KPMG

Vehicles Advice - financial analysis

Infrastructure Victoria
FINAL REPORT

9 July 2018

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Contents

Glossary

AVs	Automated Vehicles
EVs	Electric Vehicles
FCVs	Hydrogen Fuel Cell Vehicles
ICE	internal combustion engine
IV	Infrastructure Victoria
MABM	Melbourne agent and activity based model
NPC	Net Present Cost
RRC	Resource Cost Corrections
SPC	State Purchasing Contract
TAC	Transport Accident Commission
VKT	Vehicle Kilometre Travelled
ZEVs	Zero Emissions Vehicles

Executive Summary

The State and local governments in Victoria generate significant vehicle related-revenue each year, with income generated through stamp duty, registration, driver licence fees and Transport Accident Commission (TAC) premiums alone totalling over $4.5 billion in FY 2016/2017.[1] The Commonwealth also collects substantial fuel excise associated with vehicle use by Victorians. Governments also spend large amounts of money on road maintenance, road capacity and road safety enforcement.

The emergence of autonomous and zero emissions vehicles (AVs and ZEVs), and the resulting changes in consumer and business behaviour, are likely to directly impact vehicle-related government revenue and expenditure. The adoption of AVs and ZEVs are projected to have significant impacts on road capacity, road and public transport usage, vehicle ownership and petrol and electricity consumption and may require governments to reconsider the applicability of current vehicle-related revenue and expenditure arrangements.

The analysis in this report seeks to better understand the potential financial implications of AV / ZEV adoption in Victoria, with a specific focus on:

- The potential impact on State and local governments in Victoria, and Commonwealth Government revenue and expenditure categories that are considered most likely to be impacted as a result of AV / ZEV adoption;
- Potential policy interventions in response to AV / ZEV adoption;
- Vehicle lifecycle ownership costs for AVs / ZEVs in 2046 as compared to traditional internal combustion engine (ICE) vehicles; and
- Potential implications for the appraisal of transport infrastructure projects.

Financial impact on governments

The potential financial impact on governments has been assessed across a number of scenarios. These scenarios have been specified by Infrastructure Victoria and consider different rates of AV / ZEV adoption by 2046 (except Scenario 6 which considers a 2031 scenario). These scenarios are summarised below:

- **Scenario 1 – electric avenue:** The fleet is entirely composed of electric (but non-automated) vehicles which are privately owned;
- **Scenario 2 – Private drive:** The fleet is entirely composed of automated and electric vehicles which are privately owned;
- **Scenario 3 – Fleet street:** The fleet is composed of electric and automated vehicles with a shared ownership model;
- **Scenario 4 – Hydrogen highway:** The fleet is entirely composed of hydrogen powered, automated vehicles which are privately owned;
- **Scenario 5 – Slow lane:** Half of the driving population uses a shared automated fleet, while the other half continue to use traditional ICE vehicles which are not automated and which are privately owned;

[1] 2016-17 Vic Roads Annual Report, p. 27.

- **Scenario 6 – High speed:** This scenario is the same as the *Fleet street* scenario, but involves the transition to a shared fleet of zero emissions AVs being realised by 2031 rather than 2046.

  The financial impact of these scenarios have been assessed against the reference case summarised below:

- **Reference case – Dead end**: The Victorian vehicle fleet is entirely composed of traditional ICE vehicles which are privately owned. This forms a reference case in that it is similar to existing fleet composition and ownership models.

Table 1 below shows the estimated annual net financial impact on the key affected government revenue and expenditure categories across the different scenarios listed above. The table shows that all scenarios are projected to result in a significant reduction in net revenues, which ranges between $5.1 billion (2030/31) and $12.8 billion (2045/46) per annum.

Table 1 - Estimated annual net financial impact on key affected government[2] revenue and expenditure categories by scenario

Category	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
Net financial impact	-$8,100m	-$12,650m	-$12,750m	-$12,620m	-$5,110m	-$8,070m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The primary drivers of these results are:

- Diminishing fuel excise revenues as a result of the adoption of electric or hydrogen powered AVs;
- A loss of driver license revenue under autonomous vehicle scenarios;
- Reduced registration revenue due to an increased number of vehicles becoming eligible for ZEV registration discounts;
- Lost traffic infringement revenue due to the replacement of human driven vehicles with AVs;
- TAC premium revenue falling by more in absolute terms than TAC expenditure; and
- Lost parking revenue due to the ability of AVs to ‘dead run’ and avoid parking fees under certain circumstances.

This is partly offset by reductions in police expenditure associated with road safety activities and increases in vehicle stamp duty revenue due to a combination of higher projected purchase prices for AVs and increased Victoria-wide vehicle kilometre travelled (VKT) necessitating more vehicle purchases.

Potential government responses

To address the projected financial impact of AV / ZEV adoption discussed above, as well to as address other related policy challenges, this report includes high level analysis of four potential government responses. These are summarised in the table below.

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[2] Local governments in Victoria, the Victorian Government and a share of Commonwealth excise revenues assumed to be generated by Victorian vehicle use

Response	Description
Revenue neutral distance based charging	This response option seeks to offset declines in Government revenue streams by implementing a distance-based charge for kilometres travelled by vehicles on Victoria's roads. A price per VKT has been calculated for each scenario at a rate that offsets the projected net financial cost. Projected charges range from 7 cents per kilometre in Scenario 5, to 18 cents per kilometre in Scenario 3.
Area based charging	This response involves introducing a daily charge for all vehicles entering high congestion areas. The aim of the charge would be both to help control road traffic in these areas and, as with the distance based charge, to help offset the financial impact that the adoption of AVs and ZEVs is likely to have on Government across each of the scenarios. It is estimated that a charge system for vehicles entering the identified congested area (relevant inner city cordon) during different periods of the day could generate an estimated $2.3 billion (per annum) in 2046.
Promoting improved road safety through adjusted TAC premiums	Autonomous vehicles are projected to be significantly safer than non-autonomous vehicles, effectively removing the human error factor which is estimated to be the cause of approximately 94 per cent of accidents.[3] To encourage the adoption of AVs with the objective of improving road safety, this option models an increase in the TAC premium for non-autonomous vehicles. The analysis shows that a 50 per cent increase in premiums could increase TAC revenue by between $2 and $3 billion depending on the scenario.
Access and equity responses	The implementation of shared AV fleets in Victoria has the potential to generate a number of efficiencies for the Victorian economy and improve access to transport services for many Victorians. However, shared fleet based solutions may be more costly to implement in rural and regional areas compared to metropolitan centres. Potential government responses to address access and equity issues considered in this report include: • Encouraging fleet providers to operate in rural and regional areas through a per-VKT subsidy; and • A vehicle registration fee discount for those living in regional and remote areas.

Vehicle lifecycle ownership costs

In addition to the potential financial impact on government, this report also considers potential lifecycle ownership costs. These are considered across different fuel sources as well as across private versus fleet vehicle scenarios.

Different fuel sources

It is unlikely that most vehicles in the future will use petrol or diesel fuels. Instead, as indicated in KPMG's Automotive Executive Survey 2018, vehicle technology in the future may see traditional, electric and hydrogen technologies co-existing. Further, the expectation is that automated vehicles will increase mobility, improve safety and reduce costs, and through the widespread adoption of this technology, transform transport outcomes for Victorians.

To better understand the expected financial implications for consumers in 2046, KPMG has prepared high level estimates of the projected lifecycle ownership costs of traditional,

[3] See Appendix A for further details on these assumptions.

automated electric and automated hydrogen vehicles, considering purchase-related, fixed annual and variable costs.

Based on a set of plausible assumptions, it is projected that in 2046, autonomous electric vehicles will be the lowest cost fuel source option for the average Victorian who uses their vehicle to drive 15,000 kilometres per annum.[4]

Private versus fleet vehicles

Over the past decade, the emergence of car sharing has grown in Victoria, and with advancements projected across the industry, car sharing popularity is expected to grow in the coming years.[5] This growth in popularity is in part driven by consumer desire to avoid or reduce the fixed costs associated with ownership, paying instead for the time and/or distance that the vehicle is used. Autonomous vehicles make shared fleet vehicles even more attractive as they can come to the door of the user, rather than being located at nearby locations.

To better understand the financial implications that autonomous fleet vehicles may have on ownership choices of consumers, KPMG has developed high level estimates of the relative costs of private ownership of an automated electric vehicle as compared to utilising an automated electric fleet-style service.

It is projected that in 2046, it will be approximately 40 per cent cheaper for the average Victorian who travels 15,000 kilometres per annum by car to use a fleet style service than to own their own vehicle. It is estimated that for the average Victorian, even the upper bound usage cost estimate for using an autonomous electric fleet vehicle will be less than the lower bound estimate for a privately owned autonomous electric vehicle.

Implications for transport infrastructure business cases

The new technologies and scenarios described in this report have major potential implications for business cases for major transport infrastructure projects. The new technologies could unlock potential economic and social benefits for Victorians if appropriately managed. There are also a number potential dis-benefits that could occur if long-term planning does not appropriately consider these new technologies.

The key takeaway for the implications of the development of business cases under potential AV / ZEV adoption scenarios is that there will be greater uncertainty around the potential transport and economic impacts of transport infrastructure projects during the period when the new technologies are in the process of being widely adopted. The technologies could evolve rapidly, and could also have complex and unpredictable effects on consumer behaviour during this adoption period. It is important that business cases recognise this uncertainty and incorporate it as a core part of the business case analysis.

This report outlines the range of impacts that AV / ZEV adoption is likely to have on transport infrastructure business cases, including:

- Transport demand and behavioural impacts;
- Economic, social and environmental benefits and dis-benefits; and
- Financial and economic costs.

[4] It is estimated that the average Victorian travels 15,000 km per annum. Estimate in line with assumptions detailed by Thakur, P., Kinghorn, R. & Grace, R. (2016). *Urban form and function in the autonomous era.* Australasian Transport Research Forum 2016.
[5] KPMG & Arup (2017). *Model Calibration and Validation Report,* Infrastructure Victoria, Melbourne

1 Introduction

1.1 Background and context

In October 2017, Victoria's Special Minister of State Gavin Jennings requested that Infrastructure Victoria (IV) provide written advice to the Victorian Government on Victoria's infrastructure requirements to "enable the implementation of automated and zero emissions vehicles"[6]. IV's advice is referred to as Vehicles Advice throughout this document.

The scope of this advice is the infrastructure requirements that:

a) Enable the operation of highly Automated Vehicles (AVs) (otherwise referred to as autonomous vehicles, driverless vehicles or self-driving vehicles);
b) Respond to new ownership and market models which may arise from highly automated vehicles; and
c) Respond to the eventuality of Zero Emissions Vehicles (ZEVs) as a high proportion of the Victorian fleet.

To inform this analysis, IV has developed seven scenarios (outlined in *Section 1.3*) as to how the adoption of AVs and ZEVs might occur, and has commissioned studies that examine the implications of these scenarios on traffic patterns, the energy network, ICT infrastructure, environmental and population health, international markets, population and land use, and transport and engineering requirements. The studies will also extend to assessing a range of the projected financial and socio-economic impacts of these scenarios.

As part of the wider Vehicles Advice project, the purpose of the financial analysis stream of work is to inform a better understanding of the potential financial implications of AVs and ZEVs in Victoria. The specific objectives of this work are to estimate the potential impact of AV / ZEV uptake on long-term Victorian and local government revenue flows and long-term government expenditure, while also assessing the long-term financial impact of AVs and ZEVs on consumers under different adoption scenarios.

Local and state governments generate significant revenue from vehicle-related fees, with income generated through stamp duty, registration, driver licence fees and Transport Accident Commission (TAC) premiums alone totalling over $4.5 billion in FY 2016/2017.[7] The Commonwealth also collects substantial fuel excise associated with vehicle use by Victorians.

The emergence of AV / ZEVs and resulting changes in consumer behaviour are likely to directly impact governments and the revenue generated by existing vehicle-related fees and charges. This is likely to require governments to reconsider the applicability of current arrangements under different future scenarios, and to examine the viability and impact of changes to these current arrangements.

[6] Gavin Jennings (25 October 2017), *Terms of Reference – Advice from Infrastructure Victoria on automated and zero emission vehicle infrastructure.* Available from https://goo.gl/drFfgY.
[7] 2016-17 Vic Roads Annual Report, p. 27.

The financial impact of AVs / ZEVs can be examined through two distinct lenses – that is, the cost to government (including State, local and Commonwealth) and consumers (including both individual and business).

The financial impact on government is likely to arise from potential reductions in revenue from traditional vehicle-related revenue items (such as parking charges and registration fees), together with changing costs of associated infrastructure (such as road building and maintenance) and services (such as road safety enforcement).

Government revenue will be influenced by the emergence of the AV / ZEV technologies themselves, and the manner and extent to which these technologies are adopted and used by society. Broadly speaking, it is likely that the nature of the financial impact of AV / ZEV technologies will turn on whether consumers use AVs / ZEVs in the same manner that traditional vehicles are used (e.g. as privately owned assets for personal single use) or whether new models of vehicle ownership and use will be adopted (for example, shared ownership models).[8] Furthermore, adoption and use of AV / ZEV technologies will be influenced by market forces and government regulation.

Governments will also be financially impacted as a consumer through the potential acquisition of AVs and/or ZEVs for use as the government fleet.

Consumers will be financially impacted by the emergence of AVs / ZEVs, including cost differentials across different vehicle types, impacts on associated services (such as vehicle maintenance costs), and overheads and profit margins charged by private providers under a shared fleet scenario.

1.2 Scope of analysis

The scope of analysis for this report is to estimate and analyse, based on agreed assumptions, the expected impact across each of IV's nominated scenarios (outlined below) that AV and ZEV adoption would have on the following revenue, expenditure, or other impact categories:

- Vehicle registration fees;
- TAC revenue and expenditure;
- Driver licence fees;
- Stamp duty revenue;
- State and local government parking revenues;
- Traffic infringement revenue;
- Fuel excise receipts;
- Road safety policing costs;
- Road capacity investment requirements;
- Vehicle emissions-related health costs;
- Road maintenance costs; and
- Costs associated with acquiring new State Government fleet vehicles.

This report also extends to assessing the anticipated consumer lifecycle ownership costs for AVs / ZEVs, discussing a number of potential government interventions to address the revenue

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[8] See Igor Dosen, Marianne Aroozoo and Micahel Graham, *Automated Vehicles*, Research Paper no 7 (2017), p. 1, which states that "[r]esearch suggest that there will be a paradigm shift away from private car ownership towards automated ridesharing services or 'transport as a service'".

and policy challenges that may be brought about by the widespread adoption of AVs / ZEVs, and the potential impact of AV / ZEV uptake on the approach to assessing transport infrastructure business cases.

1.3 Scenario definitions

IV has specified a reference year of 2046 for scenario modelling related to the Vehicles Advice project. IV has also adopted an approach of testing a wide variety of 'book end' scenarios relating to take-up of various technologies relating to AVs / ZEVs. This report addresses seven reference scenarios that were nominated by IV. A brief description of these scenarios are provided in Table 2 below.

Table 2 - Scenario descriptions

Scenario	Description
Dead end – Reference case	The Victorian vehicle fleet is entirely composed of traditional internal combustion engine (ICE) vehicles which are privately owned. This forms a reference case in that it is similar to existing fleet composition and ownership models.
Scenario 1 – Electric avenue	The fleet is entirely composed of electric (but non-automated) vehicles which are privately owned.
Scenario 2 – Private drive	The fleet is entirely composed of automated and electric vehicles which are privately owned.
Scenario 3 – Fleet street	The fleet is composed of electric and automated vehicles with a shared ownership model. A fleet of electric and automated taxis (robotaxis) service the needs of Victoria's travellers in place of privately owned vehicles.
Scenario 4 – Hydrogen highway	The fleet is entirely composed of hydrogen powered, automated vehicles which are privately owned.
Scenario 5 – Slow lane	Half of the driving population uses a shared automated fleet (which is consistent with the *Fleet street* scenario), while the other half continue to use traditional ICE vehicles which are not automated and which are privately owned (in a manner consistent with the *Dead end* scenario).
Scenario 6 – High speed	This scenario is the same as the *Fleet street* scenario, but involves the transition to a shared fleet of zero emissions AVs being realised by 2031 rather than 2046. It is the only scenario which does not use 2046 as its reference year.

In the context of this work, AV refers to vehicles operating at levels 4 and 5 of automation (High Automation, Full Automation) as described by the Society of Automated Engineers International.[9] This means that the vehicle is able to automate all aspects of the dynamic driving task without human intervention.

[9] Society of Automotive Engineers (2016), *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.*

ZEVs are defined as vehicles which produce no tailpipe emissions. These vehicles have the potential to reduce or eliminate greenhouse gas, local air and noise pollution impacts. ZEVs is an umbrella term for Electric Vehicles (EVs) and Hydrogen Fuel Cell Vehicles (FCVs).

1.4 Structure of this report

This report is structured as follows:

- Section 2 outlines the potential impact on state and local government revenue and expenditure categories that are considered most likely to be impacted as a result of AV / ZEV adoption across each of the modelled scenarios. This analysis is based on a combination of strategic transport model outputs, economic and population projections, existing government policy settings, and a number of general and scenario specific assumptions.
- Section 3 includes a discussion on why government might undertake policy interventions in response to AV / ZEV adoption and broadly examines four potential interventions.
- Section 4 examines the potential vehicle lifecycle ownership costs for ICE and ZEV vehicles in Victoria in 2046. This analysis includes examination of the potential costs associated both with the ownership of these vehicles (both by private consumers and fleet operators) as well as the potential costs of replacing the Victorian Government's existing vehicle fleet with zero emissions AVs.
- Section 5 outlines the potential impact that AV / ZEV adoption may have on the approach to developing and assessing transport infrastructure business cases.

2 Financial impact on government

2.1 Summary of financial impact

Both State and local government in Victoria rely on a range of revenue raising mechanisms to support the vital task of maintaining, regulating, and improving Victoria's road network. Revenues associated with vehicle use also represent a substantial revenue source for the Commonwealth Government which provides transport funding to the States. Expenses including road safety enforcement, maintenance, infrastructure investment and Victoria's third party insurance scheme delivered through the TAC receive funding (either directly or indirectly) from revenue raised through Victoria's road users. Significant revenue items include fees for driver licences, registration fees, parking and congestion charges, and fuel excise.

The introduction of autonomous and zero emissions vehicles have the potential to significantly impact these revenue and expenditure categories. For example, ZEVs (be they hydrogen or electric) may effectively eliminate fuel excise revenues, and AVs may remove the need for individuals to hold a driver licence.

While the scenario analysis shows that different revenue and expenditure categories experience positive or negative financial impacts, the analysis shows that government revenue as a whole in Victoria (including Victorian local governments, the Victorian Government and Commonwealth revenue that indirectly flows to Victoria) is projected to significantly decline across all scenarios, with the most pronounced decline being seen in those scenarios that presume a future where shared AV fleets displace privately owned vehicles on Victoria's roads.

2.1.1 Summary of method

This section of the report analyses the projected financial impact of the defined scenarios on each of the revenue and expenditure categories outlined in *Section 1.2*. Analysis was largely limited to assessing the financial impact on the Victorian Government or local councils in Victoria. However, IV advised that the analysis should also be extended to Commonwealth fuel excise revenue that will be materially affected by the adoption of ZEVs. While this revenue is not collected by the Victorian Government or by local councils, it is often considered to be the source of Commonwealth funding to support new road projects, and any funding to support road maintenance.

The list of chosen categories is intended to capture the main categories likely to be affected by the scenarios, rather than being exhaustive. It should not be taken to represent the full picture of likely impacts on government revenues as a result of the adoption of ZEVs and AVs.

Generating these estimates required a number of assumptions to be made, and these are detailed in Appendix A. The estimates are highly dependent on those assumptions and, given the extended timeframe, the outputs of this modelling should be considered indicative rather than predictive.

2.1.2 Summary of results

The table below summarises the projected financial impact on government across selected revenue and expenditure categories for each scenario. These projected figures are expressed as positive or negative financial impacts relative to the appropriate reference scenarios (Scenarios 1-5 being compared to the 2046 reference scenario and Scenario 6 being compared with the 2031 reference scenario). These are per annum figures calculated for the scenario financial year (2045/46 or 2030/31). More detailed analysis on each financial impact category (including explanations of contributing factors, assumptions, and any potentially counter-intuitive results) are provided in section 2.2 below.

Table 3 – Summary of selected annual financial impacts on government across each scenario[10]

Category	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
Selected Local Government Financial Impacts						
Parking Revenue	-$0.2m	$25m	-$370m	$15m	-$170m	-$230m
Road Maintenance	$5m	$10m	$45m	$0.2m	$25m	$30m
Subtotal	**$5m**	**$35m**	**-$325m**	**$15m**	**-$145m**	**-$200m**
Selected State Government Financial Impacts						
Vehicle registration	-$1,660m	-$1,660m	-$4,070m	-$1,660m	-$2,030m	-$2,260m
Vehicle Stamp Duty	$20m	$780m	$450m	$710m	$210m	$280m
Driver Licence Fees	-	-$460m	-$460m	-$460m	-$230m	-$260m
Parking Revenue	-$0.1m	$20m	-$320m	$10m	-$150m	-$200m
Traffic Infringements	$20m	-$1,740m	-$1,740m	-$1,740m	-$600m	-$1,070m
Public Transport Farebox Revenue	$50m	-$1,100m	$2,090m	-$1,040m	$860m	$730m
Road Safety Enforcement	-$8m	$600m	$610m	$600m	$210m	$370m

[10] There may be some minor discrepancies between the sum of individual figures and totals due to rounding.

Category	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
TAC Revenue	$70m	-$5,560m	-$5,610m	-$5,570m	-$1,930m	-$3,430m
TAC Expenditure	-$40m	$3,180m	$3,210m	$3,190m	$1,100m	$1,960m
Road maintenance	-$20m	-$210m	-$50m	-$150m	-$150m	-$10m
Subtotal	**-$1,580m**	**-$6,150m**	**-$5,890m**	**-$6,110m**	**-$2,710m**	**-$3,880m**
Selected Commonwealth Government Financial Impacts						
Fuel Excise[11]	-$6,530m	-$6,530m	-$6,530m	-$6,530m	-$2,260m	-$3,990m
Subtotal	**-$6,530m**	**-$6,530m**	**-$6,530m**	**-$6,530m**	**-$2,260m**	**-$3,990m**
Total (all levels of Government)	**-$8,100m**	**-$12,650m**	**-$12,750m**	**-$12,620m**	**-$5,110m**	**-$8,070m**

Source: KPMG analysis based on assumptions and sources listed in Appendix A

These projected results suggest a significant negative impact on net revenue across all scenarios, with major drivers including:

- The introduction of AVs is projected to result in a significant decline in traffic infringement revenue due to these vehicles being assumed to have much higher compliance rates than human drivers. A decline in revenue of approximately $1.7 billion per annum is projected in 2045/2046 for all AV scenarios. It should be noted that this revenue reduction is, however, coupled with an estimated decline in the cost of road safety enforcement expenditure, which may allow consideration of alternate investment focus areas.
- The introduction of AVs is expected to bring about a significant decrease in both TAC revenue and expenditure due to lower accident rates anticipated under the scenarios featuring AVs. As baseline TAC premium revenue is higher than baseline TAC expenditure (reflecting the long tail of TAC payments and benefits, as well as the other activities undertaken by TAC), a proportional decline in both categories leads to a net decline of more than $2.3 billion per annum in Scenarios 2-4 and a notable fall of approximately $1.5 billion per annum in Scenario 6.

[11] Fuel excise is the largest Commonwealth Government revenue source likely to be impacted by the modelled scenarios. While the financial impact on the Commonwealth Government is not the primary focus of the analysis in this report, the impact on fuel excise has been modelled due to the significance of the financial impact and the potential flow-on effects this may have on the transport funds available to the Victorian Government. Fuel excise is not currently directly hypothecated to road funding but raised to, among other purposes, "recover from road users the costs they impose on society when using roads". Parliament of Australia (2000), *Petrol and Diesel Excises*, https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp0001/01RP06#WhyisExciseLevied

- Electric and hybrid powered vehicles currently attract a registration discount compared to ICE vehicles. If this discount remains in place in the scenario years, it is projected to result in a decline of approximately $1.7 billion per annum in registration revenue in 2045/46 relative to the reference case.
- Further reductions in registration revenue are possible in the event that vehicle ownership transitions from the current model of large numbers of households owning private vehicles towards one of a shared AV fleet. This transition would reduce the overall number of cars required on Victoria's roads, with total registration revenue projected to decline by $4.1 billion per annum under Scenario 4. There will likely be some corresponding reduction in VicRoads' related administrative expenditure associated with the registration processes, but this was not estimated nor included in the above estimates. These functions form one part of the VicRoads Registration and Licensing division, with staff, technology and other resources shared across registration, licensing and other functions. This area is also understood to be the focus of significant reform consideration (separate to the implications of AVs / ZEVs), which will impact the current business model and its costs. As such, it is not possible to reliably estimate the future costs of registration activities performed by VicRoads, and the proportion that might be saved under the different scenarios considered in this analysis.
- Fees charged for driver licences are expected to decline by $460 million per annum under the fully autonomous vehicle scenarios (Scenarios 2-4) as it is assumed that licences are no longer required under these scenarios. There will also be a reduction in VicRoads' licence-related administrative expenditure, but again this is not estimated, nor included in the above estimates.
- The introduction of ZEVs across all scenarios (with only Scenario 5 retaining any ICE vehicles on Victoria's roads) is projected to reduce fuel excise revenue collected in Victoria by between $2.2 billion and $6.6 billion per annum.[12]

The overall, per annum negative net financial impact on Government across the in-scope categories ranges from approximately $5.1 billion 2046 dollars in Scenario 5 to $12.7 billion in Scenario 3, where a shared fleet of zero-emissions AVs replaces all privately owned motor vehicles in Victoria. It should be emphasised that these figures are heavily assumption driven, and focused on the selected financial impact categories and should be considered indicative. The projected 2031 result for Scenario 5 is a net negative impact of $8.1 billion per annum. Of all tiers of government, the State Government had the largest number of revenue and expenditure categories impacted by all scenarios involving any large scale adoption of AVs.

The most significant decline in revenue for Victorian local governments occurs under the fleet-based AV scenarios where local governments no longer receive parking revenue. In contrast to State road maintenance costs, local road maintenance costs are projected to decline under all scenarios. This is most pronounced in the shared fleet based Scenarios 3 and 6 and is driven by a projected shift away from the use of local roads towards freeways and arterial roads.

Details on each of the in-scope financial impacts for this report are provided in the following section.

[12] As noted earlier, while the financial impact on the Commonwealth Government is not the primary focus of this report, the impact on fuel excise has been included due to the significance of the financial impact and the potential flow-on effects this may have on transport funds available to the Victorian Government. The impacts on other Commonwealth Government revenue (and indeed expenditure) categories, such as GST and customs duty, are less clear, and have not been assessed in this report.

2.2 Financial impact categories

2.2.1 Vehicle registration

Description of revenue item and approach to analysis

VicRoads collects registration revenue in relation to each non-exempt vehicle operating in Victoria. Fees differ based on vehicle type and location. Most significantly for the purpose of this analysis, registrants currently receive a $100 discount when registering an electric passenger vehicle or a hybrid passenger or heavy vehicle. Registrants of hybrid motorcycles do not pay a registration fee.

Projected future registration revenue was calculated by taking base year (2014/15) registration revenue (for all vehicle categories) and adjusting it for anticipated inflation, and growth in the driving age population of Victoria. The estimates assume a constant rate of vehicle ownership per person for all non-fleet based scenarios and the continuation of existing policy settings relating to registration discounts for hybrid and electric powered vehicles and the application of these discounts to hydrogen powered vehicles as they become more widely available.[13]

Analysis of Results

Table 4 – Financial impact of changes in per annum registration revenue across each scenario

Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
-$1,660m	-$1,660m	-$4,070m	-$1,660m	-$2,030m	-$2,260m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The model shows significant reductions in registration revenue across each of the examined scenarios as compared to the 2031 and 2046 reference scenarios. The two most significant factors driving this projected decrease in revenue are:

- Increased uptake of the registration discounts for hybrid and electric powered vehicles as ZEVs expand their market share in each scenario; and
- A steep decease in the total number of registered vehicles in scenarios where a shared vehicle fleet displaces privately owned vehicles on Victoria's roads. Transport modelling suggests that the fleet could be reduced by up to 93 per cent under the 'Fleet street' and 'High speed' scenarios. This financial modelling however is based on an 80 per cent fall in the total number of registered vehicles relative to their respective reference cases. This lower figure is intended to be conservative and to account for the potential for multiple commercial operators within the same areas, increasing the total number of registered vehicles beyond the minimum levels projected by transport modelling. The 'Slow lane scenario' includes a 40 per cent reduction in vehicle numbers, with roughly half of ICE vehicles being replaced by share fleet AVs.

[13] Given that hydrogen-powered vehicles have electric motors, it has been assumed that the registration discount for electric vehicles will be applied to them.

The impact on revenue was least pronounced in Scenarios 1, 2, and 4, where privately owned motor vehicles continued to dominate the market, and the only impact on revenue was as a result of the hydrogen and electric vehicle discounts. Even in these scenarios however, per annum revenue was projected to fall by more than $1.6 billion in 2045/46 relative to the 'dead end' reference scenario. While these figures assumed a constant rate of vehicle ownership by driving age Victorians between 2015 and 2046, the revenue figures for registration are sensitive to changes in vehicle ownership rates. A 10 per cent decrease in cars owned per driving age person in Scenario 2 for example, would decrease annual revenue by a further $320 million, and the ownership rate would need to increase by more than 50 per cent in order to fully offset the projected decline in revenue.[14]

Key dependencies/limitations

The above modelling rests on a range of assumptions. One key assumption is that existing policy settings surrounding the discounts for hybrid or electric vehicle registration will remain in place and be indexed to keep pace with inflation. It is also assumed that it will apply to hydrogen powered vehicles once these begin travelling on Victoria's roads. Given a lack of certainty over the future vehicle mix between different vehicle types and base locations, the model assumes that all zero emissions vehicles in each scenario will attract a discount equivalent in percentage terms to that currently provided to electric passenger cars registered in metropolitan Melbourne.

If the Government was to make a policy choice to eliminate the ZEV registration discount once these vehicles were widely adopted, the revenue decline under Scenarios 1, 2 and 4 would be zero, and under Scenarios 3 and 5 it would be $3.66 billion and $1.83 billion per annum respectively in 2045/46.

Another key assumption is that, for those scenarios featuring privately owned vehicles, the ratio of registered vehicles to Victoria's total driving age population remains consistent with 2015 levels.

This assumption is made on the basis that the introduction of AVs may impact decisions to purchase one or more motor vehicles in a variety of ways. Individuals not currently able to drive, due to disability or licence disqualification for example, may decide to purchase an AV, increasing the number of registered vehicles on the roads. By contrast, the ability to derive greater utilisation from a vehicle might prompt families to reduce the number of cars they own as a smaller number of AVs may now be able to fill transport needs. For example, a single AV car may be able to drop the parents off at work before coming home and dropping the children off at school. Due to a lack of sufficient evidence to conclude otherwise, the model assumes that ownership rates per driving age person will remain constant.

Finally, as noted earlier, this analysis does not quantify the potential reduction in VicRoads' registration related administrative expenditure. Due to ongoing reforms and shared resourcing across its Registration and Licensing business, this was not able to be reliably estimated through this analysis.

[14] It is not possible to predict whether this may change, however, News.com.au reported a 2016 Roy Morgan survey indicating that 67 per cent of people aged between 18 and 34 were driving, down from 72.5 per cent of the same age group in 2006. http://www.news.com.au/finance/economy/australian-economy/cars-no-more-a-symbol-of-freedom-for-young/news-story/0e122c69d7a175fbef1e14618606790e

2.2.2 Vehicle stamp duty

Description of revenue item and approach to analysis

VicRoads collects motor vehicle stamp duty revenue when a motor vehicle is registered or when the registration is transferred to another owner. Fees differ depending on whether the vehicle is new or used, a passenger or non-passenger, and whether a new passenger vehicle is valued over or under a passenger car value threshold.

Projected future vehicle stamp duty revenue has been calculated as per base year vehicle stamp duty revenue (across all vehicle categories), adjusting for anticipated inflation, growth in the driving age population of Victoria, and assuming that vehicles are turned over at a stable rate over their useful life. The estimates assume a constant rate of vehicle ownership per person for all calculations involving privately owned vehicles and the continuation of existing policy settings relating to vehicle stamp duty. The analysis assumes that AVs on average cost approximately 20 per cent more than ICEs to reflect the cost of the additional equipment required to automate the vehicle. This value is based on assumptions and analysis undertaken later in this report.

Further, this analysis considers the impact that the useful life of a vehicle has on stamp duty under each scenario, utilising vehicle kilometre travelled (VKT) as a proxy measure. Changes to the useful life of a vehicle (i.e. changes to VKT) impact the necessity and frequency of vehicle stamp duty throughout Victoria.

Analysis of Results

Table 5- Financial impact of changes in annual vehicle stamp duty revenue across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
$20m	$780m	$450m	$710m	$210m	$280m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The model shows an increase in vehicle stamp duty revenue across each of the examined scenarios as compared to the 2031 and 2046 reference scenarios. This outcome is the result of the higher anticipated price of AVs relative to non-automated vehicles, and the projected growth in VKT under each examined scenario, which is expected to diminish the useful life of vehicles, increasing the necessity and frequency of vehicle stamp duty payments.

Outcomes are most prominent in Scenarios 2 and 4, with per annum vehicle stamp duty revenue anticipated to increase by $780m and $710m respectively from the 2046 reference scenario. These outcomes are the result of an increase in projected distance travelled, with the forecast total VKT in both scenarios expected to be significantly higher than the reference scenario, as well as the pricing premium attached to AVs. Both of these scenarios involve a vehicle fleet entirely comprised of privately owned motor vehicles, however, results indicate that positive revenue outcomes are also expected for scenarios involving shared fleet-style services.

Under all scenarios involving a shared automated fleet (Scenarios 3, 5 and 6), despite the decline in the overall number of vehicles in Victoria, the expected total VKT is anticipated to remain similar to that in the reference scenario. As such, vehicles are projected to have a shorter useful life (in years), leading to increased turnover per vehicle, compensating for the decline in vehicle numbers.

Key dependencies/limitations

A key assumption of the above model is that the useful life of a vehicle is a direct product of VKT and, as such, the necessity and frequency of vehicle stamp duty under each scenario is influenced by VKT outcomes. A potential limitation of this model is that it does not consider the impact that emerging fuel sources and automation will have on the useful life of a vehicle. At this time, uncertainty remains regarding what the impact advancements in these technologies will have on vehicle useful life[15] and, as such, the underpinning assumptions must be considered when evaluating the robustness of the forecasts provided.

This approach has been determined to be the most robust method currently available, in part, due to the uncertainties surrounding projected useful life of vehicles (traditional and autonomous) in 2046. These uncertainties are a potential limitation for the model and, as technology continues to evolve, increased clarity regarding the useful life of vehicles should be considered when evaluating the robustness of forecasts provided.

Additionally, given the level of uncertainty over the future cost of vehicles, the modelling is based on the cost of vehicles in 2015, indexed to the reference year, with an additional 20 per cent premium to reflect the extra cost of AVs over non-automated vehicles. This 20 per cent value is based on analysis and assumptions outlined later in this report.

The model does not consider the potential emergence of autonomous 'pods', which some literature suggests may cost as little as half that of traditional vehicles.[16] The model also does not account for the potentially larger number of autonomous vehicles that may be subject to higher rates of stamp duty – higher rates currently apply to vehicles worth more than $65,000.

2.2.3 Driver licence fees

Description of revenue item and approach to analysis

VicRoads administers the collection of driver licence fees on behalf of the Victorian Government. This amount is not recognised as VicRoads' income, but is instead paid into the Victorian Government's Consolidated Fund. Driver licence fees differ based on the type and length of licence type.

Projected future driver licence fees have been calculated based on the base year total driver licence revenue collected by VicRoads, adjusting for projected inflation and growth in the driving age population of Victoria. For scenarios involving AVs, Level 5 autonomy (full automation) has been assumed (i.e. no human intervention required) and, as such, the model considers that individuals in these circumstances do not require a driver licence.

Analysis of Results

Table 6 - Financial impact of changes in annual driver licence revenue across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
-	-$460m	-$460m	-$460m	-$230m	-$260m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

[15] KPMG (2017). *The chaotic middle: The autonomous vehicle and disruption in automobile insurance*
[16] KPMG (2017). *Islands of autonomy: How autonomous vehicles will emerge in cities around the world.* Deloitte (2016). *Quantifying an uncertain future: Insurance in the new mobility ecosystem.*

The model estimates a significant reduction in revenue associated with driver licence fees across each of the examined scenarios as compared to the 2031 and 2046 reference scenarios (excluding Scenario 1).

The most significant influence on this outcome is the impact of automation. In scenarios where the fleet is comprised entirely of automated vehicles (Scenarios 2, 3, 4 and 6), the capacity of the Victorian Government to collect revenue associated with driver licence fees is eliminated.

Only under Scenarios 1 and 5 can the Victorian Government expect to collect revenue associated with driver licence fees as, under both these scenarios, the vehicle fleet is either non-automated (Scenario 1) or partially-automated (Scenario 4). Under Scenario 1, it is expected that there will be no change in driver licence revenue collected as compared to the reference scenario, as the entire fleet, whilst electric, remains non-automated. In Scenario 5, half the driving population is anticipated to be always using shared automated fleet vehicles, with the other half expected to be using traditional vehicles, at least some of the time. As such, driver licence revenue is expected to decline by 50 per cent from the 2046 reference scenario.

Key dependencies/limitations

A key dependency of this analysis is that AVs will operate under Level 5 autonomy (full automation), meaning that the vehicle is able to automate all aspects of the dynamic driving task without human intervention.

The Australian Driverless Vehicle Initiative predicts that Level 5 technology will emerge between 2026 and 2030. This will involve an automated system performing all driving tasks that a human driver can perform.[17] As such, the model does not consider AVs operating under Level 4 autonomy (high automation), which can only be driverless in specific domains or areas.[18] Under Level 5 automation, no driver is required, however an individual may take back control of the vehicle if needed.[19] A limitation of the model is that it does not consider the impact of stagnating the technological process, and the possibility of technology failing to deliver Level 5 autonomy as expected.

Although the estimates detailed in this section reflect current literature, key underpinning assumptions must be considered when evaluating the outputs of the model.

Finally, as noted above this analysis does not quantify the potential reduction in VicRoads' licensing related administrative expenditure which, due to ongoing reforms and shared resourcing across its Registration and Licensing business, was not able to be reliably estimated through this analysis.

2.2.4 Parking revenue

Description of revenue item and approach to analysis

Parking revenue in Victoria is collected by both State and Local Governments, and by private parking operators. This analysis focuses on parking revenue collected by Governments, namely

[17] Australia and New Zealand Driverless Vehicles Initiative, *Levels of Automation*. Available at :http://advi.org.au/driverless-technology/

[18] Level 4 autonomous vehicles can be controlled remotely when outside their design domain but have been excluded from this analysis given that it is likely that Level 5 autonomy will be achieved across most vehicles by 2046.

[19] Australia and New Zealand Driverless Vehicles Initiative. *Levels of Automation.* Available at :http://advi.org.au/driverless-technology/

parking revenue relating to the congestion levy and revenue collected by local councils from parking meters or other similar parking charges.

The congestion levy is collected by the State Government from owners of all non-exempt car park spaces inside the levy area.

Projected congestion levy revenue has been calculated by indexing total base year congestion levy revenue, adjusting for projected inflation and changes in the total number of vehicle trips along with the impact of AVs. This assumes that parking infrastructure will, over the scenario timelines, expand or contract to reflect changes to parking demand.

The second revenue stream relates to parking revenue collected by local councils on a user-pays basis from parking meters or other similar parking charges. The base year total has been calculated by taking a sample of representative councils, extrapolating a parking revenue per annum per resident, and adjusting for projected inflation. Additionally, the model also considers the impact of AVs and changes to the overall trip count under each scenario.

Analysis of Results

Table 7 - Financial impact of changes in per annum parking revenue across each scenario

	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
State Government	-$0.1m	$20m	-$320m	$10m	-$150m	-$200m
Local Government	-$0.2m	$25m	-$370m	$15m	-$170m	-$230m
Total	-$0.3m	$45m	-$690m	$25m	-$320m	-$430m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

In Scenario 1, which does not feature AVs, estimates vary only slightly as compared to the reference case. This is the result of minor changes in trip numbers resulting from the switch from ICE to electric powered vehicles.

The impact on revenue varied greatly depending on whether AVs operated as a shared fleet or as privately owned motor vehicles.

In Scenarios 2 and 4, where AVs are privately owned, total per annum revenue is estimated to increase by $45 million and $25 million respectively. While these scenarios reflected the ability of AVs to ‘dead run’ and travel back to an owner’s home to avoid parking fees, the total increase in trip count due to the extra utility of the AVs lead to increased total revenues.[20] While it may be intuitive that dead running would be more common to avoid parking costs, in reality the modelling predicts that logistical limitations (such as the need for a vehicle to be available for use after a relatively short period of time) and additional costs, such as tolls and running/maintenance costs, mean that the use of this feature is predicted to be relatively uncommon.

Scenarios 3 and 6 may make traditional parking infrastructure obsolete by implementing a smaller fleet of shared AVs. It is anticipated that these share fleets may have much higher

[20] Trip count in Scenario 2 is estimated to increase by roughly 40 per cent over 2014/15 levels, as compared to 33 per cent growth for the 2045/46 reference scenario. This growth is only partially offset by dead running, which is projected to only make up 2.7 per cent of the daily trip count in Scenario 1.

utilisation rates, and will also have dedicated fleet hubs during periods of low demand. As a result, per annum parking revenue is projected to fall by $430 million in the 2031 scenario and $690 million in the 2046 scenario relative to their respective reference scenarios.

In Scenario 5, the partial implementation of a shared AV fleet is expected to result in less severe, but still significant, reductions in parking revenues totalling $320 million for the year 2045/46.

Key dependencies/limitations

The above calculations rely on a range of assumptions which are detailed in Appendix A, with a number of the more critical assumptions detailed below.

It is assumed that the demand for parking is directly related to the total number of motor vehicle trips being made in any given scenario. That is, it is assumed that the same proportion of trips require a vehicle to be parked (as opposed to being left at a private home or other free parking location) in each of the scenarios as they did in 2015. Changes to this aspect of driver behaviour should be considered when evaluating the outputs of this model.

It is also assumed that parking infrastructure will expand or contract in line with demand. That is, if the total number of trips requiring parking spaces falls by half, the total number of spaces made available for use for a fee will be reduced by the same amount. This assumption is critical to being able to derive estimated changes in congestion levy revenue. However, in reality, it may be that parking infrastructure does not expand or contract in perfect keeping with demand, with prices and occupancy rates changing instead. In this situation, congestion levy income (which is charged per non-exempt parking space) would not change in direct proportion with demand for parking as has been assumed. Current policy settings around the congestion levy are also assumed, with Government assumed to be making no changes to the levy amount other than adjusting for inflation.

This analysis also assumes that fleet vehicles will not require paid parking facilities and will not use staging areas that would attract the congestion levy (instead remaining on the road or staging outside of the congestion levy area). A decision by the fleet operator to keep a fraction of the shared AV fleet in paid parking spaces may mitigate the decline in revenues seen in Scenarios 3, 5, and 6. Operational decisions by fleet operators should be considered when evaluating the outputs of this model.

2.2.5 Traffic infringements

Description of revenue item and approach to analysis

Fines Victoria is a Victorian Government administrative body introduced as part of the *Fines Reform Act 2014* and is the point of contact for individuals to pay or deal with unpaid fines, including traffic infringements. Fines Victoria collects fines on behalf of the Victorian Government; total revenue from fines is published in *Budget Paper 5 – Statement of Finances* on an annual basis.

For the purpose of the model, total base year traffic infringement revenue has been determined as per the sum of road safety camera fines, toll road evasion fines and 50 per cent of police on-the-spot fines.

Projected future traffic infringements have been calculated as per the base year traffic infringement revenue, adjusting for anticipated inflation and change in total VKT. Additionally, the model assumes that AVs will not incur any traffic infringement fines.

Analysis of Results

Table 8 - Financial impact of changes in annual traffic infringement revenue across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
$20m	-$1,740m	-$1,740m	-$1,740m	-$600m	-$1,070m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The estimates show that traffic infringement revenue under AV scenarios (i.e. Scenarios 2, 3, 4 and 6) will cease to be collected. This outcome is driven by the premise that Level 5 autonomous cars will be programmed to follow road rules, thus eliminating traffic-related infringements.

In Scenarios 1 and 5, Government can expect to receive revenue from traffic infringements, as under both these scenarios non-automated cars continue to exist and incur fines. In fact, in Scenario 1, the model anticipates a slight increase in traffic infringement revenue as compared to the reference scenario. This outcome is the result of a projected increase in VKT.

Key dependencies/limitations

A key dependency of the model is the assumption that 50 per cent of police on-the-spot fines relate to traffic infringements. On-the-spot fines cover a range of offences, including littering, transport, traffic and other criminal offences to be dealt with without the need for court appearance. Given the uncertainty over the composition of these offences, and the ability of society's behaviours to shift these outcomes, the underpinning assumptions must be considered when evaluating the robustness of estimates provided.

Another key assumption is that AVs will not incur any traffic infringements. For this assumption to hold, some have argued that it is imperative that law enforcement agencies begin to work with manufacturers and law makers to ensure law enforcement needs and concerns are considered in the development of AVs.[21] Further, as the future of automation becomes clearer, it will be important to consider the impact that emerging trends may have on traffic infringement revenue.

2.2.6 Fuel excise – Victoria

Description of revenue item and approach to analysis

The Commonwealth Government collects excise duties on fuel and petroleum products produced in Australia (and an equivalent customs duty on those imported from overseas). While collected by the Commonwealth Government, fuel excise revenues are an important source of funding for infrastructure creation and upkeep. As such, fuel excise revenue is a key revenue source supporting Victoria's roads which is the reason for its inclusion here.

For the purpose of this calculation, only petrol excise and diesel excise net of the fuel tax credit rebates is considered. The reasoning underpinning this is that petrol is overwhelmingly used in motor vehicles and, as such, it is reasonable to assume that petrol use would scale directly with the implementation of ZEVs. Diesel not subject to rebate is assumed to be primarily used

[21] http://www.policechiefmagazine.org/preparing-for-a-future-with-autonomous-vehicles/

in freight and privately owned motor vehicles, as opposed to generators, heavy machinery, or other applications where the adoption of ZEVs would have minimal impact. Revenue of relevance to Victoria was determined by calculating the total Commonwealth petrol and diesel excise 2014-15, scaling down the diesel component to reflect fuel tax credit rebates, indexing the total sum forward to the scenario years, scaling the result to reflect the predicted growth in VKT between 2014-15 and the scenario years, and then adjusting the result to reflect Victoria's proportion of the overall Australian population.

Analysis of Results

As may be expected, estimates show particularly heavy declines in fuel excise revenues across all of the presented scenarios as compared to the relative reference cases. Scenarios 1-4 and Scenario 6 all assume a complete displacement of ICE vehicles by ZEVs, leading to a 100 per cent reduction in projected fuel excise revenue.[22] This amounts to approximately $6.5 billion in per annum revenue in the 2046 scenarios and $4.0 billion in per annum revenue by 2031 in the case of Scenario 6.

Scenario 5 assumes that half of the driving age population will continue to use ICE vehicles by 2046. As a result, the decline in fuel excise revenue is much less pronounced than in other scenarios, however the adoption of a fleet of autonomous ZEVs results in an overall $2.3 billion decline in revenue relative to the 2046 reference case.

Across all scenarios, the decline in fuel excise revenue is expected to have a significant impact on Government revenues, particularly as a decline in revenue is not compensated for by any decline in expenditure. In the absence of a change in policy, the transition to ZEVs is thus expected to have a significant negative impact on net revenue.

Table 9 - Financial impact of changes in annual fuel excise across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
-$6,530m	-$6,530m	-$6,530m	-$6,530m	-$2,260m	-$3,990m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Key dependencies/limitations

This calculation assumes that the share of fuel excise revenue spent on Victoria is directly proportional to Victoria's share of Australia's population in the 2015 base year, and that this share will remain the same in proportional terms over time. In reality, both Victoria's share of fuel excise revenue and Victoria's share of Australia's population can be expected to change over time, and this should be considered when evaluating the outputs of the model.

This calculation also presumes that the proportion of diesel excise revenue which is subject to fuel tax credit rebates remains constant between 2014/15 and 2045/46 and across all scenarios.

The calculation for the hydrogen highway scenario assumes that hydrogen fuel remains not subject to fuel excise.

[22] Hydrogen is not currently an excisable fuel product, hence the assumption that hydrogen and electric vehicles would have similar impacts on fuel excise revenues.

2.2.7 Public transport farebox revenue

Description of revenue item and approach to analysis

The Victorian Government collects fare revenue from users of Victoria's rail, tram, and bus public transportation systems. This revenue scales with usage, being directly related to the number of train station entries and tram/bus boardings. The introduction of ZEVs and AVs is expected to impact the extent to which members of the public choose to use roads as opposed to public transport, something which this output seeks to estimate and assess.

Future public transport revenue has been estimated based on 2014-15 public transport revenue, adjusting for projected inflation and changes to the total number of public transport trips the model estimates under each scenario. This latter adjustment captures the mode shift caused by scenario-specific factors, as well as general factors including the increase in Melbourne's population.

Analysis of Results

Projected farebox revenue varies significantly across scenarios, ranging from an increase per annum in revenue of $2.1 billion for the year 2045/46 in Scenario 3, through to a $1.1 billion decline for the same year in Scenario 2 relative to the reference scenario. A key factor of these outcomes is the marginal cost of driving perceived by consumers under each scenario.

In Scenarios 1, 2, 4, and partially 5, the cost of owning a vehicle is considered a sunk cost for travellers. As a result, the only marginal cost considered when evaluating whether to use a private vehicle for a trip rather than public transport or an alternative transport method is the cost of fuel and any extra wear and tear on the vehicle. This suggests that even if a private vehicle is a less cost effective transport solution over the course of the year as compared to public transport (due to purchase, registration, and other fixed costs), individuals may still choose this option over public transport due to the lower perceived marginal cost.

Under the fleet scenarios (Scenarios 3, 6, and partially 5), fixed costs associated with vehicle ownership, as well as a profit margin for the fleet operator, are assumed to be built into the fares charged to fleet users. This means that for any given trip, the marginal cost of public transport is comparatively cheaper than under the private vehicle scenario. Another factor to consider is the need to wait for a fleet vehicle to be despatched rather than having a private vehicle permanently available for personal use.

The key outcome is that, relative to the reference scenarios, public transport revenue falls in those scenarios where ownership of privately owned AVs is apparent, and rises where the transition to an AV fleet based road transport system occurs.

Table 10 - Financial impact of changes in annual public transport farebox revenue across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
$50m	-$1,100m	$2,090m	-$1,040m	$860m	$730m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Key dependencies/limitations

The modelling of the public transport underpinning these estimates is not dynamic, with each scenario featuring a fixed public transport schedule which operates regardless of demand levels. In reality, the public transport network would be likely to respond to changing demand patterns by adjusting its schedule to better reflect the changing needs of the public.

The scenarios also assume a set investment schedule in both road and public transport infrastructure out to 2046 across all scenarios. It also assumes that service levels will be consistent across all scenarios in a given year. In reality, the relative attractiveness of public transport as opposed to personal vehicle transportation may be impacted by changes to the level of investment in public transport infrastructure and shifting service levels. It should also be remembered that this financial impact category only models government farebox revenue. It does not model payments to transport providers or to maintenance and improvement costs associated with operating the public transport system.

2.2.8 Road safety enforcement

Description of revenue item and approach to analysis

Victoria Police identifies road policing as integral to achieving community safety in Victoria, having established a vision to ensure zero deaths and serious injuries on Victorian roads.[23] As such, Victoria Police has placed a priority on building road policing capabilities and enhancing enforcement and prevention strategies.

It is difficult to precisely quantify police road safety expenditure as Victoria Police is part of the broader Justice Portfolio and road safety expenditure has not been separately published since 1999, when it was estimated at nine per cent.[24] However, this estimate is largely consistent with current allocations for road safety policing in South Australia (12.3 per cent in 2017-18) and Queensland (11.2 per cent in 2017-18). As such, the model assumes that nine per cent of the current Victoria Police budget is allocated to road safety.

Projected future police road safety expenditure has been calculated as per estimated base year expenditure, adjusting for projected inflation and VKT travelled under each scenario. For scenarios involving AVs, the model reflects the anticipated reduction in expenditure associated incidents related to human error (94 per cent).

Analysis of Results

Table 11 - Financial impact of changes in annual road safety enforcement expenditure across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
-$8m	$600m	$610m	$600m	$210m	$370m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The table above shows the estimated reduction in police road safety expenditure for all scenarios where AVs are present (i.e. Scenarios 2, 3, 4, 5 and 6) as compared to the relevant reference scenarios. The above estimates may not result in 'bankable' financial savings for the State, but could allow consideration of alternate investment focus areas.

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[23] Victoria Police. *Road Safety Strategy 2013-2018*

[24] Linking Inputs and Outputs: Activity Measurement by Police Services: Research Paper (1999)

Scenario 1 estimates show a similar level of police road safety expenditure (one per cent greater) as compared to the reference scenario. This is because road safety issues remain under Scenario 1 as vehicles are non-autonomous.

Key dependencies/limitations

The modelling is based on the assumption that AVs have an infringement rate of zero. That is, their programming will not allow them to breach established road rules and that, were an AV to commit an infringement, it would be under circumstances that would be unlikely to necessitate an infringement notice being issued to a passenger (a technical failure for example). The modelling also assumes a reduction in road accidents, and thus the need for police to attend these events.

Another key assumption used in this analysis is that nine per cent of Victoria Police's budget is still allocated to road safety and trauma. Whilst this allocation is largely in line with other Australian states and jurisdictions, a robust activity-based costing analysis would be required to confirm actual expenditure on road safety policing.

2.2.9 TAC revenue

Description of revenue item and approach to analysis

Vehicle registrants in Victoria pay a premium to the TAC, collected by VicRoads as part of the vehicle registration process. These premiums support the TAC's third party personal liability insurance provision for road accidents in Victoria. This scheme pays for treatment and benefits for people injured in road transport accidents in the State.

As they are intended to help cover the cost of injury for road accident victims, for the purposes of modelling it has been assumed that TAC premiums are tied to the number of individuals injured on Victoria's roads. While this is a simplification of the process of setting TAC premiums, it is presumed to be a reasonable assumption for the purpose of this analysis.

To estimate future TAC revenue, the 2015 revenue has been indexed forward to the scenario years at the assumed inflation rate of 2.5 per cent. This amount has then been adjusted to reflect anticipated changes to the number of accidents on Victorian roads under each scenario. This includes both accounting for an increase in the number of VKT under each scenario, and for the proportion of VKT accounted for by AVs. Any changes in revenues associated with TAC investments have not been considered for the purposes of this modelling.

The model assumes that AVs are 94 per cent safer than human driven vehicles and, as such, scenarios which feature a high proportion of AVs are likely to see a significant decline in required TAC revenue. This assumption is based on US National Highway Traffic Safety Administration figures which ascribe human error as being the critical reason for 94 per cent of accidents (with environmental, vehicle, and unknown factors being critical in the remainder).[25]

This calculation method assumes that the existing Compulsory Third Party insurance scheme will be applied to automated vehicles, and that TAC revenue will be adjusted in direct proportion to any increase or decrease in accidents on Victoria's roads. It should be noted that alternative insurance schemes for AVs are currently under consideration.

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[25] US Department of Transportation – National Highway Traffic Safety Administration (2015), Traffic Safety Facts Crash Stats – *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey* p1.

Analysis of Results

Table 12 - Financial impact of changes in annual TAC revenue across each scenario

Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
$70m	-$5,560m	-$5,610m	-$5,570m	-$1,930m	-$3,430m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Scenarios 2-6 all see significant reductions in estimated TAC premium revenue as compared to the relevant reference cases. Overall, the scale of the reductions are overwhelmingly tied to the prevalence of AVs on the roads in each scenario. The assumed 100 per cent adoption of AVs under Scenarios 2-4 and 6 result in an estimated 94 per cent reduction in road accidents per VKT travelled. With this decrease in accident rate, the modelling presumes that TAC premium revenue will contract to compensate. The peak decline is under Scenario 3, where the annual TAC premium revenue is estimated to decline by $5.6 billion for the year 2045/46 relative to the 2046 reference case. Scenarios 2 and 4 decrease by similar but slightly smaller amounts, due to those scenarios featuring relatively higher VKT as compared to Scenario 3.

Scenario 6 shows a $3.4 billion reduction in per annum TAC premium revenue. This is primarily due to the relatively lower applicable indexation and VKT growth applicable to the 2031 scenario as compared to the 2046 setting of Scenarios 1-5.

Scenario 5 shows a $1.9 billion decline in per annum revenue relative to the reference case, as an AV fleet replaces human controlled vehicles for roughly one-third of all VKT driven, leading to a commensurately lower revenue reduction than in the scenarios where all VKT is accounted for by AVs.

Scenario 1, which assumes no AVs (including those with only Level 1-4 automation which may also be able to reduce crash rates to some degree) being introduced on Victoria's roads, projects a minor increase in estimated TAC premium revenue compared to the 2046 reference case. This is as a result of a marginal increase in total VKT relative to the reference case, possibly as a result of the lower assumed marginal cost of operating electric vehicles as compared to the ICE vehicles used in the reference case.

Numerous studies examining post-crash analysis of contributory factors indicate that a vast majority of vehicle accidents are linked to human error, however the actual safety benefits of Level 5 automation remain untested and uncertain.[26] Functions such as such as speed, information processing, reasoning and perception continue to be refined as the development of automated technologies progress. The outcomes of these factors may have financial implications on TAC premium revenue. For example, if it were found that AVs were 75 per cent safer than human drivers, the outcome for Scenario 3 would show a decline of $4.5 billion in TAC premium revenue relative to the 2046 reference case. This change to automated accident rates would result in a projected $1.1 billion lower revenue reduction as compared to the Scenario 3 outcome detailed in *Table 12* ($5.6 billion decline in TAC premium revenue associated with a 94 per cent reduction in accident rates). As such, although the estimates detailed in this section of the report are based on the latest literature, the underpinning assumptions must be considered when evaluating the robustness of the forecasts provided.

[26] International Transport Forum (2018). *Safer Roads with Automated Vehicles?*

Key dependencies/limitations

The above calculation rests on a number of assumptions, all of which are outlined in Appendix A. Key assumptions and limitations include:

- The model presumes that the total amount of compensable harm to individuals as a result of road accidents will, all else being equal, change in direct proportion to VKT. This means that it is assumed that roads will become no safer or more dangerous between 2015 and 2046 (other than as a result of implementing AVs). Were roads to become safer overall for example, this would result in a decrease in TAC premiums under all scenarios (including the reference scenarios). Progress in this space should be considered when interpreting these estimates.
- It is also presumed that, for any given kilometre travelled, an AV causes 94 per cent fewer accidents than a human controlled vehicle. Any anticipated changes to the safety of AV technology by 2031 or 2046 should be considered, as it is likely to have a significant impact on the accident rate and, by extension, the premiums charged by the TAC.
- The calculation also presumes that Government will vary the amount of TAC premiums recovered from vehicle registrants in direct proportion to the overall change in safety resulting from VKT changes and AV introduction. In reality, premiums may not decrease at the same rate as compensable harm to individuals due to timing issues and the need to fund other TAC activities including road safety promotion.

2.2.10 TAC Expenditure

Description of revenue item and approach to analysis

As previously discussed, the TAC is a Government-owned body that provides third party personal liability insurance provision for road accidents in Victoria. This scheme pays for treatment and benefits for people injured in road transport accidents in the State.

TAC expenditure covers the cost of injury for road accident victims and, as such, is directly related to the number and seriousness of compensable injuries occurring on Victoria's roads.

As with TAC premium revenue, TAC expenditure has been modelled by taking 2015 revenue and indexing it forward to the scenario years at the assumed inflation rate of 2.5 per cent. This amount has then been adjusted to reflect anticipated changes to the number of accidents on Victorian roads. This includes both accounting for an increase in the number of VKT under each scenario, and for the proportion of VKT accounted for by AVs. It has been assumed that AVs are approximately 94 per cent safer than human driven vehicles, meaning those scenarios which feature a high proportion of AVs are likely to see a significant decline in required TAC expenditure.

Analysis of Results

Table 13 - Financial impact of changes in annual TAC expenditure across each scenario

Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
-$40m	$3,180m	$3,210m	$3,190m	$1,100m	$1,960m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

TAC expenditure follows the same patterns as TAC premium revenue, with the scale of the reductions again being overwhelmingly tied to the prevalence of AVs on the roads under each scenario. The assumed 100 per cent adoption of AVs under Scenarios 2-4 and 6 results in a modelled 94 per cent reduction in road accidents per VKT travelled. With this fall in accident rate, the modelling indicates that TAC expenditure will contract to compensate. The peak decline is estimated under Scenario 3, where per annum expenditure is projected to decline by $3.2 billion relative to the 2046 reference case. Scenarios 2 and 4 decrease by similar, but slightly smaller, amounts, due to those scenarios featuring relatively higher VKT than Scenario 3.

Other scenarios follow similar patterns of movement to TAC premium revenue.

Overall, TAC expenditure is predicted to fall at the same proportional rate as TAC premium revenue. This will however, have the impact of reducing the value of the gap between TAC revenue and expenditure in absolute terms. For that reason, and due to the dependencies discussed below, it may be that altered policy settings are required to support the ongoing and effective operation of the TAC.

Key dependencies/limitations

The above calculation rests on the same assumptions discussed in relation to TAC premium revenue. In the case of expenditure however, the assumption that expenditure will decline in direct correlation with the fall in accidents may not hold given the lagging nature of TAC expenditure.

TAC expenditure includes the cost of medical care and benefits for individuals lodging a claim in that year, in addition to ongoing payments to those individuals who may have been injured in previous years who require ongoing care or who delay before claiming benefits. The extent to which 2046 expenditure fails to reflect the added safety of AVs for example, depends on when the large scale adoption of AVs (and thus the fall in compensable damage) took place. If adoption only occurs in the few years immediately prior to the scenario years then TAC expenditure in the AV-heavy scenarios may be significantly higher than forecast.

2.2.11 Road maintenance

Description of expenditure item and approach to analysis

Road maintenance and upkeep activities are critical to ensuring the safety and useability of Victoria's roads. Responsibility for the upkeep of Victorian roads is divided between local roads, which are the responsibility of local councils, and those roads which are the responsibility of the State Government. This latter category includes the State's freeways and arterial roads.

Road maintenance expenditure has been calculated by using economic parameters for maintenance costs per VKT as prepared by KPMG, indexing these forward to the scenario years, and then adjusting for changes to VKT by road type in each scenario. In order to account for differences between states and to help isolate those maintenance factors which are represented in the VicRoads' budget (as opposed to being directly provided for by the Federal Government for example), the results of this modelling were compared to the actual road maintenance expenditure by VicRoads in 2015 and were a factor applied to the modelled result in all scenario years on the basis of this result.

Analysis of Results

Table 14 - Financial impact of changes in annual road maintenance expenditure across each scenario

	Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)
Freeways and Arterials	-$20m	-$210m	-$50m	-$150m	-$150m	-$10m
Local Roads	$5m	$10m	$45m	$0.2m	$25m	$30m
Total	-$15m	-$200m	-$5m	-$150m	-$125m	$20m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Each of the 2046 scenarios project an increase in road maintenance expenditure as compared to the reference case. The extent of these increases varies greatly between scenarios, with considerable differences in outcomes noted between privately owned vehicle scenarios and fleet-style scenarios.

In Scenarios 3, where the fleet is entirely shared, annual road maintenance costs are expected to be only marginally larger than the reference case ($5 million greater). This is driven by lower VKT in these scenarios due to the comparatively higher marginal cost of vehicle use.

The largest increase in maintenance costs are projected across Scenarios 2 and 4, with annual costs expected to increase by $200 million and $150 million respectively. This disparity in outcomes between privately owned and fleet-style scenarios is predominately related to maintenance costs associated with freeway and arterial road usage. In Scenario 6, declining VKT actually leads to a $20 million annual saving over the reference case for 2030/31.

It is worth noting that the projected maintenance costs for local roads shows a decrease in expenditure across all scenarios relative to the 2046 reference scenario. This is most pronounced in the shared fleet based Scenarios 3 and 6 and is driven by a projected shift away from the use of local roads towards freeways and arterial roads. This is likely due to improved traffic flow in fleet scenarios, coupled with the higher marginal cost of using a car, resulting in more local and short distance trips being replaced with public transport as compared to the private drive scenario.

Key dependencies/limitations

The above modelling rests on a range of assumptions which are outlined in Appendix A. One key assumption is that the ratio used to adjust the maintenance costs derived from the model in line with actual Victorian expenditure in 2015 is assumed to also apply in the case of local roads. Were this assumption not to hold, the absolute values of the local road maintenance items projected would change, but not the overall pattern of movements in those costs across scenarios.

It is also assumed that road maintenance is entirely a product of VKT, as per the chosen model. In reality, weather erosion, geological factors, and simple age would likely cause degradation to roads even in the absence of traffic. As a result, road maintenance costs are not likely to be as linear as the model suggests.

It should be noted that any additional maintenance costs required to facilitate the effective operation of the AVs themselves have not been quantified. It may be that, depending on their mode of operation, AVs require clearer lines, signage, or other aids to assist their operation.

These costs have not been quantified due to the lack of a clear basis by which to determine them, and uncertainty over the likely capabilities of AVs in 2031 and 2046.

2.3 Other impact categories

Other categories that are likely to be impacted by the introduction of autonomous and zero emissions vehicles are the impact on road capacity investment, as well as health-related costs associated with vehicle emissions. While it has not been possible to quantify the direct financial impact on the State for these categories (due to a lack of data and an inability to split estimated costs between different levels of government, the private sector and individuals), the sections below provide an economic and qualitative assessment of the potential impacts.

2.3.1 Road capacity investment

Landscape

A major challenge for decision makers is to appropriately identify capacity expansion opportunities across the transport network that help bring together cities, suburbs and rural towns.

Over $30 billion has been committed by the Victorian Government over the next five years (2017-2021) to improve the transport system, with a focus on making the most of existing assets, building for the future, connecting regional Victoria and developing smarter transport solutions.[27]

With Victoria's population expected to grow and vehicle technology continuing to evolve, ensuring transport solutions meet the needs of the community will continue to be imperative. The State Government has taken steps to ensure the success of future infrastructure investment, with IV developing Victoria's first ever 30-year infrastructure strategy, which aims to ensure that all Victorians have access to jobs, education and services.[28]

Population Growth

It is estimated that Melbourne's transport system will require the capacity to cope with an additional 10.4 million trips a day by 2046 – up from the current figure of 12.5 million trips a day; this is primarily driven by projected population growth.[29] Population projections indicate that over the next 30 years, 80 per cent of the State's population growth is expected to be in Melbourne, with strong growth also anticipated around regional cities such as Geelong, Ballarat, Bendigo and Wodonga.[30] As such, having the right infrastructure in place will be critical for accommodating this growth and meeting increased and differing demands for services and housing across Victoria.

Autonomous Vehicles

Another key driver of road capacity investment decisions is the growing emergence of autonomous technologies, which are expected to impact the functionality of the transport network and shift consumer behaviours. The challenge for decision makers will be to consider

[27] Department of Premier and Cabinet (2016), *Victorian Infrastructure Plan*
[28] Infrastructure Victoria (2016). *Victoria's 30-Year Infrastructure Strategy*
[29] Department of Premier and Cabinet (2016), *Victorian Infrastructure Plan*
[30] Department of Environment, Land, Water and Planning (2016). *Victoria in Future 2016: Population and household projections to 2051*

how AVs will impact how Victorians travel, and by extension how this will impact road capacity investment, presenting opportunities to accelerate or defer road capacity investment.

Road capacity investment considerations

Projected road capacity

KPMG's transport modelling suggests that by 2046 (under the reference scenario and Scenario 1), many of Victoria's major roads will be operating close to or above optimal capacity, with average journey times across Melbourne anticipated to increase by more than 20 per cent.[31] Medium term pipeline projects are anticipated to alleviate some pressures, however projected growth in travel demand is anticipated to increase overall congestion and hinder the level of services across many aspects of the transport network.[32] The Victorian Government has acknowledged these emerging concerns, indicating that whilst there has been record investment in road and rail projects, ongoing investment and support is required.[33]

Emergence of automated technologies

The emergence of AV technology (i.e. Scenarios 2 to 6) brings with it an expectation that AVs will be able to leverage improved vehicle-to-vehicle and vehicle-to-infrastructure communication to more efficiently utilise the existing capacity of the road network, allowing for increased vehicle speeds and flow.[34] The efficiencies associated with these scenarios may present Government with an opportunity to defer road capacity investment, freeing up additional funding to be used for other Government priorities.

However, as discussed in *Section 2.2.7* of this report, the cost of owning a vehicle is considered a sunk cost for travellers and, as such, under Scenarios 2 and 4, where AVs are privately owned, only the marginal cost of travel is considered when an individual evaluates whether to use a private trip rather than public transport. Under both these scenarios, it is anticipated that private trips will grow, leading to a large increase in traffic – this would partially offset the efficiencies that AV technology is expected to bring.

To maximise the benefits of AVs, a push towards fleet services (Scenarios 3 and 6) would help minimise congestion due to the decline in empty vehicle movements. This may also allow a deferral of road capacity investment.

Another key consideration is the impact that AVs will have on consumer behaviour and preferences. KPMG insights suggest that, in the future, AVs may be 'mission-specific', with example vehicle types including 'pods' for shorter-duration trips, 'office-on-wheels' which are safer on freeways and have room for work, and 'living- room-on-wheels', which are spacious and comfortable and allow for entertainment.[35] As such, the introduction of AVs is expected to make long distance travelling more appealing to travellers, primarily due to lower operating costs and the behavioural shifts in the perceived costs of travel (e.g. individuals are able to be more productive, consume greater entertainment, rest or relax under automated scenarios).[36]

These factors could increase the attractiveness of urban development along Melbourne's long distance road corridors, increasing urban sprawl.[37] These changes in traveller behaviour and

[31] KPMG (2016). *Preliminary Demand Modelling and Economic Appraisal*
[32] KPMG (2016). *Preliminary Demand Modelling and Economic Appraisal*
[33] Department of Premier and Cabinet (2016), *Victorian Infrastructure Plan*
[34] KPMG (2016). *Preliminary Demand Modelling and Economic Appraisal*
[35] KPMG (2017). *Islands of autonomy: How autonomous vehicles will emerge in cities around the world*
[36] KPMG (2016). *No U-turn*
[37] KPMG (2016). *No U-turn*

preference may drive an increased number of individuals to road travel, offsetting the anticipated road capacity outcomes associated with automation.

Key takeaways

The impacts of changing circumstances (in particular, population growth and the emergence of autonomous technologies) should be considered for all future road capacity investment decisions. In particular, the potential impact of AVs on traffic flow, the value of time, and the attractiveness of road versus other modes of transportation may warrant consideration when determining future road capacity investment plans. As the impact of autonomous technology becomes clearer, Government may consider opportunities to accelerate or defer road capacity investment as required. IV's commitment to continue to refine and update Victoria's 30-year strategy every three to five years to reflect the arrival of new evidence will allow decision makers to make informed decisions on road capacity investment. Further detail on how the adoption of AV technology may impact the road capacity analysis included in transport infrastructure business cases can be found in section 5 of this report.

2.3.2 Toll Revenue

There is an expectation that automation will increase mobility, improve safety and reduce costs. However, the question of how these technologies may impact toll revenue remains unclear.

Currently, there are two major toll operations in Victoria, CityLink and Eastlink, both of which are operated by private companies. The price for usage varies according to frequency of use.

Eastlink's operator, ConnectEast, has the right to operate until the expiration of its concession period in 2043. Following this, the Victorian Government could take over the operation of this road network.

It is anticipated that toll road operators will benefit from capacity and efficiency improvements associated with the introduction of autonomous vehicles.[38] However, ensuring that road infrastructure is conducive to these technological advances is required.

Level 5 autonomy (full automation) will mean that a vehicle is able to automate all aspects of the dynamic driving task without human intervention. Victorian toll roads present the ideal place for this setting, with a limited number of entry and exit points. Victoria toll roads are well instrumented with sensors, electric power, and communication, and would be among the first places to provide vehicles with data wirelessly, using telemetry and other cues.[39]

There is considerable discussion about how toll roads can prepare for the expected wave of automation. Already, there have been trials of partially automated vehicles on Victoria's toll roads, with the Victorian Government partnering with Transurban, VicRoads and the Royal Automobile Club of Victoria to better understand how Victorian roads infrastructure can be prepared for automated vehicles.[40]

The trial identified a number of challenges for vehicle manufacturers and infrastructure providers, which are likely to be addressed by new technologies but also through

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[38] Macquaire (2016). *The impact of technological change on the infrastructure sector.*

[39] Conduent Public Sector Public Transportation & Mobility (2017). *Connected and Automated vehicles: the Role of Toll Road Operators.*

[40] Transurban (2018). *Victorian connected and autonomous vehicle trials (phase one – partially automated vehicles).*

developments and investment in toll roads. Investment in toll roads includes ensuring guiding lines are more visible, and that road repairs and chevrons are signposted.[41]

With the Eastlink concession set to expire in 2043[42], there may be an opportunity for the Victorian Government to capture the revenues from the expected increase in capacity and efficiency associated with the introduction of autonomous vehicles. However, it has not been possible to estimate the net revenue implications as ConnectEast is now a private company and does not publish revenue or expenditure data.

2.3.3 Vehicle emissions (health cost)

Description of expenditure item and approach to analysis

Internal combustion engines generate a range of harmful gaseous emissions during ordinary operation. These are expelled as exhaust, and many of them can have a deleterious impact on the environment and on human health. The damage to human health as a result of vehicle emissions ultimately functions as a healthcare cost that must be borne either by Government or by individuals themselves. The implementation of ZEVs would result in a reduction of these emissions, with a consequential benefit for public health relative to the relevant reference cases.

The health cost is calculated by applying Austroads' air pollution externality costs for vehicle emissions to each of the scenarios, adjusting for projected inflation, changes in VKT, and the adoption of ZEVs across each scenario. These externality costs range from three hundredths of a cent per VKT for passenger cars traveling on rural roads to 44.55 cents per VKT for freight traffic in urban areas. This range reflects the different scale of vehicle emissions and the varying danger of exposure of human beings to the emissions.

These externality costs are intended to provide a holistic assessment of the economic impact on human health of these vehicle emissions. In reality, only a fraction of any externality cost or saving would be likely to translate to the State Government's revenue or expenditure in the form of changing health care expenditure, with other elements of this cost being borne by Federal and Local Government, the private healthcare system, or individuals themselves.

Analysis of Results

All six scenarios see reductions in the health costs associated with vehicle exhaust emissions, with Scenarios 1-4 seeing a $10.0 billion reduction in per annum costs in 2045/46 as a result of the complete replacement of ICE vehicles by ZEVs on Victoria's roads. Scenario 5 provides for only approximately one-third of VKT being done by ZEVs, resulting in a commensurately lower decrease in total savings. Scenario 6 estimates a $4.6 billion annual benefit in 2031 relative to the 2031 reference scenario. While not illustrated in this table, realising this benefit by 2031 would also suggest that similar savings would be made in each year from 2032 through to 2046, amplifying the total benefit realised relative to the 2046 scenarios.

Table 15 – Change in per annum economic impact of vehicle emissions-related health costs across each scenario

Scenario 1 - Electric Avenue	Scenario 2 - Private Drive	Scenario 3 - Fleet Street	Scenario 4 - Hydrogen Highway	Scenario 5 - Slow Lane	Scenario 6 - High Speed (2031)

[41] Transurban (2018). *Victorian connected and autonomous vehicle trials (phase one – partially automated vehicles).*

[42] VicRoads (2015). *Annual Report 2014-15*

$10,060m	$10,060m	$10,060m	$10,060m	$3,660m	$4,610m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Key dependencies/limitations

The above modelling rests on a range of assumptions. One key assumption is that the adoption of ZEVs will result in a 100 per cent reduction in vehicle emissions-related health costs. In reality, it may be that some emissions remain, for example as a result of tyre wear.

Due to the scope of modelling outputs provided by Melbourne agent and activity based model (MABM), the estimates here assume that all VKT within the MABM area (primarily metropolitan Melbourne) are urban areas, while all those areas outside the MABM area are rural. In reality, significant VKT will occur in built up areas outside of Melbourne, which includes regional cities such as Geelong, Bendigo, Ballarat and Horsham. Some VKT within the MABM area will also occur on stretches of road that are sparsely populated and where emissions are unlikely to have the same health impacts as they would have in a built up area in the Melbourne CBD. The result of this is that there is a relatively high level of uncertainty involved in estimating these health costs.

It should also be re-emphasised that these savings represent a holistic estimate of the economic impact of vehicle emissions-related health costs, and only a fraction of these savings would likely be realised by State Government in the form of reduced public healthcare and prevention costs.

3 Government responses

3.1 Rationale for government responses

The large scale introduction of ZEVs and AVs into Victoria has the potential to change the lives of Victorians. Their introduction offers an opportunity for Government and the wider community to realise significant benefits. These benefits may include:

- Improved health and environmental outcomes as a result of the widespread adoption of ZEVs;
- The introduction of AVs saving lives and reducing injuries associated with road accidents;
- Reduced congestion due to more efficient usage of roads by AVs;
- Economic benefits to families or groups that require fewer vehicles as a result of automation; and
- Transport access benefits for those individuals currently incapable of driving (for example, as a result of a disability or impairment) who would be able to own and operate an AV.

At the same time, the financial modelling in *Section 2* of this report demonstrates that the introduction of ZEVs and AVs is likely to be highly disruptive to the existing revenue model underpinning road funding and maintenance in Victoria.

As a result, the Victorian Government seeks to mitigate the projected financial impact to fund roads expenditure. The aim would be to address this impact while continuing to encourage the adoption of ZEVs and AVs by Victorians (to help secure the social, economic, and environmental benefits associated with their use).

This section of the report examines a number of potential policy responses which may be employed to achieve these goals. These are intended for discussion and consideration, and do not constitute a recommendation or endorsement of any of these policies. It should be noted that the below responses could be implemented in a number of combinations in response to the projected revenue gaps under each scenario.

3.2 Potential responses

3.2.1 Response 1 – Revenue neutral distance based charge

The financial modelling presented throughout this report is focused on existing Government revenues and expenditures that may be impacted as a result of the wider adoption of ZEVs and AVs. Many of these revenue categories, such as fuel excise and licence revenue, are partly or wholly eliminated by the mass adoption of ZEVs and/or AV.

Major expenditure categories, such as road maintenance, however are not projected to decrease due to the adoption of these new technologies. In some scenarios, the increased utility of automated vehicles is projected to drive an increase in VKT and the associated maintenance costs, while significantly reducing revenue in a number of areas. One option to ensure that this reduction in net road-related revenues does not inhibit Victoria's ability to effectively and fairly maintain the State's road network is to create new, alternative revenue streams that are focused on ensuring that funding is sufficiently and equitably raised.

This response would create a user pays system for Victorian roads by implementing a distance based charge for all vehicles driving on Victorian roads. The fee would be charged on a per kilometre travelled basis.

The below table sets out the required charge per VKT that would be necessary to make up the relative decline in net revenue projected across each of the examined scenarios. This ranges from seven cents per kilometre in Scenario 5 (where the continued operation of ICE vehicles preserves some fuel excise revenue and a number of other revenue categories) through to 18 cents per kilometre in Scenario 3, where the full scale implementation of a ZEV / AV shared vehicle fleet make obsolete a number of entire revenue categories including fuel excise and parking.

This intervention would likely be easier to administer in those scenarios which rely on shared vehicle fleets, as it can be presumed that these fleets would already rely on a VKT based calculation to help determine the relevant fares. Adjustments to the VKT charge could hypothetically be made on a range of factors, including vehicle type (emergency or community critical vehicles could for example be entirely exempted).

Table 16 - Estimated charge per VKT to achieve revenue neutrality by scenario

	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
No intervention	-$8,100m	-$12,650m	-$12,750m	-$12,620m	-$5,110m	-$8,070m
Estimated charge per VKT to achieve revenue neutrality	$0.11	$0.16	$0.18	$0.16	$0.07	$0.13

Source: KPMG analysis based on assumptions and sources listed in Appendix A

In considering these numbers, it is important to note that this analysis does not model the disincentive such a charge would have on people driving. In reality, it can be expected that a distance based charge model would make public transport or walking relatively more attractive for certain trips where individuals might otherwise use a car. As a result, the scheme would likely not recover the full projected amount, as VKT could be expected to contract under the policy. If the intention was to implement the intervention in order to be revenue neutral as compared to the reference scenario, the per VKT charge would likely need to be set slightly higher than set out above in order to compensate for this disincentive.

3.2.2 Response 2 – Implementing an area based charge

The Victorian Government currently employs a congestion levy, payable by holders of all non-exempt car parks within the designated congestion levy areas, as one of its policy tools to discourage vehicles from entering high congestion areas. The adoption of AVs in Victoria is expected to diminish the efficacy of this existing policy response. Under scenarios where AVs are privately owned, this is partially due to the likely use of the 'dead running' capability of AVs to send their vehicles out of the levy zone rather than parking them. This would have the effect of avoiding the need for a parking space (which is subject to the congestion levy) but actually increasing the amount of time a vehicle spends on congestion zone roads (as the vehicle may return to the zone later to pick up the person or people that it originally carried into the zone). The fleet scenarios presume the use of staging areas outside of the congestion zone or the unoccupied running of vehicles to bypass the use of paid parking facilities. Under both models, the impact of the congestion levy as a disincentive is lessened relative to the reference case.

Model outputs also suggest that the adoption of ZEVs / AVs may make road travel relatively more attractive by lowering the marginal cost of vehicle operation (by reducing petrol costs) as well as improving traffic flow and the capabilities of vehicles (as a result of being able to exploit the autonomous capabilities of vehicles for dead running purposes or simply allowing individuals to make better use of their time while in a vehicle). All else being equal, this is likely to increase the number of vehicles traveling within the congestion levy zone.

In order to dis-incentivise over-use of vehicles in congestion zones, the Government may consider implementing an area based charge, levied on all vehicles that enter a congested area. Focusing the levy on vehicles rather than parking spaces could help remove the ability of AVs to partially or fully bypass the congestion levy, while potentially raising additional revenue in the context of declines in other vehicle-related revenue categories.

To produce an indication of the potential impact of such a policy, a revised version of Scenario 2 was tested in MABM with the addition of an area based charge for a selected section of Metropolitan Melbourne. The charge had the following parameters:

Each day is divided into four time periods, where people are charged a peak or off peak rate for each period in which their vehicle uses any road within the area (excluding freeways) regardless of the distance travelled:

- 0700 – 0900hrs : $5
- 0900 – 1500hrs : $2.5
- 1500 – 1800hrs : $5
- Other times : $2.5

Under this model, a maximum of one charge is applied per vehicle per time period, but vehicles could pay multiple times per day if their use extended beyond a single time period.

It is projected that due to changes in travel behaviour, a charging regime would raise approximately $2.3 billion per annum in 2046.

3.2.3 Response 3 – Promoting improved road safety through adjusted TAC premiums

The financial modelling presented in *Section 2* of this report assumes that TAC premiums for the registration of AVs would be lowered in direct proportion to their increased safety relative to non-AVs (assumed to be 94 per cent for the purpose of this model). The 94 per cent assumption is driven by data which suggests that approximately 94 per cent of road crashes are a result of human error, and the parallel assumption that AVs would not make similar or equivalent errors.[43] This reflects the relative differences in the cost to the TAC of making insurance payouts to individuals involved in incidents caused by autonomous and non-autonomous vehicles.

The difference in TAC payouts however, does not capture the full range of benefits associated with reduced vehicle collisions and injuries. Among other things, TAC payouts do not fully

[43] See Appendix A for further details on these assumptions.

reflect pain and suffering caused to families and friends of the deceased and injured, the lost economic productivity caused by serious injuries or death, the inconvenience and costs associated with road closures due to accidents, or the apprehension and fear caused by 'near misses' that do not attract any TAC payouts under existing policy settings. Given this, the proposed 94 per cent cost differential between AVs and regular, non-autonomous vehicles is unlikely to adequately capture the full safety, social, and economic benefits associated with AV use.

In order to better reflect these benefits, and to encourage a more rapid uptake of potentially life-saving technologies, the Victorian Government could choose to partially or fully offset forgone revenue by lowering premiums for AVs by increasing TAC charges for registering non-autonomous vehicles.

The below table compares the financial impact of increasing TAC premiums for a non-autonomous vehicle by 50 per cent to having no intervention (to offset the discount for AVs in Scenario 5 and help overcome barriers to the adoption of AVs in Scenario 1).

Table 17 - Financial impact of safety adjusted TAC premiums – change relative to reference case

	Scenario 1 - Electric Avenue (2046)	Scenario 2 - Private Drive (2046)	Scenario 3 - Fleet Street (2046)	Scenario 4 - Hydrogen Highway (2046)	Scenario 5 - Slow Lane (2046)	Scenario 6 - High Speed (2031)
No intervention	$70m	-$5,560m	-$5,610m	-$5,570m	-$1,930m	-$3,430m
Road safety premium	$3,080m	-$5,560m	-$5,610m	-$5,570m	$20m	-$3,430m

Source: KPMG analysis based on assumptions and sources listed in Appendix A

The impact of this intervention is most significant in Scenario 1, where it is presumed that there is zero uptake of AVs. In this scenario, the road safety premium for non-AVs results in an additional $3,080 million in revenue in 2046. It should be noted that this analysis does not account for the increased uptake of autonomous vehicles that is likely to occur following introduction of a road safety premium.

The intervention is perhaps most realistically applicable to Scenario 5, where autonomous and non-autonomous vehicles co-exist. The additional premiums payable by non-autonomous vehicles effectively offset the originally forecast revenue decline driven by the discounted premiums paid for AVs. The new result is a $260 million increase in revenue over the 2046 reference case, along with a disincentive against owning relatively more dangerous non-autonomous vehicles. Again, this analysis is based on applying the higher premiums to non-AVs with the scenario parameters on the proportion of AV vs non-AV ownership. This is essentially a 'first round' impact that would over-state revenues, as people dynamically respond by changing the mix of vehicles owned in response.

There is no change to revenue in Scenarios 2, 3, 4, or 6, as these scenarios presume 100 per cent autonomous adoption. In these cases, the intervention may instead have a role to play in incentivising the adoption of AVs leading up to the scenario year, increasing the probability that AV adoption occurs relatively faster than it would in the absence of the intervention. While the impact of this is not obvious in the scenario years, it would presumably have resulted in a relatively lower rate of accidents in the years between the implementation of this intervention and the scenario year than would otherwise have been the case.

3.2.4 Response 4 – Access and equity responses

The implementation of shared AV fleets in Victoria has the potential to generate a number of efficiencies for the Victorian economy and benefits for many Victorian residents. It has the potential to reduce the overall number of vehicles required to serve Victoria's population, support individuals who travel by road on an infrequent or short distance basis, and diminish demands for parking infrastructure among other things.

The adoption of AVs also has the potential to significantly improve the mobility options for many Victorians who are unable to drive conventional vehicles. Moreover, shared fleet based solutions have the potential to benefit those who cannot afford the substantial fixed costs associated with owning a car.

However, in the event that shared fleet based solutions gain prominence in Victoria, it may be the case that rural and regional areas receive a lesser level of access to the new shared fleet as compared to other areas. This may occur if the lower population density of these areas causes fleet providers to refrain from establishing the infrastructure and presence required to adequately support these areas. Further, if fleet based solutions are implemented alongside distance based charging, individuals in rural and regional areas who need to travel long distances for professional or personal purposes may end up carrying a higher burden compared to individuals commuting short distances within the metropolitan Melbourne area.

A number of policy options are available in the event that Government chooses to intervene to increase access to shared AV fleet based road transport in rural and regional areas. These include:

- **Subsidisation of rural and regional VKT**

  Government could seek to encourage the operators of a shared AV fleet to provide affordable service in rural and regional areas by providing incentive payments on a per VKT basis. This could take the form of a discount on any per VKT distance based charge imposed by Government for VKT travelled in rural and regional areas, or a subsidy paid directly to fleet operators for these VKT.

  All else being equal, this would make offering fleet services in rural and regional areas more attractive than it otherwise would be. This may encourage competition in these areas, help lower consumer fares, and support access to road transport services for Victorians living in communities that may otherwise not receive an appropriate level of service under a pure shared AV fleet scenario.

  Alternatively, this subsidy or discount could be subject to a threshold level per person in the relevant areas, rather than being applied to all fleet trips on an area basis. This would mean that the subsidy or discount would only apply up to a certain level of VKT per individual per year. This could add additional administrative complexity but allow for the benefit to be more closely focused on specific individuals or classes of individuals felt to be in need of additional support.

  Either form of this intervention would come at a cost to Government, and would require compensating revenue in order to ensure overall revenue neutrality. Consideration would also need to be given to the fact that access issues are unlikely to be consistent across rural and regional Victoria, which may require a relatively complex system of area based incentive payments in order to effectively support access and equity without distorting market outcomes.

  This intervention also presumes that fleet access is the appropriate means of transport for individuals in rural and regional areas. It may instead be the case that rural and regional areas are better served by continuing to rely on privately owned motor vehicles even if metropolitan areas transition to a shared AV fleet model. Such an approach would be better supported by an alternative intervention.

- **Registration fee discounts to support individuals with limited fleet access**

  One alternative to supporting shared fleet access in rural and regional areas would be making it more affordable for individuals in these areas to continue to rely on other forms of transportation, including privately owned motor vehicles. The provision of a further registration fee discount or exemption for individuals living in rural and regional areas is likely to make it relatively more affordable for individuals to own their own (automated or otherwise) motor vehicles even as shared fleets are more widely implemented.

  This approach would obviously involve Government forgoing revenue (which would require a compensating revenue increase to maintain cost neutrality). It may also involve foregoing some of the efficiencies that can be realised with shared vehicle fleet implementation, including reduced parking requirements and a higher overall utilisation rate for vehicles on Victorian roads.

4 Consumer lifecycle ownership costs

4.1 Introduction

The continued development of autonomous technologies and progressive trends towards car sharing are expected to disrupt transport patterns and challenge society's understanding of mobility.

It is anticipated that automation will ultimately remove the need for human drivers, and that car-sharing fleet services will reduce the need for private vehicle ownership, yielding substantial economic, social and environmental benefits.[44] There are a variety of possible future scenarios, however, and it is currently unclear what the financial costs associated with each scenario will entail for consumers.

This section of the report provides a quantitative assessment of the potential:

- Vehicle lifecycle ownership costs, comparing the relative costs of traditional vehicles, autonomous electric vehicles and autonomous hydrogen vehicles;
- Costs associated with owning an autonomous electric vehicle as compared to utilising a fleet-style service; and
- Costs of replacing the Victorian Government's fleet vehicles with AVs.

4.1.1 Summary of method

This analysis focuses on projected vehicle lifecycle ownership costs in Victoria in 2046, and considers the following:

- Purchase costs, including the cost of purchasing the vehicle and related supporting infrastructure;
- Fixed annual costs, including the costs of vehicle registration, driver licences and insurance;
- Variable costs, including costs associated with fuel, tyres, maintenance and battery replacement; and
- Vehicle lifespan, including the expected useful life of a vehicle based on average annual distance travelled.

These inputs have been determined in consultation with experts from across the KPMG network and reflect current literature. Details of each input utilised in this assessment can be found in Appendix A.

This section of the report firstly considers the financial impact of different fuel source scenarios (i.e. traditional, automated electric and automated hydrogen vehicles), then provides a high level

[44] KPMG (2017). *Reimagine Places: Mobility as a Service.*

comparison of the costs for a consumer of private ownership relative to an automated fleet-style service. Further, this section provides an assessment of the potential impacts that progress in autonomous and fuel technologies may have on the Victorian Government fleet.

4.2 Different fuel sources

It is unlikely that cars of the future will be powered predominantly by petrol and diesel as most cars are today. Instead, as indicated in KPMG's Automotive Executive Survey 2018, vehicle technology in the future may see traditional, electric and hydrogen technologies co-existing.[45]

Further, the expectation is that automated vehicles will increase mobility, improve safety and reduce costs, and the emergence of this technology looks set to transform transport outcomes for Victorians. Already, the first AVs are being developed, with *Waymo*, a Google-launched company conducting Level 4 high-automation tests. The Australian Driverless Vehicle Initiative predicts that we will see Level 5 technology emerging between 2026 and 2030, in which the automated system will perform all driving tasks, under all conditions in which a human driver could perform them.[46]

Whilst there remains a degree of uncertainty in estimating the timeframes for these likely advancements, it is clear that continued autonomous innovation and the expected global shift towards co-existing fuel sources will present consumers with varying choices of private vehicle types.

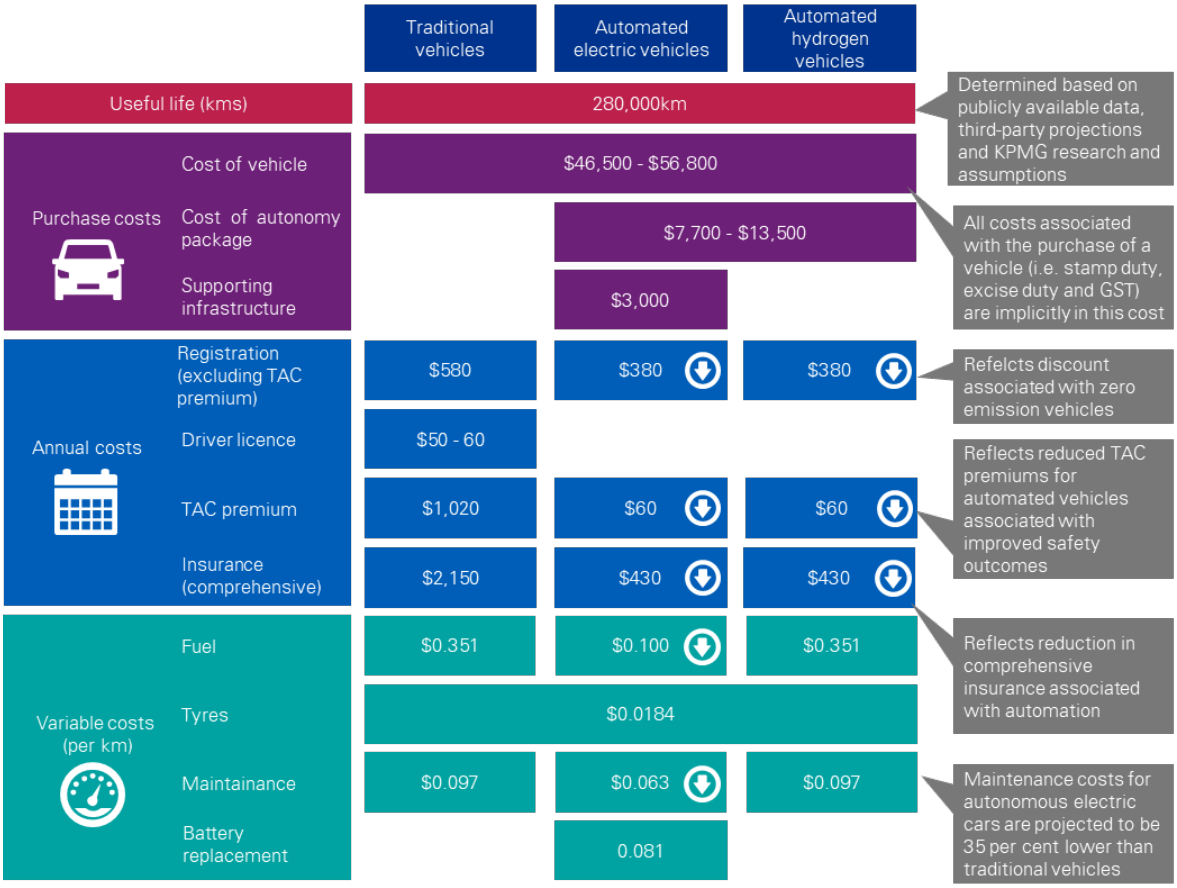
To better understand the expected financial implications for consumers in 2046, KPMG has prepared high level estimates of the projected lifecycle ownership costs of traditional, automated electric and automated hydrogen vehicles.

[45] KPMG (2018). *Autonomous Vehicles Readiness Index – Assessing countries openness and preparedness for autonomous vehicles.*
[46] Australia and New Zealand Driverless Vehicle Initiative, *Levels of Automation.* http://advi.org.au/driverless-technology/

4.2.1 Analysis considerations

A high-level summary of the approach and cost estimates considered in this analysis are summarised in Figure 1.

Figure 1 - Overview of estimated lifecycle cost considerations (cost in 2046 AUD$)



A full list of assumptions and sources is provided in Appendix A.

Purchase costs

Existing literature suggests that the cost of purchasing automated electric and hydrogen vehicles in the future is likely to remain higher than the cost of purchasing a traditional, ICE vehicle, primarily due to the costs associated with the installation of autonomy packages and supporting infrastructure.[47] These estimates account for some reduction in the cost of technology over time, however there is significant uncertainty around how much these costs will reduce over the next 28 years.[48]

[47] Boston Consultancy Group (2015). *Revolution in the Driver's Seat: The Road to Autonomous Vehicles*
[48] KPMG (2015). *The clockspeed dilemma: What does it mean for automotive innovation?*

For the purposes of this analysis, the cost of a vehicle across all three scenarios is based on the average price of a 2017 Toyota Camry Atara S, indexed to the reference year[49]. Further detail of these costs are provided in Appendix A.

The costs associated with autonomy packages are dependent on the progress of multiple hardware and software components, particularly sensor technologies that can analyse and respond continuously to the vehicle's environment. It is anticipated that cost efficiencies for autonomy packages will be related to uptake, and will be based on economies of scale.

Due to the variable nature of uptake, and significant uncertainty surrounding the cost projections, this analysis considers both the lower and upper bound potential costs for autonomy packages under both a progressive and conservative scenario. A progressive scenario is based on high global uptake, resulting from the introduction of safe and reliable technical solutions, significant cost reductions in hardware, a supporting regulatory environment and consumer acceptance of technologies.[50] A conservative scenario considers low global uptake based on inefficiencies relating to level 5 technology not being addressed, regulatory barriers and consumer unwillingness to adopt technologies.[51]

The analysis projects that, under a progressive uptake scenario (lower bound), autonomy packages are estimated to add an additional $7,700 (or 12 per cent) to the average purchase price of vehicles in 2046. Under a conservative uptake scenario (upper bound), autonomy packages are estimated to add an additional $13,500 (or 21 per cent) to the average purchase price of vehicles with this technology in 2046.

Supporting home infrastructure (i.e. home chargers) will also need to be installed for automated electric vehicles. Consideration of these likely costs are based on both charger and installation costs as at 2018, indexed to the reference year. It has been assumed that there are no supporting infrastructure requirements for automated hydrogen vehicles for the consumer; rather, it is expected that these vehicles will be refuelled at service stations, in a similar manner to traditional vehicles.

Annual fixed costs

Annual costs are expected to be significantly lower for automated electric and hydrogen vehicles as compared to traditional vehicles. Efficiencies are likely to be experienced across all four cost categories, most considerably across the insurance (TAC premium) and insurance (comprehensive) cost categories.

Under current policy, a registration discount of $100 is applied to all electric and hybrid passenger vehicles within Victoria.[52] This has been reflected in the analysis, and has also been applied to hydrogen vehicles.

Level 5 automation technology does not require a human driver and, as such, the need for a driver licence has been excluded from the calculation of annual costs for both automated scenarios.[53]

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[49] All costs associated with the purchase of a vehicle (i.e. stamp duty, excise duty and GST) are implicitly included in the purchase cost estimations. These costs are assumed to be constant across the three vehicle types and are therefore not explicit detailed as independent variables.

[50] Archambault, P., Delaney, M., Yuzawa, K., Burgstaller, S., Tamberrino, D., & Duval, A. (2015). *Monetizing the rise of Autonomous Vehicles*. Goldman Sachs - Cars 2025, 3, 81

[51] McKinsey, & Stanford University (2016). *Automotive revolution – perspective towards 2030*. Stanford University, PEEC Sustainable Transportation Seminar, (January 1st), 1–20

[52] After adjusting for future inflation, this discount is approximately $200 in 2046 dollars.

[53] KPMG (2016). *Autonomous vehicles: The public policy imperatives*

The widespread adoption of AVs is expected to reshape the insurance landscape, reducing accident rates and shifting liability for most accidents from the consumer to the manufacturer.[54] It is estimated that human error is currently responsible for 94 per cent of accidents and that, under an autonomous scenario, the level of TAC premium required to support those who have been injured is expected to drop dramatically. This outcome is expected to reduce the annual TAC premium expense for consumers. Additionally, the cost of comprehensive insurance is expected to decline by 80 per cent due to the considerable safety benefits that AVs are anticipated to bring (noting that some insurance payouts associated with fire and theft may not decline).[55]

Variable costs

Variable costs per kilometre are expected to be lower under electric vehicle scenarios, largely due to lower fuel and maintenance costs.

Fuel costs for electric vehicles are projected to be 2.5 times lower than both traditional and automated hydrogen vehicles by 2046, whilst tyre costs are project to remain consistent across all scenarios.

Electric vehicles have fewer moving parts as compared to those in a traditional vehicle. Moreover, many of the costs associated with the electric vehicles are relatively simple to replace. Given this, the literature suggests that maintenance costs (excluding battery replacement) for electric vehicles are likely to be 35 per cent lower as compared to conventional vehicles.[56]

These efficiencies for electric vehicles are partly offset by the costs involved in battery replacement. The estimated cost of battery replacement for electric vehicles is based on the use of a lithium-ion battery for a 2018 Nissan LEAF, which has capacity and warranty for up to 160,000 km. It is assumed that automated hydrogen vehicles will not require fuel cell replacement during their useful life, considering the US Department of Energy targets for fuel cell durability of over 240,000 km.[57]

4.2.2 Analysis outcomes

To allow comparison between the three vehicle types, the net present cost (NPC) of each vehicle type has been estimated per vehicle kilometre travelled (VKT).[58] As this analysis is based on the lifetime costs of purchasing a vehicle in 2046, ongoing variable and annual costs incurred beyond this point (e.g. fuel, maintenance, etc.) have been discounted back to 2046 dollars.

As detailed in Table 18, it is projected that in 2046, autonomous electric vehicles will be the lowest cost fuel source option for the average Victorian driver who travels 15,000 km per annum.

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[54] KPMG (2017). *The chaotic middle: The autonomous vehicle and disruption in automobile insurance*
[55] Deloitte (2016). *Quantifying an uncertain future: Insurance in the new mobility ecosystem*

[56] Bosch, P., Becker, F., Becker, H., & Axhausen, K. (2017). *Cost-based analysis of autonomous mobility services.* Transport Policy (64), *p. 76-91*
[57] The Department of Energy (US) targets fuel cell power durability of 5,000 hours (equivalent to approximately 240,000 km of driving). Available: https://www.energy.gov/eere/fuelcells/doe-technical-targets-polymer-electrolyte-membrane-fuel-cell-components
[58] NPC calculates the present (2046) cost of the purchasing and operating a vehicle. The calculation considers the lifecycle costs of purchasing and operating a vehicle, which are then discounted back to 2046 dollars.

Table 18 - Net present cost per vehicle kilometres travelled (cost in 2046 AUD$)

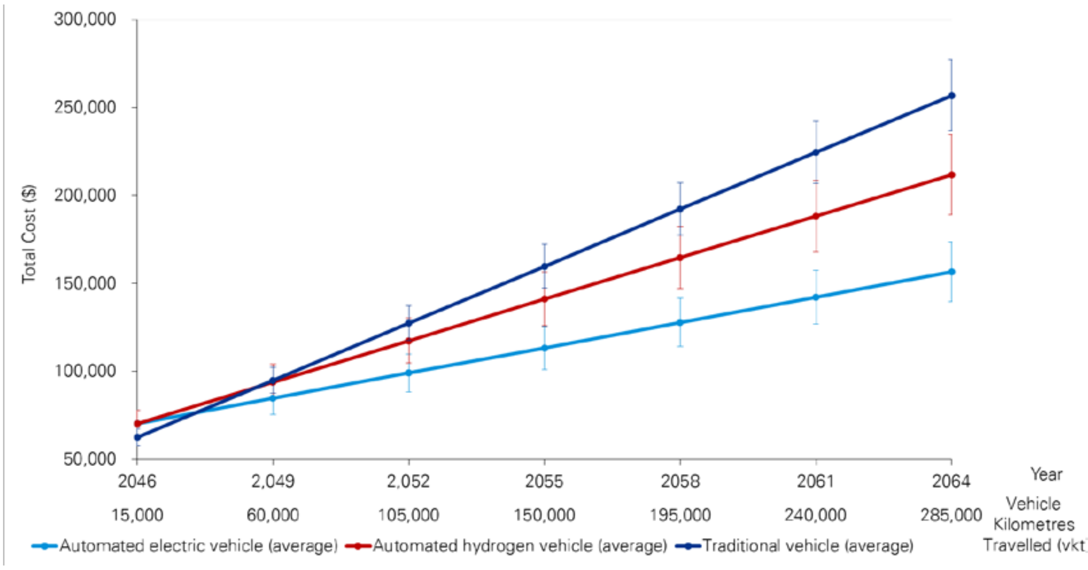
NPC ($) / VKT	Lower bound	Upper bound	Average
Traditional vehicle	0.52	0.60	0.56
Automated electric vehicle	0.35	0.43	0.39
Automated hydrogen vehicle	0.44	0.54	0.49

Source: KPMG analysis based on assumptions and sources listed in Appendix A

Estimates indicate that even under an obstructed uptake scenario (upper bound cost result), automated electric vehicles present the more cost effective option for the average consumer than progressive estimates (lower bound cost result) for traditional and automated hydrogen vehicles.

Figure 2 below shows the projected total cost of ownership over time for a motorist who purchases a traditional, automated electric or automated hydrogen vehicle and drives 15,000 km per annum (including an error bar which illustrates the uncertainty associated with upper and lower bound outcomes). The figure highlights that despite initially having a lower purchase price, the estimated lifetime cost of a traditional vehicle quickly exceeds both automated electric and hydrogen vehicles.

Figure 2 - Cumulative cost comparison between fuel sources (cost in 2046 AUD$)



Source: KPMG analysis based on assumptions and sources listed in Appendix A

4.2.3 Key dependencies and limitations

Despite the rise of alternative fuel sources and autonomous technologies developed in recent years, the road ahead for AVs continues to be uncertain. The above analysis does not consider the potential emergence of autonomous 'mission-specific' vehicles, including 'pods' that may replace traditional vehicles.[59] Some literature suggests that production costs for pods may be

[59] KPMG (2017). Islands of autonomy: How autonomous vehicles will emerge in cities around the world

as little as half that of traditional vehicles.[60] Changes to the characteristics of AVs could further reduce the net present cost of automated electric and hydrogen vehicles.

Key dependencies of this outcome include the projected efficiencies in both annual fixed costs (i.e. reduction in registration, removal of driver licence requirements and decreased insurance premiums) and variable costs (i.e. reduced fuel and maintenance costs) and, as such, autonomous electric vehicles are projected to be the most cost effective.

Annual costs for electric AVs are assumed to be three times lower than costs associated with traditional vehicles, with efficiencies assumed across all categories. Additionally, variable costs for autonomous electric cars are assumed to be 72 per cent lower than for both traditional and automated hydrogen vehicles. A detailed list of assumptions is provided in Appendix A.

Projected vehicle costs will become clearer as the technology continues to develop, and as industry consensus forms on the major inputs required for autonomous hydrogen and electric vehicles. This includes costs associated with autonomy packages (software and hardware), maintenance costs and further operating requirements.[61] As such, although the estimates detailed in this section of the report are based on the latest literature and input from subject matter experts, the underpinning assumptions must be considered when evaluating the robustness of the forecasts provided.

4.3 Private versus fleet vehicles

Over the past decade, the emergence of car sharing has grown in Victoria, and with advancements projected across the industry, car sharing popularity is expected to grow in the coming years.[62] This growth in popularity is in part driven by consumer desire to avoid or reduce the costs associated with ownership, paying instead for the time used. This emergence of on-demand services has created social changes that are difficult to ignore. With increased money flowing into the shared vehicle industry, companies such as Uber have begun testing the feasibility of autonomous car sharing vehicles. It is expected that over the next few years, widespread testing of AV fleets will continue to occur. It is anticipated that automated fleet-style services may provide increased availability and access to mobility, improve traffic efficiency and reduce costs for consumers. Fleet-style services may also allow space currently used for parking to give way to more housing and public spaces in urban areas.[63]

To better understand the financial implications that autonomous fleet vehicles may have on consumers, KPMG has developed high level estimates of the relative costs of private ownership of an automated electric vehicle as compared to utilising an automated electric fleet-style service.

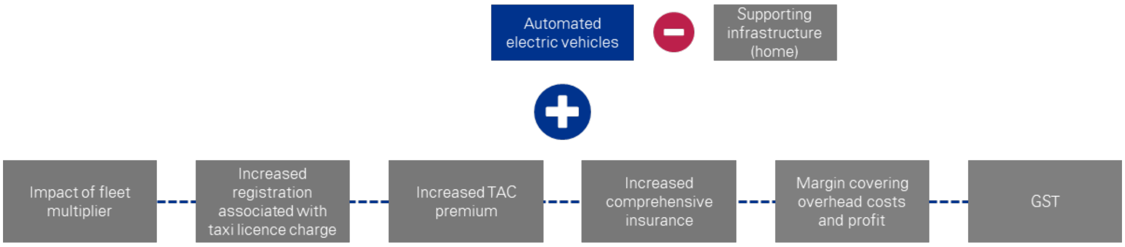
4.3.1 Analysis considerations

For the purpose of this analysis, it has been assumed that autonomous fleet services will serve a single passenger, transporting them from a designated pickup point to a designated

[60] KPMG (2017). *Islands of autonomy: How autonomous vehicles will emerge in cities around the world;* Deloitte (2016). *Quantifying an uncertain future: Insurance in the new mobility ecosystem*
[61] KPMG (2018). *Autonomous Vehicles Readiness Index – Assessing countries openness and preparedness for autonomous vehicles*
[62] KPMG & Arup (2017). *Model Calibration and Validation Report,* Infrastructure Victoria, Melbourne
[63] KPMG (2018). *Autonomous Vehicles Readiness Index*

destination. The additional cost considerations associated with autonomous fleet vehicles are detailed below in Figure 3.

Figure 3- Overview of autonomous electric fleet lifecycle cost considerations



It is anticipated that fleets of automated electric vehicles may reduce the total number of vehicles in Victoria. Building on outcomes previously discussed in this report, it is estimated that the total number of automated vehicles required to service the Victorian population will be 80 per cent lower under a fleet-style scenario as compared to the private ownership model. As such, a fleet multiplier of five has been utilised, estimating that one shared fleet vehicle will replace five private vehicles. This analysis assumes that each fleet vehicle has a useful life of 280,000 kilometres and travels 75,000 kilometres per annum on average.

In October 2017, significant changes were made to commercial passenger vehicle regulations in Victoria, enabling the provision of low-cost licences for taxis. These costs are supplementary to registration, and have been considered as part of KPMG's estimates.

The move towards autonomous technology is expected to shift insurance risk away from the individual and fleet vehicle owners and onto the vehicle manufacturer.[64] However, fleet services incur commercial automotive insurance, which is a higher level of comprehensive insurance as compared to personal automotive insurance. This additional level of comprehensive insurance, and the expected increase in TAC premiums relating to the fleet multiplier effect, have been considered as part of this analysis.

For the purpose of this analysis, it is assumed that fleets are owned by mobility providers, and that the adopted business model covers the cost of the vehicle, and also charges an additional 30 per cent margin to cover overhead costs (i.e. administration, IT costs, etc.) and profit requirements.

4.3.2 Analysis outcomes

As detailed in Table 19, it is projected that in 2046, it will be approximately 40 per cent cheaper ($0.24 per VKT compared to $0.39 per VKT) for the average Victorian who travels 15,000 kilometres per annum to use a fleet style service than to own their own vehicle. It is estimated that for the average Victorian, even the upper bound usage cost estimate for using an autonomous electric vehicle is lower than the lower bound estimate for a privately owned vehicle.

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[64] KPMG (2017). *The chaotic middle: The autonomous vehicle and disruption in automobile insurance*

Table 19 - Net present value per vehicle kilometre travelled (cost in 2046 AUD$)

NPC ($) / VKT	Lower bound	Upper bound	Average
Automated electric vehicle (private ownership)	0.35	0.43	0.39
Automated electric vehicle (fleet-style service)	0.21	0.26	0.24

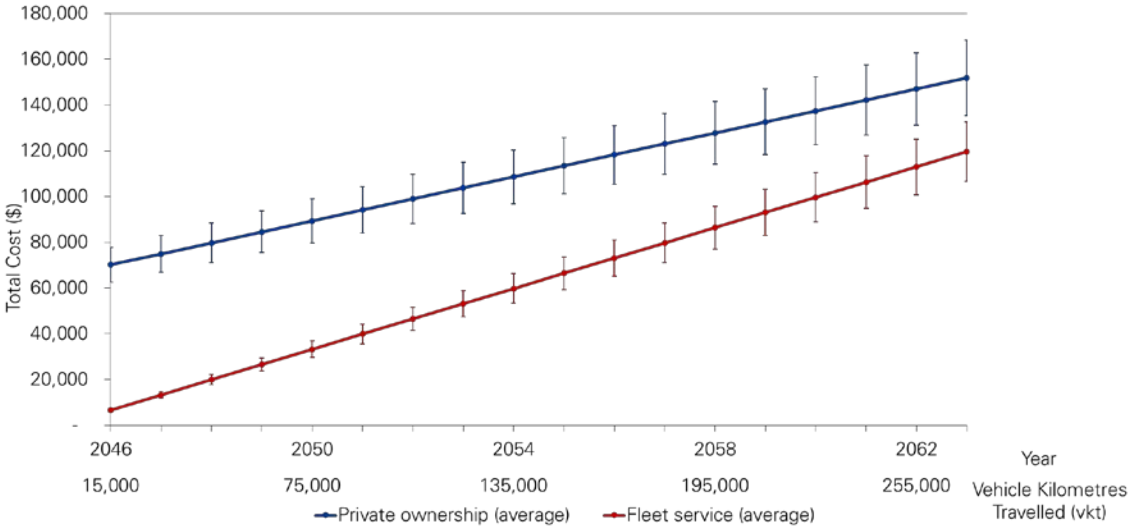
Source: KPMG analysis based on assumptions and sources listed in Appendix A

Figure 4 below shows the range of projected lifetime costs under the private versus fleet scenarios. The lines indicate the average costs, with the bars indicating the upper and lower bound of these estimates. The chart shows how lifetime costs accumulate over time, with the range being driven primarily by uncertainty around projected upfront purchase costs. There is also some uncertainty around ongoing operating costs which is why this range increases over time.

For the average Victorian, the lifetime cost of a private vehicle is greater than that of a fleet style service. Estimates indicate that even under an obstructed uptake scenario (upper bound cost result), a fleet style service is more cost effective for the average consumer than a progressive estimate (lower bound cost result) for private vehicle ownership. The projected additional lifetime cost decreases as the number of kilometres travelled increases.

For individuals travelling more than the average Victorian, the appeal of private ownership increases in direct correlation to distance travelled. This is due to the impact of increased variable costs, profit and GST, which become more significant under a fleet style service as distance travelled rises. High level estimates suggest that the 'tipping point' for private ownership, that is, the point at which the net present cost is the same under both scenarios, is approximately 43,000 km per annum. Victorians who travel this distance would expect to incur an average net present cost of approximately $0.42 per vehicle kilometre travelled under both private ownership and fleet service models.

Figure 4 - Projected lifetime costs of private ownership v. using fleet style service (cost in 2046 AUD$)



Source: KPMG analysis based on assumptions and sources listed in Appendix A

4.3.3 Key dependencies and limitations

Our estimates suggest that for many people, the transition from private ownership to an automated fleet-style service is likely to occur due to the expected financial benefits. However, consideration should also be given to additional factors, for example, the intrinsic value of owning a private vehicle for recreational drivers, individuals who may require a vehicle for employment (e.g. storage of tools and other specialised work equipment), and the circumstances of individuals living in remote locations.

The key assumptions leading to this outcome are annual fixed costs and the margin applied to cover overhead costs and profit. Under a fleet style scenario, taxi licence charges, increased TAC premiums and increased comprehensive insurance influence the fixed annual costs. Additionally, under a fleet style scenario, variable costs are predominantly impacted by a margin of 30 per cent, which has been applied to cover overhead costs and required profit. A detailed list of assumptions is provided in Appendix A.

The key assumptions that underpin this analysis are based on current literature and input from subject matter experts. However, as widespread testing of AV fleets continues over the next few years, improved clarity will help in refining the robustness and rigour of analysis to help inform the direction of the industry.

4.4 Victorian Government fleet vehicles

The Victorian Government's overarching policy on motor vehicle use is to ensure the effective support of government service delivery, whilst also ensuring positive outcomes in relation to safety, efficiency and environment.

VicFleet supports the effective management of the Victorian Government vehicle fleet, and is also responsible for the operational management of the Motor Vehicle State Purchasing

Contract (SPC). As at February 2018, VicFleet had a total of approximately 8,500[65] vehicles under lease that included a number of passenger and light commercial vehicles; this full fleet management service is provided to 20 Victorian Government departments and agencies.[66]

Currently, lease terms are three years or 60,000 kilometres for traditional vehicles. The Victorian Government fleet currently includes several hybrid and plug-in hybrid electric vehicle models and no all-electric models.

With autonomous technologies continuing to develop, the Victorian Government has an opportunity to be an early adopter of AVs. Whilst the road ahead for AVs remains uncertain, the Victorian Government can play a significant role in supporting its growth trajectory.

It has been found that the Department of Treasury and Finance (DTF) does not currently have targets for inclusion of fully battery operated electric vehicles in the Victorian Government fleet, nor do they have comprehensive charging infrastructure to support them.[67] Initially, the Victorian Government can seek to transition its existing fleet vehicles from traditional fuel sources to either electric or hydrogen fuel sources as lease terms come to an end, along with supporting the rollout of appropriate vehicle charging and refuelling infrastructure.

This transition is already occurring in other states and territories, with the ACT Government committing to transition its fleet to electric vehicles, with all newly leased government vehicles to be zero-emission from 2021. Locally, the Victorian Government has committed $1 million to help Moreland City Council transition local government vehicles to a zero emissions fleet.[68] The Victorian Government can play an active role in developing critical infrastructure and promoting the adoption of electric vehicles, as well as laying the foundations for the transition to AVs.

In 2046, KPMG estimates a financial benefit of approximately $2,600 per annum for the transition of each traditional government fleet vehicle to an automated electric vehicle.

Accounting for population growth, the number of Government fleet vehicles is anticipated to reach ~13,500 by 2046.[69] It is estimated that if the Government fleet were entirely automated at this time, a financial saving of $35 million per annum could be realised, as compared to a fleet comprised entirely of traditional vehicles.[70] It must be noted however, that this analysis does not reflect the transition of Victorian Government emergency service vehicles (e.g. police vehicles, ambulance vehicles and fire trucks, etc.) to automated electric vehicles.

Transitioning to electric fuel sources is a viable, medium-term objective for the Victorian Government, however further policy consideration is required regarding the role of autonomous technologies across the entire Government fleet. This is particularly the case in emergency services.

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[65] Total VicFleet numbers includes a number of passenger and light commercial vehicles but excludes Victorian Government emergency service vehicles such as police vehicles, ambulance vehicles and fire trucks.

[66] Inquiry into electric vehicles (2018). Parliament of Victoria. *Legislative Council Economic Infrastructure Committee*

[67] Inquiry into electric vehicles (2018). Parliament of Victoria. *Legislative Council Economic Infrastructure Committee*

[68] Victorian Government Media Releases (2018). *Hydrogen to Fuel Transport Manufacturing Innovation*

[69] Growth in government vehicle fleet numbers is in line with projected population growth figures (as detailed in *Appendix A).*

[70] This calculation exclude the Victorian Government emergency service vehicles

5 Implications for transport infrastructure business cases

The new technologies and scenarios described in this report have significant implications for the development of robust business cases to inform future investments in major transport infrastructure projects. The new technologies could unlock major economic and social benefits for Victorians if appropriately managed. There are also potential dis-benefits that could occur if long term planning does not appropriately take these new technologies into account.

Current guidance requires project proponents to consider non-build options as part of the business case projects. The interface between communications technology and automated vehicles further highlights the necessity of consideration of non-build options in business case submissions.

The remainder of this section includes an analysis of how new transport technologies may need to be considered in transport infrastructure business cases. This analysis is provided in the context of four separate but related and interdependent perspectives:

- Uncertainty and flexibility;
- Demand and behavioural impacts;
- Economic, social and environmental benefits and dis-benefits; and
- Financial and economic costs.

5.1 Uncertainty and flexibility

The technologies and scenarios in this report highlight that Victoria's transport future is subject to a greater degree of uncertainty than in recent times, potentially since the advent of the automobile in the early 20th century. The technologies could evolve rapidly, and could also have complex and unpredictable effects on consumer behaviour. Business cases will need to recognise this uncertainty and incorporate it as a core part of the business case analysis. In order to do this, business cases will benefit from incorporating scenario analysis, and also consider tools such as real options assessment.

The following scenarios may be considered as part of business case analysis:

- Changes (likely increases) in the willingness of people to accept longer travel times due to greater comfort and convenience of automated vehicles;
- Changes in standing and running costs for vehicles due to automation and new propulsion technologies (e.g. electric or hydrogen propulsion);
- Automated taxis (shared fleet vehicles) as a large proportion of daily travel (i.e. to replace or largely replace private vehicle ownership);
- Changes in the fixed and variable and perceived and unperceived components of travel costs, including the costs of private and shared car ownership;
- Changes in the flow capacity of road infrastructure due to AVs (i.e. platooning);

- The advent of 'empty running' (i.e. vehicles with no occupants) for either or both of vehicles with shared or private ownership, including any impacts on parking or staging (i.e. pick-up and drop-off locations) of vehicles;
- The potential ability for a larger proportion of the community to use cars without requiring a driver license (e.g. young children 'driving' to school in an AV).
- Different potential timing and sequencing of mass take-up of the various technologies (i.e. automated vehicles, shared ownership, zero emissions vehicles); and
- Alternative land use scenarios, including scenarios where land use changes as a result of the new technologies due to accessibility impacts (i.e. changes in residential and business location choice).

5.2 Demand and behavioural impacts

The advent of autonomous vehicles has the potential to profoundly change travel patterns, and consequently to affect land use, service delivery, and social interactions. When a change of this magnitude last changed, with the widespread introduction of the private motor car, the impact on the community was both widespread and largely unpredicted. The same is likely to be true with this new technology.

The following scenarios are likely to have the greatest impacts on the outcomes of demand modelling:

- Potential rise of automated taxis as a pervasive mode of transport for everyday travel - demand models will need to be able to explicitly model taxi fleets;
- Changes (likely increases) in road capacities resulting from automation;
- Changes (likely reductions) to marginal utility of travel time (value of time) due to AVs (i.e. people may be willing to accept longer travel times due to greater comfort and convenience of travel times);
- Changes (likely reductions) to perceived vehicle operating costs due to electric or hydrogen vehicles;
- Changes in the proportion of vehicle operating costs that are perceived (e.g. automated taxis may lead to a greater proportion or the entirety of vehicle operating costs to be perceived on a per-trip basis);
- Changes in vehicle ownership (including the mix of private and shared vehicle ownership);
- Changes to trip generation and attraction rates and the proportion of the population as "public transport captive" due to the ability for those without a car or a license to undertake "car driver" trips.
- Land use feedbacks and/or direct integration with land use modelling due to the large potential land use impacts of new technologies; and
- Empty running of both private and shared vehicles (i.e. automated taxis) and their direct and indirect impacts on congestion.

5.3 Economic, social and environmental benefits and dis-benefits

There are various likely implications for parameters used in estimating benefits of transport infrastructure projects. Impacts from demand modelling (described in the previous sub-section) will have major flow-on impacts for economic analysis, primarily due to changes in levels of congestion and/or public transport crowding.

In addition, the following components of economic analysis are likely to be directly affected by the adoption of autonomous vehicles:

- The valuation of travel time savings may reduce for travellers in AVs due to increased comfort and convenience;
  Vehicle operating costs (and therefore vehicle operating costs savings) may reduce due to lower running costs of electric vehicles relative to internal combustion engine vehicles (see Section 4);
- Accident parameters are likely to change – accident rates per kilometre per road class are likely to decline, potentially by an order of magnitude or two, with automated vehicles;
- Resource Cost Corrections (RRCs) will be affected if there are material changes between perceived and unperceived costs with pervasive shared ownership;
- There may be amenity benefits due to changes in congestion and/or traffic in local areas – robust methods may need to be designed to assess this; and
- Productivity benefits (e.g. Wider Economic Benefits) are likely to be significantly impacted, particularly if modelled land use changes in scenarios with new technologies are significant. Methodologies to measure these impacts may need to be refined in response.

There will also be a wide range of social impacts, as people who previously could not travel by car are able to use autonomous vehicles. These include those who are unable to drive (for example, due to age, previous driving offenses, disabilities) or who use public transport. Many of these important social impacts will not be able to be quantified, but will need to be included in business cases in qualitative analysis.

In addition, environmental parameters are like to change with the widespread adoption of ZEVs – rates of air pollution, and greenhouse gas pollution per kilometre are likely to decline, potentially to zero, with zero emissions vehicles, while levels of noise pollution could also be affected.

5.4 Financial and economic costs

Financial and economic cost estimates are important components of business case submissions and economic analysis. Changes in costs due to new technologies should be incorporated in cost estimates. These may include costs of communication technologies, road-side equipment or units, changes to road geometry, intersection design, line markings, on-street parking provision, pedestrian and cyclist interaction and any other relevant factors.

Appendix A: Assumptions

A.1 Overarching assumptions

The table below provides a list of overarching assumptions that have been used across various components of this analysis.

Category	Assumption	Source(s) and comments
Indexation	All future years have been indexed at an assumed inflation rate of 2.5 per cent per annum.	This is the midpoint of the Reserve Bank of Australia's inflation target https://www.rba.gov.au/inflation/inflation-target.html
Population	The Australian Population in 2015 is assumed to be 23.78m	3101.0 - Australian Demographic Statistics, Jun 2015
Population	All Victorian Population assumptions are in line with Victoria in Future estimates.	Victoria in Future population estimates
Population	The proportion of the Australian population who live in Victoria remains constant between 2015 and 2046.	KPMG Assumption
Annualisation	For the purpose of annualising VKT based figures, there are 330 days in the year.	Transport model assumption – as the model generates a typical working Tuesday, an annualisation factor of 330 helps compensate for those days in the year which have considerably less traffic (weekends and certain public holidays).
VKT	All VKT figures for the MABM area are supplied directly by the transport modelling stream of work for the Vehicle Advice.	Vehicle Advice – transport work stream based on MABM.
VKT	VKT figures for areas outside the MABM area are assumed to be equal, on a per driving age population basis, to the MABM area.	Vehicle Advice – transport work stream based on MABM. Modelling work did not extend to the impact of all scenarios on a State-wide basis. This method was chosen as it allowed for consistent analysis across all scenarios.
Trip Count	All trip count figures for the MABM area have been sourced from the transport modelling work stream of the Vehicle Advice.	Vehicle Advice – transport work stream based on MABM.
Trip Count	Trip count figures for areas outside the MABM area are assumed to be equal, on a per driving age population basis, to the MABM area.	Vehicle Advice – transport work stream based on MABM.

Category	Assumption	Source(s) and comments
Dead Running	The proportion of dead running VKT and trips for Scenarios 2 and 4 are presumed to be equal.	Vehicle Advice – transport work stream based on MABM.
AV Performance and Safety	AVs will have an accident rate 94 per cent lower than human driven vehicles in each of the scenario years.	U.S. Department of Transportation (2015), *Traffic Safety Facts* https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115
AV Performance and Safety	AVs will not commit traffic violations or incur traffic infringements.	Assumption – a correctly programmed AV is presumed to never commit a traffic violation except under circumstances where the law would excuse it (speeding to avoid a collision for example).
AV Performance and Safety	AVs require roughly 94 per cent less road safety enforcement effort than human controlled vehicles.	Assumption – based on the assumption around reduced crash rates compared to human operated vehicles. It is presumed that in those 6 per cent of cases where factors other than human error are at fault, police resources would still be required to respond to incidents and to monitor and control related risks.
AV Licence Requirements	It is presumed that a driver licence is not required to operate an AV in any of the modelled scenarios.	Under the assumed Level 5 automation, no driver is required - Australia and New Zealand Driverless Vehicles Initiative. Levels of Automation. Available at :http://advi.org.au/driverless-technology/
Vehicle purchase price for AVs	+20.2 per cent as compared to non-autonomous vehicle.	Based on cumulative uptake and cost reduction rates as calculated by Boston Consultancy Group (2016), indexed to the reference year.
Freight VKT Composition	Freight VKT in 2046 scenarios are assumed to comprise 41 per cent rigid trucks and 59 per cent articulated trucks. Freight VKT in 2031 scenarios are assumed to be divided between rigid trucks (42 per cent) and articulated trucks (58 per cent).	Vehicle Advice – transport work stream based on MABM.
Population growth projections	Derived from Victoria in Future population projections	Victoria in Future 2015.
Public transport use	All public transport usage figures for the MABM area are supplied directly by the transport modelling stream of work for the Vehicle Advice.	Vehicle Advice – transport work stream based on MABM.
Government Investment	All scenarios assume the same schedule of infrastructure investment and the same changes to public transport service levels over time.	Vehicle Advice – transport work stream based on MABM.

Financial impact assumptions

The table below provides a list of assumptions that have been used specifically for the financial impact analysis in this report.

Cost type	Category	Assumption	Source(s)
Registration Revenue	Registration Discount for ZEVs	ZEVs receive an average 34.4 per cent discount on their registration fees in each scenario.	Discount percentage calculated based on the average vehicle being a privately owned car registered in the metropolitan area. https://www.vicroads.vic.gov.au/registration/registration-fees/vehicle-registration-fees
Registration Revenue	Vehicle ownership	The number of vehicles owned per driving age person remain static at 2015 levels in all scenarios not featuring a shared AV fleet.	Assumption – while there are factors which may lead to increased or decreased ownership per driving age person, insufficient evidence exists to conclude whether they will result in a net increase or decrease in vehicle numbers.
Registration Revenue	Vehicle ownership	For shared fleet scenarios, the same assumption as to vehicle ownership applies as above, but it is assumed that one shared AV can replace five privately owned vehicles.	Assumption – this assumption is common across the various Vehicle Advice reports commissioned by Infrastructure Victoria.
Registration Revenue	Premium per shared vehicle registration	Shared AV fleet vehicles are assumed to pay 21 per cent higher registration fees per vehicle than vehicles for private use.	Based on the current annual cost for a taxi licence relative to the ordinary cost of registering a privately owned car in the metropolitan Melbourne area - Taxi.vic.gov.au
Registration Revenue	Policy Settings	It is assumed that the cost of registering a vehicle will not change other than to account for inflation.	Assumption – existing policy settings.
Stamp Duty Revenue	Vehicle lifespan	Vehicle lifespan is assumed to be measured in kilometres travelled, rather than years.	Assumption – while it may be that age can cause vehicles to become unreliable or be obsoleted, for simplicity of analysis the lifetime of a vehicle is measured in kilometres travelled rather than time since manufacture.

Cost type	Category	Assumption	Source(s)
Stamp Duty Revenue	Vehicle lifespan	ZEVs and AVs are presumed to have similar useful lives to ICE vehicles in 2015. This is based on the assumption that non-engine-related components of the vehicle will reach the end of their useful life at the same time across all vehicle types. In reality it may be that ZEVs or AVs have longer useful lives than ICE vehicles, however this analysis could not identify any robust sources that prove this.	KPMG Subject Matter Experts (UK, US and India).
Stamp Duty Revenue	Vehicle turnover rate	Vehicles are assumed to be turned over a consistent number of times over their useful lives across all scenarios.	Assumption – agreed due to lack of evidence on how turnover rates may change across the various scenarios.
Stamp Duty Revenue	Policy Settings	It is assumed that the stamp duty rates will not change.	Assumption – existing policy settings.
TAC Premium Revenue	Road Safety	It is assumed that the total value of compensable harm and injury on Victoria's roads per VKT on Victoria's roads will remain constant from 2014/15 to 2045/46, with the exception of any impact made by AVs.	Infrastructure Victoria Assumption – while current trends suggest the roads are becoming safer per VKT, this trend cannot logically be extrapolated out forever and insufficient grounds exist to identify where this trend is likely to level off. Assuming a static rate of harm per VKT allows for better isolation of the impact of AVs.
TAC Premium Revenue	Policy Settings	TAC Revenue is assumed to decline in direct proportion to falls in the total amount of compensable harm incurred on Victoria's roads.	Assumption based on alignment of TAC Premiums to support those injured on Victoria's Roads. http://www.tac.vic.gov.au/about-the-tac/our-organisation/transport-accident-charge
TAC Expenditure	Road Safety	It is presumed that the total value of compensable harm and injury per VKT on Victoria's roads will remain constant from 2014/15 to 2045/46 with the exception of any impact made by AVs.	Infrastructure Victoria Assumption – while current trends suggest the roads are becoming safer per VKT, this trend cannot logically be extrapolated out forever and insufficient grounds exist to identify where this trend is likely to level off. Assuming a static rate of harm per VKT allows for better isolation of the impact of AVs.

Cost type	Category	Assumption	Source(s)
TAC Expenditure	Policy Settings	TAC Expenditure is assumed to decline in direct proportion to falls in the total amount of compensable harm incurred on Victoria's roads. This presumes that all harm being compensated for by TAC payments in the scenario year fully reflects the added safety benefits of AV implementation up to the levels specified in the scenarios.	Assumption based on alignment of TAC Premiums to supporting those injured on Victoria's Roads. http://www.tac.vic.gov.au/about-the-tac/our-organisation/transport-accident-charge
Licence Fees	Policy Settings	It is assumed that the cost of a driver licence will not change other than to account for inflation.	Assumption – existing policy settings.
Parking Revenue	Policy Settings	It is assumed that the prices charged for parking, and the rate of the congestion levy, will not change from 2014/15 to 2045/46, other than to account for inflation.	Assumption – existing policy settings.
Parking Revenue	2015 Revenue	2014/15 congestion levy revenue was $110.6 million.	State Revenue Office - https://www.sro.vic.gov.au/congestion-levy-statistics
Parking Revenue	2015 Revenue	MABM area parking revenue for 2014/15 calculated based on a per-head extrapolation from the average parking revenues of the Frankston and Stonnington councils.	Stonnington 2014/15 council annual report p122. Frankston 2014/15 council annual report p119.
Parking Revenue	2015 Revenue	Non-MABM area revenue for 2014/15 calculated based on a per-head extrapolation from the average revenues of the Swan Hill and Horsham Councils.	Swan Hill 2014/15 council annual report p124. Horsham 2014/15 council annual report p111.
Parking Revenue	Relation to trip count	Parking and congestion levy revenue are presumed to scale directly with changes in the amount of trips taken.	KPMG assumption.
Parking Revenue	Trip count composition	The proportion of trips which are made to locations where parking would (in the absence of AV capabilities) be required remains constant between 2014/15 and 2045/46.	Assumption – no grounds to project a change in behaviour.
Parking Revenue	AV Impact	Each 'dead running' trip by an AV is presumed to offset the parking requirements of one occupied vehicle trip.	KPMG Assumption.

Cost type	Category	Assumption	Source(s)
Parking Revenue	AV Impact	Shared fleet AVs are presumed to have their own staging facilities and to be capable of moving themselves to avoid paid parking facilities.	KPMG Assumption.
Infringement Revenue	Policy Settings	It is assumed that there will be no change to the existing traffic infringement regime in Victoria, other than to account for the impact of indexation on penalty values.	Assumption – existing policy settings.
Infringement Revenue	VKT Impact	All else being equal, infringement revenue is assumed to increase or decline in direct proportion to changes in total VKT on Victorian roads.	KPMG Assumption.
Fuel Excise Duty	Policy Settings	It is assumed that there will be no policy change relating to fuel excise between 2014/15 and 2045/46 (and all scenarios) other than through the indexation of excise rates.	Assumption – existing policy settings.
Fuel Excise Duty (Petrol)	VKT Impact	It is assumed that 100 per cent of petrol is used by ICE road vehicles. As a result, 100 per cent ZEV scenarios are presumed to have zero petrol-related fuel excuse duty revenues.	KPMG Assumption.
Fuel Excise Duty (Diesel)	Collection attribution	It is presumed that Victoria accounts for a share of total fuel excise revenue equal to its share of the total Australian population.	KPMG Assumption.
Public Transport Farebox Revenue	Policy Settings	All Government policy settings and agreements related to public transport in Victoria (other than planned infrastructure investment and service level requirements as assumed by the transport model) are assumed to be static between 2014/15 and 2045/46 and each scenario. Ticketing prices are assumed to adjust for inflation but not to otherwise change.	Assumption – existing policy settings.

Cost type	Category	Assumption	Source(s)
Public Transport Farebox Revenue	Farebox Revenue	The total proportion of public transport use by individuals claiming concession fares is assumed to remain constant across all scenarios and years.	KPMG Assumption.
Public Transport Farebox Revenue	Farebox Revenue	It is assumed that all public transport station entries, tram boardings, and bus boardings are of the same value, meaning that total revenue scales directly with an increase in total entries/boardings regardless of any change in which mode of public transport is used.	KPMG Assumption.
Road Safety Enforcement Expenditure	Road safety enforcement expenditure	Road safety enforcement expenditure is assumed to account for 9 per cent of the Victoria Police annual budget in 2014/15. This is broadly consistent with road safety enforcement expenditure in other states.	Linking Inputs and Outputs: Activity Measurement by Police Services: Research Paper (1999)
Road Safety Enforcement Expenditure	Road safety enforcement expenditure	Road safety enforcement expenditure in each scenario is assumed (other than as a result of AV implementation) to grow in direct relation to VKT between 2014/15 and 2045/46.	KPMG Assumption.
Road Safety Enforcement Expenditure	Road safety enforcement expenditure	Road safety enforcement expenditure is assumed to undergo indexation at the rate of 2.5 per cent per annum.	Assumption – insufficient evidence to otherwise estimate changing enforcement operations costs over the 2014/15 – 2045/46 period.
Vehicle Emissions (health cost)	Vehicle Emissions (health cost)	Externality costs for vehicle emissions impact on population health per VKT are assumed to be the following in 2014/15: Private Vehicle (Metro): $0.0311 Private Vehicle (Rural): $0.0003 Freight Vehicle (Metro): $0.4455 Freight Vehicle (Rural): $0	Austroads guide to project evaluation, Part 4: Project Evaluation Data p30 Austroads guide to project evaluation, Part 4: Project Evaluation Data p34
Road Maintenance Costs	Per VKT Road Maintenance Costs	Road maintenance costs per VKT (prior to adjustment) are assumed to be the following in 2014/15: Car or motorcycle: $0.0411 Rigid truck: $0.0514 Articulated truck:$0.1754	Transport for NSW – Economic Parameters Values and Valuation Methodologies, p65.

Cost type	Category	Assumption	Source(s)
Road Maintenance Costs	State vs local maintenance	Upkeep of freeways and arterials is presumed to be a State Government cost while local road upkeep is presumed to be the responsibility of local councils.	KPMG Assumption.
Road Maintenance Costs	Actual State Road Maintenance Costs	Actual VicRoads road maintenance expenditure for 2014/15 was $468.5 million.	VicRoads 2014/15 annual report p11.
Road Maintenance Costs	Per VKT Road Maintenance Costs	To calculate road maintenance costs across scenarios, changes in economic parameter derived road maintenance expenditure (as modelled through MABM) have been used to estimate changes in actual observed road maintenance expenditure.	Vehicle Advice – transport work stream based on MABM.

A.2 Consumer lifecycle ownership cost assumptions

The table below provides a list of assumptions that have been used specifically for the consumer lifecycle ownership cost analysis in this report.

Cost type	Category	Assumption	Source(s)
Rates	Discount Rate	7.0 per cent	Department of Treasury and Finance: *Economic Evaluation for Business Cases – Technical guidelines (August 2013).*
Rates	Exchange rate (British pound to Australian Dollar)	1.8	May 2018 Exchange Rate.
Vehicle lifespan	Annual distance travelled	15,000km	Thakur, P., Kinghorn, R. & Grace, R. (2016). *Urban form and function in the autonomous era.* Australasian Transport Research Forum 2016.
Vehicle lifespan	Useful life (kms)	~280,000km	KPMG Subject Matter Experts (UK, US and India).

Cost type	Category	Assumption	Source(s)
Purchase cost	Cost of vehicles (2046)	Lower bound ~$46,500 Upper bound ~$56,800	Vehicle cost based on average price of a 2017 Toyota Camry Atara S, indexed to the reference year. All costs associated with the purchase of a vehicle (i.e. stamp duty, excise duty and GST) are implicitly included in the purchase cost estimations Information available at: https://www.carsguide.com.au/toyota/camry/price/2017/atara--s Lower bound assumes a 10 per cent reduction in vehicle costs, whilst upper bound assumes a 10 per cent increase in vehicle costs.
Purchase cost	Autonomy package for automated electric and hydrogen vehicles (2046)	~$7,700 - $13,500	Based on cumulative uptake and cost reduction rates as calculated by Boston Consultancy Group (2016), indexed to the reference year. Lower bound costs based on uptake curve of approximately 10 per cent. Upper bound costs based on uptake curve of approximately 85 per cent. Further information available at: Boston Consultancy Group (2016), *Revolution in the Driver's Seat: The Road to Autonomous Vehicles*.
Purchase cost	Supporting infrastructure required at home (2046)	Traditional vehicles – N/A Automated electric vehicles ~$3,000 Automated hydrogen vehicles - N/A	Estimated costs are based on the costs for a home charger and installation, indexed to the reference year. Further information available at: http://electricvehiclecouncil.com.au/wp-content/uploads/2015/05/Recharging-the-economy.pdf No supporting infrastructure required for traditional and automated hydrogen vehicles.
Fixed annual costs	Registration - excluding TAC (2046)	Traditional vehicles ~$580 Automated electric vehicles ~$380 Automated hydrogen vehicles ~$380	Vehicle registration fees (excluding TAC component) for vehicles (i.e. sedan, station wagon, hatch and 4WD vehicles) within a metropolitan area (high-risk zone), as at April 2018, indexed to reference year. Registrants registering an electric or hybrid vehicle receive a $100 discount in 2018. This discount has been indexed to the reference year.

Cost type	**Category**	**Assumption**	**Source(s)**
Fixed annual costs	Annual driver licence cost (2046)	Traditional vehicles ~$50-60 Automated electric vehicles - N/A Automated hydrogen vehicles - N/A	Driver licence fees for traditional vehicles based on 10 year licence fee as at April 2018, indexed to reference year. No driver licence required under the automated electric and hydrogen vehicle scenarios due to Level 5 autonomy (no requirement for human intervention).
Fixed annual costs	TAC premium (2046)	Traditional vehicles ~$1020 Automated electric vehicles ~$60 Automated hydrogen vehicles ~$60	TAC Premium for traditional vehicles based on January 2018 high risk zone rates published in Transport Accident Charges including GST and Duty (TAC), indexed to reference year. Under both automated situations, considerable safety benefits are anticipated to be realised as accidents relating to human error are eliminated (94 per cent).
Fixed annual costs	Insurance - comprehensive (2046)	Traditional vehicles ~$2,150 Automated electric vehicles ~$430 Automated hydrogen vehicles ~$430	Insurance (comprehensive) for traditional vehicle based on 2018 RACV quote for 2018 Toyota Camry, indexed to reference year. Under both automated situations, comprehensive insurance is expected to decline by 80 per cent. Further information is available at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-cons-insurance-in-the-new-mobility-ecosystem.pdf
Variable costs	Fuel (2046)	Traditional vehicles - $0.351 per km Automated electric vehicles - $0.100 per km Automated hydrogen vehicles - $0.351 per km	As per Infrastructure Victoria's assumption register, indexed to the reference year.
Variable costs	Tyres (2046)	All vehicles - $0.0184 per km	Traditional vehicle tyre costs based on Toyota Camry Atara S, as per RACV (2017) *Motoring Cost Report*, indexed to reference year. Consistent wear and tear is estimated across all three vehicle types, indexed to reference year.

Cost type	Category	Assumption	Source(s)
Variable costs	Maintenance (2046)	Traditional vehicles - $0.097 per km Automated electric vehicles - $0.063 per km Automated hydrogen vehicles - $0.097 per km	Traditional vehicle maintenance costs based on Toyota Camry Atara S, as per RACV (2017) *Motoring Cost Report*, indexed to reference year. Autonomous electric vehicles maintenance costs estimated to be 35 per cent lower than traditional vehicles. Further information available at: https://www.ethz.ch/content/dam/ethz/special-interest/baug/ivt/ivt-dam/vpl/reports/1201-1300/ab1225.pdf Maintenance costs for autonomous hydrogen vehicles assumed to be the same as traditional vehicles.
Variable costs	Battery replacement (2046)	Traditional vehicles – N/A Automated electric vehicles - $0.081 per km Automated hydrogen vehicles – N/A	Battery replacements costs for automated electric vehicles based on Nissan Leaf 24 kWh battery in 2018, indexed to the reference year. Further information available at: http://renew.org.au/energy-efficiency/keeping-your-ev-battery-healthy/ No battery replacement required for automated hydrogen vehicles, as the US Department of Energy ultimately targeting 8,000 hour hydrogen fuel power cell, which would power the vehicle for approximately ~380,000km, exceeding its projected useful life. Further information available at: https://www.energy.gov/sites/prod/files/2017/05/f34/fcto_myrdd_fuel_cells.pdf
Fleet provider (AEV)	Margin - overheads and profit (2046)	30 per cent	Consistent with estimations provided by Thakur, P., Kinghorn, R. & Grace, R. (2016). *Urban form and function in the autonomous era.* Australasian Transport Research Forum 2016
Fleet provider (AEV)	Registration – excluding TAC (2046)	~$490	Factors in current taxi licence charge, indexed to reference year. Further information available at: http://taxi.vic.gov.au/owners-and-operators/taxi-owners-and-operators/fees-and-charges#taxi
Fleet provider (AEV)	TAC premium (2046)	~$180	Based on ratios determined by Thakur, P., Kinghorn, R. & Grace, R. (2016). *Urban form and function in the autonomous era.* Australasian Transport Research Forum 2016
Fleet provider (AEV)	Insurance – comprehensive (2046)	~$1,230	Based on ratios determined by Thakur, P., Kinghorn, R. & Grace, R. (2016). *Urban form and function in the autonomous era.* Australasian Transport Research Forum 2016

Cost type	Category	Assumption	Source(s)
Fleet provider (AEV)	Goods and Services Tax (2046)	10 per cent	GST of 10 per cent in line with current policy. Further information available at: https://www.ato.gov.au/Business/GST/

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