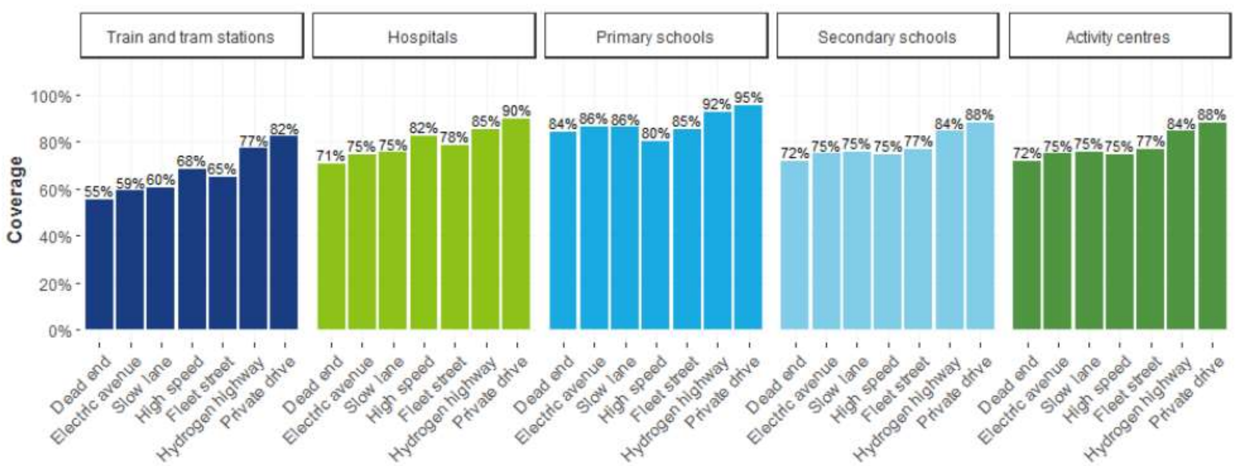
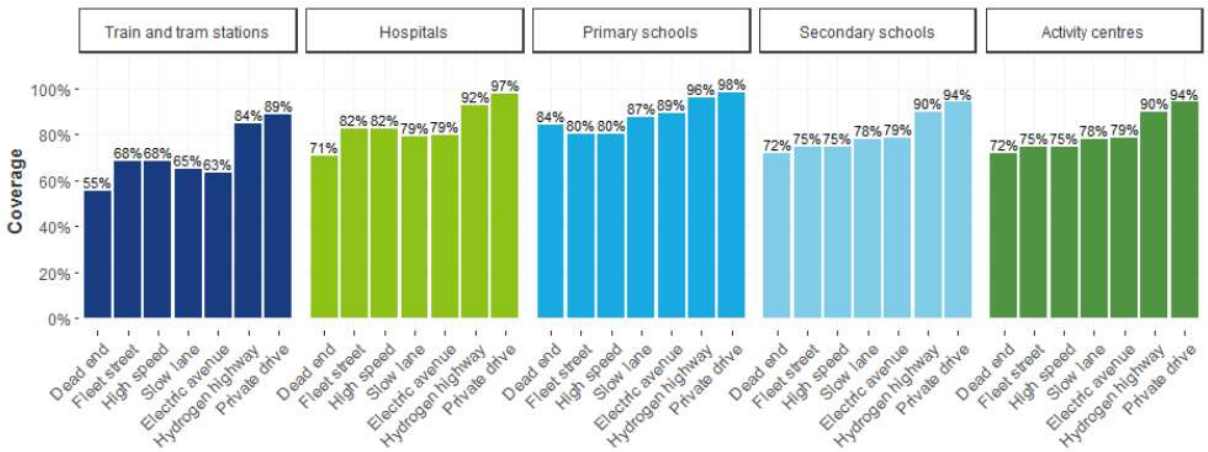


Chart 2.8: Population weighted coverage in 2046



Under each scenario and for each type of critical infrastructure, the level of access to services is higher in 2031, indicating that ZEVs and AVs have improved access to services overall (Chart 2.7). Private Drive and Hydrogen Highway increase the level of access to services the most by 2031.

The modelling uses 2031 as the year by which individuals on lower incomes begin to take up ZEVs and AVs, such that the improvement between 2031 and 2046 is primarily through improved access to services for lower income groups.

The ongoing uptake of ZEVs and AVs to 2046 results in increased access to services across all scenarios. Private Drive has the highest level of access to services in 2046 (Chart 2.8).

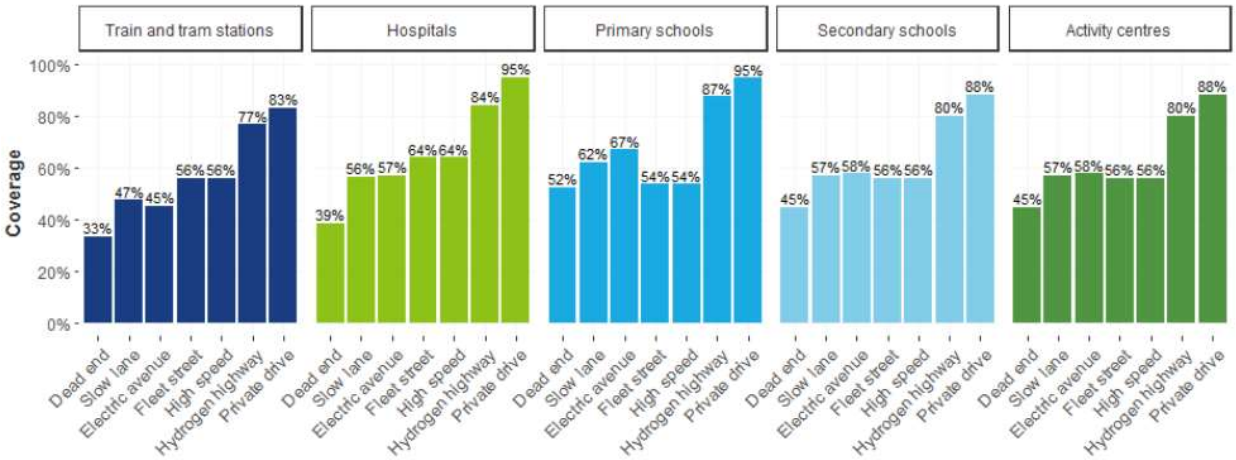
In terms of inequality in outcomes, it is also important to note that there are moderate to large increases in access to train stations under all scenarios. This has important implications for lower income individuals, those living a significant distance from urban areas and those without a driver's licence. These increases in access to public transport (train/tram stations) may benefit these groups more, noting that it may take longer for these benefits to be realised.

Comparing scenarios, Private Drive had the largest increase in overall access to services, closely followed by Hydrogen Highway. The improvement in access to services is driven by a decrease in out-of-pocket costs and an assumed reduction in the value of travel time, where Private Drive has the lowest out-of-pocket costs for users.

In order to account for areas with very high existing levels of access to services (as shown in Section 2.2.1.3), additional analysis was undertaken to isolate and examine the impact of ZEVs and AVs on areas with lower levels of access to services. This was achieved by removing SA2 areas with coverage rates of 95% or above (in the Dead End scenario).

These filtered results are shown in Chart 2.9. Clearly, after removing areas with existing higher coverage, the differences between scenarios are much starker. For example, in 2046, there is a much larger difference between Private Drive and Dead End. This emphasises the improvements and benefits for areas with lower initial levels of coverage.

Chart 2.9: Filtered population weighted coverage in 2046 (removed areas with initially high access to services)



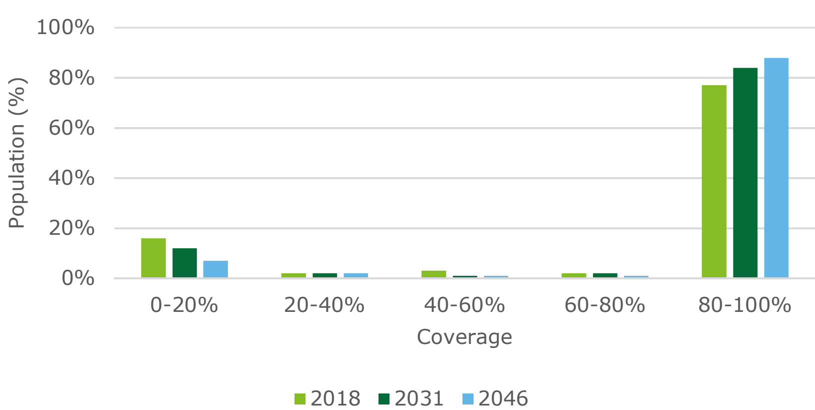
2.2.2.2 Overall increase in access to services by population

The section summarises changes in access to services. The gradual improvement in overall access to services is shown in Chart 2.10, comparing the initial distribution, a midpoint, and a full adoption scenario.

In 2018, 77% of Victorians have 80-100% access to activity centres. This increased to 84% in 2031 after the introduction of ZEVs and AVs, and then 88% after full adoption in 2046. However, notably 7% of Victorians in 2046 still have a relatively low access of 0-20% coverage to activity centres, representing a material number of residents.

Examining the distribution of the population coverage over time reveals insights into what happens to individuals with low levels of coverage. Additional results are modelled and reported in Appendix A.

Chart 2.10: Percentage of Victorians with coverage of activity centres under Private Drive over time



Summary of change in access to services for different population groups across scenarios

Dead End

Of the total population of Victoria, around 59-74% live in an SA2 region with 80-100% coverage of hospitals, primary and secondary schools. Around 6-18% live in an SA2 region with 0-20% coverage of hospitals, primary and secondary schools. Activity centres have the highest coverage by population with 77% of the population living in an area with 80-100% coverage. Train stations have the worst coverage, with 41% of the population with 80-100% coverage and 32% living in an area with 0-20% coverage.

Electric Avenue

As users have more access to services through EVs, more of the population have increased coverage of key services. This increase is slight increasing the percentage of population with 80-100% coverage of key services by around 3-13%. There is still 25% of the population with 0-20% coverage of train stations in 2046 with the full adoption of EVs.

Private Drive

This results in the largest increase in users' access to services. By 2046, only 4-9% of the population have 0-20% coverage of train stations and secondary school. Of the Victorian population, more than 95% have coverage of hospitals and primary schools. However, even under this scenario 10% of the population still have 0-20% coverage of activity centres.

Fleet Street

Around 12-18% live in an SA2 region with 0-20% coverage of hospitals, primary schools, secondary schools and activity centres. The critical infrastructure with the largest percentage of the population with very low coverage in 2046 is train stations, with 26% of the population having 0-20% coverage.

Hydrogen Highway

Around 2-6% of the population with 0-20% coverage of hospitals and secondary schools. Of the Victorian population, more than 93% have coverage of primary schools. In 2046, there is still 14% of the population with low coverage of activity centres and 11% of the population with low coverage of train stations.

High Speed

Same trend as Fleet Street, however it is achieved in 2031 instead of 2046.

Slow lane

Slight increases in the percentage of the population with coverage of key services. By 2046, 70-80% of the population live in an SA2 region with 80-100% coverage of hospitals, primary schools, secondary schools and activity centres. However, still 22% of Victoria's population only has 0-20% coverage of trains in 2046.

2.2.2.3 Access to services outcomes by income group

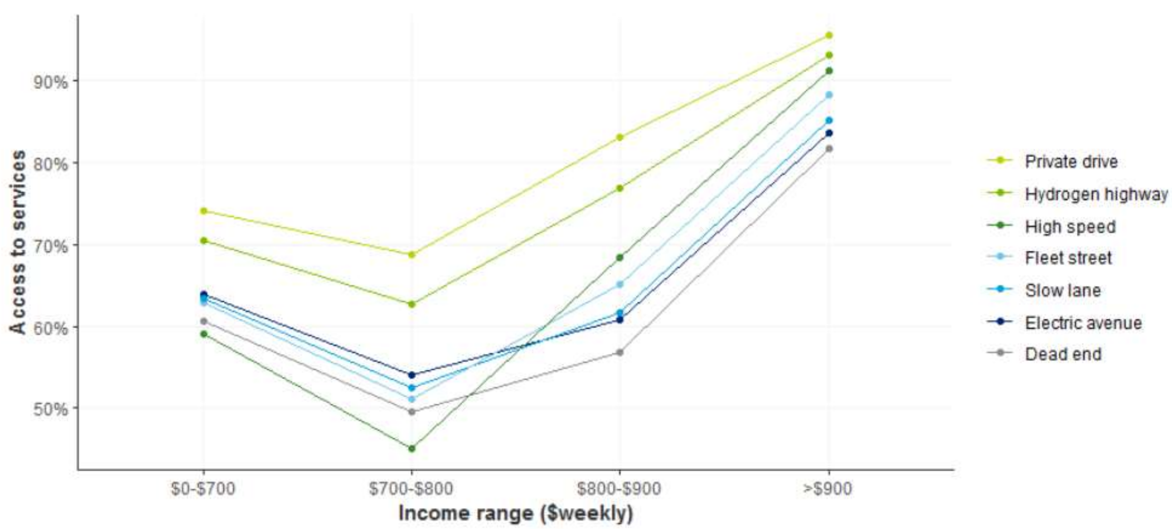
In the previous sections, inequality outcomes were examined through changes in the coverage levels of key services and how this materialises over different geographies and scenarios. This section examines the relationship between income and access to key services to analyse how improvements in coverage are distributed across income groups.

First, an average access to services measure was created using average coverage of each key service by SA2. These SA2 areas were then divided in groups with average weekly incomes of $0-700, $700-800, $800-900 and more than $900. The groups were chosen based on the distribution of average weekly incomes in Victoria, such that there are approximately 100 SA2 areas within each income group. The average income within each group was plotted against the average access to services for each scenario (see Chart 2.11 and Chart 2.12).

Across all scenarios (aside from High Speed), areas with higher income levels have higher levels of access to services. Under High Speed, those in the $700-800 weekly income group actually have the lowest level of access to services.

The largest change in access to services occurs in the $700-800 group, which is also the group with the lowest initial access to services. In contrast the income group of more than $900 receive the smallest marginal benefits, in part due to their very high initial levels of access to services.

Chart 2.11: Relationship between average access to services and income range in 2031

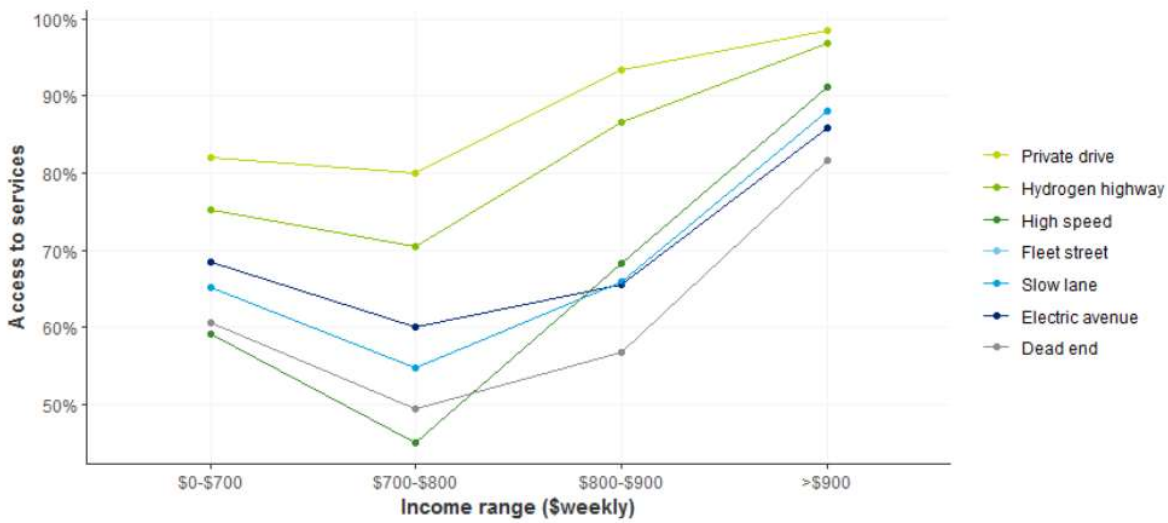


Notably, these results suggest that the Private Drive results in not only the largest improvement in access to services by 2046, but also the most equalised access to services in terms of narrowing the gaps between income groups.

Slow Lane and Electric Avenue increased the overall access to services for all income groups in 2046. Electric Avenue increased access to services for the $700-800 income group to a higher average level compared to Hydrogen Highway.

Hydrogen Highway, High Speed and Fleet Street show large amounts of variability in access to services across income groups in 2046. Under Hydrogen Highway, all income groups experience an improvement in access to services, however, these scenarios have relatively small effects on equalising access. Under Fleet Street and High Speed, those in the $0-700 and the $700-800 group still have lower access to services compared to Dead End.

Chart 2.12: Relationship between average access to services and income range in 2046

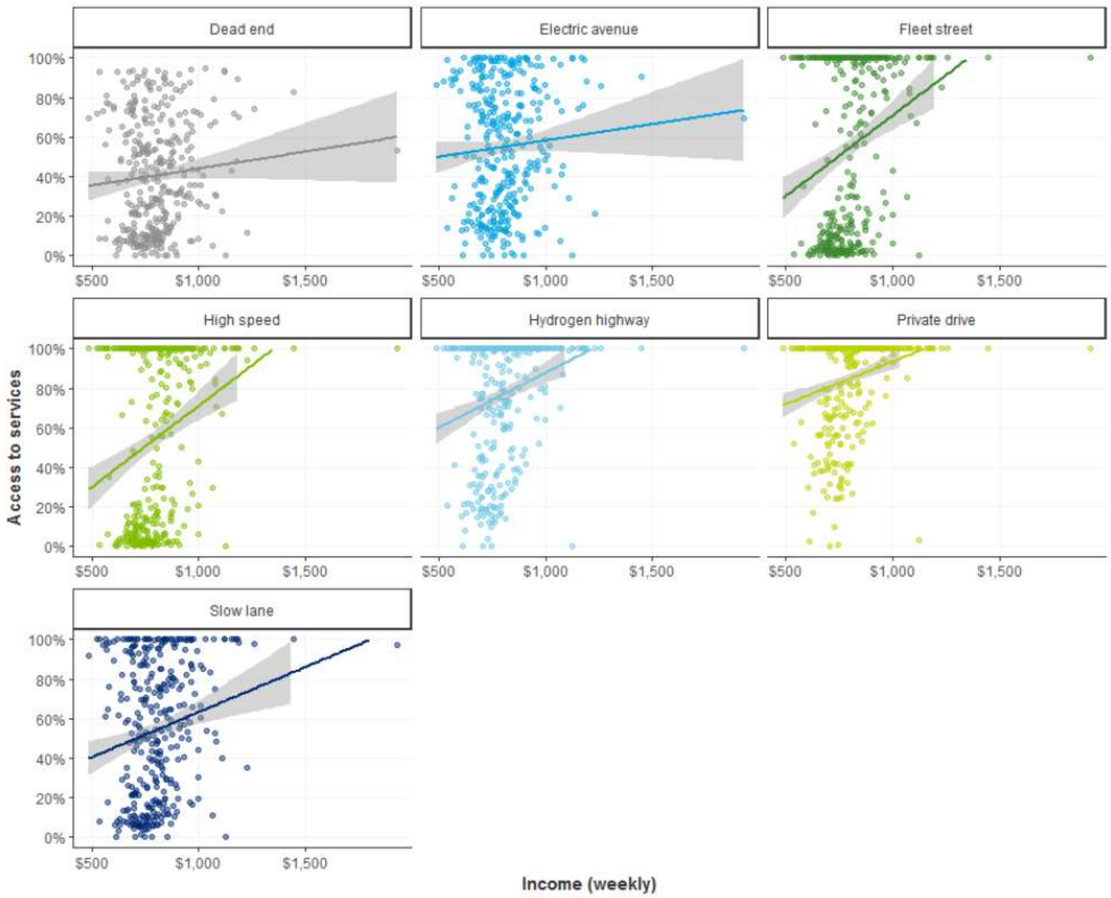


Note: High Speed and Fleet Street have identical access to services results in 2046. Therefore, the High Speed data points cover the Fleet Street data points within the figure above.

To examine these inequality effects further, areas with high initial levels of access to services (over 95% coverage) were filtered out. Each of the remaining SA2 areas were plotted on weekly average income (x-axis) and average access to services (y-axis) (Chart 2.13).

The results show a weak relationship between income and access to services under the Dead End scenario, but higher levels of inequality in the other scenarios. A positively sloped line indicates a positive correlation between areas with higher incomes and areas with greater access to services. This relationship appears to be slightly larger in Fleet Street, High Speed and Hydrogen Highway, indicating that these scenarios are likely to have the highest levels of inequality in outcomes.

Chart 2.13: Scatter plot of income and access to services in 2046



A regression was used to more precisely measure the correlation between income and access to services (Table 2.10). This analysis also filtered out areas with high initial access in order to isolate areas with lower levels of initial coverage.

This regression indicates that, under the Dead End scenario, a $100 increase in the average weekly income of an SA2 area is correlated with a 1.71% increase in average access to services. However, this relationship is not statistically significant at the 10% significance level. Electric Avenue was also not statistically significant at the 10% significance level.

In this regression, Fleet Street and High Speed revealed the largest relationship between access to services and average weekly income. A $100 increase in average weekly incomes was correlated with an 8% increase in average access to services. This relationship is statistically significant at the 1% level.

The remaining scenarios, Private Drive, Hydrogen Highway and Slow Lane, also had statistically significant relationships estimated using the regression model, albeit smaller in size to the Fleet Street and High Speed scenarios.

Table 2.10: Relationship between access to services and income in 2046 with areas of initial high access to services filtered out

Scenario	Increase (%) in access to services from a $100 increase in average income
Dead End	1.71
Electric Avenue	1.66
Fleet Street & High Speed	8.15**
Hydrogen Highway	5.54**
Private Drive	4.32**
Slow Lane	4.56**

Note: ** = significant at the 1% statistical significance level

2.2.2.4 Overall findings on inequality

The section explored how changes in access to services may vary by income groups, and thus lead to inequalities. While the introduction of ZEVs and AVs were modelled to benefit all Victorian in each scenario, the benefits were largest under Private Drive and Hydrogen Highway due to larger decreases in out-of-pocket costs and larger assumed reductions in the value of travel time.

Coverage and access to services in 2046 was greatest for Private Drive, followed by Hydrogen Highway, Electric Avenue, Slow Lane and then Fleet Street and High Speed.

Regions with smaller average incomes were associated with larger changes in coverage over time, however this was primarily driven by low initial levels of coverage. Many high-income SA2 areas are already close to 100% coverage, while many lower income areas have significantly lower levels of coverage, and hence a greater ability to improve their coverage over time.

Even after the full adoption of ZEVs and AVs, there are still regions with relatively low levels of access to critical infrastructure. However, this is partially driven by a lack of critical infrastructure and/or very large geographic size. Policy-makers may wish to target these specific regions in order to achieve equitable outcomes.

Across all scenarios, moderate to large increases in access to train stations were modelled. This has important implications for lower income individuals, those living a significant distance from urban areas and those without a driver’s licence.

Most income groups experienced an improvement in access to services across each scenario. However, there is still inequality across different income groups, for example, under Fleet Street and High Speed, those in the $0-700 and the $700-800 group had lower access to services compared to Dead End. For income groups over $700 per week, income was positively correlated with greater access to services. Private Drive equalised access to services the most across income groups and also led to the largest increase in overall access across all groups.

After isolating regions with low levels of initial coverage, Fleet Street and High Speed were found to have the largest relationship between income and access to services. A $100 increase in average weekly income was correlated with a greater than 8% increase in overall access to services. This suggests, that even after full adoption in 2046, income still influences access to services.

2.3 Sensitivity analysis – subscription

This section presents the results of a sensitivity analysis on the main results discussed in detail above. This sensitivity analysis represents an alternative policy option where driverless, shared, on-demand services are accessed on the basis of a subscription service. This subscription sensitivity analysis has implications for the Fleet Street, Slow Lane and High Speed scenarios. For consistency with previous results, all scenarios will be reported in this section.

The critical change in assumptions for this sensitivity analysis relates to the approach to charging for driverless, shared, on-demand services. These assumptions are set out in detail in Section 2.1.1. In summary, under a subscription approach, both the initial flag fall and ongoing travel costs are lower. This reflects that the subscription fee is used to reduce the per journey costs for the passenger. As the subscription fee is a sunk cost it doesn't factor into decisions for each individual journey – similar to the way that the initial costs of purchasing a vehicle outright don't generally affect daily travel decisions.

First, considering effective travel distances, the maximum distance that individuals are willing to travel by trip purpose and average incomes (at the SA2 level) in 2031 is shown in Chart 2.14 with 2046 being shown in Chart 2.15.

The results in this sensitivity analysis show significant increases in the effective travel distance per trip under Slow Lane, Fleet Street and High Speed. For example, in the main results the effective travel distance for High Speed in 2046 for Train Stations is around 6km while in the subscription sensitivity analysis this increases significantly to around 14 kilometres.

By 2046, Private Drive maintains its position as the scenario with the highest effective travel distances as it still has the lowest marginal cost of travel. In this sensitivity analysis, by 2046, High Speed and Fleet Street now exceed Hydrogen Highway in terms of effective travel distance and Slow Lane exceeds Electric Avenue. These results are in contrast to those in the main results.

As in the main results, in 2031, as higher income individuals are expected to adopt new vehicle technology earlier than others, there is some variation in acceptable travel distances. This is shown by the vertical spread for each scenario (aside from High Speed).

Chart 2.14: Effective travel distance for trips in 2031 – sensitivity analysis

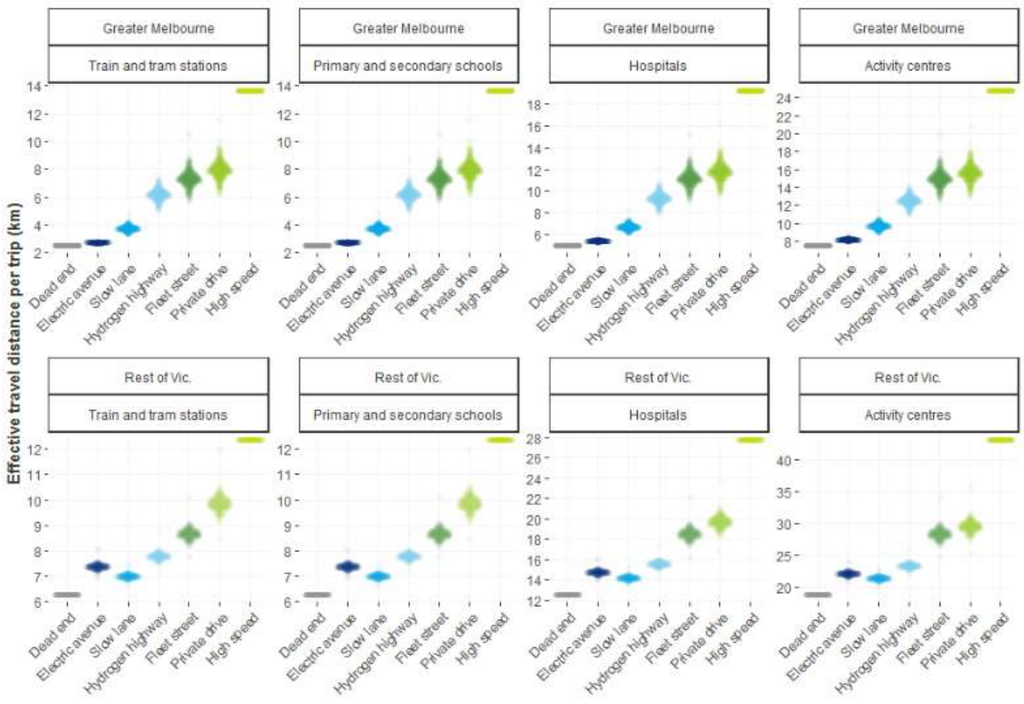
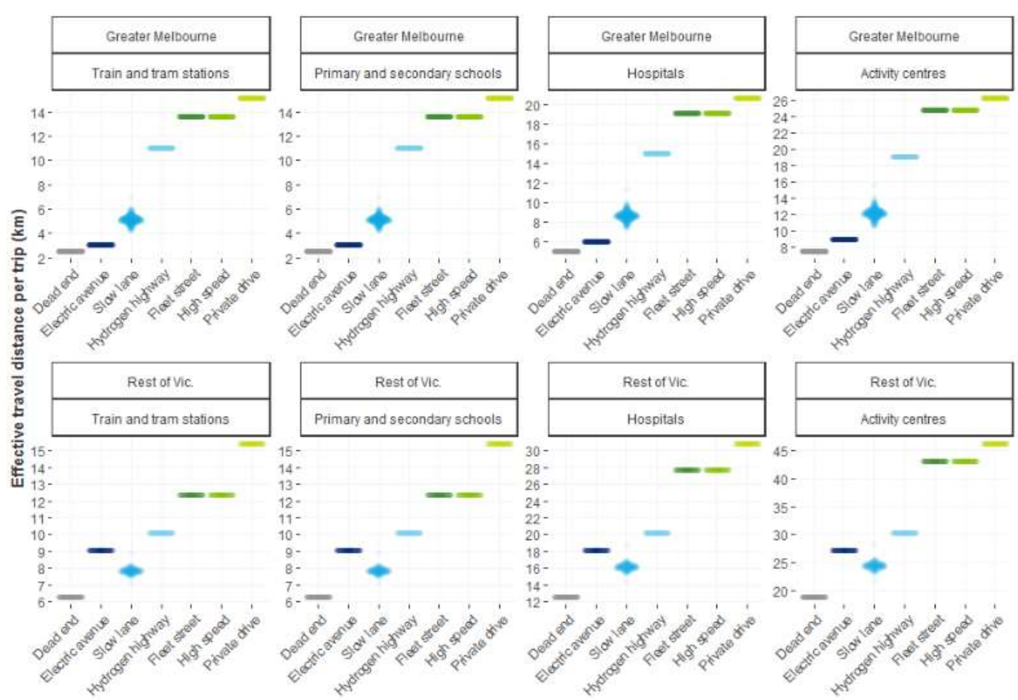


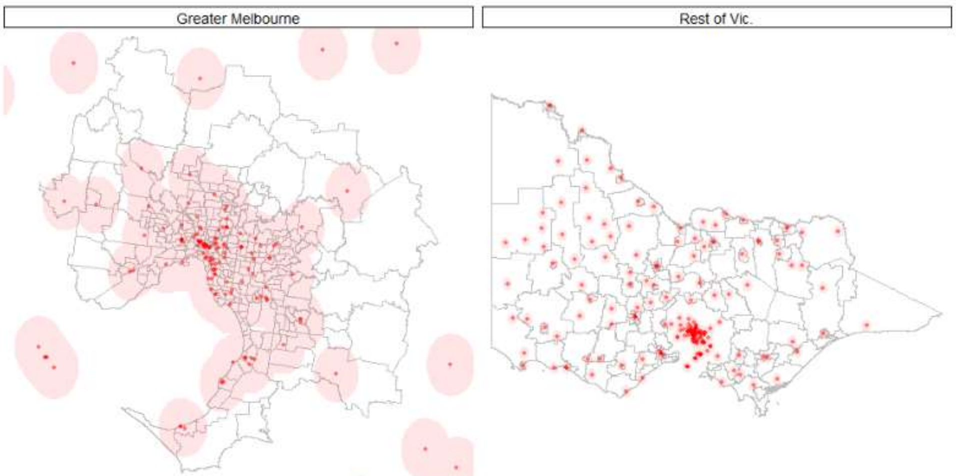
Chart 2.15: Effective travel distance for trips in 2046 – sensitivity analysis



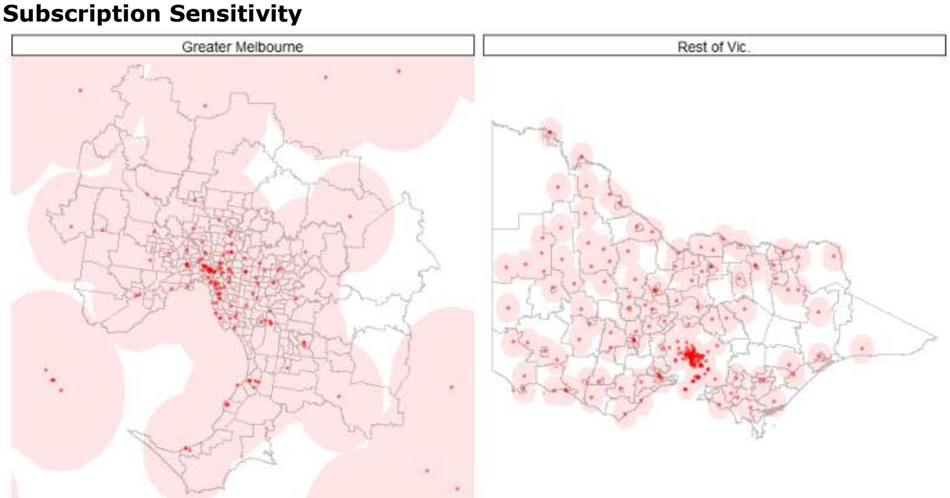
The improvement in effective travel distance within this sensitivity analysis translates directly into improvements in access to services for Slow Lane, Fleet Street and High Speed. As passengers are willing to travel further they are naturally able to access more services. For example, Figure 2.11 compares accessibility of Hospitals in 2046 under Fleet Street in the main results and in the sensitivity analysis. There is a clear increase in the area covered and, hence, in accessibility.

Figure 2.11: Access to hospitals under Fleet Street – sensitivity comparison

Main Results



Subscription Sensitivity

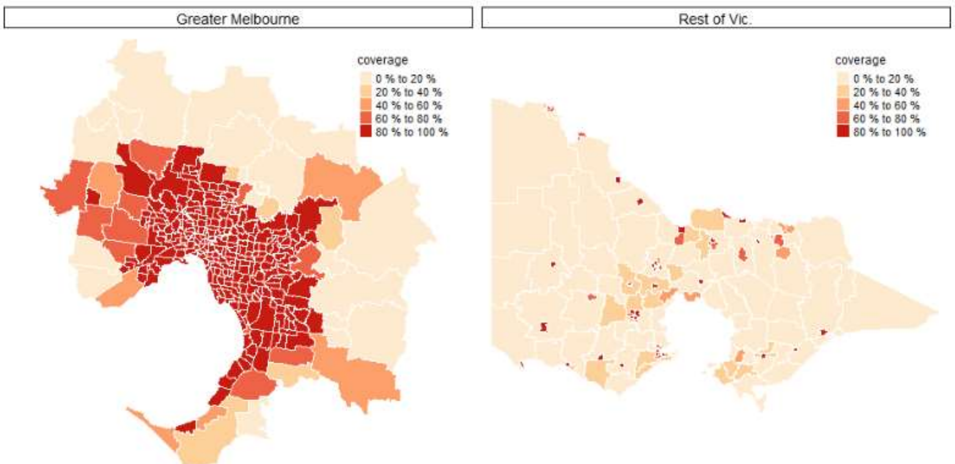


Similar results hold for Slow Lane, Fleet Street and High Speed and across all different types of critical infrastructure. This is because the reduction in trip costs associated with the subscription sensitivity affects all three scenarios in the same way and applies to trips related to all types of critical infrastructure.

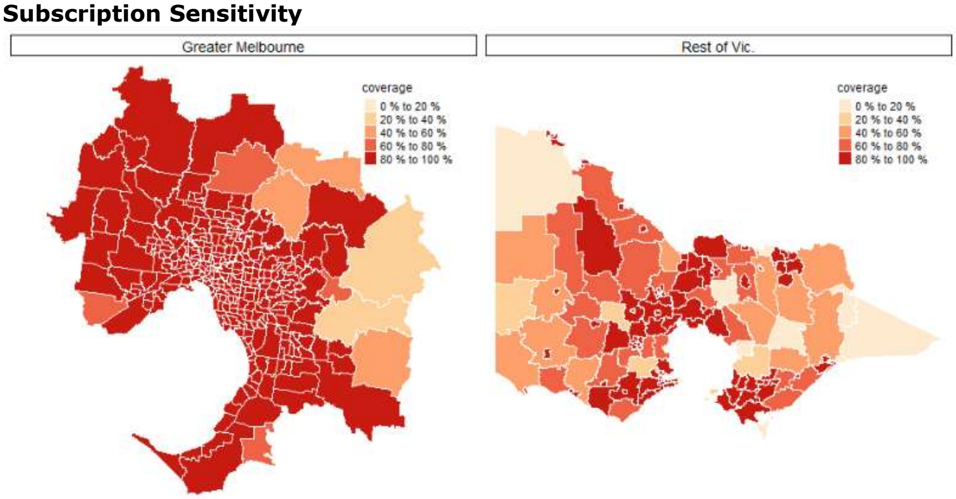
As in the main results, these accessibility results can be translated to show variation in the percentage of the SA2 that has access to critical infrastructure, this is shown for hospitals under Fleet Street in 2046 in Figure 2.12. Very significant improvements in access can be seen in regional areas and outer suburban areas – reflecting the importance of distance related costs to travel decisions in areas with relatively sparse access to critical infrastructure.

Figure 2.12: Access to hospitals under Fleet Street – sensitivity comparison

Main Results



Subscription Sensitivity



To summarise the changes in access that occur under Fleet Street, and hence flow through to both Slow Lane and High Speed; there are widespread increases in access to train stations, hospitals, primary schools, secondary schools and activity centres in some outer regions in Melbourne by 2046 when compared to the main results. Individuals are willing to travel further due to savings in both flag fall and ongoing travel costs. These effects are particularly strong in the rest of Victoria. There is still relatively low access to services in some parts of the rest of Victoria to train stations, hospitals, primary school and secondary schools and activity centres in 2046 – particularly in the far east and far west of the state.

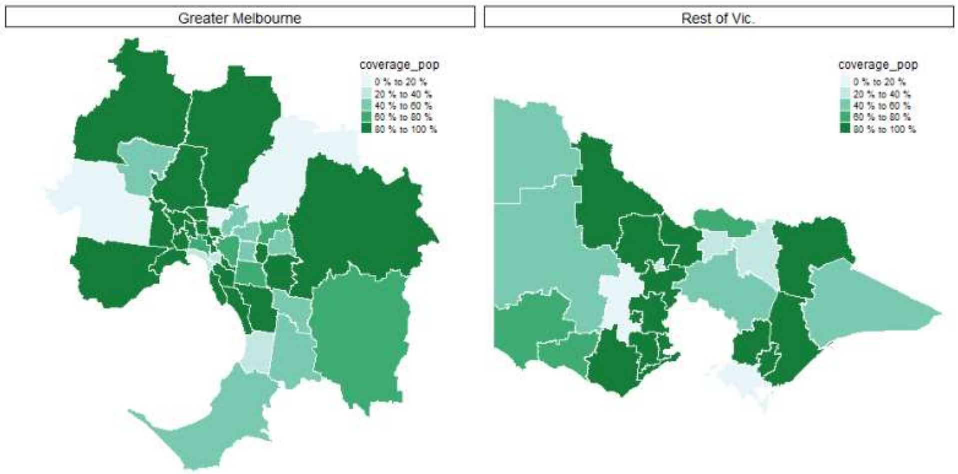
Although mitigated, there still remains differences between access to services in Melbourne and the rest of Victoria in Fleet Street in the sensitivity analysis. For example, there is near complete access to primary and secondary schools in Melbourne in 2046, with lower levels of access to services in the rest of Victoria aside from some regional areas on the periphery of Greater Melbourne and some regional centres.

Considering access to services by population, the percentage of population within each SA2 area with access to services for hospitals in Fleet Street in 2046 is shown in Figure 2.13. The relative improvement in population access is notably smaller than geographic changes in accessibility. This is because areas of relatively high population have somewhat similar levels of accessibility in both the main results and the sensitivity analysis. This means that, once the improvements in accessibility are weighted by population, the drastic changes in geographical coverage become more muted.

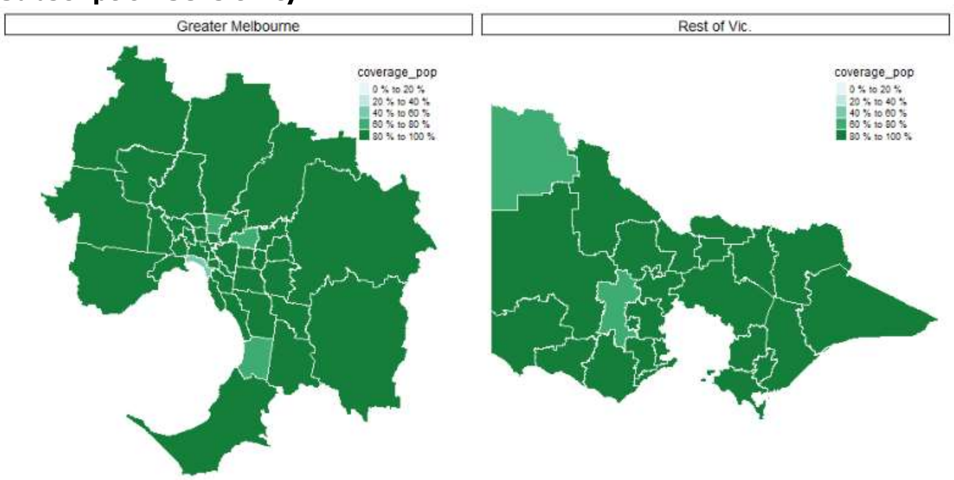
Having said that, there are, however, across the board improvements in access to services by population. This measure improves for Slow Lane, Fleet Street and High Speed and across all different types of critical infrastructure. For example, for hospitals in Fleet Street in 2046, most people in most parts of the state have high levels of access, this is true even in areas such as the far east and far west that have relatively poor geographic based coverage.

Figure 2.13: Population access to hospitals under Fleet Street – sensitivity comparison

Main Results



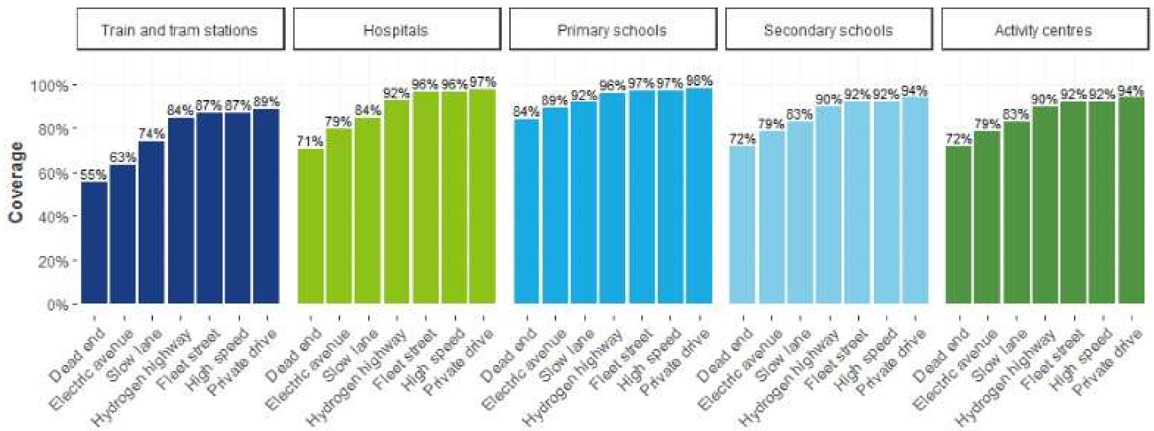
Subscription Sensitivity



The overall benefits of the introduction of ZEVs and AVs can be seen in Chart 2.16, which shows a summary measure of population weighted coverage in 2046 at the state level (the comparator to this chart for the main results is Chart 2.8). Comparing the results indicates that there are significant improvements for Slow Lane, Fleet Street and High Speed.

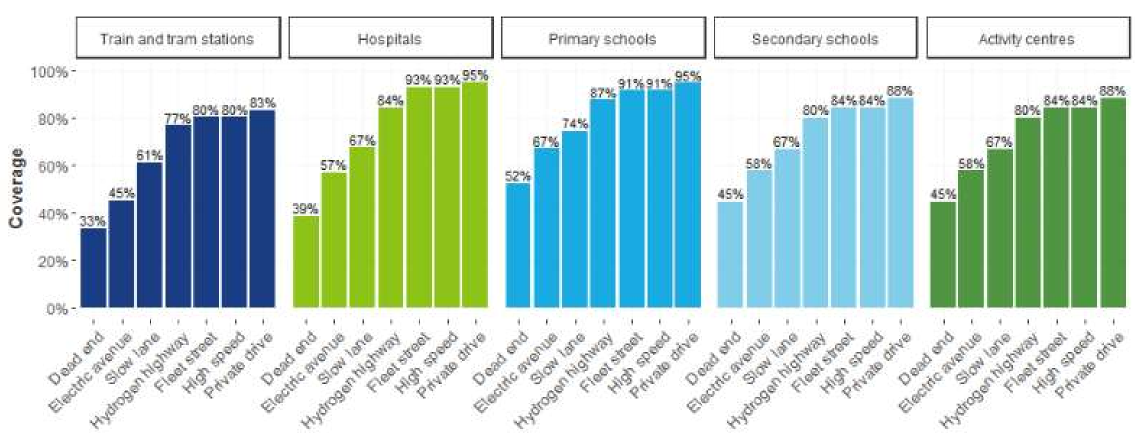
Particularly strong improvements are seen for train and tram stations where coverage increases for Fleet Street and High Speed from around 66% up to around 87%. Similarly, large increases are also seen for Secondary schools and Activity centres. These results confirm the earlier results of the sensitivity analysis that a subscription based approach to driverless, shared, on-demand services generates significant improvements in accessibility relative to a non-subscription based approach – nearly achieving levels of accessibility seen under Private Drive.

Chart 2.16: Population weighted coverage in 2046 – sensitivity analysis



In order to account for areas with very high existing levels of access to services, additional analysis was undertaken to isolate and examine the impact of ZEVs and AVs on areas with lower levels of access to services. This was achieved by removing SA2 areas with coverage rates of 95% or above (in the Dead End scenario). These filtered results are shown in Chart 2.17. These results confirm that, under the subscription sensitivity, accessibility is improved to a point near that seen under Private Drive.

Chart 2.17: Filtered population weighted coverage in– sensitivity analysis



Finally, considering inequality in outcomes, Chart 2.18 and Chart 2.19 show the relationship between income and access to key services in 2031 and 2046 respectively. As in the main results, across all scenarios, areas with higher income levels have higher levels of access to services.

Comparing the results of the sensitivity analysis to the main results indicates that a subscription based approach to driverless, shared, on-demand services has significant benefits in terms of reducing inequality as well as boosting access overall. For example, in the main results there is a very strong relationship between income and access to services under Fleet Street in 2046, with those in the $700-$800 income a week range seeing accessibility roughly half that of those in the >$900 income range, within the sensitivity analysis this differential falls considerably.

Chart 2.18: Relationship between average access to services and income range in 2031 – sensitivity analysis

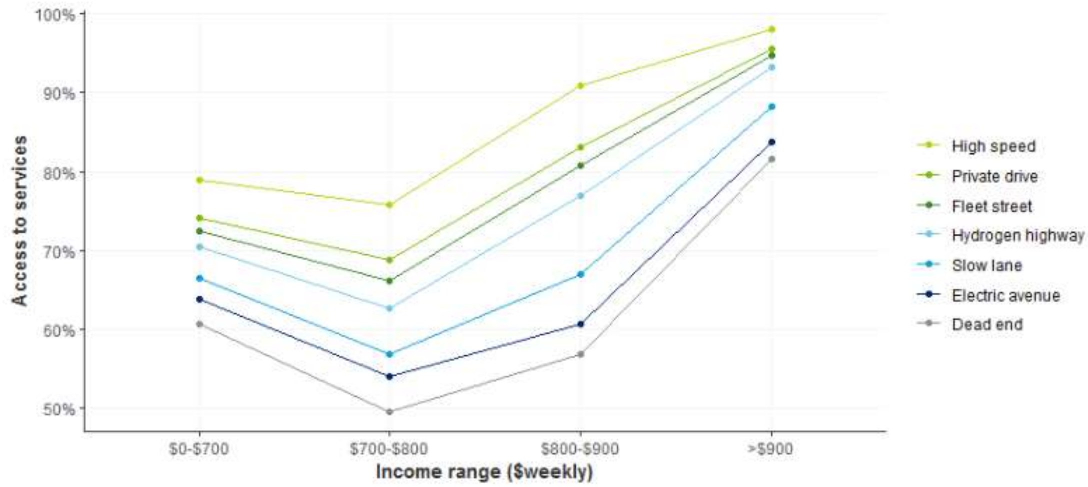
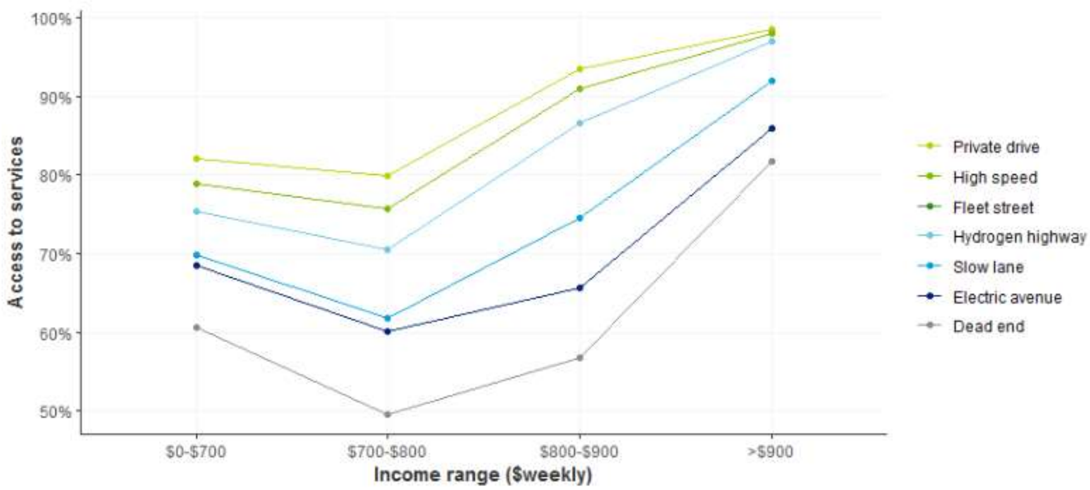


Chart 2.19: Relationship between average access to services and income range in 2046 – sensitivity analysis

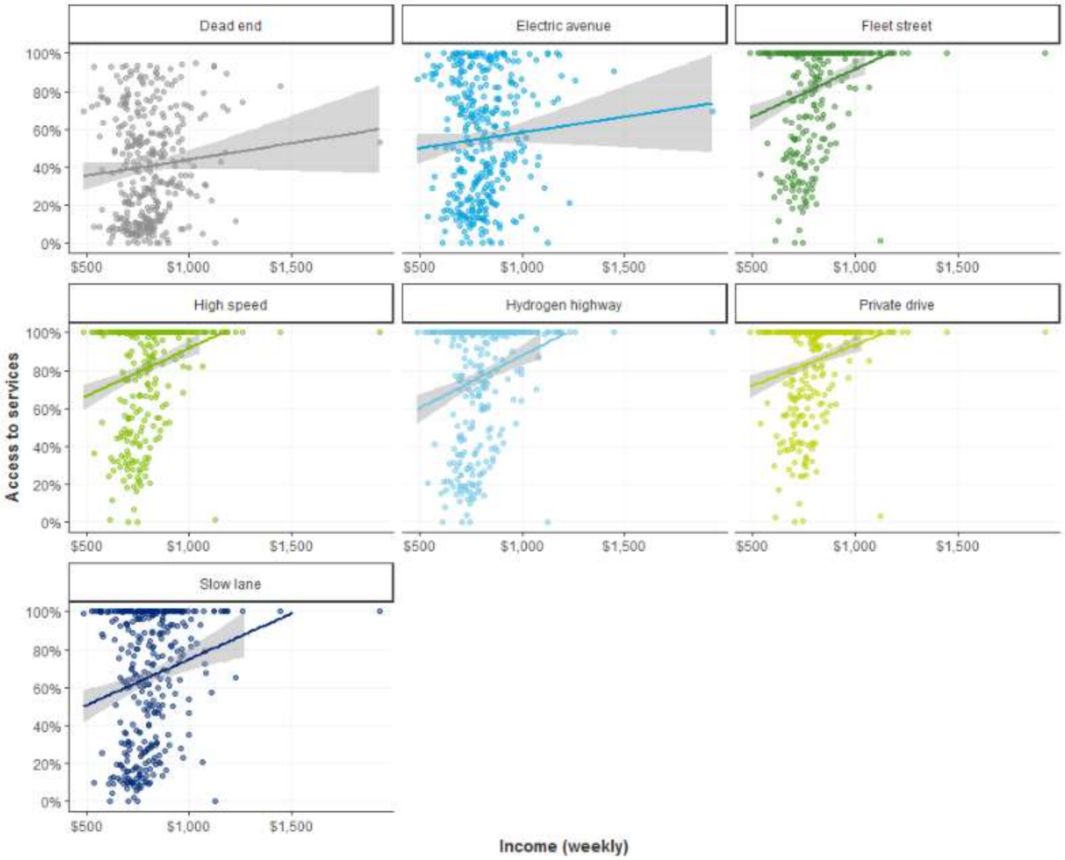


Note: High Speed and Fleet Street have identical access to services results in 2046. Therefore, the High Speed data points cover the Fleet Street data points within the figure above.

As in the main results, to examine these inequality effects further, areas with high initial levels of access to services (over 95% coverage) were filtered out and each of the remaining SA2 areas were plotted on weekly average income (x-axis) and average access to services (y-axis) (Chart 2.20).

Comparing these findings to the main results indicates that there is both an upward shift in the level of accessibility as well as a reduction in the slope of the relationship between accessibility and income. This confirms the findings in the previous chart that a subscription based approach to driverless, shared, on-demand services has significant benefits in terms of reducing inequality as well as boosting access overall.

Chart 2.20: Scatter plot of income and access to services in 2046 – sensitivity analysis



3 Employment risks and opportunities

Key findings in this chapter

- Workers in the transport industry are most at-risk, particularly those in freight, taxis and hire cars, and road public transport.
- The key forces of change are (1) automation replacing drivers, (2) fleet operations resulting in significantly fewer cars, (3) changing commuter behaviours, and (4) changes in the servicing of electric vehicles.
- How ZEV and AV technologies manifest will likely result in very different impacts for workers. Across the six scenarios in this analysis, job roles removed range from around 30,000 to almost 200,000 in 2046.
- Notwithstanding these targeted loss of roles, CGE modelling suggests that in response to improvements in capital productivity, the overall economy will grow faster and demand more workers in total.
- In fact, modelling suggests that the 72,200 roles removed in the Transport industry will be offset by positive employment growth of 83,700, with the largest job growth in Construction, Trade and Other Business Services.
- Governments have a number of opportunities to both facilitate these workers to transition into other industries, and also for Victoria to take advantage of these technological advancements.

Transport and motor vehicles are fundamental components of the Victorian and Australian economies. In 2017, there were 3.8 million passenger vehicles and another 1 million other vehicles in Victoria, representing over a quarter of all vehicles in Australia.[12]

The transport industry in Victoria is responsible for 113,000 jobs, or one in every 25 employed persons.[13] A transition to ZEVs and AVs is likely to have a large impact on many of these workers, in particular freight and truck drivers, public transport operators, and taxi and hire car drivers.[14] Other at-risk workers are likely to be in the maintenance and repairs, fuelling and vehicle retail sectors.

This chapter explores the possible employment effects of the introduction and adoption of AVs and ZEVs in Victoria, and is organised as follows:

- Section 3.1 describes the current state of employment in Victoria, including identifying key at-risk sectors and geographical considerations;

[12] ABS Motor Vehicle Census July 2017. Other vehicles include trucks, vans, buses and motorcycles.
[13] ABS Census 2016. Excludes air, water and space transport. Total employment in Victoria 2.73 million in 2016.
[14] While ride-sharing vehicle drivers may be similarly impacted, these workers are more likely to be mobile and/or supplementing their primary work. At a practical level, it is difficult to identify these workers, and hence are not explicitly identified in this analysis.

- Section 3.2 provides baseline future population and employment forecasts;
- Section 3.3 outlines the possible major employment impacts described by the literature, including estimates of the impact on employment by industry;
- Section 3.4 presents empirical findings from economy-wide CGE modelling to explore the possible flow-on effects from these employment shocks; and
- Section 3.5 concludes with a discussion on the broader economic opportunities and challenges for policy makers.

Methodology and approach

- An initial scan of the literature and consultation with Deloitte's global ZEV and AV practitioner network was used to inform a base understanding and quantitative estimates of the likely employment impacts of adopting ZEVs and AVs.
- Deloitte's in-house macroeconomic forecasting model was used to extrapolate these job loss estimates to 2046.
- Deloitte's in-house Computable General Equilibrium (CGE) model represents the connections between different sectors in the economy, as well as the behaviour of firms, consumers and government. It encompasses all economic activity and is the most reliable and respected basis for determining the net impact of changes or 'shocks' to the economy.
- Job losses are introduced into the CGE model through improvements in capital productivity, which result in businesses in that sector substituting labour for capital in order to optimise output.
- The CGE model then models how the economy responds and how the economy reaches a new equilibrium, i.e. where the displaced labour goes and where the entering capital comes from, as well as how other sectors respond to these changes.
- Notably, the 'best' way to utilise the CGE model is to introduce materially large and isolated shocks. The model then shows how the economy dynamically responds.
- Key assumptions involved in this modelling include the linear introduction of ZEV and AV technologies and that the technologies are introduced consistently throughout Australia. See Appendix C for a more detailed discussion on the CGE model.

3.1 Current employment and how it relates to ZEVs and AVs

Key employment sectors

The economic impacts of the introduction of ZEVs and AVs are anticipated to be structurally profound – eliminating the need for certain skills, creating demand for new skills, and potentially fundamentally changing who does what, where and when for many parts of the workforce.

The analysis in this chapter isolates the likely employment effects, in order to better understand – from an employment perspective – which sectors of the Victorian economy can be expected to be most impacted.

The analysis focuses on seven key sectors across three broader industry groups, representing over 100,000 workers that are most likely to be directly affected by ZEVs and AVs – see Figure 3.1 and Chart 3.1.

Employment forecasts for these sectors are presented in Section 3.2, while the dynamics and estimates for changes in employment are explored in greater detail in Section 3.3. Focusing on these sectors and workers provides a more transparent and tractable basis upon which to progress the economic modelling.

Notably, there are likely to be further-reaching flow-on effects from the introduction and adoption of AVs and ZEVs. While these secondary or 'further down the line' industries and sectors are very likely to be impacted, the effects are less certain and may instead involve an adjustment in the type of work, rather than displacement of workers and jobs.

For example – traffic controllers may shift focus from managing accidents to facilitating traffic flows and managing congestion, while insurance firms may redirect efforts from vehicle products to homes and personal insurance or resilience initiatives.

The productivity benefits of moving to AVs and ZEVs are likely to be significant, and produce income gains well above a baseline case (without any transition to AVs and ZEVs). The broad based employment gains which would result from the expected productivity and income gains are taken into account in Section 3.4.

Figure 3.1: Key sectors and industry groups for this analysis

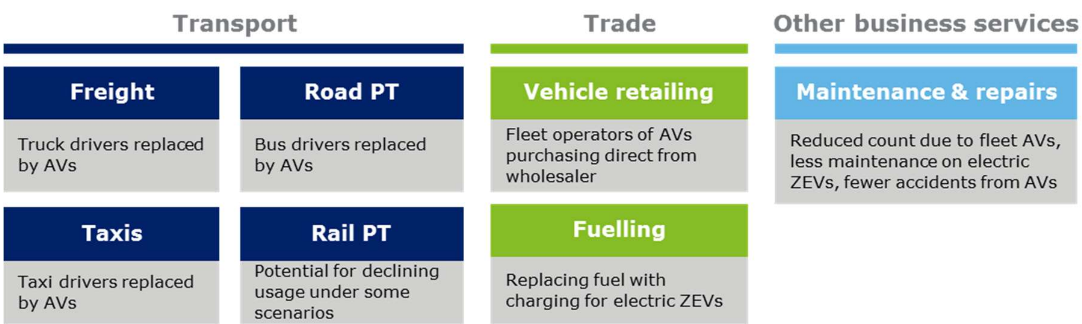
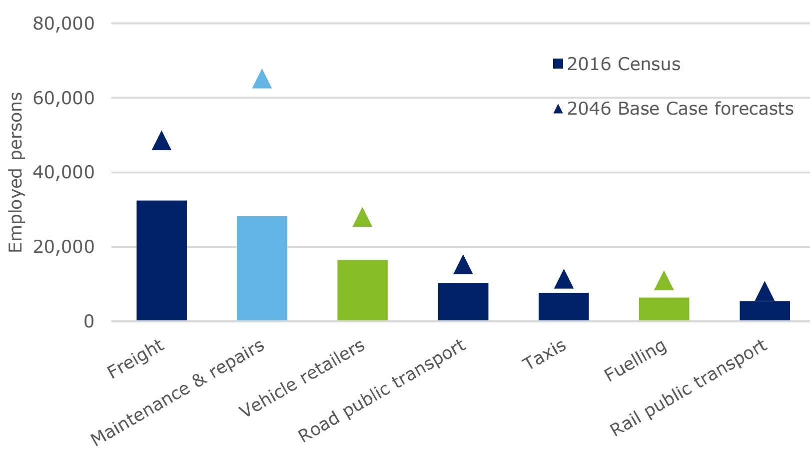


Chart 3.1: Employment forecasts for relevant sectors (Victoria, 2016-2046)



Source: Deloitte Access Economics 2015. ABS Census 2016. Note: Colours represent industry groupings.

Geographic distribution of at-risk employment

Not only do these key sectors represent a significant number of Victorian workers, but these workers are also more likely to be more concentrated in the northern and western Greater Melbourne regions.

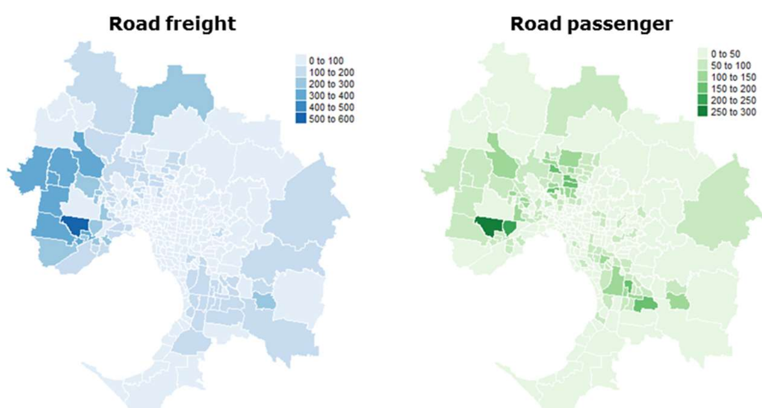
Understanding regional clustering of occupations is important to the extent that the adoption of AVs and ZEVs may lead to pockets of unemployment, which can negatively impact communities and also increase the difficulty for recently unemployed workers to regain employment.

Current employment patterns reveal that truck drivers are more likely to reside in Melbourne's west – workers in areas like Melton, Sunbury and Werribee are more likely to be in the Road Freight sector (Figure 3.2).

Taxi operators are also more likely to reside in these western regions, as well as in northern areas like Fawkner, Glenroy and Lalor. Road Passenger Transport employment (including urban and rural bus drivers) covers the same western and northern regions as the previous two groups, as well as pockets in the south-east, such as Dandenong, Springvale and Noble Park.

Notably, employment in the Transport industry is predominately within Greater Melbourne, with fewer workers for the rest of Victoria and less clear employment patterns (i.e. no strong regional clustering of employment).

Figure 3.2: Distribution of transport employment (Greater Melbourne, 2016)



Source: ABS Census 2016. Note: Note: 'Road passenger' includes taxis and hire cars, and road public transport.

3.2 Baseline future of employment

The Deloitte Access Economics in-house macroeconomic model forecasts industry-specific employment across the 19 ABS ANZSIC industry groups and has previously been used in reporting by Infrastructure Victoria.[15]

Importantly, forecasts are only estimates and in many instances simply rely on historical trends observed in the economy. They are, in many cases, a continuation of 'business as usual' and as such, do not necessarily consider sudden shifts in how the future economy may function, in particular, how fundamental technological shocks (such as ZEVs and AVs) can and will change the structure of the economy.

Notwithstanding these constraints, forecasts do provide an indication of the size and composition of the future economy, including which industries – based on current trends and patterns – are likely to grow faster than others. This is useful for understanding the likely magnitudes and relativities of key sectors.

While the projections in this section are consistent with a steady rate of technology change, the next section (Section 3.3) explores the likely changes in employment (from these baseline positions) as a result of the adoption of ZEV and AV technologies.

Population forecasts

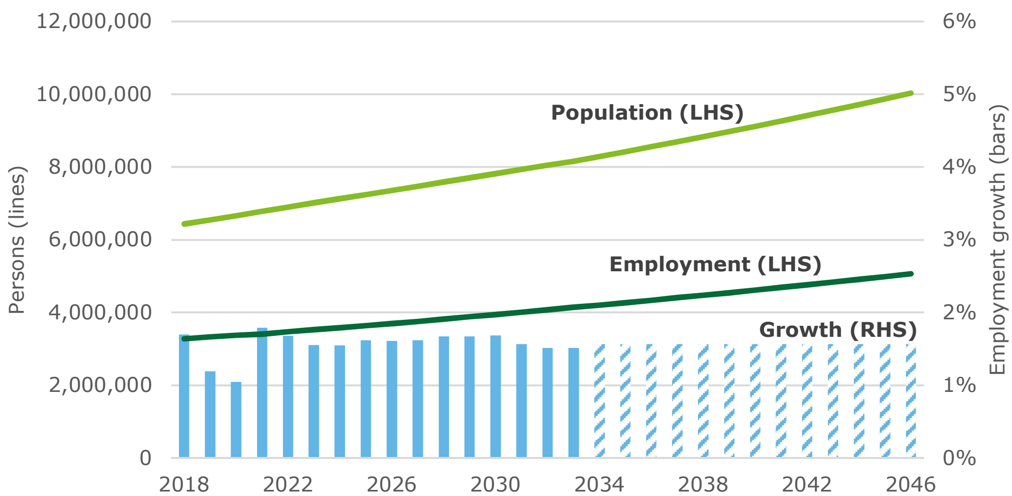
Victoria in Future 2016 sets out forecasts of a future state population of 9.5 million by 2046, at a total growth rate of 51% from 2016 and an average of 1.5% per year. The highest growth regions are forecast to include Mitchell, Melton and Cardinia.

The analysis in this report relies on employment forecasts from the Deloitte Access Economics in-house macroeconomic model, and for consistency, the corresponding population forecasts from this model are referred to. Notably, these population forecasts are slightly higher, at 10 million people by 2046, at an overall growth rate of 56% and an average of 1.6% per year (Chart 3.2).

Over the same period, total employment is expected to grow at a slightly slower rate (to population) of 1.56% per year to a total of 5.1 million workers.

[15] See *The Current and Future State of Victoria: a macroeconomic perspective*, Deloitte Access Economics advice for Infrastructure Victoria, 2016.

Chart 3.2: Population and employment forecasts (Victoria, 2018-2046)



Source: Deloitte Access Economics 2015. Forecasts go to 2033, with the average growth trajectory applied to each following year to 2046.

Industry forecasts

By 2046, Victoria is expected to be the residence for over 5 million workers, including 188,000 workers in what are deemed the most at-risk sectors, including:[16]

- 48,600 in freight;
- 65,200 in vehicle maintenance and repairs;
- 28,000 in vehicle retail;
- 15,300 in road public transport;
- 11,500 in taxis and hire cars;
- 10,900 in fuelling; and
- 8,100 in rail public transport.

While this represents a large potential number of workers, it is a relatively small overall share of the Victorian economy, representing 3.7% of total jobs.

The largest industry employment forecast is for Health Care and Social Assistance (1.1 million by 2046), which is also the fastest growing at 151% growth from 2018 levels (an average of 3.3% per annum).

Other large industries include Professional, Scientific and Technical Services (630,000, 114%), Retail Trade (530,000, 43%), and Education and Training (500,000, 90%). Notably, total employment in Agriculture, Forestry and Fishing, Mining, and Manufacturing is also forecast to decline.

The key at-risk industry – Transport, Postal and Warehousing – is currently forecast to grow by 38% to a total of 230,000 workers. While this industry includes ancillary sectors such as postal and delivery services, water and air transport, and warehousing and other storage services, 2016 Census

[16] Forecasts are for the total 'Transport, Postal and Warehousing' industry. This analysis applies a constant average growth rate to each sector, such that is assumes the relative proportions of each sector remain constant.

estimates reveal that 47% of workers in this industry are employed in Road Transport, indicating the relevance of this sector to the test scenarios.

3.3 Direct impact on employment of ZEVs and AVs

The adoption of ZEVs and AVs is expected to have large impacts on the workforce and therefore would significantly affect the baseline forecasts described earlier. At a high level, these workforce effects can be described by four forces:

1. Autonomous technology removing the need for human drivers;
2. Autonomous technology prompting a change in ownership structures from private to fleet operators;
3. Autonomous technology changing the way people commute and use public transport; and
4. Electric vehicle technology and engines displacing traditional combustion engines.

While these forces are expected to provide significant positive benefit to the overall Victorian economy and society (as discussed later), for the key sectors of interests, the workforce impacts are likely to be negative.

The links between each force to the primary or 'most direct' employment impacts are summarised in Table 3.1, noting that they are all interrelated and likely to affect many industries and workers. The remainder of this section explores each of these forces in greater detail and provides estimates of the direct employment effects from the literature.

Table 3.1: Mapping technological changes to employment impacts

Industry:	**Transport**				**Other business services**	**Trade**	
Sector:	**Freight**	**Road PT**	**Taxis**	**Rail PT**	**Maintenance & repairs**	**Fuelling**	**Retailers**
Removing drivers	✓	✓	✓		✓		
Private to fleet					✓		✓
Commuter behaviours		✓		✓	✓		
Electric engines					✓	✓	

The rate of adoption of ZEVs and AVs, and hence impacts on employment, will be determined by a myriad of factors, including technological advancement, cost and scale efficiencies, as well as regulatory and legal considerations.

For the purposes of estimating the direct longer-run employment impacts of these technologies – and consistent with the approach taken by Infrastructure Victoria – this section focuses on the complete adoption of ZEV and/or AV technologies. While transition implications are not explicitly considered, the CGE modelling exercise in the next section does incorporate how the economy may transition to each of the scenario end-states.

This is in contrast to the previous chapter on 'Equity and access to services', as the socio-economic impacts are more likely to be informed by the patterns of take-up and variations in transitions across the state.

Drivers likely replaced by autonomous operators

The introduction of AVs will have the most certain and direct impact on *driver workers* – that is, occupations whose primary function is to operate a vehicle in transporting goods or people from one place to another. This will affect both road vehicles and non-road vehicles, such as forklifts and cranes. However, the focus of this report is on road vehicles, such that the main employment industries affected for the purposes of this report are:

- Trucking and freight drivers;
- Taxis, hire car and ride-share operators; and
- Public transport operators – particularly bus drivers.[17]

When the technology is available and as community expectations change, individuals and corporations will likely transition to autonomous operators, particularly once safety, labour cost and capital efficiency are considered.

This is likely to result in the total removal of the need for human drivers, putting at-risk 113,000 roles in the transport industry, and in particular, a likely complete loss of 32,500 roles in freight, 10,300 in road transport, and 7,700 taxi and hire care drivers.[18] The scenario impacts can be summarised as:

- 100% of roles removed in freight, road public transport and taxis for all AV scenarios: Private Drive, Fleet Street, Hydrogen Highway and High Speed;
- 50% of roles removed for Slow Lane; and
- No change for Electric Avenue.

A US Department of Commerce study (2017) identified that freight drivers in particular were more likely to be male, older, less educated and on lower wages, and hence find it more difficult to find alternate employment.

A Commonwealth Department of Industry, Innovation and Science submission (2017) arrived at similar findings for Australia. The submission also considered a transition using 'platooning' which would soften the employment impacts.[19] The Department posits that the older nature of these workers may also result in workers ending careers and retiring as AVs are introduced, which would mitigate the number of transitioning unemployed workers, although potentially lead to lower retirement incomes for those affected.

As in the discussion in Section 3.1, employment in these sectors is concentrated in pockets around the western, northern and south-eastern borders of Greater Melbourne. However, while these areas have greater

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[17] To the extent that AV road technology is adapted to include rail transport.
[18] ABS Census 2016. Excludes air, water and space transport. Freight is defined by 'Road freight transport', road public transport is defined by 'Road passenger transport' excluding 'Taxis and other road transport', which then defines taxis and hire cars.
[19] Platooning refers to a semi-autonomous transition for freight, whereby a lead truck (with a driver) operates a small platoon of trucks. The following trucks have continuous communication with the leader and operate more efficiently (i.e. at closer distances) and at significantly lower labour costs.

counts of these workers, they are still relatively diversified and represent a relatively small proportion of workers in these locations.[20]

Fleet operations likely to reduce the number of cars

AV technology is being aggressively pursued by a number of very large global corporations – including technology firms Waymo (Google), Uber, Zoox and Tesla, as well as traditional auto industry businesses such as General Motors, Mercedes-Benz, Renault-Nissan, Audi, BMW, Toyota and Ford.

These firms (as well as prominent industry analysts, such as Goldman Sachs, Morgan Stanley and Boston Consulting Group) have identified that the returns of delivering and operating a fleet of AVs are likely to be large, and may also be a necessity for traditional car firms to maintain relevance in the future. Furthermore, a first-mover to successfully deliver an AV may be able to dominate a 'winner-take-all' market position.

As the cost of ride-sharing falls and the convenience of shared vehicles increases, private ownership may give way to corporate owned and operated fleets. A shared fleet is likely to reduce the total number of cars, due to the greater utilisation of the fleet, which will also impact car sales and servicing, as the total number of vehicles falls.

In 2016, there were an estimated 28,100 workers in the automotive repair and maintenance sector.[21] For shared fleet scenarios, such as Fleet Street and High Speed, it is estimated that there could be an 85% reduction in the total number of cars, which it has been assumed corresponds to an 85% reduction in roles for maintenance and repairs. Accordingly, this equates to a 43% loss of vehicle repair and maintenance roles in Slow Lane.[22] This sector is discussed in further detail later in this section.

In addition, corporate fleet operators are more likely to purchase direct from wholesalers or produce cars themselves.[23] These large purchasers are likely to have the buying power and scale to enter in agreements with wholesalers rather than purchase from retailers.

Subsequently, this analysis assumes that the 16,400 roles in the vehicle retail market will be lost for Fleet Street and High Speed, while 50% will be retained for Slow Lane. Other scenarios are not impacted by these fleet ownership considerations.

Although workers in the vehicle retail industry are likely to have specialised knowledge that relates to motor vehicles, these workers are also likely to have the business and sales skills in order to transition to another retail or other sector.

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[20] The obvious contrast are regions where the majority of employment is in a single sector, typically one of mining, forestry or agriculture.
[21] ABS Census 2016.
[22] Advice received by Infrastructure Victoria from TU Berlin suggests that a shared AVs will be 15% of current fleet sizes.
[23] For example - Tesla only conducts sales direct from the manufacturer. While showrooms do exist, they do not allow for traditional retailers.

Vehicle use is likely to change

The increasing appeal and comfort of AVs will likely induce greater vehicle usage, which will increase maintenance and servicing requirements. An OECD study (2015) of autonomous and shared vehicles in Lisbon, Portugal estimated a 50-90% increase in car travel per vehicle.[24]

This analysis uses the average of this estimate and assumes that is translates to a 65% increase in employment in vehicle maintenance and repairs for all autonomous scenarios (Private Drive, Fleet Street, Hydrogen Highway, High Speed) and 33% for Slow Lane due to increased usage. The net impacts, as well as other changes in maintenance costs, are discussed further on in this section.

As a further consideration, fleet operators may better maintain vehicles with more ongoing servicing, compared with private owners, however this may be offset by potentially poorer use of interiors by shared users. As the size of these opposing forces are likely to be relatively small, they are considered to offset each other and hence are not included in the employment modelling.

The future of rail is uncertain

The effect of road-based AVs on rail transport is unclear. On one hand, the adoption of AVs is likely to address the 'first and last mile' issue by offering a cheap, efficient and convenient option for commuters to access public transport.[25] Furthermore, road transport cannot substitute the scale that rail can achieve in transporting large volumes of workers in and out of a CBD during peak hours.

On the other hand, the availability of cost-effective car commuting without parking considerations – as AVs will be able to return home or park outside of busy CBD areas – may lead to a large increase in and shift towards road usage and a renewed urban sprawl.

Therefore, while public transport may be further incentivised for some users, others may in fact substitute towards vehicles. As a result of this uncertainty, the modelling assumes no change in employment. [26]

Capital and labour requirements for rail transport are more greatly determined by peak service requirements. If these are relatively unchanged (as discussed earlier) then employment in the sector may also be relatively unchanged. Having said this, a BCG study (2016) surveyed rail users in the Netherlands and identified a likely 40% reduction in rail use due to the introduction of AVs.

Notably, this estimate does not influence the following CGE modelling, as the 'shock' to the economy is primarily entered through improvements in the productivity of the road Transport industry. In the results below, any

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[24] These estimates are based on changes in car-kilometres travelled over a 24-hour weekday. Notably, a precise estimate has been developed in a parallel transport modelling stream.

[25] Most commuters require the same routes as others for the majority of their travel, bar the starting and final points. Where these destination points are made difficult to combine with public transport, i.e. out of walking distance or no parking options, they present as barriers to access.

[26] Notably, this is inconsistent with other modelling completed for Infrastructure Victoria, but does not have material impacts on the subsequent employment modelling analysis.

reduction in rail activity comes about as a result of the enhanced competitiveness of road transport.

Although out-of-scope for this study, the adoption of AVs may also see the development of autonomous rail technology, which is likely to have a significant direct employment impact on the rail sector.[27]

Safer vehicles and electric motors will require less servicing
In addition to the employment effects on maintenance and repairs discussed earlier in this section, vehicle safety and a switch to electric motors will have significant effects for these 28,100 workers.

The US Department of Transport estimates that 94% of accidents are due to human error (2017), which could in turn be eliminated by the introduction of AVs. As only a proportion of car servicing are accident-related, it has been assumed that the corresponding reduction in accidents results in a 20% reduction in roles.[28]

The possible concurrent adoption of electric ZEVs will also reduce demand for maintenance and repairs, due to the significantly fewer parts in their design and operation, compared to traditional combustion engines. Researchers from the University of California, Berkeley (Becker, Ikhlaq, & Burghardt, 2009) use a 25% reduction in ongoing maintenance requirements for electric ZEVs, which has been applied as a 25% loss of roles in the maintenance and repairs sector.

Furthermore, electric vehicles do not require fuelling and can be charged using self-service or semi-automated charging stations. Notably, these charging stations can be deployed at small-scale with limited capital requirements, compared to traditional fuelling stations. Accordingly, 100% of roles in the fuelling sector are assumed removed for the four electric ZEV scenarios (Electric Avenue, Private Drive, Fleet Street, High Speed), and a 50% reduction for Slow Lane.

Hydrogen ZEVs on the other hand will still require fuelling, which may be delivered in a similar scale and fashion to traditional fuel stations. As it is less clear how these new fuelling stations may be operated, a no-change in jobs impact is estimated for the Hydrogen Highway scenario.

[27] There are over 40 autonomous urban train systems worldwide, with this number expected to rapidly increase. Furthermore, this includes automation of drivers as well as other crew (i.e. signalling staff).
[28] One interpretation of this assumption is that 1 in 5 vehicle servicing activities is related to a traffic accident.

Unpacking the employment impacts on maintenance and repairs

This section has described numerous ways that the vehicle maintenance and repairs sector will be impacted by AVs and ZEVs. Using the Fleet street scenario as an example, this box describes how the introduction of an autonomous, electric, shared fleet is likely to result in an 80% loss of jobs in this sector.

Notably, the most significant 'driver' of lower maintenance requirements and employment is the transition to fleet ownership and the corresponding reduction in total vehicles.

Description	**Change in jobs**	**Cumulative change in total jobs**
Base position		0%
Lower vehicle count due to fleet operations	-80%	-80%
Reduced maintenance requirements of electric motors	-25%	≈-80%+(-25%*20%) = -85%
Increased usage	+65%	≈-85%+(65%*15%) = -75%
Fewer accidents due to automation	-20%	≈-75%+(-20%*25%) = -80%
Better fleet maintenance, offset by shared good costs	0%	**-80%**

Note: The first column describes each employment impact, the second column provides at estimate of the change in jobs due to that force, and the third column is a cumulative calculation for the total jobs in the sector, where each subsequent force is applied to the remaining jobs.

Summary of results

This section has explored how the introduction and adoption of AVs and ZEVs may directly impact employment in key relevant sectors and industries. These findings are summarised for each of the six modelling scenarios in Table 3.2 and Table 3.3, and form the key inputs used in the CGE modelling in Section 3.4 to understand the wider economic impacts of these employment shocks.

To help illustrate the magnitude of these shocks and compare each scenario, forecasted future employment levels are used to estimate job losses across each scenario (Table 3.4).

By 2046, it is estimated that up to 180,900 workers will need to find new jobs as a result of the adoption of electric, autonomous, shared fleet vehicles (Fleet Street). At the lower end of the spectrum, 30,200 jobs are at-risk from electric ZEVs (Electric Avenue).

Table 3.2: Summary of negative direct changes in employment by occupation sector and industry

Industry	**Transport**				**Other business services**	**Trade**	
Sector	**Freight**	**Road public transport**	**Taxis & hire cars**	**Rail public transport**	**Maintenance & repairs**	**Fuelling**	**Retailers**
1 Electric Avenue	0%	0%	0%	0%	-25%	-100%	0%
2 Private Drive	-100%	-100%	-100%	0%	0%	-100%	0%
3 Fleet Street	-100%	-100%	-100%	0%	-80%	-100%	-100%
4 Hydrogen Highway	-100%	-100%	-100%	0%	32%	0%	0%
5 Slow Lane	-50%	-50%	-50%	0%	-43%	-50%	-50%
6 High Speed	-100%	-100%	-100%	0%	-80%	-100%	-100%

Note: '-50%' is interpreted as 50% of the future workforce will no longer be employed in this industry.

Table 3.3: Aggregated employment shocks by industry (percentage)

Scenario	**Transport**	**Other business services**	**Trade**
1 Electric Avenue	0%	-2%	-1%
2 Private Drive	-46%	-0%	-1%
3 Fleet Street	-46%	-5%	-4%
4 Hydrogen Highway	-46%	2%	0%
5 Slow Lane	-23%	-3%	-2%
6 High Speed	-46%	-5%	-4%

Table 3.4: Aggregated employment shocks by industry

	Future employment shocks (2046, 2031)			
Scenario	**Transport**	**Other business services**	**Trade**	**Subtotal**
Total employment forecast	*169,524*	*1,046,188*	*937,277*	***2,152,988***
1 Electric Avenue	0	-16,292	-10,931	**-27,224**
2 Private Drive	-89,761	0	-10,931	**-100,693**
3 Fleet Street	-89,761	-52,135	-38,967	**-180,863**
4 Hydrogen Highway	-89,761	20,854	0	**-68,907**
5 Slow Lane	-44,881	-28,023	-19,483	**-92,387**
6 High Speed^	-75,425	-38,397	-33,023	**-146,845**

Source: ABS Census 2016, Deloitte Access Economics 2015. ^Employment shocks for 'High Speed' are calculated using 2031 employment forecasts.

3.4 Flow on employment effects

This section uses the employment shocks from the previous section (see Table 3.3) in a CGE framework to understand and model how the economy may well react to the introduction of AVs and ZEVs.

A CGE model represents the connections between different sectors in the economy, as well as the behaviour of firms, consumers and government. For significant changes to the economy (such as the introduction of a new technology) a CGE model is able to estimate how sectors of the economy will react and where economic activity is likely to shift to.

In order to introduce an employment shock into the CGE model, the capital productivity of the transport industry is increased, such that employers substitute labour for capital.[29] The effects of these capital productivity improvements, the induced capital investments and the displacement of workers are then modelled throughout the economy to better understand the subsequent flow-on effects of these changes.

This capital improvement is introduced nation-wide. This is both a more likely scenario compared to a Victoria-only adoption, and avoids any distorting flows of capital and labour between states.

This section outlines the resulting **economic impacts of a capital productivity shock which directly results in a 46% decline in transport roles by 2046**, including economic output, employment, investment and exports.[30]

The direct capital productivity 'shock' to the economy is isolated to the transport industry, and does not include direct effects in other industries, for the following reasons:

[29] The introduction of new technologies allows for the substitution of capital for labour, i.e. vehicles for workers, in order to achieve higher levels of output. This defines capital productivity.
[30] For simplicity, this is achieved over a linear profile from 2020 to 2046.

- In order for the model to produce meaningful results, the shock needs to be sufficiently large in terms of the magnitude and proportion of economic activity within an industry.
- Isolating a single industry shock allows for a more transparent and tractable interpretation of the subsequent economic effects, and better allows for intuitive discussions.
- The CGE model is designed to trace relationships and interdependencies between supply industries, such that the flow-on effects of a shock are inherently dealt with within the model.

Notably, this modelling is most applicable for the Private Drive, Fleet Street and Hydrogen Highway scenarios. The change in transport employment is the same for High Speed, resulting in a faster transition, while the change in transport employment if halved for Slow Lane, which suggests a slower transition. The direction of these effects are all the same, unlike in Electric Avenue where the magnitude of the employment shocks are too small to have a meaningful impact on the model.

Key findings from the CGE modelling

The economic impacts of the productivity improvements related to ZEVs and AVs and the associated 46% decline in transport employment to 2046 can be summarised for Victoria as:

- A 72,200 decline in direct employment, which is offset elsewhere in the economy by an increase in jobs by 83,700 resulting in an overall increase employment of 11,500 jobs;
- A $14.9 billion increase (2.0%) in economic output or GSP by 2046, and a similar pattern for consumption, which increases by $6.7 billion;
- An extensive period of employment transition, particularly among machinery operators and drivers;
- An approximate 100% gain in investment expenditure for road transport, as well as a 5.7% increase for construction; and
- Increasing imports and decreasing exports throughout the economy.

Economic output

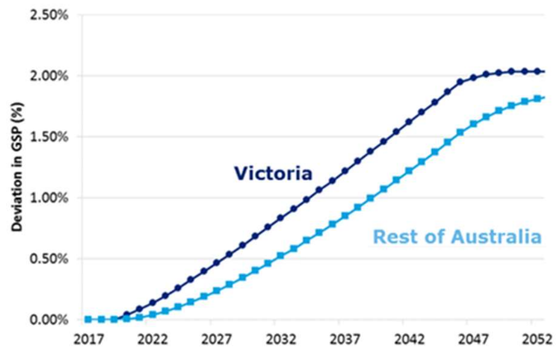
While employment declines for Transport, the technological advancements and productivity gains result in higher GDP output (compared to a future baseline) for the overall economy for Private Drive, Fleet Street and Hydrogen Highway scenarios. These productivity gains have compounding effects which result in increasing GDP growth as shown in Chart 3.3.

Productivity improvements reflect the economy’s ability to produce greater outputs from the same set of inputs. It can reflect better methods of production, higher quality inputs or technological advancements. Higher productivity helps to drive higher incomes and is broadly beneficial for consumers and society alike.

By 2046, output in Victoria is modelled to be $14.9 billion higher (2.0%), while output for the rest of Australia is $36.8 billion higher (1.5%).

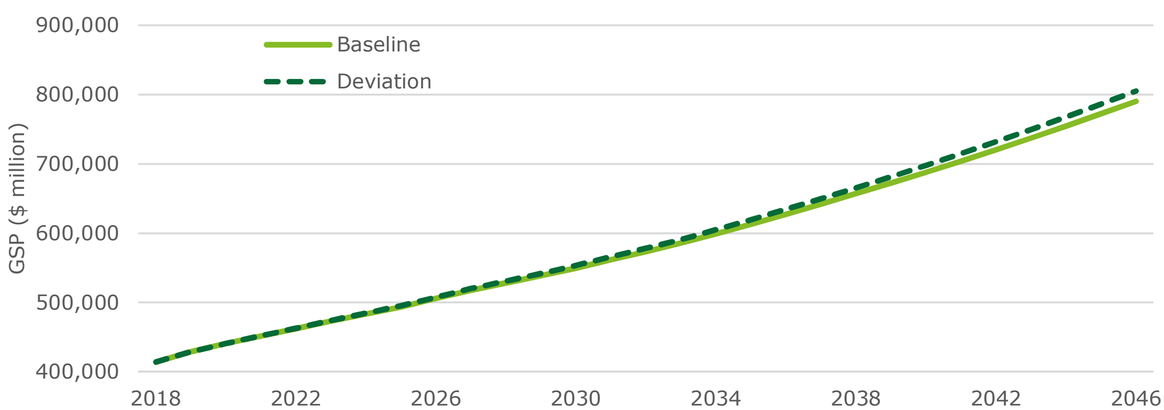
There are no material changes to the composition of output, i.e. the proportion of economic activity allocated to each industry, as the Transport industry (which initiates the shock) only comprises around 3% of total value added economic activity.

Chart 3.3: Deviations in economic output from baseline forecasts (shock from 2020)



Source: Deloitte Access Economics 2018

Chart 3.4: Economic output levels from baseline forecast (Victoria)



Source: Deloitte Access Economics 2018

Employment and labour

As large numbers of Transport workers are displaced, many of these workers will re-engage in other industries. Furthermore, capital efficiencies and improvements are likely to spill over in other industries, partially driven by efficiencies in Transport.

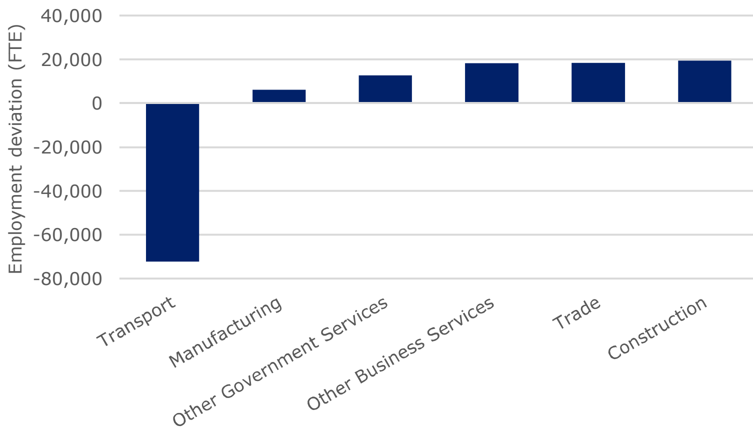
A large loss in roles for the Transport industry – 72,200 – is shown in Chart 3.5. However, this is more than offset by positive employment growth of 83,700, predominately across Construction, Trade and Other Business Services. Overall, this suggests that the introduction of ZEVs and AVs will be a net employment benefit of 11,500 jobs in Victoria.[31]

The effects of this shock will differ for workers with different skill sets, as illustrated in Chart 3.6. The loss of workers in the Transport sector is predominately in 'Technicians, trades workers, machinery operators and drivers', who are likely to re-enter employment through Construction, Manufacturing and Other Business Services.

[31] Note, for Slow Lane, the net overall change in jobs is 42% of Fleet Street, or 4,830 jobs.

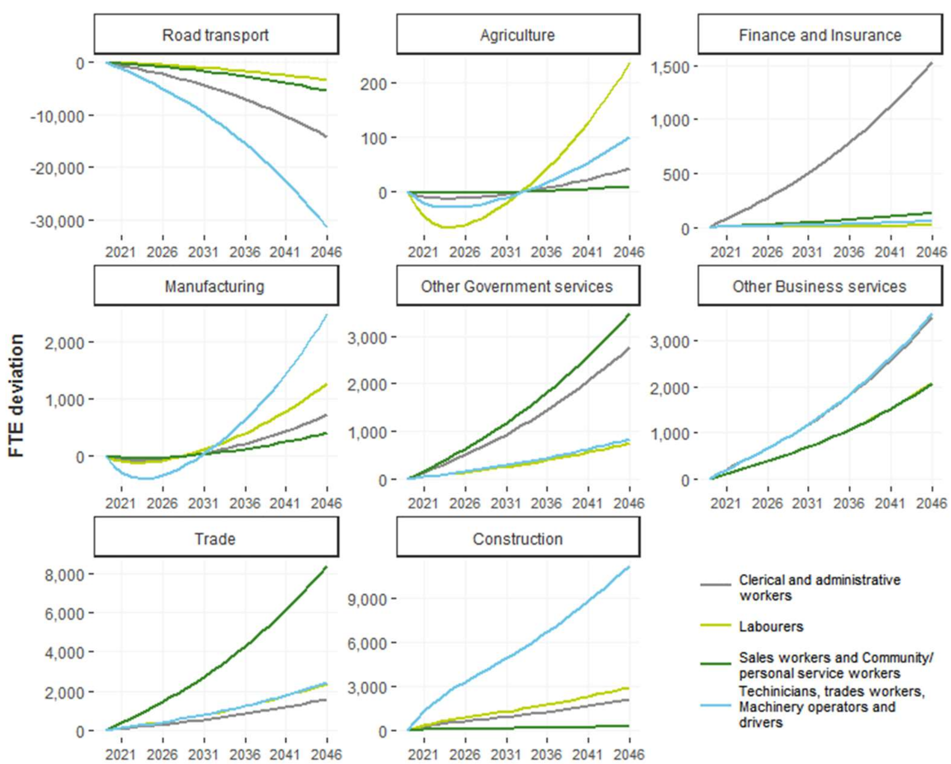
Notably, Manufacturing experiences a small negative change in employment once the shock begins. This may be due to the high demand for labour in Construction, which is likely driven by high growth in this industry in response to the needs of the Transport industry (e.g. charging station infrastructure, road upgrades etc.).

Chart 3.5: Change in employment by key industries (Victoria, 2046)



Source: Deloitte Access Economics 2018

Chart 3.6: Change in employment by industry and skill level (Victoria, 2020-2046)



Source: Deloitte Access Economics 2018

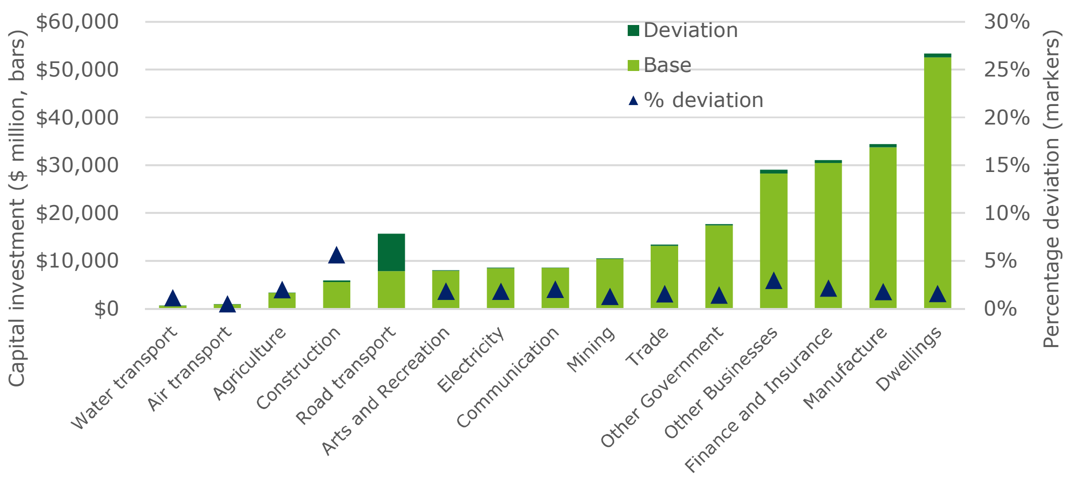
Investment and capital

Increasing productivity of capital induces the substitution of labour for capital, as the returns to capital increase. This draws in investment to build the capital stock of the economy. This is clearly identified in the modelling by the almost doubling of capital expenditure for Transport as presented in Chart 3.7.

Other industries also experience an increase in total capital due to technology spill overs. Construction (5.7%) has the largest response likely due to the increasing capital and infrastructure requirements induced by a transition to a more capital-intensive Transport industry.

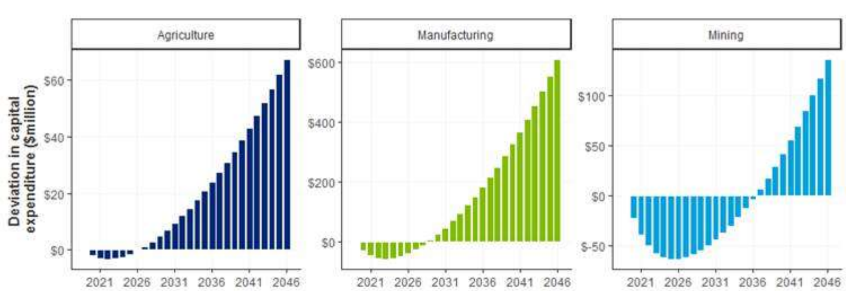
Although by 2046 these industries experience increasing capital expenditures, during the initial take-up there are declines in capital spending for Agriculture, Manufacturing and Mining as shown in Chart 3.8. This is likely due to the initial substitution of capital into the Transport industry. The larger negative shock for Mining, is likely due to the more capital-intensive structure, and hence greater responsiveness to investment opportunities.

Chart 3.7: Change in capital investment (Victoria, 2046)



Source: Deloitte Access Economics 2018. Note: Education and Health are captured in the Other Government industry. Percentage deviation for Road transport is 100%.

Chart 3.8: Trends in capital investment for selected industries (Victoria 2020-2046)



Source: Deloitte Access Economics 2018

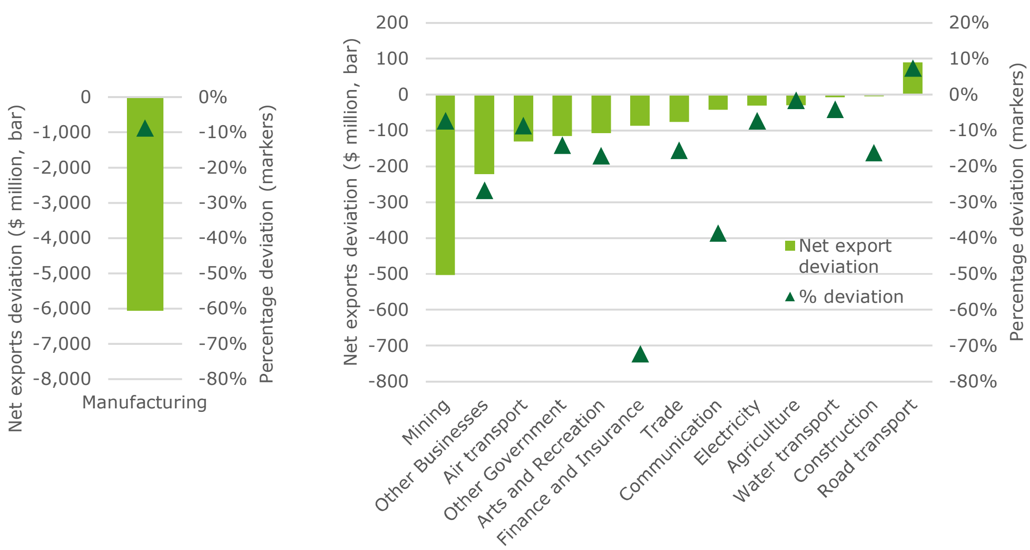
Exports and imports

Overall, the net trade position is expected to worsen (i.e. imports increasing at a greater rate than exports) throughout the Victorian economy. It is likely that this is driven by an inflow of investment into the country. This investment is to support the broad range of capital investments required to support the transition to ZEVs and AVs. Greater foreign investment exerts upwards pressure on the exchange rate, thus reducing the international competitiveness of exports throughout the economy and making imports relatively more appealing. Together these two effects result in a declining trade position overall.

Likewise, imports become comparatively more attractive and net trade position declines as shown in Chart 3.9 below, which also shows that this is primarily driven by a large increase in imports for Manufacturing ($6 billion, 8.8% from base).

Although small in absolute dollar terms, the net export position for Finance and Insurance services decreases by over 70%. This is likely due to increasing demand for financial services required to support the increase in capital and infrastructure spending that is modelled to occur.

Chart 3.9: Changes to exports by industry (Victoria, 2046)



Source: Deloitte Access Economics 2018. Note: Education and Health are captured in the Other Government industry.

Impacts of a faster transition

The results in this section have focused on the economic impacts modelled from a 46% loss of roles in transport employment to 2046. This is the key employment shock for the Fleet Street, Private Drive and Hydrogen Highway scenarios.

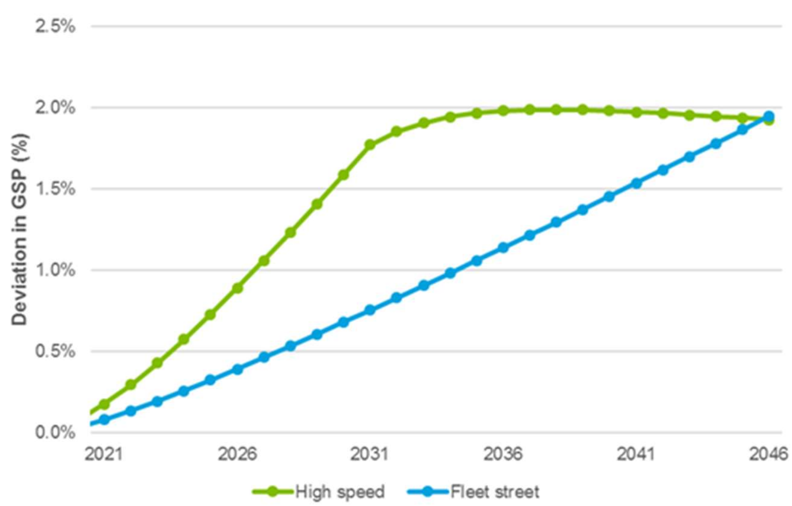
Notably, the High Speed scenario is a faster version of the Fleet Street scenario and can be modelled using the same shock, but implemented over a shorter timeline, i.e. the full employment shock by 2031.

The trends and magnitudes of the economic impacts for this scenario are very similar to the earlier analysis, albeit occurring sooner. This is best illustrated in Chart 3.10, which shows a faster growth pattern for High Speed, which plateaus, allowing for the Fleet Street scenario to catch up by 2046.

More broadly, this result is consistent for other economic indicators, that is, a similar change achieved sooner, but in the long run the change is consistent with the other scenarios. Employment changes are shown in Chart 3.11.

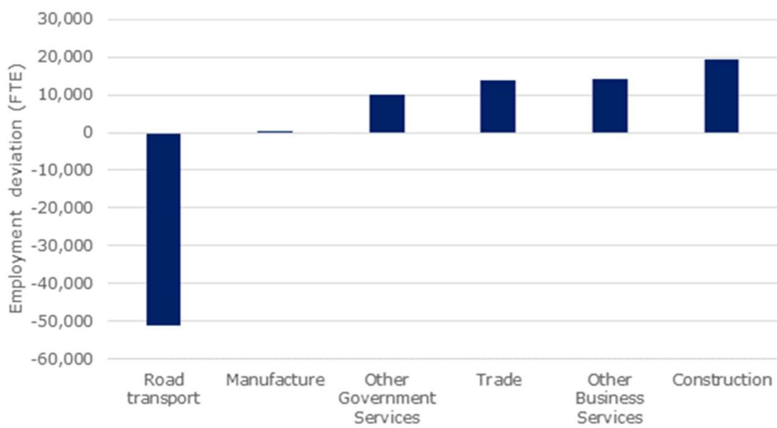
Over the total period, there are greater cumulative benefits under High Speed, as this high positive change is achieved sooner and so generates benefits over a longer period of time. In terms of economic output, the cumulative GSP value over 2021-46 is $29.6 billion higher for High Speed compared to Fleet Street (in net present value terms).

Chart 3.10: Comparing deviations in GSP across scenarios (Victoria)



Source: Deloitte Access Economics 2018

Chart 3.11: Change in employment in key industries (Victoria, 2031)



Source: Deloitte Access Economics 2018

3.5 Ability to respond to changes

This section concludes the employment chapter by considering opportunities in response to the changes posed by ZEVs and AVs. The following discussions are not inputs into the earlier modelling, but rather are quantitative and qualitative considerations for policy makers that relate to the earlier outputs.

Opportunities for job growth

The focus of this chapter and analysis has been on the negative direct employment shocks following the introduction of AVs and ZEVs. However, while many workers are at-risk of redundancy, other workers may experience a productivity boost.

The US Department of Commerce (2017) uses the term *on-the-job drivers,* for workers whose primary occupation is a service, which is then enabled by delivering that service to a specific site – for example, emergency services and trades occupations.

For many of these skilled workers, the driving aspect of a job is likely to be replaced by AVs, but the primary service provided will still be in demand. These workers are likely to experience better working conditions and an increase in productivity from the introduction of AVs.

Furthermore, the increasing access to services and decreasing cost of travel may introduce new mobile services with increasing growth opportunities for a range of occupations. For example, at-home care or medical treatment may become more viable.

Moreover, as travel becomes less costly in both financial (i.e. direct monetary costs) and time (i.e. minutes of in-vehicle time and in value of travel time terms), access to favourable work opportunities may increase for workers, particularly for those living in outer urban and regional areas.

Relatedly, while the costs of technology may be higher for non-road or non-urban environments, specialised vehicle operators may also be at-risk from AVs, particularly as firms face high labour costs for many ports, construction and mining sites. The impact on these workers is less clear due to their specialised skills and the opportunity for new roles (i.e. virtually controlled equipment).

Opportunities and requirements for transition

The previous section described key economic shifts in the Victorian economy following a large improvement in capital productivity – and a subsequent decline in employment – in the transport industry.

For these outcomes to materialise, there are a number of assumptions in the CGE model in terms of the movement of inputs and outputs in the economy.

Furthermore, and perhaps more importantly, there are opportunities for policy-makers to intervene in order to facilitate these flows. For example, a significant movement described earlier in Section 3.4 is the large decline in transport employment, which precedes a large increase in demand for labour in the construction industry (perhaps in response to AV and ZEV infrastructure requirements).

Some workers will have the requisite skills in order to transition smoothly from employment in one industry to another. However, others may not have the right skills or find these jobs may be less geographically accessible. Workers and employers also need to be matched and be able to find each other, as well as other social considerations.

Government can facilitate these transitions with targeted training and reskilling programs, providing job search services, or prioritising capital works in areas with more displaced workers.

While some workers are likely to be motivated to retrain, others may – rightly so – not be able to see the benefits of learning new skills in the face of uncertain job market outcomes. A likely example could be older workers from the freight sector. As discussed in Section 3.4 these workers may instead exit the workforce and retire early. Governments will need to consider their role in supporting these workers.

The table below summarises the likely vulnerabilities for workers in different sectors.

Table 3.5: Summarising worker vulnerability by sector

Sector	Vulnerability	Description
Freight	Highly vulnerable	The older age profile of truck drivers could see natural attrition in the industry as workers retire and no new workers enter the industry. A first shift to 'platooning' may also limit the initial job losses. However, this could result in early retirements and a greater reliance on government assistance. Freight may also be one of the first movers in automation, which could mean a much more rapid uptake of AVs and subsequently, more rapid job losses.
Road public transport	Highly vulnerable	Bus drivers are highly likely to be at-risk of displacement by AVs. These workers likely have a lower skill profile and hence may find greater difficulty in transferring to other industries, particularly those less affected by autonomous technologies. These workers are likely to require significant retraining and reskilling.
Taxis	Highly vulnerable	Taxi and hire care drivers will be highly at-risk of being displaced by AVs. The rise of ride-share operations has already proven to impact the taxi industry, and AVs will further reduce costs and increase the attractiveness of ride-share alternatives for consumers. A potential transition path could lead to employment in taxi services become part of the 'gig-economy' with full-time drivers retiring their careers and new drivers entering as part-time workers in a more intermittent market.
Rail public transport	Uncertain	While the future of rail is uncertain, there is the potential scenario for some downside. Importantly, technology advancements that lead to road AVs may see spill overs in rail AVs. This group of workers will likely require focused retraining and reskilling. While there will be little opportunity to transfer workers' skills to freight rail, good opportunities may be available in specialised equipment operations, such as maritime or construction equipment.
Vehicle maintenance & repairs	Vulnerable, but opportunities to adapt	Workers in this sector have been undergoing a gradual shift towards higher technology and higher skill requirements. This will need to be maintained by actively upskilling and developing the capability to work with modern ZEVs and AVs and their components. This may require additional training in adjacent new areas.
Fuelling	Vulnerable but some commercial options	In electric scenarios, fuel stations are at-risk of obsolescence, however, these sites may remain as convenience stores or other retail stores, which present an opportunity for these workers. In a hydrogen ZEV scenario, these workers are less likely to be at-risk of redundancy and may only need to acquire a small number of additional skills, which are similar to their existing capabilities.
Retailers	Vulnerable, but likely to adapt	While many retail workers may be at-risk in fleet scenarios, these workers are likely to have the ability to transition into other sectors, particularly other non-vehicle retail employment.

4 Infrastructure and policy response

Previous sections of this report have identified that the introduction of ZEVs and AVs will have significant impacts on mobility and access to services and that these impacts will differ by socio-economic group. Further, there are expected to be quite large employment consequences – particularly in terms of transition between industries.

This suggests that there is a role for government to play in helping to manage socio-economic outcomes, reduce inequality where appropriate and help ease the pains of transition in employment.

While there are many ways for government to assist in these areas, this section explores the impact of ZEVs and AVs on infrastructure and infrastructure related policy from a socio-economic perspective. Broader policy responses such as education programs, land-use changes and taxation changes are beyond the scope of the current report.

Section 4.1 first provides an overview of how current infrastructure planning and strategy relates to ZEVs and AVs through a socio-economic lens. Section 4.2 translates this into a view on how government could potentially approach thinking about ZEVs and AVs currently and Section 4.3 provides a set of five focus areas for government to consider when looking at the intersection of Infrastructure policy, ZEVs and AVs, and socio-economic outcomes.

4.1 Impacts on current plans

There are currently a range of major infrastructure plans of relevance in Victoria. A number of current major infrastructure plans were reviewed, with the focus being on plans by the State Government of Victoria, Federal Australian Government and other related organisations. This included organisations such as the Public Transport Victoria, Transport for Victoria, VicRoads, Department of Economic Development, Jobs, Transport and Resources Victoria, Infrastructure Victoria, Department of Infrastructure, Regional Development and Cities, Intelligent Transport Systems Australia and Infrastructure Australia.

A summary of these key plans is provided in Table 4.1, which also describes whether a detailed consideration of the impacts of ZEVs and AVs or a focus on socio-economic issues are provided.

The review finds that the majority of the relevant planning documents either focus on the impact of ZEVs and AVs on transport infrastructure or the impact of transport infrastructure on socio-economic issues, but rarely considers both together.

Only Infrastructure Victoria's 30-year strategy addresses the impact of the transition to ZEVs and AVs on transport infrastructure from a socio-economic perspective. Overall, within the majority of the current and planned infrastructure projects, there seems to be a gap in analysis of the impact of ZEVs and AVs on infrastructure and policy considered from a socio-economic perspective.

Table 4.1: Summary of major planning documents reviewed

Project	Organisation	Type	Impact of ZEVs and AVs?	Socio-economic issues?
Public transport	Public Transport Victoria	Current and planned construction		✓
Road investment (partially regional road)	VicRoads	Current and planned construction		✓
National priority projects	Infrastructure Australia	Current and planned construction		✓
National Policy Framework for Land Transport Technology	Department of Infrastructure, Regional Development and Cities	Framework and action plan	✓	
Trials and pilots	Intelligent Transport Systems Australia	List of current trials and pilots in Victoria	✓	
Victoria's 30-year infrastructure strategy	Infrastructure Victoria	Recommendations for future strategy	✓	✓

Of the planning documents reviewed, the majority did not have a strong explicit consideration about the socio-economic role ZEVs and AVs can play in current infrastructure plans. Select organisations do focus on some of the specifics of ZEVs, AVs, and the transport system but then tend to have very little focus on the socio-economic implications of ZEVs and AVs.

This is somewhat problematic as these plans cover the period over which ZEVs and AVs will begin to affect the economy and society directly. This potentially means that the proper infrastructure for ZEVs and AVs to operate efficiently might not be there and may not currently be being planned for.

Further, many of these documents are focused on the identification, assessment and prioritisation of major infrastructure projects. Of the plans, those that had a major project with a focus on improving socio-economic outcomes or was specifically related to ZEVs and AVs were identified. Appendix B contains a summary of each of these major projects identified and if they consider the impacts of ZEVs and AVs on these projects.

Many of the major projects identified in these plans do not consider the potential impact of ZEVs or AVs. This is true both in terms of how ZEVs and AVs may affect the projects themselves or how the services provided by ZEVs and AVs could augment the desired socio-economic outcomes of the projects. To do so would require detailed consideration of how ZEVs and AVs are likely to affect travel behaviour and how this, in turn, affects the options that are available to address the goals of the project. For example, the introduction of ZEVs and AVs could create new options to address the problems that infrastructure projects are designed to address.

Having said this, in many of these plans, there seems to be an emerging role for integrated transportation, the treatment of transport from a service oriented point of view and a focus on how to best get different modes of transport to work together. This is a positive sign as it will be a key foundation for managing the transition to a future of ZEVs and AVs. However, this area will need to be significantly developed over the coming years.

Victoria's 30-year infrastructure strategy bears further analysis as the major infrastructure planning and analysis document that addressed both the potential for ZEVs and AVs as well as providing a focus on socio-economic issues related to infrastructure.

The 30-year infrastructure strategy includes "137 recommendations for improving the provision, operation, maintenance and use of the state's infrastructure" (Infrastructure Victoria, 2016, p. 3). This plan covers the social, economic and environmental needs of the whole state of Victoria and takes in account all sectors through the analysis of evidence and stakeholder consultations.

Specifically, it discusses how to harness technology to address the social, economic and environmental needs of Victoria. In particular, it explores infrastructure technology adoption with a socio-economic perspective. For example, some of the particular issues associated with infrastructure technology are how to:

- Improve access to services for people with mobility challenges;
- Provide access to high-quality education infrastructure to support lifelong learning;
- Meet growing demand for access to economic activity in central Melbourne;
- Improve access to middle and outer metropolitan major employment centres; and
- Improve access to jobs and services for people in regional and rural areas.

Infrastructure Victoria is currently exploring the impact of the transition to ZEVs and AVs in its *Autonomous and Zero Emissions Vehicles Infrastructure Advice.* One key area of this transition Infrastructure Victoria will focus on is the social, economic and environmental impacts. This is also emphasised in its consultation summary where one key focus area is the social consequences and opportunities. This report forms part of the evidence in analysing the social and economic impacts of the adoption of ZEVs and AVs.

4.2 Governments' role in infrastructure and policy responses

Despite the present lack of prominence of ZEVs and AVs in planning documents, government will have an important role in facilitating the introduction and adoption of ZEV and AV technologies.[32] As there is likely still some time before ZEVs and AVs replace traditional vehicles, this presents an opportunity for government to use this time to decide on the role that it wants to have in informing and influencing the future of transport.

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[32] See International Transport Forum report (2017) for an example of how governments could proactively approach managing a transition to AVs for the freight industry.

Private companies are aggressively pursuing these technologies and seeking opportunities to implement them throughout the economy and 'disrupt' existing businesses and markets. Similarly, governments must proactively respond to the potential changing nature of transport and establish its role in affected markets.

Policy makers could use these technological advancements as an opportunity to change the way governments in general think about policy and regulation, and how the public sector responds to or pre-empts 'disruption'.

For example, Infrastructure Victoria's advice will provide evidence on the impacts from the transition to ZEVs and AVs. It will explore the future of Victoria with these technologies and each stakeholder's role in shaping this future.

Facilitating the conversation on the role of AVs
Government can start by considering how AVs should be incorporated into society and how the broader community should be expecting their associated benefits to be realised.

It is unlikely that a one-size-fits-all approach will be appropriate, and instead governments will need to consider tailored policies for different groups, technologies and markets. This is particularly important when considering socio-economic issues, such as equity and access to services.

Changing the definition of passenger transport
One of the key challenges for government will be the need to broaden its definition of passenger transport.

Future transport ecosystems will need to be integrated into systems management, with customer information systems and government visibility on operations. This will allow for the optimisation of the overall transport network. These considerations need to be included into government investment planning and frameworks, such that future infrastructure systems can incorporate and facilitate future technologies.

The nature of public transport may involve a large number of smaller operators with varying business models, compared to today's state of either government-managed service providers or contracted services to a small number of very larger private sector providers.

Clearly, governments will need to change the way they approach, interact with and govern these new market structures, and decide which systems or regulations should be centrally controlled, versus left safely (and optimally) to the market.

Similarly, for transport more broadly, governments may need to re-think their traditional focus and direct more attention to mobility services, and achieving efficient and equitable transport outcomes for customers.

Proactively positioning for real option values
In the immediate term, an overarching goal for Victoria could be to ensure that real option values are being created – that is, identify the investments and decisions that can be made now, which will best allow governments to respond quickly to future advancements in technology.

It is clear that the future of transport is uncertain and the specifics could vary widely (see scenario options), however, there are likely to exist commonalities across different case scenarios. Investing now in the structures that can support these commonalities will help to realise the benefits of these new technologies.

In particular, governments will have key roles in:

- Regulatory frameworks to ensure that passengers are safe and service provision is acceptable. This may include data transfers, collection and feedback systems, as well as minimum standards or accreditation.
- Standards and harmonisation of legal frameworks and practical applications, such as road signage and protocols.
- Physical investments in areas where early preparation may allow for significant benefits in the future, particularly for groups that may be disadvantaged in terms of take-up.

Regulation and standards will clearly be an important consideration for governments to facilitate the introduction of ZEVs and AVs. However, the scope and focus of this report and chapter is on infrastructure options, which is discussed in greater detail in the next section.

4.3 Potential infrastructure options

Beyond the discussion in the previous section, there are areas of infrastructure where governments may wish to intervene to address socio-economic issues.

This analysis has not considered what specific projects could be implemented in specific regions at specific times, but instead has identified five focus areas where ZEVs and AVs will intersect with infrastructure and socio-economic considerations. While these focus areas will require government investment, the nature of this investment will ultimately be determined by how government define their role in these markets.

These areas have been identified through consultation with Deloitte’s global ZEV and AV practitioner network, including consultations with experts from China and Germany, and include:

1. Financial and regulatory support to strategically target charging infrastructure;
2. Considerations of the potentially perverse impacts of autonomous-only vehicle lanes;
3. Developing and improving intermodal and interchange options and facilities for enabling public transport;
4. Supporting investment to enhance the value proposition in regional areas; and
5. Investing in infrastructure to facilitate greater communication AVs and existing transport.

Supporting targeted charging infrastructure

Vehicle charging infrastructure will likely be a mix of commercial, private-owner and semi-public investment – that is, firm-provided fuelling or charging, at-home charging stations, and facilities provided for high-density or high-frequency locations, i.e. housing communities, apartments or shopping centres.

While it is not clear that there is a need for a public charging network in general, there are likely to be benefits from targeted investments by government., particularly to address socio-economic challenges and opportunities This may warrant further investigation, including the use of detailed cost benefits analysis.

Greater access to charging infrastructure may accelerate and promote private investment in ZEVs and AVs, and may also enable uptake from lower socio-economic groups. For example – a small public investment in a charging stations for a lower income area may help to support the decision and cost of investing in ZEVs.

Initial public investments may also lead to crowding-in of other companies, services and investments that could be used to drive localised growth. Governments could focus on developing a geographic area into an innovation hub – similar to a precinct design approach – in an attempt to generate a critical mass of adoption of ZEVs and AVs.

Broadly, the approach to targeted public investments should be based on driving societal welfare and equity outcomes, supporting informed decision-making and positive consumer behaviours. As an example, Section 2.2 shows how different geographic and socioeconomic groups are likely to experience different outcomes, with some groups and areas doing better than others. Targeted investment may help to account for these differences.

For example – working with the private sector to develop concessions or co-investments for charging around public transport hubs, shopping centres or large residential compounds may promote greater use of public transport and higher utilisation of individual vehicles.

Alternatively, governments could approach regional subsidies by incorporating integrated community service coverage requirements with commercial operators, particularly in less densely populated areas around regional centres. This may help to introduce ZEVs and AVs in otherwise less commercially viable areas. It could also help to reduce any range anxieties due to lack of charging infrastructure.

Furthermore, governments could investigate whether there are any regulatory, planning or legal barriers to beneficial private investments, and whether it is appropriate for policy-makers to help to alleviate these constraints.

Considering the socio-economic impacts of autonomous-only lanes
As AVs are introduced into the road network, policy makers may consider introducing autonomous-only lanes. These lanes could operate at faster speeds with greater utilisation, and in effect become priority lanes that incentivise investment, while also leading to safer roads for all passengers.

However, the prioritisation for passengers in AVs could lead to perverse and regressive socio-economic outcomes, in the form of greater benefits from public spending for those with higher socio-economic status. Investments in autonomous-only lanes may initially be predominately utilised by those living in higher socio-economic areas, but the infrastructure would likely be developed throughout cities, including in areas with lower take-up of AVs. Governments should consider these implications in the design, decision-making and implementation or AV vehicle infrastructure.

Improving intermodal interchange options
The future of rail and AVs is uncertain (see Section 3.3). One likely scenario is that AVs will better enable commuters to access public transport, particularly for commuters travelling longer distances from outer urban or lower socio-economic status areas.

In order to better facilitate the use of an integrated transport system, more efficient and higher capacity drop-off and pick-up infrastructure may be required for train stations, as well as popular destinations such as schools, hospitals or shopping malls. Augmented reality technologies could also support passengers to navigate to a vehicle, in contrast to having large congested pick-up zones.

Investments to facilitate the changing nature of travel could range from simple road signage and communication of rules, to significantly more complicated systems, such as fully integrated and optimised dynamic drop-off sites in train stations. Technology to understand and monitor the flows of commuters arriving and departing could help to support a more dynamic public transport network with greater on-demand services.

Policy makers should also consider options that encourage greater use of nearby public transport interchanges. A risk is that commuters use AVs to travel as close to their destination as possible before switching to public transport for the last and most congested part of their journey, rather than accessing their nearest interchange.

Innovative road user charging and public transport pricing – which can be designed and implemented in advance of AVs – may encourage greater use of public transport. For example, rail pricing could be lower in peak periods or constant for any distance travelled, this could potentially be in contrast to traditional pricing methods.

Supporting investment to enhance the value proposition for AVs in regional areas

Two key value propositions for AVs are the potential for greater utilisation of vehicles and reduced congestion. Clearly, the costs – and therefore the associated benefits and commercial viability – are highest in high density, high congestion areas, whereas more regional areas are less likely to face similar challenges.

While the commercial benefits are less likely, there are many social benefits from AVs. These include reduced accidents, emission abatement, greater choice of housing and increased access to services to amenities and other drivers of economic growth, as illustrated in Section 2.2. For these reasons, government may look to enhance the value proposition of AVs in regional areas, by providing supporting infrastructure or facilitating commercial arrangements to ensure the appropriate investments are made.[33]

One approach to developing opportunities in regional areas could be to focus on regional centres and using AVs to expand their coverage and scope of providing amenities and employment throughout the surrounding region, as well as developing the ability to travel between regional centres.

The reach of regional centres is limited by insufficient scale (for public transport, for example) as well as large distances that can't be traversed safely and timely by traditional vehicles. AVs could allow for travel at lower cost and higher speeds (and therefore longer distances), and also be supported by new autonomous-only roads.

Governments could also consider leveraging future commercial investments. For example, private firms may invest in regional infrastructure to support commercial autonomous freight operations. Governments may be able to utilise this infrastructure in order to promote the uptake and adoption of AVs in regional communities.

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[33] As illustrated in Section 2.2.2.2.

Infrastructure to facilitate communications between AVs and existing transport

Connectivity and communications will be critical for an autonomous transport ecosystem. This will involve connectivity with traditional telecommunications networks, but could also include other connected objects, such as signs, roads, people, bicycles, public transport stops etc.

While connectivity can be achieved without a telecommunications network connection, having a constant and globally connected transport system will be able to better support AVs, and also improve safety and accident prevention, particularly for pedestrians and other non-vehicle road users.

It is likely that modern 5G networks will be required to deliver this level of connectivity and government will have a role in determining how to distribute and manage competition for bandwidth in an environment of increasing demand.[34]

In order for an interconnected network of transport vehicles and objects, these different things will need a common language in order to communicate and a common understanding of what information to convey and how to interact or respond to new information. While Australia is likely to be an adopter of technology standards developed overseas, local policy makers will have a role in ensuring it is adequately adopted and adapted to Victorian requirements, and also provide overarching governance on how this data is managed and exchanged across the system.

Alongside regulations and standards will be the investments in communication infrastructure to ensure strong and consistent 5G coverage across the state. Government should ensure that these communications are consistent across geographic or socio-economic region, as not doing so could lead to variations in safety, quality of service and adoption or provision of AVs.

[34] See https://www.itscanada.ca/files/2_CVAV1_Kirk_Automated_Vehicles.pdf.

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Appendix A: Access to services

Please refer to attached workbooks.

Appendix B: Major projects of relevance

Public transport projects in Victoria

There are many major public transport projects currently underway in Victoria. The Melbourne Metro Tunnel is being expanded to increase its capacity, reliability and efficiency. This project aims to address current socio-economic issues by improving the access to services of users to Melbourne's university and hospital precinct and major employment centres. This project also aims to address future population growth in certain areas as it paves the way for construction and extensions of the railway.

The Rail Revival project and Regional Network Development Plan both aim to improve rail services in Victoria. The Regional Network Development Plan has short, medium and long-term priorities around more tracks, more trains, better facilities and more services. The Rail Revival project is a $1.7 billion initiative of the Australia and Victorian government and focus on improving rail stations, signalling and tracks across Victoria.

There is an initiative by Transport for Victoria to improve trams. This includes some projects to provide stops that are more physically accessible, real-time customer information, segregation between trams and general traffic, tram priority at traffic signals and better intermodal connectivity with the timetables of trains and buses.

Other initiatives include the Better Bus network aims to improve bus services within communities with high growth in both Melbourne and the rest of Victoria.

There is no specific mention of ZEVs and AVs within any of these project plans. ZEVs and AVs could potentially complement the socio-economic aims of these project as they increase the access to services of people to public transport options.

The adoption of ZEVs and AVs combined with the investment in public infrastructure can work together to increase access to range of other services, locations and opportunities. However, by not clearly considering the potential adoption of ZEVs and AVs over time, there is a risk of public transport infrastructure being poorly designed for the transition to ZEVs and AVs.

Over-capacity of new public transport investments might occur where ZEVs and AVs improve the mobility of users so much that they do not need to use public transport anymore. In this case, ZEVs and AVs could substitute for public transportation in some areas. This could potentially leave an underutilised form of infrastructure that locks in investment that could have been used more effectively to address other socio-economic objectives.

Under-capacity might occur where ZEVs and AVs improve the mobility of individuals (especially those individuals who were no able to access public transport before due to issues of cost, distance or physical limitations) and greatly increase their access to public transport. This would increase the demand of public transport in certain areas. Not taking into account the potential higher levels of demand for public transport can result in overcrowding and unpleasant experiences for the public transport user in that area.

Without accounting for the potential impact of ZEVs and AVs in these public infrastructure plans, there is a potential that negative consequences for certain socio-economic groups might not have been considered.

Investment in roads by VicRoads

As a single example, VicRoads plans to invest $21 million into the planning and development of future road projects in outer Melbourne and regional Victoria. These plans aim to rebuild and improve current roads and with plans to specifically to support growth with regional areas. The plans include short- and long-term goals for the maintaining and planning of a better regional road network with an emphasis on encouraging freight, tourism and economic prosperity within these areas. Road maintenance is also an important focus, in particular addressing current issues by fixing country roads and creating an action plan for high-risk roads.

There is currently no clear or specific mention of ZEVs and AVs within any of these project plans.

While the aim of this plan was to invest in regional roads to bring more access to opportunities in regional areas, by not considering the role of ZEVs and AVs, these plans might result in different economic and social outcomes for these regional areas as they transition to ZEVs and AVs.

The design of the road for proper infrastructure that can support the adoption of ZEVs and AVs is particularly important to ensure regional areas are not left behind in the transition to ZEVs and AVs. For example, whether the road would be able to support AVs, through clearer physical marking or whether the road has the potential of upgrading to smarter infrastructure over time, are important considerations for current investments. These considerations would encourage adoption of ZEVs and AVs within these regional areas and ensure that these regional areas are able to access the benefits that the transition to ZEVs and AVs would bring such as increased access to services.

The transition to ZEVs and AVs will also greatly impact the road design aspect of the plans. Fully automated AVs (in theory) are accident free. Therefore, the goal of having safer roads can be achieved by encouraging the adoption of AVs. To ensure that all Victorians have access to the potential safety benefits of AVs there needs to be more consideration in regards to encouraging adoption within the certain socio-economic groups that might be less likely to adopt AVs (such those with lower levels of income, lower levels of education and are not very tech-savvy). This can include more targeted educational outreach to inform and encourage adoption within socio-economic groups that might be slower in adoption. This can also include investment of suitable upgrades of roads that would support the use of AVs on the roads and that the road infrastructure is not a barrier against transition within certain areas.

The Victorian Government's Road Safety Account Plan briefly mentions the potential of impacts of ZEVs and AVs as "cars of the future" in improving safety. However, no specific socio-economic impacts of ZEVs and AVs were considered.

National Priority Projects by Infrastructure Australia

In Infrastructure Australia's current national infrastructure priority list, there are two projects set in Victoria – the high-priority M80 Ring Road upgrade and the priority Inland Rail (Melbourne to Brisbane via inland NSW). The M80 Ring Road aims to address urban congestion and is proposed to be delivered within the next 5 years, while the Inland Rail aims to address freight connectivity between Melbourne and Brisbane and is proposed to be delivered within the next 10-15 years. In addition to these plans by Infrastructure Australia, the Victorian Government has submitted a business case to Infrastructure Australia of a North East Link with the aim of reducing congestion and crashes and boosting work opportunities. The proposed plans aim to connect the M80 Ring Road with the Eastern Freeway at Greensborough.

Currently, there are no clear or specific considerations in these plans about ZEVs or AVs.

Both of these projects will be affected by the transition into ZEVs or AVs. ZEVs and AVs can address some of the socio-economic problems that the M80 project is aiming to address. For example, the adoption of ZEVs can also help reduce the negative environmental impacts of fuel consumption and air pollution, creating better social outcomes for all users. The integration of AVs with multiple occupancy and smart infrastructure can reduce congestion issues faced by the users of this major road, while still sustaining the economic and population growth of the surrounding areas.

However, the reverse might be come true. With ZEVs and AVs increasing the users' access to services, there might actually be more vehicles on the roads, resulting in congestion and negative impacts for the users of this road. Congestion might also act as a limit the economic and population growth of the areas surrounding this road.

By not considering these alternative scenarios for future transport in its project business evaluation, there is a risk of the evaluation did not consider all the potential socio-economic effects.

A similar argument can be made for the Inland Rail project. Not considering the potential impacts of ZEVs and AVs on freight movements may mean that this investment in rail might actually increase the cost of freight and reduce the competitiveness of these industries, negatively impacting the economy and society. Since the adoption of ZEVs and AVs is potentially going to occur within the timeframe for construction of Inland Rail, it is important to consider the effects that ZEVs and AVs could have on these plans to ensure all potential outcomes are properly considered.

National Policy Framework for Land Transport Technology by Department of Infrastructure, Regional Development and Cities

This framework uses a principles-based approach to enable the implementation and adoption of transport technology across Australia in an efficient, effective and consistent way. It includes a national policy objective, strategic contexts of current and emerging transport technologies, keys issues for the government regarding deployment, the role of the Australian government and includes a National Transport Technology Action Plan.

This framework is about the potential impacts of ZEVs and AVs within the transport system. The framework does explain that increasing access to services for all users as an important outcome from the adoption of the technology. The action plan focuses mainly on the regulatory aspects of these transport technologies, there is not specific points to ensure social inclusion or equal social outcomes from the technology within the action plan. While this framework is very useful and does consider the impact of ZEVs and AVs on the transport system, there needs to be more focus on incorporating more of a socio-economic perspective into this framework and its action plans.

Trials and Pilots reported by Intelligent Transport Systems Australia

Intelligent Transport Systems (ITS) Australia promotes the development and implementation of transport technologies in the air, sea, road and rail. ITS is an independent not-for-profit organisation that represents many stakeholders within this space such as transport users, transport businesses, ITS providers, government bodies and academia. It highlights some of the trials and pilots that are currently going on in Victoria, including:

- Victorian connected and automated vehicle (CAV) Trials – exploring how CAVs interact with infrastructure on the motorway.
- ITS Grants Program – projects which include CAVs on highways and technology to support priority of trams.
- Partnership between the Transport Accident Commission (TAC) and VicRoads with Bosch Highly Automated Driving Vehicles.
- Eastlink Driver Assisted Technology – where with Victorian Government, Australian Road Research Board and together with La Trobe University are testing vehicles with network and driver assisted technologies.
- The Monash-CityLink-Tullamarine corridor automated vehicle trails by RACV, Transurban and VicRoads.
- Australian integrated multimodal ecosystem (AIMES) by the University of Melbourne – large scale partnership with government and industry leaders to test multimodal connected urban transportation.

These projects contribute test how ZEVs and AVs could actually work within the Victorian transport system. There are many infrastructure recommendations from the results of these trials and pilots that can aid the implementation of these technologies. A review of these projects indicated that these projects had zero or very little analysis on the socio-economic effects of ZEV and AV adoption. While these trials and pilots do result in advancing the implementation of ZEVs and AVs, it is also important to consider the different effects the transition to ZEVs and AVs can have on different socio-economic groups, so certain groups are no left behind in the transition.

Appendix C: CGE model

Introduction

A change in any part of the economy has impacts that reverberate throughout the economy. For example, the doubling of government expenditure on disability support services will involve increased economic activity in the disability services industry but it will also have a range of impacts in other parts of the economy:

- As the sector expands it will draw in an increased volume of primary factors as well as intermediate inputs from related service, manufacturing and mechanical repair sectors.
- The additional taxation associated with funding the scheme may have an impact on peoples' labour supply (given it is partly funded by the Medicare levy) as well as other firm and household decisions (given it is also funded from consolidated revenue and thus company tax and a collection of indirect taxes).
- Apart from the direct effects of expanding services and taxation, the roll-out will result in changed consumer spending by households whose income and employment have changed with the change in economic activity. This could mean a change in investment flows and consequently a changed capital stock.
- Importantly, increased activity will be recorded in the regions where this transformation is concentrated but there will also be altered activity levels in other areas which export to those more directly affected.

A Regional Computable General Equilibrium (CGE) model is the best-practice method available for capturing the different impacts highlighted above. The reason for this is that it is able to explicitly account for behavioural response of consumers, firms, governments and foreigners while evaluating the impacts of a given policy change.

At the same time, it observes resource constraints meaning that the estimated economic impact which comes from a CGE model will account for 'crowding out' whereby increased activity will draw resources from other sectors. This is especially important in the context of modelling small regional economies where key sectors account for a major share of output and thus changes in these sectors' activity levels will have large ramifications within the region.

DAE-RGEM

The Deloitte Access Economics regional general equilibrium model (DAE-RGEM) belongs to the class of models known as Computable General Equilibrium (CGE), or Applied General Equilibrium (AGE) models. Other examples of models in this class are the Global Trade and Analysis Project (GTAP) model, the Victoria University Model (the Vic-Uni Model) and The Enormous Regional Model (TERM).

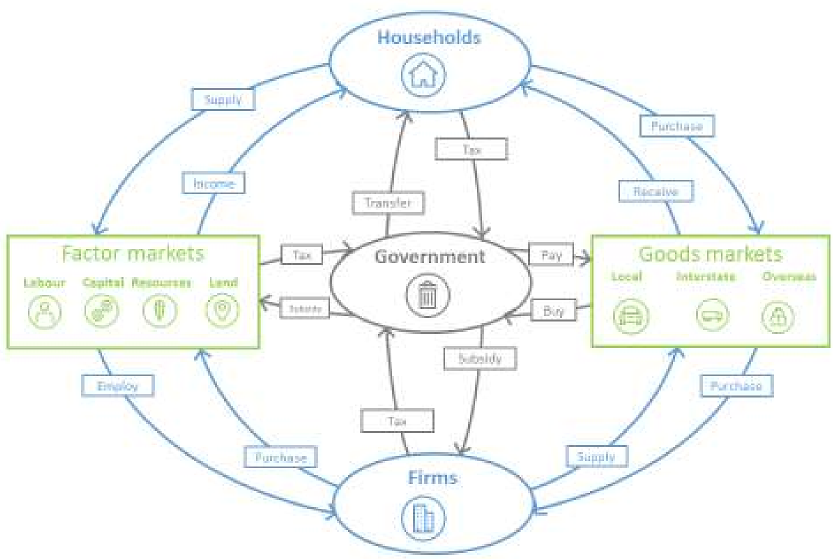
Like GTAP, DAE-RGEM is a global model, able to simulate the impact of changes in any of the 140 countries in the GTAP database (including Australia) onto each of the 140 countries. The ability to incorporate the flow-on impacts of changes that may occur in rest of the world is a key feature of global models that is not available in single-country models, such as the Vic-Uni Model or TERM.

However, like those models, DAE-RGEM is a bottom-up model of regional Australia. So DAE-RGEM is able to project the impacts on different States and sub-State regions of Australia of changes occurring in any region of Australia or in rest of the world within a single, robust, integrated economic framework.

This model projects changes in macroeconomic aggregates such as GDP, employment, export volumes, investment and private consumption. At the sectoral level, detailed results such as output, exports, imports by commodity and employment by industry are also produced.

The following diagram gives a stylised representation of DAE-RGEM, specifically a system of interconnected markets with appropriate specifications of demand, supply and the market clearing conditions determine the equilibrium prices and quantity produced, consumed and traded.

Figure 4: A stylised representation of DAE-RGEM



The model rests on the following key assumptions:

- All markets are competitive and all agents are price takers.
- All markets clear, regardless of the size of the shock, within the year.
- It takes one year to build the capital stock from investment and investors take future prices to be the same as present ones as they cannot see the future perfectly.
- Supply of land and skills are exogenous. In the business as usual case, supply of natural resource adjusts to keep its price unchanged; productivity of land adjusts to keep the land rental constant at the base year level.
- All factors sluggishly move across sectors. Land moves within agricultural sectors; natural resource is specific to the resource using sector. Labour and capital move imperfectly across sectors in response

to the differences in factor returns. Inter-sectoral factor movement is controlled by overall return maximizing behaviour subject to a CET function. By raising the size of the elasticity of transformation to a large number we can mimic the perfect mobility of a factor across sectors and by setting the number close to zero we can make the factor sector specific. This formulation allows the model to acknowledge the sector specificity of part of the capital stock used by each sector and also the sector specific skills acquired by labour while remaining in the industry for a long time. Any movement of such labour to another sector will mean a reduction in the efficiency of labour as a part of the skills embodied will not be used in the new industry of employment.

DAE-RGEM is based on a substantial body of accepted microeconomic theory. Key features of the model are:

- The model contains a 'regional household' that receives all income from factor ownerships (labour, capital, land and natural resources), tax revenues and net income from foreign asset holdings. In other words, the regional household receives the gross national income (GNI) as its income.
- The regional household allocates its income across private consumption, government consumption and savings so as to maximise a Cobb-Douglas utility function. This optimisation process determines national savings, private and government consumption expenditure levels.
- Given the budget levels, household demand for a source-generic composite goods are determined by minimising a CDE (Constant Differences of Elasticities) expenditure function. For most regions, households can source consumption goods only from domestic and foreign sources. In the Australian regions, however, households can also source goods from interstate. In all cases, the choice of sources of each commodity is determined by minimising the cost using a CRESH (Constant Ratios of Elasticities Substitution, Homothetic) utility function defined over the sources of the commodity (using the Armington assumption).
- Government demand for source-generic composite goods, and goods from different sources (domestic, imported and interstate), is determined by maximising utility via Cobb-Douglas utility functions in two stages.
- All savings generated in each region are used to purchase bonds from the global market whose price movements reflect movements in the price of creating capital across all regions.
- Financial investments across the world follow higher rates of return with some allowance for country specific risk differences, captured by the differences in rates of return in the base year data. A conceptual global financial market (or a global bank) facilitates the sale of the bond and finance investments in all countries/regions. The global saving-investment market is cleared by a flexible interest rate.
- Once aggregate investment level is determined in each region, the demand for the capital good is met by a dedicated regional capital goods sector that constructs capital goods by combining intermediate inputs in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these intermediate inputs subject to a CRESH aggregation function.
- Producers supply goods by combining aggregate intermediate inputs and primary factors in fixed proportions (the Leontief assumption). Source-generic composite intermediate inputs are also combined in fixed proportions (or with a very small elasticity of substitution under a

CES function), whereas individual primary factors are chosen to minimise the total primary factor input costs subject to a CES (production) aggregating function.

- Labour in DAE-RGEM is distinguished by occupational classes. The exact number of the occupation class depends on the aggregation dictated by the engagement at the time of model application. However, version 9 of the GTAP database recognises five occupational classes. These occupational classes are substitutable with each other and with other factors of production.
- Demand for each occupational class in each production sector in each region is met by the workers equipped with different skill levels (educational degree and discipline). The composition of skills in each occupation and sector is dictated by cost minimisation rule subject to a CES aggregation function. The smaller the elasticity of skills substitution within a given occupation, the difficult it becomes for occupational labour to move across skills regardless of the wage differences. This means that a given skill will be employed in a given occupation. The number of skill types also depends on the need at the time of model application. In the default aggregation, DAE_RGEM solves with one occupation class and one skill type.
- The supply of skills is exogenous to the model. However, following the literature on the wage curve, DAE-RGEM maintains that the skill specific unemployment rate in each region responds negatively to rise in corresponding real wage rate. In other words, the skill specific unemployment rates in DAE-RGEM are endogenously determined and they fall with the rise in equilibrium real wage rates.
- Normally international migration in DAE-RGEM is treated as exogenous, but interstate migration within Australia is derived endogenously. It is maintained that wage differences in the regions observed in the base year reflects the risks and remoteness differences, any difference is the growth rates in the skill-specific regional real wage rates induces interregional migration.
- With respect to the sources of intermediate inputs, producers minimise costs by choosing between domestic, imported and interstate intermediate inputs subject to a CRESH aggregating function.
- Prices are determined via market-clearing conditions that require sectoral output (supply) to equal the amount sold (demand) to final users (households and government), intermediate users (firms and investors), foreigners (international exports), and in Australia to other Australian regions (interstate exports).

For internationally-traded goods (imports and exports), the Armington assumption is applied whereby the same goods produced in different countries are treated as imperfect substitutes. But, in relative terms, imported goods from different regions are treated as closer substitutes than domestically-produced goods and imported composites (home-bias). Goods traded interstate within the Australian regions are assumed to be closer substitutes than overseas imports.

Limitation of our work

General use restriction

This report is prepared solely for the internal use of Infrastructure Victoria. This report is not intended to and should not be used or relied upon by anyone else and we accept no duty of care to any other person or entity. The report has been prepared for the purpose of set of analysing the socio-economic impacts of ZEVs and AVs. You should not refer to or use our name or the advice for any other purpose

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