Mobility Disruptions

Strategic Options Assessment
Department of Transport and Main Roads

9 November 2018

Disclaimers

Inherent Limitations

This report has been prepared as outlined in the Purpose and Scope Section. The services provided in connection with this engagement comprise an advisory engagement, which is not subject to assurance or other standards issued by the Australian Auditing and Assurance Standards Board and, consequently no opinions or conclusions intended to convey assurance have been expressed.

No warranty of completeness, accuracy or reliability is given in relation to the statements and representations made by, and the information and documentation provided by, the Department of Transport and Main Roads management, personnel and stakeholders consulted as part of the process.

KPMG have indicated within this report the sources of the information provided. We have not sought to independently verify those sources unless otherwise noted within the report.

KPMG is under no obligation in any circumstance to update this report, in either oral or written form, for events occurring after the report has been issued in final form.

The findings in this report have been formed on the above basis.

Third Party Reliance

This report is solely for the purpose set out in the Purpose and Scope Section and for the Department of Transport and Main Roads information, and is not to be used for any other purpose without KPMG's prior written consent.

This report has been prepared at the request of the Department of Transport and Main Roads in accordance with the terms of KPMG's contract dated 16 March 2018. Other than our responsibility to the Department of Transport and Main Roads, neither KPMG nor any member or employee of KPMG undertakes responsibility arising in any way from reliance placed by a third party on this report. Any reliance placed is that party's sole responsibility.

Executive Summary

Purpose of this report

This report has been developed for the Department of Transport and Main Roads (TMR) to estimate and analyse the expected economic and financial impact of a number of strategic options Government could take to respond to disruptive mobility technologies. Specifically, this report analyses the impact of Automated Electric Vehicle (AEV) technologies, and the service models that could be adopted to deploy these technologies in South East Queensland (SEQ).

The strategic options to be evaluated are comprised of a set of government actions (e.g. policy or investment initiatives) that will help deliver a set of outcomes defined by three potential future scenarios, as identified by the Department of Transport and Main Roads (TMR):

1. **Privately owned AEVs:** AEVs have minimal effect on car ownership and the future fleet of AEVs are privately owned.
2. **Door-to-door fleet AEVs:** AEVs are deployed under a commercial fleet model, whereby fleet owned vehicles compete with traditional public transport services.
3. **Mobility as a Service:** AEVs are deployed under a commercial fleet model that is integrated (through feeder services) with mass transit / public transport services.

These scenarios focus on passenger and freight movements across the road and rail network; aviation and maritime are not within the scope of this analysis.

The results of this strategic options assessment will support TMR in identifying the most effective policy platform to facilitate the introduction of automated vehicles onto the transport network, to ensure that the widely discussed economic and social benefits of an autonomous network are maximised.

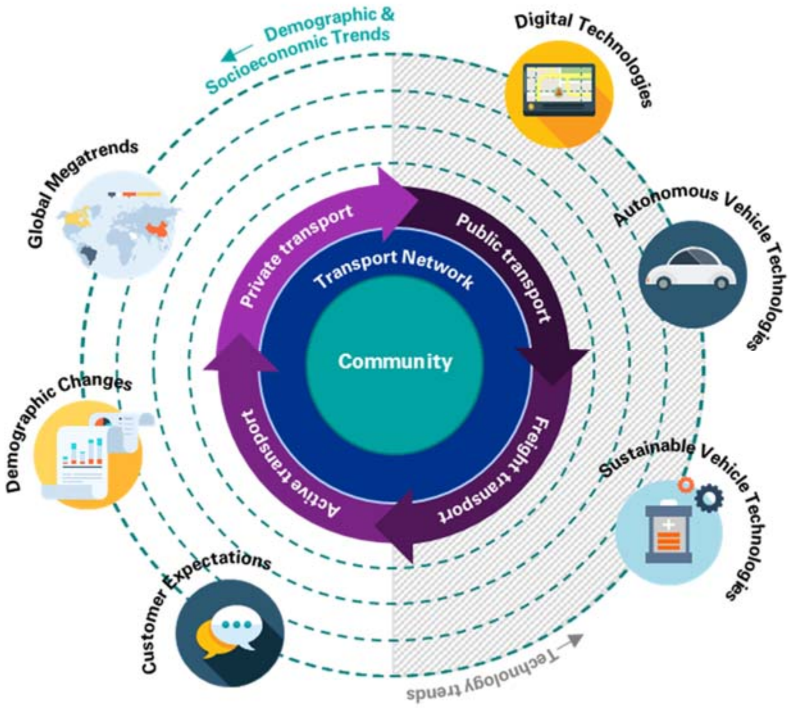
Importantly, the intention of this report is to provide the foundation for further, more detailed, analysis on the strategic options identified by TMR. Detailed design and planning was considered out of scope, as was any further transport modelling. The high-level analysis contained within this report is intended to guide strategy development and should not be used as the foundation for investment decisions.

Technology trends driving changes in mobility

A host of new advanced technologies and services, coupled with demographic and socio-economic trends, are reshaping mobility. This ‘mobility disruption’ is challenging transport agencies globally to proactively plan, adapt and respond to growing customer expectations, while also managing growing populations, urbanisation, rising congestion, and aging transportation infrastructure.

In the context of this report, there are three primary technology trends driving changes in mobility - automated vehicle technologies, sustainable vehicle technologies and digital technologies.

Trends driving changes in mobility



Impacts of Automated Electric Vehicles

The advent of AEVs has the potential to profoundly impact travel patterns, and consequently affect land use, service delivery, and social interactions. The mass adoption of AEVs offers an opportunity for government and the wider community to realise significant economic, environmental and social benefits.

Broadly, as identified in the research and literature, these benefits will arise from the following factors: improved road safety, reduced vehicle travel times, increased highway and intersection capacity due to reduced headways and lower reaction times, the electrification of vehicles, greater travel choices, and finally enhanced mobility and accessibility.

Automated vehicle deployment models

The degree to which these benefits are realised will be influenced by both the emergence of AEV technologies themselves, and also the manner and extent to which AEVs are adopted, used and integrated with the transport system (the deployment model).

Accordingly, while the private sector is anticipated to drive the deployment of AEVs, government intervention may be necessary where coordinated action is required, where commercial incentives are insufficient to achieve equitable outcomes, or where public investment will benefit the network as a whole.

The critical questions guiding the potential role for government in the deployment of AEVs include:

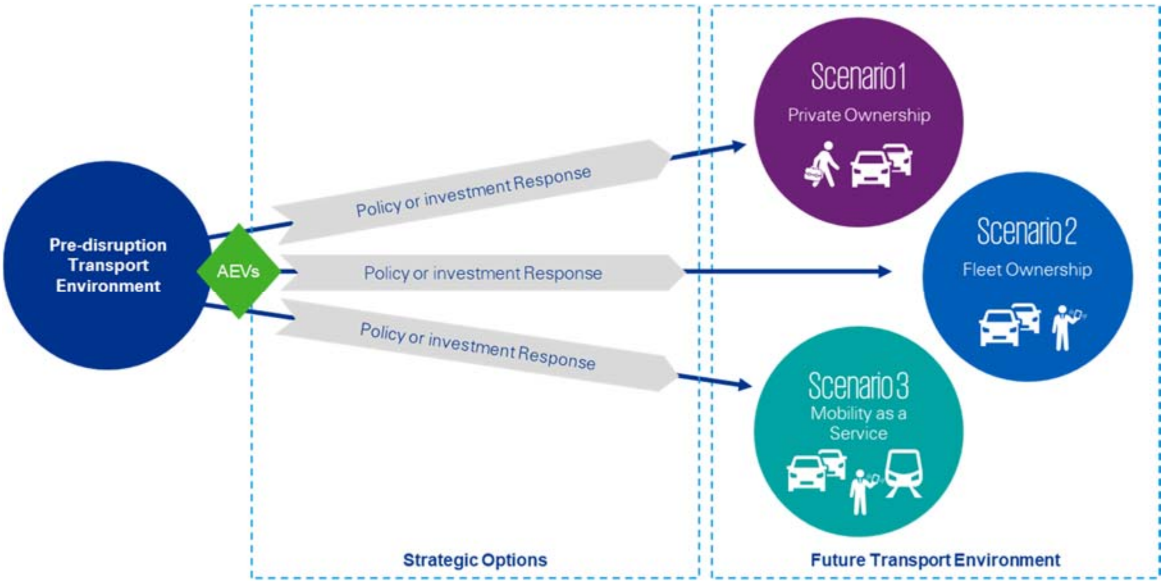
- How will AEVs impact on demand for road space and thus impact congestion?; and
- How will AEVs impact on the competitiveness and demand for public transport?

Alternative models for the deployment of AEVs, and potential interventions by government to drive these models, result in different outcomes to the above key questions.

Economic and financial appraisal

The following analysis is based on three broad scenarios that describe the potential outcomes that may arise under different service models for the deployment of AEVs and associated policy responses by Government.

Conceptual overview of scenarios



These scenarios, while not exhaustive, have been defined in such a way to attempt to cover the likely range of alternative deployment and usage scenarios for AEVs.

In these scenarios it is assumed that the initial deployment of AEVs occurs in 2025 at a Level 4 of automation, and Level 5 by 2035. The uptake is a gradual process, with all vehicles on the road assumed to be AEVs by 2041.

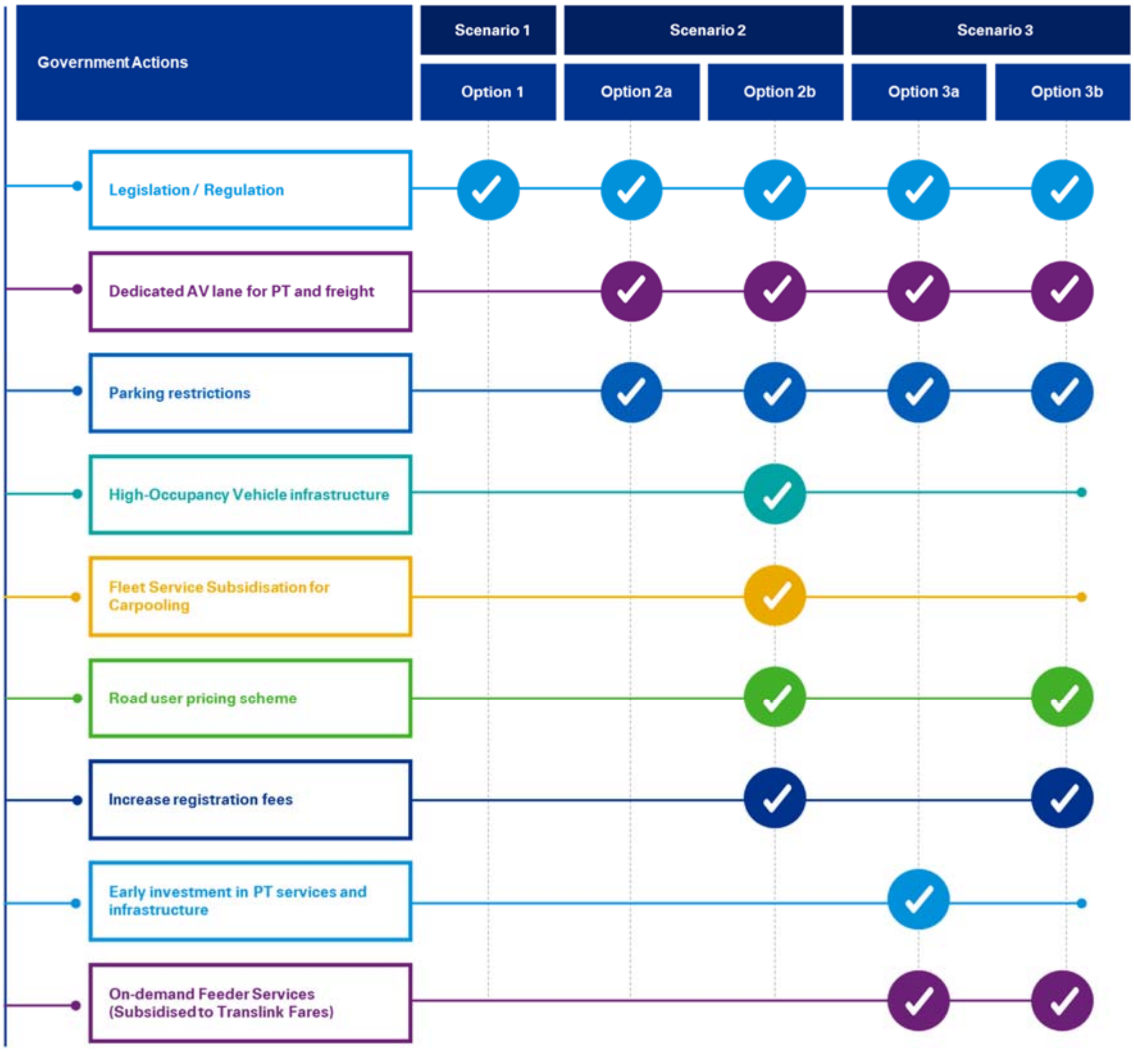
Options summary

The options, and corresponding combination of actions (described below), were identified and confirmed in a series of workshops with key TMR stakeholders. The table and image below provides a concise description of the options assessed as part of the cost-benefit analysis (CBA) and the government actions that comprise these options.

Description of options assessed in CBA

Option	Description of actions
Base Case	AEVs are not deployed, and investment and regulation by Government is at existing levels.
Option 1	AEVs predominately privately owned by individual households.
Option 2A	AEVs predominately fleet owned in a door-to-door model with minimal government intervention.
Option 2B	AEVs predominately fleet owned in a door-to-door model with government pricing intervention to support higher rates of car-pooling.
Option 3A	AEVs predominately fleet owned, with government subsidisation of on-demand feeder services for public transport, and early investment in public transport infrastructure and services.
Option 3B	AEVs predominately fleet owned, with government subsidisation of on-demand feeder services for public transport. Investment in public transport infrastructure and services is deferred, with a $10 CBD cordon charge implemented to drive mode shift.

Composition of options assessed in CBA



It is acknowledged that there are innumerable combinations of actions that could support the achievement of a desired scenario, however these have been simplified for the purposes of this report which is intended to provide high-level strategic guidance.

Considerations

To inform the economic and financial appraisal of each of the options, strategic transport modelling outputs were used to represent each of the options to be assessed. This modelling was undertaken by TransPosition in September 2017, with some supplementary scenarios run in June 2018.

The travel projections output by the transport model are dependent on a large range of factors including; land use projections, travel behavioural changes, future acceptance of flexible working arrangements, future infrastructure and service investment, and the form of future technologies. The cost-benefit analysis by necessity adopts the same key assumptions.

Notably, transport modelling of future scenarios inherently have a higher degree of uncertainty and error associated with them than current year scenarios. This is as a result of the compounding potential for error across interdependent input assumptions to the model. This high degree of uncertainty necessitates that caution is used in interpreting the results of the economic and financial analyses which are dependent on transport modelling projections as key inputs.

Importantly, and recognising the inherent limitations of transport modelling in this context, the model underpinning this analysis was fit-for-purpose and provides valuable insight into the potential implications of the deployment and operation of AEVs.

Economic evaluation

The results presented below are the outputs of the CBA which compared each option against a non-AEV Base Case. This involves measuring the difference in costs (e.g. travel time, crash costs, infrastructure investments, etc) between each option and the Base Case.

The selection of a non-AEV base case enables the comparison of performance of each option against a 'business-as-usual' scenario, including changes to network outcomes resulting from alternative deployment methods for automated vehicle technology.

The table below presents the core findings of the CBA.

Summary of CBA results at 7 per cent discount rate

Option	Benefit-Cost Ratio	Net Present Value
Option 1 - Private Ownership	-1.7	-$21.5 bn
Option 2A - Fleet Ownership	-0.1	-$6.9 bn
Option 2B - Fleet Ownership (Subsidised Carpooling)	4.4	$21.7 bn
Option 3A - Mobility as a Service (Early PT Investment)	5.0	$39.6 bn
Option 3B - Mobility as a Service (Deferred PT Investment)	6.5	$45.7 bn

The non-AEV Base Case scenario presents better travel time performance than either Options 1, 2A or 2B in which door-to-door AEV travel is the prevalent mode. This is a consequence of the increased number of trips induced by the increased accessibility offered by AEVs, with the additional demand outweighing the improved capacity offered by the technology.

Option 2B results in a positive NPV despite reduced travel performance compared with the non-AEV base case. Although travel time savings are normally critical in determining the success of transport initiatives, in this instance the benefits associated with reduced crashes and reduced car ownership outweigh the increased cost of congestion. Reducing car ownership costs frees up this sizeable household spending for other purposes.

Overall, this analysis suggests that if the efficiency of the technology deployed does not outweigh the travel demand it induces, then an approach of minimal government intervention in transport regulation and services will see increased congestion and a net negative impact on the Queensland economy.

This is further demonstrated through the results of Options 3A and 3B, which both show a strong positive return on investment. These options present with positive net travel benefits as a result of the more efficient use of the transport network by having on-demand transport services affordably shuttle people to public transport nodes along key transport spines.

Option 3B presents both the highest BCR as well as the highest NPV across all options. This is a result of deferring large infrastructure investment by using pricing and regulatory methods to drive travel behaviour changes once automated vehicle technology is deployed.

Both Options 3A and 3B present potential pathways to delivering Scenario 3, which is a MaaS model that supports the integration of AEVs with trunk public transport services along major spines to move large numbers of customers.

The strong BCR and NPV for both of these options indicates that this is the priority scenario to pursue in the context of the form of AEV technology assumed in the underlying transport modelling.

Sensitivity Analysis

A sensitivity analysis has also been undertaken to illustrate the high-level implications of uncertainty in this analysis. The sensitivity analysis demonstrates the effects of a change in analytical assumptions on key economic decision criteria including BCR and NPV, which is valuable in understanding which benefit streams are driving the CBA results.

The results of the sensitivity analysis for all options are presented below:

Outputs of the sensitivity analysis

Scenario		Option 1	Option 2A	Option 2B	Option 3A	Option 3B
Central Case	BCR	-1.7	-0.1	4.4	5.0	6.5
	NPV	-$21.5 bn	-$6.9 bn	$21.7 bn	$39.6 bn	$45.7 bn
1. Increased Occupancy of AV Carpool (2B Only) #	BCR	-	-	6.9	-	-
	NPV	-	-	$37.1 bn	-	-
2. Car Ownership Savings Omitted	BCR	-3.3	-4.1	0.3	2.3	3.3
	NPV	-$34.7 bn	-$33.1 bn	-$4.5 bn	$13.3 bn	$19.5 bn
3. Travel Benefits Omitted	BCR	4.4	7.5	7.6	4.9	5.9
	NPV	$27.5 bn	$42.2 bn	$42.5 bn	$39.0 bn	$41.1 bn
4. Both Car Ownership and Travel Benefits Omitted	BCR	2.8	3.4	3.5	2.3	2.8
	NPV	$14.3 bn	$15.9 bn	$16.2 bn	$12.7 bn	$14.8 bn
4. Total Cost + 100%	BCR	-0.8	-0.03	2.2	2.5	3.2
	NPV	-$29.6 bn	-$13.4 bn	$15.2 bn	$29.6 bn	$37.4 bn
5. PT Costs + 100%	BCR	-	-	-	3.7	5.2
	NPV	-	-	-	$36.1 bn	$43.7 bn
6. PT Costs + 200%	BCR	-	-	-	2.9	4.3
	NPV	-	-	-	$32.6 bn	$41.7 bn

This scenario uses outputs from a transport modelling scenario run by TransPosition which increases the average occupancy of automated carpool vehicles (subsidised AEVs) from the standard input of 2 to 5 people. This value was selected to align with the average occupancy of the PT Feeder mode in Option 3 which was assumed to be subsidised to the same cost (Translink fares) and was calculated as an output of the model.

In the central case results, car ownership cost savings represent the highest proportion of benefits. Excluding these from the analysis decreases the BCR and NPV of each option, however the order of results is maintained in terms of NPV.

Travel benefits are typically the primary reason for investment in transport initiatives as they often represent the majority of benefits. When travel benefits (including travel time savings and vehicle operating cost savings) are omitted from the analysis the BCR and NPV for Options 1, 2A and 2B increase significantly. This is due to the increased congestion and reduced travel performance that was projected by the TransPosition modelling for these scenarios. The BCR and NPV for Options 3A and 3B decline slightly as these options were projected to alleviate the congestion induced by the introduction of AEVs.

Given the uncertainty associated with the cost inputs for this analysis, a sensitivity analysis was undertaken by increasing all costs by 100 per cent. While this analysis saw the BCRs of Options 3A and 3B decrease, the relativity to other options remained the same and these two options still presented the highest NPVs.

A separate sensitivity analysis was undertaken to assess the impact of increasing the costs associated with improving public transport services and infrastructure. Two analyses were performed to assess a 100 per cent increase in costs, as well as a 200 per cent increase in costs. Both of these analyses demonstrated a decline in the BCR and NPV, however both Options 3A and 3B still present with NPVs higher than any other option even at a 200 per cent cost increase for public transport investment.

The sensitivity analysis highlights the relative degree of uncertainty implicit in the assumptions underpinning this analysis. The results vary significantly depending on the parameter benefit measures tested, and highlights the importance of further analysis to better understand the implications of AEVs on the value of travel time parameters and subsequently travel behaviour.

Financial appraisal

A high-level financial analysis of Queensland Government revenue under each of the options modelled was undertaken. The analysis looked at the nature of the financial implications of the government actions that comprise the strategic options with respect to government revenue and expenditure, as opposed to a detailed comparative analysis of the options.

A summary of the results of the analysis are presented in the table below.

Summary of projected changes to existing Queensland Government revenue sources

Analysis Period	Non-AEV Base Case	Private Ownership	Fleet Ownership	Mobility as a Service
2018	$3.4 bn	$3.4 bn	$3.4 bn	$3.4 bn
2041	$9.2 bn	$5.0 bn	$2.3 bn	$2.8 bn
2041 Difference to Base Case		-$4.2 bn	-$6.5 bn	-$6.4 bn
30 Year Total (2018-2048)	$217.9 bn	$148.0 bn	$96.9 bn	$106.1 bn

Analysis Period	Non-AEV Base Case	Private Ownership	Fleet Ownership	Mobility as a Service
30 Year Difference to Base Case		-$70.0 bn	-$121.0 bn	-$111.8 bn

This table sums the projected revenue from vehicle registration duty, motor vehicle registration (renewals), drivers licence fees, public transport fare revenue, and traffic infringement revenues. No changes to registration rates are assumed beyond escalation at CPI. Potential revenue associated with road pricing is not included in this summary.

From the table above it is clear that if current revenue policies were to be held constant, Queensland Government revenue is likely to substantially decline when AEVs are deployed.

This decline in projected revenue largely stems from the reduced number of automated vehicles required to service the same level of transport demand impacting motor vehicle registration, particularly renewals. Motor vehicle registration in Queensland is higher than many other states in Australia, resulting in an increased sensitivity to reduced vehicle ownership.

The decline in revenue projected under fleet ownership models is more pronounced due to smaller fleet sizes compared with private ownership. Under a private ownership model it is assumed that car ownership per household declines by 20 per cent to take advantage of the efficiencies in travel that AEVs present to users. Under a fleet model, the number of private vehicles is assumed to decline to 25 per cent of the value projected for non-AEVs to meet peak period demand.

This would see the projected number of cars in South East Queensland in 2041 decline from 3.51 million under the non-AEV scenario to 2.81 million under a private ownership AEV scenario, or to only 878,000under a fleet ownership AEV scenario.

Revenue from traffic infringements as well as drivers licence fees are assumed to decline to zero once AEVs are fully deployed due to their driverless nature.

Mobility as a Service (MaaS) options are also assumed to incur additional expenditure in the form of government subsidies to fleet providers to support key public transport routes. The additional recurring expenditure assumed for these options couples with the projected decline in revenue to have a more pronounced fiscal impact.

Policy considerations

While CBAs are a powerful tool in informing decision-making, they are only one of a range of measures used in policy analysis. In only considering economic impacts to the whole of society, CBAs can often mask important policy implications which can affect the feasibility of implementing each option.

Land use

One of the most important considerations that sits across all options evaluated in the analysis are the land use outcomes that each option facilitates. While the CBA considered land use to be independent of the transport network, service, and regulation, in practice land use responds to varying accessibility.

In terms of disruptive mobility technology, one of the modelling outputs for AEVs was an increase in length of travel both in terms of time and distance as a result of a shift in perceived value of time.

While this in itself is no certainty, if realised it would likely have the effect of hastening the demand for urban sprawl. If people are content to travel longer, then some of the barriers to living in newer suburbs on the urban fringe are removed.

Car pooling

Option 2B considered measures aimed at increasing the attractiveness of car-pooling as a mode of travel, however car occupancy has proven to be a difficult factor to change and will likely remain so without significant change in pricing signals.

Desire to share passenger cars contrasts with high occupancy in peak hour bus services. It is possible that the deployment of alternative vehicles such as on-demand minibuses or passenger vans may help to overcome this artificial barrier to car-pooling, and bridge the gap between passenger dense buses and low occupancy cars.

On-demand transport

Both Options 3A and 3B assumed that on-demand automated fleet services would be subsidised by Government to provide shuttle services to key public transport nodes. In these options the improved accessibility offered by these on-demand services allowed low-frequency suburban bus services to be rerouted to deliver more high-frequency trunk services. This is a policy that a number of cities across the world are now implementing.

While existing ride-sourcing companies have been incredibly successful in creating a consumer base across SEQ in recent years, on-demand travel is still a comparatively small mode type for general commuting. If a MaaS fleet based offering is the preferred scenario, then it is important to ensure that there are few impediments to people being able to take-up this option and forgo the need for a personal car.

Road pricing

Options 2B and 3B both returned strong BCRs, largely as a result of the use of a pricing mechanism. The introduction and operation of a cordon charge (or any other pricing mechanism) has a low cost associated with it, but has a significant impact on travel behaviour and consequently the travel benefits for road users. Road pricing also introduces a new revenue stream for government, either through ongoing user payments or sale of the tolling concession.

The benefits associated with such an approach are clear, however the evidence that not a single city in Australia has implemented such a policy highlights the lack of social licence that such a policy currently faces.

The likely strong public opposition to the introduction of a new road pricing scheme is not considered in the CBA, and underlines why such an appraisal tool should only be used as one of a number of means through which to inform decision-making.

Mobility as a Service

The MaaS solution that underpins Options 3a and 3b is driven by the reconfiguration and integration of the transport system to promote multiple-seat journeys and reduce private vehicle ownership. This transport system change represents just one MaaS component and is complimented by the digital infrastructure and business platform to comprise the MaaS service model.

Inherently, the MaaS service model requires the involvement of both public and private sector stakeholders. While the development and operation of the digital MaaS platform (and some transport services) is anticipated to be led by the private sector, government oversight will remain important, particularly where there are key linkages, interdependencies and potential overlap with existing public transport system operations. In Queensland, government has an opportunity to define its roles and responsibilities which will shape the broker-government interface for MaaS in the state.

Notably, and importantly, the MaaS model described above can be delivered completely independently of the introduction of automated and electric vehicle technologies. In fact, a number of the benefits of this model can be realised now, with opportunities to enhance and increase the breadth of impacts once these technologies are introduced. Over the long term, there is significant opportunity for the convergence of emerging vehicle technologies with the current MaaS model.

Implications for planning and investment

The Queensland Government has a critical role in setting the policy direction for Queensland, and in ensuring that planning and investment decision-making maximises economic, environmental and social outcomes for Queenslanders.

Accordingly, there is an increasing need for Government to review current approaches to the planning, assessment and funding of transport infrastructure and services to identify where emerging trends and uncertainty can be better factored into decision-making. Given the future cannot be predicted, the key question for the Government is:

How can the Government appropriately preserve flexibility to maximise societal outcomes given uncertainty in the future?

To support Government in answering this question, there are a range of factors that need to be considered at each stage of the planning and investment lifecycles. The factors described here do not comprise an exhaustive list and accordingly should be used as a starting point to identify the questions and issues Government will need to consider over the short- and long-term.

Planning paradigm

Transport planning is critical in supporting the strategic policy direction of Government, and in guiding decision-making and investment.

As with policy, proactive and forward looking planning is important in guiding the development of our cities and regions, however the accelerating (and unpredictable) pace of change means that the traditional static planning paradigm is no longer best practice. There is a growing need for flexibility in planning; planning must be agile and responsive to sudden and unforeseeable change.

In this context, long term multi-modal transport (network, corridor, area, route and link) planning should remain a priority. However, in identifying long term planning objectives, it will be important to commit to shorter-term actions which can be reviewed and revised to respond to current circumstances. Measuring and monitoring performance will also remain a priority for Government.

Integrated transport and land use planning

The integration between land use and transportation planning has always been recognised as a central feature of good planning, however in the face of significant mobility disruption this integration has never been more important.

The accessibility effects of AEVs have the potential to significantly change development patterns as increased mobility changes the cost and attractiveness of travel. AEVs can potentially alter the trade-offs that households make between where they choose to live and their daily mobility patterns.

Accordingly, these factors should not be treated as exogenous in planning. Transport planning should be integrated with key land use planning priorities and policies to create a shared vision for cities and regions. Within this framework, strategic transport initiatives need to be conceptualised within the context of a preferred urban structure rather than a traditional approach where transport investment simply responds to demonstrated demand.

Transport modelling

Technology-driven trends have the potential to significantly change travel behaviour, however the uncertainty surrounding how this behaviour will change brings into question the appropriateness of modelling techniques used in assessing policy and investment decisions such as those explored in this analysis.

There is an opportunity to leverage more advanced modelling approaches such as land use transportation interaction (LUTI) or activity based modelling to better guide strategic planning and investment decision-making under uncertainty. These approaches help planners understand the land use impacts of investment/policy decisions, and/or the travel behaviour of individuals based on the nature and purpose of each journey. Understanding these interactions will provide a firmer evidence base to guide government investment in infrastructure, not just for transport but for the provision of social infrastructure e.g. schools, medical facilities etc.

Investment decision-making

In the context of the rapidly changing transport environment, there should be a renewed focus on historical investment decision-making and analysis frameworks to incorporate this new risk and uncertainty. In order to do this, consideration should be given to:

- adjusting current parameters and methodologies used to measure these impacts in economic appraisal, e.g. value of travel time, vehicle operating costs, safety parameters and environment externalities;
- incorporating scenario analysis into investment appraisal;
- using tools such as real options analysis which captures the inherent value in preserving flexibility which may be required in the future to deal with uncertainty surrounding technology systems, user behaviour or commercial outcomes;
- alternative funding mechanisms to account for changes to the existing revenue model underpinning road funding and maintenance; and
- alternative approaches to infrastructure delivery, such as increased opportunities for Private-Public Partnerships.

Further, the introduction of AEVs and new mobility service models is likely to have implications for the Queensland Government’s current infrastructure investment program, and highlights the importance of reviewing existing planning and investment appraisal processes (as described above). In line with the objectives of the Government’s strategic planning process, the investment decision-making process must consider the long-term implications of individual investments within the context of the whole transport network, and the coordination of transport projects with broader infrastructure and policy initiatives.

Behavioural considerations

Public policy, particularly in transport, is often developed under the implicit assumption that people are rational decision-makers who assess all information available, and subsequently make decisions that maximise individual and societal outcomes. However, in reality, decision-making is significantly based on individual's proclivities and limitations. In the case of travel behaviour and mode choice, individual's make decisions based on a range of factors including known information relating to cost and convenience, in addition to psychological factors such as perceived prestige, safety and privacy.

This has a number of consequences when consideration is given to how society will change their behaviours and adopt to the new mobility environment brought about by AEVs and related business models. Realising the benefits of new mobility requires society to reduce overall car ownership and embrace new vehicle technologies. The speed at which this change occurs hinges not only on technological and regulatory advances, but also on how quickly consumer expectations and behaviours shift.

By understanding key cognitive biases, Government is able to design solutions that respond to how people actually behave. While separate, these tools complement conventional policy initiatives (such as the provision of incentives, or restricting choice) by acknowledging the importance of choice in guiding and supporting behavioural change.

Overcoming cognitive biases

Strong emotional attachments and cognitive biases are not simple to overcome. However, measures can be taken to carefully construct how information and choices are presented, which may help guide better decision-making and influence behavioural outcomes.

While these measures are intended to support and enhance policy and investment decisions, they can be implemented in advance, and in isolation, of these decisions. In fact, there is an opportunity to proactively engage with the community (prior to the introduction of AEVs) to work towards overcoming potential cognitive biases and barriers, particularly relating car ownership. This has the potential to generate some benefits now, while also supporting the future transition to new modes and forms of mobility. Accelerating the adoption of new technology has the potential to support the early realisation of benefits.

Accordingly, in the context of new forms of mobility and the required behavioural changes, Government would benefit from developing an engagement strategy to inform government policy and messaging.

Looking ahead

The analysis undertaken suggests that if the efficiency of automated vehicle technology does not outweigh the travel demand it induces, then an approach of minimal government intervention will see increased congestion and a net negative impact on the Queensland economy. While this analysis is preliminary in nature, the results indicate that there are gains from proactive planning and investment, and highlights the opportunity for Government to work together with industry to achieve a common vision.

With reference to the strategic options, the economic appraisal indicates that Options 3A and 3B will deliver the greatest return on investment in terms of net present value to the Queensland economy. These options present two alternative pathways to delivering approximately the same transport outcome for SEQ – Mobility as a Service.

Notably, achieving the desired future transport outcome has implications for the functions of TMR as a department, and the policy direction guiding transport planning and investment in Queensland. While Option 3A and 3B achieve a relatively equivalent outcome, they are underpinned by disparate policy positions. Option 3A leverages incentives to motivate behaviour change through the provision of greater choice and higher quality of services, while Option 3B uses disincentives through pricing mechanisms. This poses a challenge to policy-makers, who will be required to re-evaluate Queensland's policy platform in the context of future disruption.

Recommendations

Based on the analysis, and with reference to the broader transport and technology trends explored within this report, there are a series of recommendations Government may wish to consider. Importantly, these recommendations do not constitute policy or investment decisions. Rather, they are intended to guide further analysis that will provide a strong evidence base to support the Queensland Government in effectively responding to emerging technological disruptions.

Recommendation 1: Undertake further analysis into the preferred option.

1(a). Refine economic assumptions and modelling

As indicated in this report, there were a number of limitations resulting from the economic assumptions and parameters underpinning the transport modelling. To support any future economic appraisal it is recommended that:

- the model is tested with user defined input data and model parameter values which support the testing of different variables (e.g. vehicle occupancy under a fleet model);
- and the modelling assumptions are further refined.

1(b). Undertake a strategic-level real options analysis

It is recommended that TMR undertake further strategic analysis, leveraging the principles of real options analysis, to articulate the full range of decision pathway/s (implementation pathways) available to Government to achieve Scenario 3.

The decision pathway/s should identify the incremental or "staged" actions (e.g. policy or investment initiatives) Government could take to support the achievement of Scenario 3. These pathways should be tested against different potential future uncertainty scenarios to identify how Government can effectively preserve the flexibility to adapt to emerging technology and future changes in network demand over the long-term.

The Queensland Government, in partnership with Data61, have defined a series of future uncertainty scenarios for Queensland transport. These scenarios provide a useful and pragmatic strategic setting that could be used to support this analysis.

Where appropriate, complementary studies being undertaken by TMR (such as the MaaS Roadmap and the Automated Freight modelling) should also be incorporated into this analysis.

The results of this strategic real options analysis should provide guidance to TMR regarding what actions are of immediate priority, and are appropriate for detailed investigation over the short-term.

Recommendation 1: Undertake further analysis into the preferred option.

1(c). Assess feasibility of short-term actions.

Based on the outcomes from 1(a), it is recommended that TMR evaluate the feasibility of the identified priority actions, and where required, refine the geographic scope for potential implementation or delivery.

1(d). Undertake a detailed financial analysis to better understand the potential financial impact of AEVs to Government under Option 3.

It is recommended that TMR undertake further, more detailed, financial analysis to estimate the potential impact of AEV uptake (in alignment with the assumptions underpinning Option 3, and the outcomes of Recommendation 1(a)) on long-term Queensland and local government revenue flows and long-term government expenditure.

As indicated by the outcomes of the high-level financial analysis in this report, the impact of AEVs is likely to require governments to reconsider the viability of current revenue arrangements, and to consider where new policy responses may be required.

Recommendation 2: Assess implications of emerging vehicle technologies in rural and regional areas.

2(a). Undertake strategic analysis to assess the implications of emerging vehicle technologies in rural and regional areas.

It is recommended that TMR undertake a strategic analysis to assess the implications of emerging transport technologies in rural and regional areas, in addition to identifying the unique service models and strategic opportunities that exist for the deployment of this technology.

Combined, the rural / regional and urban analysis provides Government with a whole-of-state overview of the impact of emerging technologies and subsequent mobility disruptions.

Recommendation 3: Develop a communications and engagement strategy to promote travel behaviour change.

3(a). Develop a communications and engagement strategy to promote travel behaviour change.

It is recommended that TMR develop a communications and engagement strategy which focuses on measures targeted at overcoming potential cognitive biases that may inhibit the full realisation of the benefits of emerging technology and new forms of mobility.

This strategy should identify both short and long term actions, with the intention of promoting positive behavioural change prior to the introduction of AEVs.

As appropriate, components of this strategy should be integrated into the Queensland Transport Strategy (QTS) communications and engagement plan.

Recommendation 4: Investigate opportunities to promote consistency in transport planning and investment appraisal for initiatives significantly impacted by uncertainty.

4(a). Evaluate existing transport planning framework and guidelines.

It is recommended that TMR evaluate existing planning frameworks and guidelines to identify where opportunities exist to better factor in future uncertainty. Consideration should be given to providing further guidance regarding the required timing and recommended process for undertaking the interim review/revision of long-term plans.

4(b). Undertake further research to define a consistent approach for the assessment of transport investments.

It is recommended that TMR further investigate opportunities to define a consistent approach for the appraisal of transport initiatives under uncertainty. Consideration should be given to developing further guidance regarding the economic parameters to be used in economic appraisal, and the modelling requirements that underpin transport analysis.

Contents

1 Introduction

Around the world, rapid advancements in emerging automated vehicle technologies are changing the way governments, and consumers, view transportation. Mobility disruptions stand to not only transform how society moves, but also the form and function of our cities and regions themselves.

As the transport sector evolves, new vehicle technologies and business models offer the potential to move people and goods in a more efficient, safe and sustainable way. However, the degree to which these benefits are realised will be influenced by both the emergence of the technology itself, and also the manner and extent to which new automated vehicles are deployed, adopted and integrated with the transport system.

Currently, the exact timing of automated vehicle technology deployment is unknown; the transition to an autonomous era is characterised by uncertainty. Accordingly, proactive and considered policy, planning and investment by government is required to help shape a path of relative certainty, for citizens and businesses alike.

In light of this, the Queensland Government recognises the importance of planning for, and being involved in, the advancement of automated vehicles and new mobility solutions in Queensland.

1.1 Purpose and scope

The purpose and scope of this report is to estimate and analyse the expected economic and financial impact of a number of strategic options Government could take to respond to disruptive mobility technologies, and the service models that could be adopted to deploy these technologies. Consistent with the transport modelling that underpins this analysis, automated vehicles are assumed to be electric and thus termed Automated Electric Vehicles (AEVs) throughout this report.

The strategic options to be evaluated are comprised of a set of government actions (e.g. policy or investment initiatives) that will help deliver a set of outcomes defined by three potential future scenarios, as identified by the Department of Transport and Main Roads (TMR):

4. **Privately owned AEVs:** AEVs have minimal effect on car ownership and the future fleet of AEVs are privately owned.
5. **Door-to-door fleet AEVs:** AEVs are deployed under a commercial fleet model, whereby fleet owned vehicles compete with traditional public transport services.
6. **Mobility as a Service:** AEVs are deployed under a commercial fleet model that is integrated (through feeder services) with mass transit / public transport services.

These scenarios focus on passenger and freight movements across the road and rail network, and are described in further detail in Section 4.1 below. Aviation and maritime are not within the scope of this analysis.

The results of this strategic options assessment will support TMR in identifying the most effective policy platform to facilitate the introduction of automated vehicles onto the transport network, to ensure that the widely discussed economic and social benefits of an autonomous network are maximised. Notably, the geographic scope for the analysis has been limited to South East Queensland (SEQ).

Importantly, the intention of this report is to provide the foundation for further, more detailed, analysis on the strategic options identified by TMR. Detailed design and planning was considered out of scope, as was any further transport modelling. The high-level analysis contained within this report is intended to guide strategy development and should not be used as the foundation for investment decisions.

1.2 Limitations

This study is intended to inform policy development and should not be used to support investment decisions.

Transport Modelling

The results of both the economic and financial analysis contained within this report are dependent upon transport modelling inputs. It is important to note that undertaking transport modelling of future scenarios inherently has a higher degree of uncertainty and error associated with it (compared to current year scenarios). This is as a result of the compounding potential for error across interdependent input assumptions to the model.

Importantly, and recognising the inherent limitations of transport modelling in this context, the modelling underpinning this analysis was fit-for-purpose and provides valuable insight into the potential implications of the deployment and operation of AEVs.

Options Assessment

The scenarios and strategic options that comprise this analysis were defined in collaboration with the TMR through an iterative workshop process.

A number of assumptions were made in the definition of the options used for analysis as set out below:

- Land use assumptions including geospatial distribution and density of population and employment are assumed to be in line with QGSO projections;
- Transport network and service assumptions across future years are as per TransPosition modelling, with future road network upgrades assumed across all options.
- Broader commuting behaviour such as time of departure and propensity to work remotely are assumed to be constant based on current behaviour;
- Disruptions and potential changes to technology such as AEVs are implemented as per TransPosition modelling assumptions;

Where any forecasts, projections or other prospective financial estimations have been prepared for this study, KPMG do not warrant that the forecasts, projections or estimations will be achieved.

1.3 Outline

Following this introduction, the remainder of this report is structured as follows:

Chapter 2: Technology trends driving changes in mobility explores a range of technology trends that are reshaping mobility including, automated vehicle technologies, sustainable vehicle technologies and digital technologies.

Chapter 3: Impacts of Automated Electric Vehicles details the potential economic, environmental and social benefits that could arise following the advent of AEVs.

Chapter 4: Economic appraisal presents the economic appraisal results, as well as the methodology and assumptions that underpin a cost-benefit analysis of a series of options that represent potential pathways for Government to achieve alternate scenarios for the deployment of AEVs.

Chapter 5: Financial appraisal presents the results of a high-level financial analysis of Queensland Government revenue and expenditure under each of the options modelled.

Chapter 6: Policy considerations identifies and discusses the broader policy considerations surrounding each of the options considered for analysis.

Chapter 7: Implications for planning and investment explores current approaches to the planning, assessment and funding of transport infrastructure and services in Queensland to identify where emerging trends and uncertainty can be better factored into decision-making.

Chapter 8: Behavioural considerations uncovers some of the important behavioural barriers that may inhibit the adoption of AEVs and impact on the full realisation of the anticipated benefits.

Chapter 9: Looking ahead summarises the outcomes the outcomes of the strategic options assessment and outlines a series of recommendations and next steps.

1.4 Strategic alignment to Government plans and policies

Further understanding and evaluating the impact of emerging vehicle technologies on the transport system aligns to the objectives of a number of Federal and State Government policies and plans (Table 1).

Across all levels of government there is a consistent recognition of the importance of policy that promotes the development, adoption and use of technology to support liveable communities and economic growth. Accordingly, understanding the direct outcomes of the emerging technologies (and opportunities created by these technologies) is important for government, particularly where policies can be introduced to maximise social outcomes.

Table 1: Strategic alignment to Government plans and policies

Policy / Plan	Alignment
Federal Government Smart Cities Plan	In April 2016, the Federal Government launched its Smart Cities Plan. The Smart Cities Plan sets out the Government's commitment to smart investment, smart policy and smart technology. Specifically, the plan recognises the potential role of new smart technology in transforming how cities are planned and function, and how the economy grows. The Smart Cities Plan outlines how the Federal Government is examining the extent to which new technologies are used to improve the efficiency and sustainability of infrastructure networks as part of new infrastructure projects.

Policy / Plan	Alignment
Australian Infrastructure Plan	The Australian Infrastructure Plan (AIP) sets out the infrastructure challenges and opportunities Australia faces over the next 15 years and the solutions required to drive productivity growth, maintain and enhance standard of living. The AIP complements the Smart Cities Plan by highlighting that a greater use of technology in planning and designing infrastructure has the potential to deliver substantial benefits. The AIP specifically identifies that technology is transforming the way infrastructure is delivered and operated, and offers opportunities for expanding the productivity-enhancing potential of our infrastructure. Similarly, emerging technologies allow existing infrastructure to be upgraded and repurposed, providing customer-focused solutions to better meet the demands of a changing world.
National Policy Framework for Land Transport Technology	The National Policy Framework for Land Transport Technology was prepared by the Transport and Infrastructure Council. The Framework outlines Australia's potential approach to emerging transport technologies. The objective of the framework is to foster an integrated policy approach for governments to develop and adopt emerging transport technologies in order to achieve improved transport safety, efficiency, sustainability and accessibility outcomes.
State Infrastructure Plan	The State Infrastructure Plan provides a clear vision for the future of infrastructure investment in Queensland. The Plan delivers an infrastructure strategy and program which addresses key opportunities, challenges and drivers that inform Queensland's infrastructure needs. The Plan recognises that new technologies will play an increasing role in how Queensland plans future infrastructure capacity, presenting challenges in adaption but also opportunities with increases in efficiency.
Queensland Transport Coordination Plan	The Transport Coordination Plan (TCP) is the Department of Transport and Main Roads response to ensure the delivery of coordinated planning and management of transport in Queensland. The objective of the TCP is to plan, manage and invest in the transport system in order to improve regional and economic development and the quality of life of Queenslanders. The TCP provides the basis to respond to emerging technologies, automated vehicles, digital capability and big data. The TCP recognises that technology, along with new ways of funding transport services and infrastructure, will provide more accessible, more affordable, tailored transport solutions for Queenslanders.
Queensland Transport Strategy (in development)	The Department of Transport and Main Roads' 30 year Queensland Transport Strategy (QTS) is being prepared to ensure the transport system meets the future needs of customers. The strategy recognises new technologies and emerging business models are already beginning to transform the way people and goods move. The strategy aims to maximised benefits from disruptive technologies and service models are and minimise the potential negative impacts.

Policy / Plan	Alignment
Network Optimisation Framework	The Department of Transport and Main Roads has developed the Smarter Solutions: Network Optimisation Framework to support the Queensland Government is prioritising low-cost and non-infrastructure solutions. These network optimisation solutions aim to improve performance by increasing the capacity of, or demand for, elements of the current transport network, without delivering major infrastructure. These solutions include leveraging current and emerging technology to improve the efficiency and effectiveness of the existing transport network. The framework aligns to the network optimisation principles (Reform, Better Use, Improve Existing and Build New) reflected in both the Australian Infrastructure Plan and the State Infrastructure Plan, as well as in TMR's Transport Coordination Plan and Guide to Traffic Impact Assessment.
The Future is Electric (Queensland's Electric Vehicle Strategy)	The Future is Electric – Queensland's Electric Vehicle Strategy – aims to ensure the state is prepared for, and is encouraging, the uptake of an emerging electric vehicle market. The Queensland Government recognises its role in lowering the barriers to adoption to capitalise on a wide range of social, economic and environmental benefits that electric vehicles can offer. The Future is Electric includes 16 initiatives such as providing a fast-charging charging network across the state, increasing electric vehicles in government fleets, and providing opportunities to engage the public, as well as remaining dynamic through research and state consultation.

1.5 Automated vehicles in Australia

1.5.1 National Transport Commission

In November 2016, the Council of Australian Governments (COAG) Transport and Infrastructure Council agreed that a national performance-based assurance regime should be developed to ensure the safe operation of automated vehicles in Australia, in line with international practices.

Accordingly, the National Transport Commission (NTC) has been working with government, industry, and the community to deliver a roadmap of reform which achieves a nationally consistent regulatory framework for the introduction of automated vehicles on public roads.

The agreed reforms include:[1]

- developing national guidelines governing conditions for trials of automated vehicles;
- developing national enforcement guidelines that clarify the regulatory concepts of 'control' and 'proper control' for different levels of driving automation;
- designing and developing a safety assurance regime for automated road vehicles;
- developing legislative reform options to clarify the application of current driver and driving laws to automated vehicles, and to establish legal obligations for automated driving system entities;

[1] http://www.ntc.gov.au/roads/technology/automated-vehicles-in-australia/

- supporting jurisdictions in reviewing current exemption powers to ensure legislation can support on-road trials;
- supporting jurisdictions in reviewing injury insurance schemes to identify any eligibility barriers for occupants of an automated vehicle, or those involved in a crash with an automated vehicle; and
- developing options to manage government access to automated vehicle data that balances road safety and network efficiency outcomes and efficient enforcement of traffic laws with sufficient privacy protections for automated vehicle users.

1.5.2 Automated vehicle trials

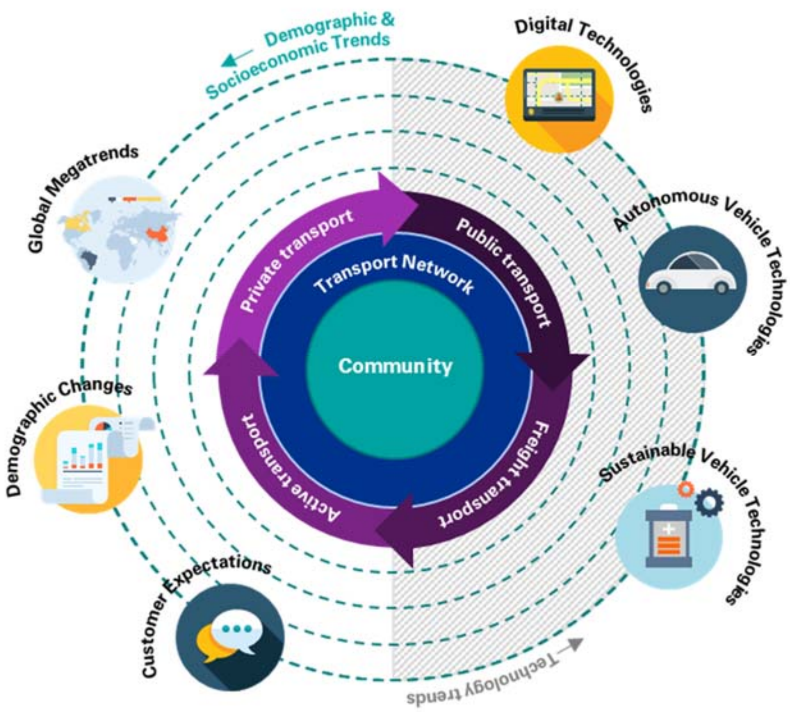
There are a number of automated vehicle trials underway in Australia on public roads, as well as controlled environment tests. At the time of writing this report, the following trials were either planned, in operation or completed:

Figure 1: Automated vehicle trials in Australia

2 Technology trends driving changes in mobility

A host of new advanced technologies and services, coupled with demographic and socio-economic trends, are reshaping mobility. This 'mobility disruption' is challenging transport agencies globally to proactively plan, adapt and respond to growing customer expectations, while also managing growing populations, urbanisation, rising congestion, and aging transportation infrastructure.

Figure 2: Trends driving changes in mobility



As shown in Figure 2, there are three primary technology trends driving changes in mobility - automated vehicle technologies, sustainable vehicle technologies, and digital technologies. The convergence of these technological trends with emerging demographic and socioeconomic trends is changing customer expectations and subsequently the customer experience. The changes in mobility come not just from the technology itself but from the new operating models technology can support and enable. The emergence of new operating models, such as ride-sourcing and demand-responsive transport services is driving a new ecosystem of mobility within the transport industry; customers now expect faster, cheaper, cleaner, safer and more reliable travel.

Understanding the nature and impact of these emerging trends is important in informing transport policy, planning (transport, land use and regional development) and future investment priorities.

2.1 Cooperative and automated vehicles

Automated vehicle technology is fast advancing, and the introduction of cooperative and automated vehicles (AVs) poses to significantly change the future of transportation. AVs are anticipated to transform not only how people and goods move, but also influence the locational choices of society regarding where they work, live and engage in leisure and recreation.

AVs have the potential to deliver a number of significant benefits, headlined by safety improvements, more efficient and productive transport networks, and enhanced mobility for those unable to drive.

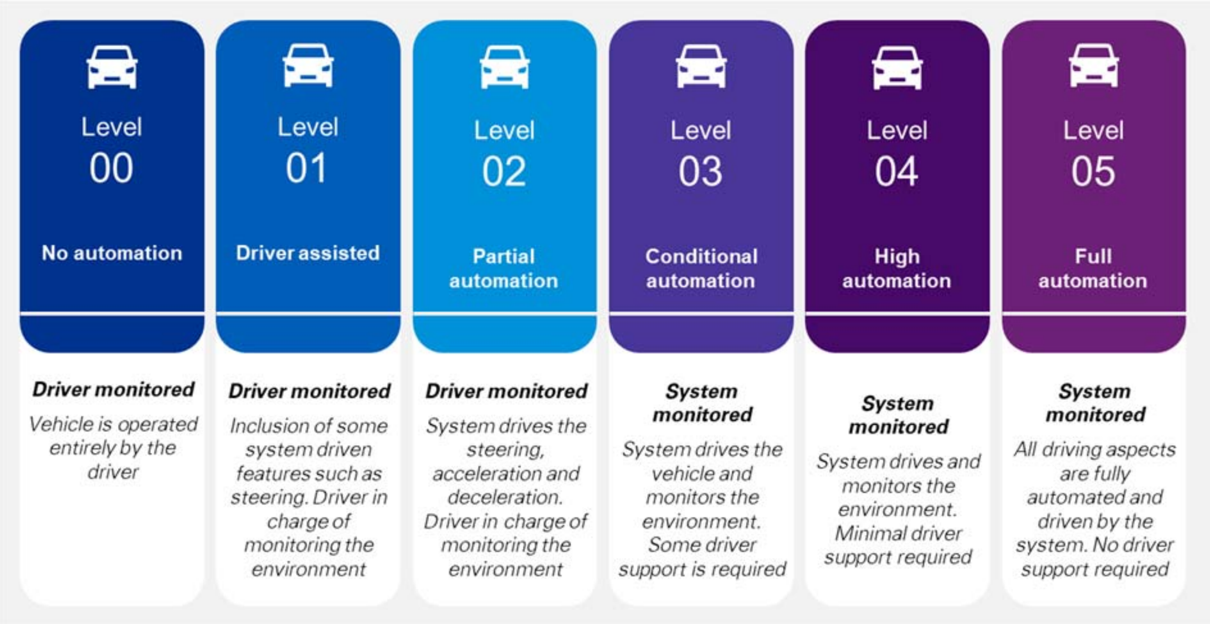
2.1.1 Pathway to automation

The term 'automated vehicle' is used for vehicles that are capable of completing journeys safely, without driver intervention or support, in all traffic, road and weather conditions.

There are currently six established levels of vehicles automation, as defined by the SAE International standard J3016. Levels of automation range from no automation of driving controls through to automated applications that assist the human with the driving task, to fully and highly automated vehicles that can drive themselves. Each level has a specific set of requirements that the vehicle system must meet before it can be considered to operate at that level.

As illustrated in Figure 3, the pivotal change occurs between Levels 2 and 3, when responsibility for monitoring the driving environment shifts from the driver to the system.

Figure 3: Levels of automation



The speed of innovation in the advancement of cooperative and automated vehicle technologies and vehicle capabilities is significant, motivated by the widespread interest by government, car manufacturers and technology companies globally. While some driverless features (Level 1 or 2) are already available in vehicles today (such as adaptive cruise control, automated parallel parking, side collision warning and auto steering), a fully automated vehicle (Level 5) is not anticipated to be commercially available for many years.

Vehicle manufacturers have set ambitious targets for the development and deployment of fully automated vehicles. Tesla has announced that the vehicle manufacturer will introduce a fully automated vehicle by the end of 2018.[2] Whilst other manufacturers, such as Nissan and Audi, have planned to release commercial AVs by 2020.[3] Despite these announcements, the timeframes for commercially available AVs remains unsettled, and the market penetration of these vehicles even more so. Aside from the technical specifications, there are a range of legislative, liability, infrastructure and social barriers that must be overcome. The speed of adoption of AVs is contingent on how government and industry responds to these broader issues.

At a global level, the preparedness of countries in terms of progress and capacity for adapting AVs varies. Regulatory reform in countries such as the Netherlands, Singapore and the United States (where there is also a strong automotive industry presence) has enabled the testing of AVs on public roads, which combined with progress towards enhancing AV capabilities across technology, legislation and infrastructure, indicates these regions may be first-movers in introducing automated vehicles to the fleet mix. While the policy and regulatory setting is a current barrier for China, the country's large auto industry market (largest in the world by production and sales) has the potential to support China in developing as a world leader in the piloting and deployment of AVs.[4]

Locally, it is acknowledged that the market scale in Australia is unlikely to rival countries such as those mentioned above. However, with an appropriate regulatory and policy setting, Australia is likely to be an early adopter of the technology once AVs are commercially available. As detailed in Section 1.4.1, the NTC is currently delivering a roadmap of reform to prepare Australia for the introduction of AVs. Under the guidance of NTC, state and territory governments are progressing AV trial initiatives and working towards ensuring that the policy, legislation and infrastructure is appropriate to allow for the safe, commercial deployment of AVs.

2.2 Sustainable vehicle technologies

Electric vehicles are driving the change towards sustainable vehicle technologies, supported by advancements in battery technology and a continued global focus on climate change.

While the initial adoption of electric vehicles has been slow, growth is picking up speed driven by government support, an improved product offering and price competitiveness, and increasing familiarity and willingness to buy by consumers. According to the International Energy Agency, over 750,000 electric vehicles were sold in 2016, led by sales in China (336,000 vehicles) and the United States (160,000 vehicles).[5] In Australia, just 1,369 electric vehicles were sold during the same period, representing 0.1% of the total Australian vehicle market.[6]

From an international perspective, various measures have been used by governments to encourage adoption - directly through consumer subsidies and financial incentives, and indirectly through greenhouse gas reduction targets, fleet efficiency standards and infrastructure provision (e.g. charging stations). Importantly, the electric vehicle market is still in its infancy and policy support will remain critical to lowering barriers to adoption over the immediate term.

Within the context of AVs, automated and electric vehicle technologies are complementary. AVs require a range of electrically powered sensors and actuators, and the system is more easily

---

[2] http://www.wired.co.uk/article/fully-autonomous-cars-are-almost-here
[3] http://www.businessinsider.com/companies-making-driverless-cars-by-2020-2017-1/?r=AU&IR=T/#baidu-a-beijing-based-search-company-is-aiming-to-have-a-commercial-model-of-its-driverless-car-ready-by-2018-12.
[4] As identified by KPMG's 20*18 Autonomous Vehicles Readiness Index* which assessed countries against 4 criteria – Policy and Legislation; Technology & Innovation; Infrastructure; and Consumer Acceptance.
[5] International Energy Agency, 2017, *Global EV Outlook.*
[6] Electric Vehicle Council, 2017, *The state of electric vehicles in Australia.*

controlled with electric motors. Electric vehicles require a better understanding of travel patterns due to their smaller energy capacity (relative to a standard internal combustion engine) and charging requirements. Accordingly, the electrification of vehicle propulsion should enable greater connectivity and automation in vehicle design and functionality.

Future vehicle design, and the proliferation of AEVs, is likely to result from the convergence of sensor-based technologies, high precision positioning systems, and electric motors (including high efficiency battery storage technologies).

2.3 Digital technologies and service models

Over the past few decades there has been rapid growth in the advancement and sophistication of digital technologies. Smart phones, the internet, open data, and the creation of mobile applications and digital platforms has improved the ability to collect, analyse, process and distribute information.

As a result, businesses are able to enhance customer experiences, improve the efficiency of operational processes, and develop new business models to create and capture value. Digital technology forms the interface for enabling the better connection of supply with demand. This has had significant implications for industries such as hospitality (AirBnB) and transportation (Uber), where there are underutilised assets that can be shared peer-to-peer (otherwise known as the sharing economy). Through the advent of easy-to-use and innovative digital platforms, customer expectations are changing and customers now demand choice, personalisation and convenience (including on-demand services).

There are a number of applications for digital technologies within the transport sector, evidenced by the emergence of ride-sourcing, demand-responsive transit, and Mobility as a Service business models. Digital technologies are changing not only how the travel task is delivered, but also the nature of the travel task itself, with the adoption of e-commerce and teleworking shifting travel patterns and behaviour.

FACT CHECK: Definitions

Emerging digital technologies are impacting a wide variety of transport modes, and resulting in the introduction of new mobility services. How these services are described differs within the literature and research. For the purpose of this report, these services are defined and distinguished as follows:

Ride-sourcing: a pre-arranged or on-demand transport service where individuals use their personal cars to offer door-to-door transportation services. Ride-sourcing, also known as ride-booking or ride-hailing, leverages digital technologies to connect drivers with riders. Ride-sourcing is commonly mislabelled as ride-sharing.

Ride-sharing: the terms ride-sharing and carpooling can be used synonymously. Both terms describe where individuals share a car journey with another passenger, this can be arranged through ride-sourcing platforms (as in the case of UberPOOL) or can be arranged privately.

Demand responsive transport: a form of public transport characterized by flexible routing and scheduling of small to medium sized vehicles operating in a shared mode between pick-up and drop-off locations according to passenger needs.

2.3.1 Ride-sourcing

Ride-sourcing, also known as ride-booking or ride-hailing, is described as a pre-arranged or on-demand mobility service that enables ordinary motorists to use their personal cars to offer door-to-door transportation services. These services are enabled by mobile and GPS technologies which efficiently connects drivers (supply) with passengers (demand). Since their introduction, ride-sourcing has disrupted the personalised transport industry by adding competition and differentiated services through its service quality, pricing strategy and convenience. Uber, Lyft and Go Catch are examples of ride-sourcing companies.

CASE STUDY: Uber[7]

Uber is one of the most prominent ride-sourcing companies in the sharing economy. Uber was first launched in San Francisco in March 2009, and now services 633 cities worldwide.

Unlike traditional transportation companies, Uber has an incredibly light infrastructure – it owns no vehicles, employs no drivers, and pays no vehicle maintenance costs. Instead, it uses peer-to-peer coordination between drivers and passengers, enabled by sophisticated software and a reputation system.

Uber is focused on providing a personalised customer experience for all users. The Uber model leverages an easy to use, quick and flexible booking system allowing users to select their preferred service level (see below) and location of pick-up / drop-off. Uber also provides real-time price estimates and allows customers to see the exact location of their driver in real-time.

Uber service levels

Uber offers a range of services to choose from, each with a different rider capacity, a different cost, and a different purpose. These services range from UberX which provides a private ride in a standard car, to UberBLACK which provides a luxury vehicle, to UberPOOL which connects customers going in the same general direction and allows sharing a vehicle at a reduced fare.

2.3.2 Demand responsive transport

Demand responsive transport (DRT) is broadly recognised as a flexible (route and timetable), shared-ride, passenger transport service which delivers an alike form of public transport, on-demand travel. Currently, DRT is primarily used to service areas of the transport network where there is insufficient demand for public bus services to be feasible. DRT services are also used to provide reliable first- and last-mile services to improve customer access to mass transit routes. DRT services are provided by either the public or private sector, e.g. TransLink trial of DRT in Logan (public), or Bridj available in Sydney (private).

2.3.3 Mobility as a Service

'Mobility as a Service' (MaaS) is an emerging business model which aims to provide seamless access to a wide variety of transport services and modes. At its most developed, every public and private transport option is presented in a single app, handling payment and bookings through the same platform and providing dynamic route-planning information to users.

MaaS is a mobility platform that lets users plan and book door-to-door trips, optimizing transport resources while catering for individual preferences (for example, time and convenience versus cost).

[7] https://www.uber.com/en-AU/

A mature mobility platform will have the ability to combine advances in the Internet of Things, big data and cognitive analytics to more efficiently align supply and demand.

As a business model, MaaS does not change the physical operation of the transport system, rather it is intended to make public and shared transport options more convenient by allowing customers to manage their transport needs through a single mobility service. The intention is to add more variability and convenience into the supply side of transportation, incentivising the use of public transport and multiple-seat journeys.

TMR are currently working with SMEC to undertake a combined investigation into the potential impacts of MaaS, in combination with automated vehicles and DRT in Townsville and Cairns.

CASE STUDY: Whim[8]

Whim, the world's first MaaS solution, was launched in Helsinki by MaaS Global in December 2017 (Beta model launched in October 2016).

Whim contains travel planning, routing and mobile ticketing for mobility services such as public transport, taxis and rental cars. Whim plan on including city bikes and bike sharing soon. The application is free of charge but users pay for mobility services via pay as you go or subscription packages. The monthly subscription option allows three different price structures, depending on usage. All the fees and pricing used in the service are based on the bilateral agreements between MaaS Global and transport service providers.

Whim will expand to West Midlands (United Kingdom) in 2018, with further expansion anticipated into the United Kingdom, Europe, America and Asia.

Mode choice with Whim

A survey of Whim users has indicated some changes in mode choice since the apps launch:

- 26% increase in public transport mode choice
- 20% reduction in private car mode choice.

These preliminary observations indicate the potential for Whim to reduce the reliance on private vehicle use (and ownership). However, it is too early to observe the long term impact of Whim on travel choices and transport network performance.

Mobility as a Service – TMR Program Management Office

To support TMR in preparing for the future of mobility disruptions, and to support innovation in MaaS in Queensland, a new MaaS Program Management Office (MaaS PMO) has been established in the Director-General's office.

The MaaS PMO will collaborate with industry, government and key community stakeholders to assess TMR's readiness for MaaS. It will further co-design, prototype and test possible MaaS project and concepts, including the development and implementation of a MaaS Roadmap.

2.3.4 E-commerce

Enabled by advanced digital technologies, the rapid evolution of e-commerce is changing consumption patterns and driving strong growth in online retail. Since 2006, global internet retail sales

[8] Whim, 2018, *MaaS – An accelerating revolution and the lessons learned to date.*

have grown by over 18 per cent per year on average, which is driving demand for courier and parcel delivery services.[9] Further, consumers expect fast, on-demand and same day delivery of online purchases.

This has implications for the transport network as more commercial vehicles are required to travel within key activity centres and urban areas to service demand. Accordingly, commercial vehicles may contribute to the exacerbation of congestion, particularly where curbside infrastructure is not designed to accommodate loading zones.

Notably, technological advancements within the logistics sector, such as delivery drones, has the potential to ameliorate the negative implications of increased light commercial vehicles in urban areas. Combined with broader vehicle technology advancements, there are significant opportunities for improvements in the efficiency and effectiveness of the retain supply chain.

2.3.5 Teleworking

Technological advancements and the digitisation of work has significantly increased the flexibility employees have regarding their hours and location of work. Portable hardware, such as smart phones and laptops, and improvements in wireless communication, has enabled employees to be connected to work from virtually anywhere, anytime. According to an international survey conducted by Vodafone, 75 per cent of companies surveyed have now introduced flexible working policies to enable employees to vary their hours and use the latest technologies to work from home or on the move.[10]

From a transport perspective, technology-enabled flexible working arrangements can support the management of congestion, particularly during peak periods, as workers choose to either commute outside of peak periods, commute to an alternative location, or not commute at all. By altering demand, the continued adoption and growth of flexible work arrangements has the potential to change urban congestion patterns, reducing the requirements for further investment in transport capacity.

[9] International Post Corporation, 2017, *Global Postal Industry Report.*
[10] Vodafone, 2016, *The Flexible: friend or foe?*
The Flexible: friend or foe? survey was conducted by Morar on behalf of Vodafone between September and October 2015. The countries surveyed were Germany, Hong Kong, India, Italy, Netherlands, Singapore, South Africa, Spain, the UK and the USA. A total of 8,000 employers and employees were interviewed online across 10 countries.

3 Impacts of Automated Electric Vehicles

The advent of AEVs has the potential to profoundly impact travel patterns, and consequently affect land use, service delivery, and social interactions. The mass adoption of AEVs offers an opportunity for government and the wider community to realise significant economic, environmental and social benefits. These benefits are described below.

Importantly, the extent to which these benefits are realised will be influenced by the ownership and service delivery model of AEVs, and thus will depend on how AEVs are used. This is described in further detail in Section 3.4.

For this section of the report, all of the benefits detailed below assume that AEVs are operating at level 5 of automation (full automation) network wide.

3.1 Economic impacts

The economic benefits of AEVs include those benefits generated directly for the users of the transport system, and the indirect benefits to overall productivity that are shared by society as a whole. AEVs will facilitate these benefits by:

- improving road safety;
- enabling better use of road capacity;
- enhancing mobility;
- improving freight productivity; and
- enabling the repurposing of land use.

The relationship between the direct and indirect benefits of transport improvements is further detailed in Appendix A. While it is out of the scope of this report, understanding the macroeconomic and wider economic benefits of AEVs (through quantification and analysis) is important to further guide their development and deployment.

3.1.1 Road safety

Automated vehicles are anticipated to significantly improve road safety through advanced driverless vehicle technologies (such as autonomous steering, accelerating and lane guidance) which remove the requirements for human control, and subsequently human error. Currently, road accidents are primarily caused by human errors such as distraction, failure to obey rules, fatigue or the influence of substances such as alcohol or drugs. In 2016, 35.9 per cent of all accidents in Queensland involved drink driving, while 33.6 per cent involved speeding, and 19.5 per cent were identified as involving driver fatigue.[11]

Road crashes impose intangible, financial and economic costs on society. These costs include reduced quality of life, reduced productivity, medical, and property damage. During the 12 months to June 2017, there were 241 fatalities and 4,336 hospitalisations due to car accidents on Queensland roads, estimated to cost approximately $3.6 billion to Queensland. [12] The avoidable cost of road crashes (which resulted in fatality or hospitalisation) was $2.9 billion over this period.[13]

Accordingly, the impact of enhanced safety through AEVs is expected to be substantial; reducing vehicle incidents will significantly reduce the avoidable economic and social cost of road trauma and associated productivity loss.

3.1.2 Better use of road capacity

The continued urban traffic congestion across Australian cities is adversely affecting economic activity, constraining productivity and output. According to the Bureau of Infrastructure, Transport and Regional Economics (BITRE), the total avoidable cost of congestion is projected to increase from $16.5 billion (2015) to over $37 billion by 2030. For Brisbane, the avoidable cost is projected to increase from $2.3 billion to over $4 billion during this period.[14]

Automated vehicle technologies such as vehicle-to-vehicle communication, automated cruise control, and automated intersection control systems, have the potential to improve traffic flow by supporting reduced headways, greater vehicle speeds, and optimised intersection movements. This has the potential to improve the efficiency of travel and reduce congestion. The extent of these benefits is dependent on the level of efficiency enabled by the technology, and the demand for road space once deployed. Preliminary modelling by BITRE has indicated that, based on existing congestion projections, highly automated vehicles have the potential to reduce the aggregate congestion costs in Australian cities by $10.0 billion (to $27.0 billion in 2030).[15]

AEVs also have the potential to increase the effective density of economic activity by reducing the spatial proximity between firms, customers, suppliers and the labour market. Improved travel efficiency and accessibility may lead to greater labour market flexibility and productivity through agglomeration economies.

3.1.3 Enhancing access and mobility

AEVs have the potential to enhance access and provide independent mobility for people who cannot currently cost-effectively access transport, such as those who cannot drive, including adolescents, the elderly and people with disabilities. This will increase their capacity to engage in employment, recreation and leisure; enhancing the quality of life for individuals, and promoting increased economic activity.

In Queensland, 15 per cent of persons with a disability that are able to work are unemployed.[16] While the nature and severity of disability impacts on an individual's ability to engage in the workforce, there are likely to be unserved or underserved groups of society who are unemployed due to transport disadvantage, or due a reliance on transportation through others (including government assistance).

---

[11] Queensland Government data, November 2017, *Factors in road crashes.*
[12] Queensland Government data, November 2017, *Road crash locations.*
[13] BITRE, 2010, *Social cost of road crashes*, indexed using ABS CPI Series cat. no. 6401.0
[14] BITRE, 2015, *Information Sheet 24: Traffic and congestion cost trends for Australian capital cities.*
[15] BITRE, 2015, *Information Sheet 24: Traffic and congestion cost trends for Australian capital cities.*
[16] Persons aged 15-64 years, living in households, in the labour force. ABS, 2017, *2015 Disability, Ageing and Carers, Australia,* Cat No. 4430.0.

AEVs will not directly result in employment for all unemployed persons with a disability, however they do offer an opportunity to enhance economic participation.

3.1.4 Freight efficiency and productivity

The adoption of automated and electric vehicle technologies in freight is anticipated to have significant impacts on the productivity of the industry – for rail freight, long haul road freight and short haul road freight (such as small parcel delivery).

Operating costs

Variable vehicle operating costs, comprised of fuel, labour, oil, tyres and vehicle maintenance costs, contribute significantly to the road freight service price.[17]

For road freight, the electrification of vehicle motors will improve the operational efficiency of freight by reducing fuel costs. This impact is anticipated to be significant – currently, fuel is estimated to comprise over 30 per cent of long haul road freight vehicle operating costs.[18] The electrification of freight vehicles also has the potential to reduce vehicle maintenance and whole-of-life costs.

For both road and rail freight, automation may lower labour costs by eliminating, or significantly reducing, the requirements for drivers. While manual freight handling will likely remain a requirement over the short to medium term (particularly at loading/unloading/distribution facilities), as the degree of automation increases across the supply chain, labour costs will continue to decline.

Given the competitive nature of the Australian road freight transport industry any reductions in vehicle operating costs, whether through elimination of fuel costs, reduction in labour costs or maintenance costs, should translate into reductions in the price Australian users pay for road freight services, and hence into improvements in the international competitiveness of those users.

Efficient use of road capacity

In addition to the reduction in operating costs, automated and electric vehicle technologies (for road freight) have the potential to alter how freight vehicles use road capacity. Vehicle-to-vehicle communications could enable automated trucks to travel with very short headways in a platoon. Platooning enables the more efficient use of road capacity by facilitating the automatic braking, steering, and acceleration of all vehicles in the convoy, based on the actions of the leading truck. The platooning of automated trucks has the potential to reduce congestion and increase throughput.

Further, because of their environmental performance and reduced noise levels, electric freight vehicles have the potential to enable the 24 hour operation of freight, significantly increasing the total capacity of the freight vehicle fleet.

The aggregate impact of these benefits could significantly improve the efficiency and thus increase the productivity of the industry. Automated and electric freight has the potential to improve the national and international competitiveness of exports.

3.1.5 Repurposed parking

By enabling "empty running", AEVs may reduce and potentially eliminate the need for private and street-side parking within core activity centres, shifting the demand to cheaper peripheral zones. This would create opportunities for infill development, releasing large amounts of floor space within

[17] IBISWorld, 2018, *Road Freight Transport*
[18] BITRE, 2009, *Information Sheet 34: Road and rail freight: competitors or complements?*

activity centres for alternative higher value commercial, urban redevelopment, or community use. In Brisbane, approximately 360km^2 of parking space would be made available for alternative uses.[19]

This infill development could result in higher urban densities, and where the released land is used for commercial purposes will increase the density of economic activity and may lead to agglomeration economies (particularly within already dense activity centres).

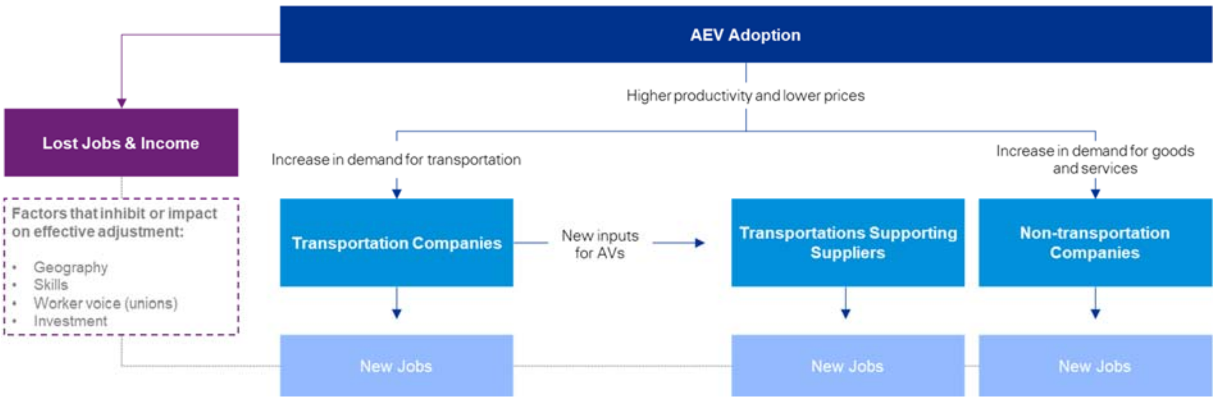
Further, under a fleet model (whereby individual households do not own a private vehicles), housing design may no longer need to cater for garaging a car. The subsequent increase in the amount of residential land afforded by removing parking spaces and driveways could improve residential land value uplift. The release of land may further lead to the reconfiguration of residential land (subdividing) and subsequent increase in urban density.

3.1.6 Workforce

The rapid introduction of new vehicle technologies may lead to sizeable impacts on the labour force, and subsequently on economic activity and output. The exact size and scope of this impact cannot yet be determined, however is likely to vary by industry and occupation, with the most significant disruption anticipated to occur for jobs which can be substituted by automation, such as drivers. While temporary challenges will be faced by a number of workers, there are also significant opportunities that the new AEV environment creates. These opportunities exist within, and outside of, the transportation industry and may arise due to increases in the demand for transportation, goods, or services as the result of improved business productivity and lower prices.

The workforce changes induced by the adoption of AEVs can be summarised by the following figure (Figure 4).

Figure 4: Framework for conceptualising labour market changes from the adoption of AEVs[20]



[19] *Colliers, 2015, The evolution of car parking: technology creating risk and opportunity*; Brisbane City Council, 2000, *Brisbane City Plan*

[20] Adopted from Groshen, E., Helper, S., MacDuffie, J., & Carson, C. 2018. *Preparing U.S. Workers and Employers for an Autonomous Vehicle Future.*

3.2 Environmental impacts

Operation

In Queensland, the transport sector contributes 14.3 per cent to the total generated emissions, with approximately 87 per cent of those emissions produced by road vehicles and rail.[21, 22] Accordingly, the conversion of the current fleet (predominately comprised of vehicles with internal combustion engine vehicles) to electric vehicle technology could enable significant and sustained reductions in greenhouse gas emissions, and in the local air and noise pollution impacts of the vehicle fleet during operation.

Notably, electric vehicles are not exempt from an environmental footprint; the production and disposal of batteries can impose a material environmental cost to society.

Production

A significant amount of power is required in the production of batteries, estimated at close to double that of internal combustion engines.[23] Locally, the environmental impact of this power generation is anticipated to decline as the Queensland approaches its 50 per cent renewable energy target by 2030.

Disposal

The toxic composition of batteries (namely, lithium) makes them difficult to dispose of and harmful to the environment. While there are no standards currently in place, there will be an ongoing need to implement and manage an effective recycling system for batteries.

3.3 Social impacts

As mentioned above, AEVs have the potential to enhance mobility and improve the quality of life for individuals who currently cannot drive or readily access public transport. By enabling independent mobility, AEVs have the potential to reduce social exclusion and promote equitable access to employment and recreation opportunities. This can result in a number of benefits, including improved financial independence, a better standard of living, and improved physical and mental health.[24]

Further, AEVs could lead to broader city revitalisation impacts by improving community amenity through the management of traffic and congestion, and through the repurposing of parking into shared community spaces and other social uses (green spaces, sporting facilitates, etc.).

---

[21] Queensland Government, 2016, *Greenhouse gas emissions, in carbon dioxide equivalent (CO2 - e), of transport sector.*
[22] Queensland Government, 2016, *Total annual greenhouse gas emissions in carbon dioxide equivalent (CO2 - e).*
[23] Brennan, J., & Barder, T, 2016, *Battery Electric Vehicles vs. Internal Combustion Engine Vehicles,* Arthur D Little,
[24] It is also worth noting that improved access to motor vehicle transportation may reduce physical activity by incentivising a mode shift away from active transport. This may have adverse health outcomes, however the scale of this impact has not been well researched or assessed.

3.4 Automated vehicle deployment models

The degree to which the benefits outlined above are realised will be influenced by both the emergence of AEV technologies themselves, and also the manner and extent to which AEVs are adopted, used and integrated with the transport system (the deployment model).

Accordingly, while the private sector is anticipated to drive the deployment of AEVs, government intervention may be necessary where coordinated action is required, where commercial incentives are insufficient to achieve outcomes equitable outcomes, or where public investment will benefit the network as a whole.

The critical questions guiding the potential role for government in the deployment of AEVs consist of:

- How will AEVs impact on demand for road space and thus impact congestion?
- How will AEVs impact on the competitiveness and demand for public transport?

Alternative models for the deployment of AEVs, and potential interventions by government to drive these models, result in different outcomes to the above key questions. For the purposes of this report, three alternative deployment models have been identified which are intended to support the realisation of the scenarios described in Section 4 below:

1. AEVs have no effect on car ownership and the future fleet of AEVs are privately owned.
2. AEVs are deployed under a commercial fleet model, whereby fleet owned vehicles compete with traditional public transport services.
3. AEVs are deployed under a commercial fleet model that is integrated with mass transit / public transport services, such as Mobility as a Service.[25]

[25] MaaS in this context refers to the design of the transport system to support integrated movements, it is not referring to MaaS as a business model (e.g. Whim).

4 Economic appraisal

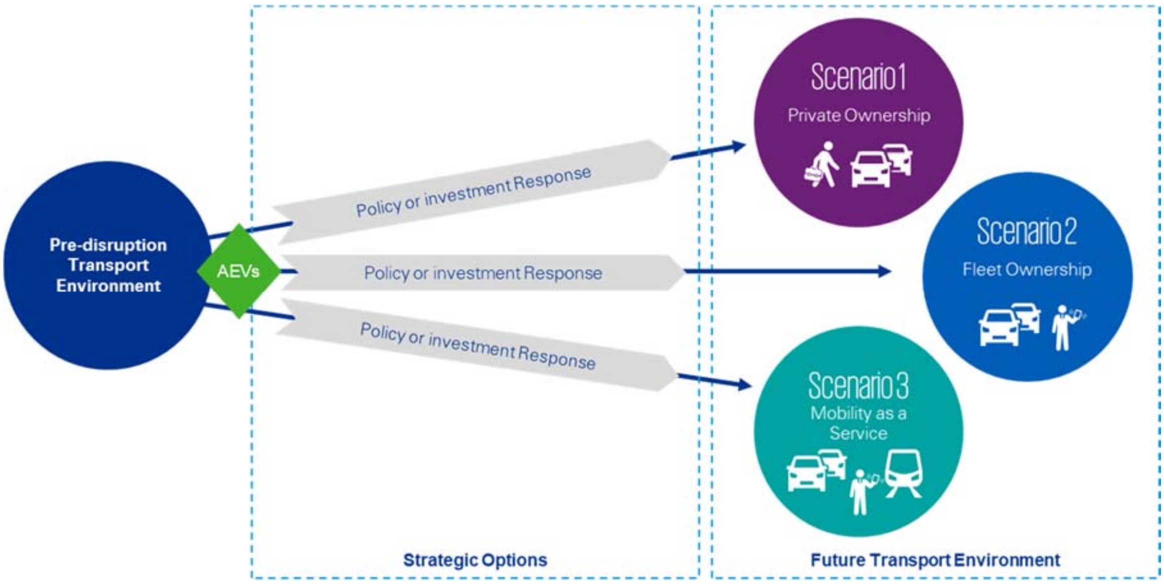
This section presents the results, as well as the methodology and assumptions that underpin an economic appraisal of a series of strategic options that represent potential pathways for the Queensland Government to respond to disruptive mobility technologies and the service models that could be adopted to deploy these technologies. The structure of the chapter is as provided below:

- Section 4.1 provides an overview of the three scenarios, and corresponding strategic options, that have been defined to inform the cost-benefit analysis (CBA) process.
- Section 4.2 discusses the strategic transport modelling that was provided as an input to the CBA, including a detailed description of the options modelled, as well as overarching considerations.
- Section 4.3 outlines the assumptions for costs associated with each of the options modelled, including both capital and operating expenditure.
- Section 4.4 outlines the methodology that has been adopted in calculating the benefits associated with each option.
- Section 4.5 presents and provides discussion on the results of the CBA.

4.1 Overview

The following analysis is based on three broad scenarios that describe the potential outcomes that may arise under different service models for the deployment of AEVs and associated policy responses by Government.

Figure 5: Conceptual overview of scenarios



These scenarios, while not exhaustive, have been defined in such a way to try to cover the likely range of alternative deployment and customer use scenarios for AEVs. Importantly, the scenarios are underpinned by a number of assumptions regarding how government, industry and society will respond to the emerging technologies. These assumptions are based on known travel behaviour, previous analysis undertaken by TMR, and the outcomes of international literature and research.

4.1.1 Scenario 1

Scenario 1 has been defined to represent a **private ownership scenario** for AEVs.

In this scenario, it is common for individuals and households to purchase their own AEVs upon initial deployment in 2025 at a Level 4 of automation, and Level 5 by 2035. The uptake is a gradual process, with all vehicles on the road assumed to be Level 5 AEVs by 2046 to align with the final projection year used in the TransPosition modelling.

There is minimal intervention by Government under this scenario, beyond enabling regulation and legislation for automated vehicles. Investment in infrastructure is maintained at trend levels.

4.1.2 Scenario 2

Scenario 2 has been defined to represent a **fleet ownership scenario** for AEVs.

In this scenario AEVs are primarily purchased by commercial fleet providers upon their initial deployment in 2025 at a Level 4 of automation, and Level 5 by 2035. While private ownership of AEVs is possible, it is uncommon due to the high costs associated with ownership, and the existence of affordable on-demand door-to-door commercial services. In this scenario, Government takes action to encourage the deployment of AEVs under a fleet ownership model.

The uptake of AEVs is accelerated under this model as an investment which ensures a critical mass of vehicles to provide a viable on-demand service. All vehicles on the road are assumed to be Level 5 AEVs by 2046 to align with the final projection year used in the TransPosition modelling. The predominant means of travel is still door-to-door car travel, and investment in infrastructure is assumed to be maintained at trend levels.

4.1.3 Scenario 3

Scenario 3 has been defined to represent a **mobility as a service scenario** for travel throughout SEQ.

In this scenario, AEVs are primarily purchased by commercial fleet providers upon their initial deployment in 2025 at a Level 4 of automation, and Level 5 by 2035. All vehicles on the road are assumed to be Level 5 AEVs by 2046 to align with the final projection year used in the TransPosition modelling.

Government also takes action to encourage the deployment of AEVs under a fleet ownership model, and encourages their use to service key public transport nodes and corridors as opposed to a door-to-door service.

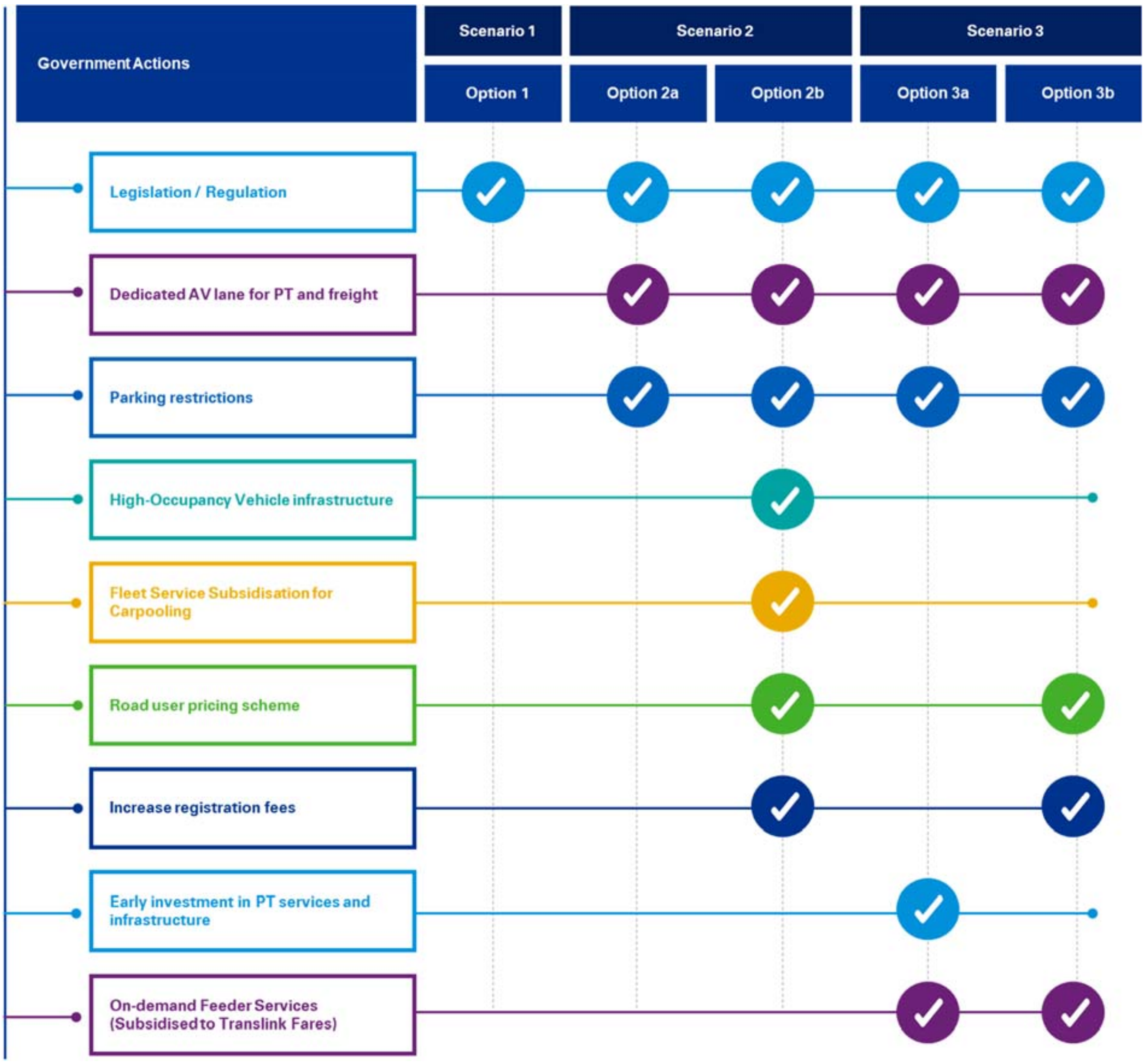
Feeder services to public transport (e.g. train stations and bus rapid transit stops) are provided by fleet owned AEVs, with existing services rerouted to increase service frequency on key public transport trunk routes. Government takes action to encourage higher public transport mode share through either regulation, pricing or intervention.

4.1.4 Options

In traditional scenario analysis, the appraiser typically defines a feasible sequence of actions and tests the causal relationship between key drivers of these actions to reveal alternative outcomes, or scenarios. In contrast, this analysis fixed these end state outcomes (as determined by the scenarios) and the process operated in reverse, whereby the focus was on identifying the sequence of actions policy makers could take to influence behavioural change and achieve the desired outcomes.

The options, and corresponding combination of actions, described below were identified and confirmed in a series of workshops with key TMR stakeholders (Figure 5). It is acknowledged that there are innumerable combinations of actions that could support the achievement of a desired scenario, however these have been simplified for the purposes of this report which is intended to provide high-level strategic guidance.

Figure 6: Strategic options comprised of government actions



4.1.5 Base Case

In CBA, the choice of base case is a critical decision point as it is this option that is used to compare all other options against. For this strategic options assessment the base case used for comparison is a 'do minimum', non-AEV option.

The primary reason for the choice of the non-AEV option as the base case, is that it allows the relative benefits and costs associated with the change in travel behaviour to be assessed. The transport modelling undertaken by TransPosition (see Section 4.2) projects greater congestion through increases to both travel time and distance upon deployment of automated vehicle technology under some options.

The cost and scale of these impacts would not be visible if Option 1 (i.e. an AEV scenario) were to be selected as the base case for comparison.

4.2 Transport modelling assumptions

4.2.1 Overview

To inform the economic and financial appraisal of each of the options, strategic transport modelling outputs were used to represent each of the options to be assessed. This modelling was undertaken by TransPosition in September 2017, with some supplementary scenarios run in June 2018.

TransPosition utilised their in-house multi-modal 4S Model to undertake the modelling as documented in their report *'Impacts of autonomous vehicles on public transport'* prepared for the TMR.[26]

Land use assumptions are common across all options modelled, and are not dependent upon changes in travel behaviour or network performance.

Similarly, travel behaviour across SEQ is held constant in terms of commuting patterns. The potential for increasing acceptance and take-up of flexible working opportunities is not considered for future scenarios.

All modelling outputs provided for the analysis are for a single reference year, with a common 2016 base year across all options.

For further details on the transport modelling refer to TransPosition's modelling reports:

- *Impacts of autonomous vehicles on public transport.* [26]
- *Conceptual sensitivity modelling and analysis on the introduction of autonomous vehicles.* [27]

Modelling of automated vehicles

In undertaking the strategic transport modelling, TransPosition have incorporated a number of mode types corresponding with AEVs. While this technology has been proven to be successful in on-road trials across the world, it has yet to be successfully deployed at a large scale at a full level of automation (Level 5). This means that the impacts of the widespread adoption of AEVs will have on travel behaviour in urban centres, as well as the efficiencies that these vehicles present, are uncertain.

There are three key modelling assumptions regarding automated travel that shape the results of the analysis.

The first is that the deployment of AEVs induces additional trips on the network. This uplift in trip numbers is based on the combination of improved accessibility and reduced cost, and ranges from 10 per cent to 16 per cent depending on the option modelled.

TransPosition note that increased trip rates will occur for a number of reasons, including:[27]

- Trips are likely to have lower costs (real and perceived) making them more attractive;

[26] TransPosition, 2017, *The impacts of autonomous vehicles on public transport.*

[27] TransPosition, 2016, *Conceptual sensitivity modelling and analysis on the introduction of autonomous vehicles.*

- Parking will become easier;
- It will become easier to share a vehicle, allowing for trips to be made that are currently impossible;
- People will be able to make trips at times that they currently could not, including when fatigued and after drinking; and
- There will be new trips made by people who currently cannot drive, including adolescents, the elderly, and those with disabilities.

The second key assumption is that perceived value of travel time for car passengers is reduced once AEVs are deployed, ranging from zero to 40 per cent reduction in value of travel time. [27] TransPosition note that this has the effect of making longer trips (both in length and duration) more attractive to passengers.

The third key transport modelling assumption is the degree of travel efficiency, and increased lane capacity provided by the deployment of AEVs, which are assumed to be connected vehicles. TransPosition's modelling assumes a relatively marginal 20 per cent increase in lane capacity once AEVs are fully deployed and no longer need to share the road with manually operated conventional vehicles.

This assumption is relatively conservative, with other researchers suggesting that more significant increases in lane capacity could be achieved, particularly through platooning on motorways. [28, 29] Capacity increases of 40 to 80 per cent are cited by Friederich for instance, depending on the mix of heavy vehicles on the motorway segment.[28]

4.2.2 Alignment with modelling scenarios

The modelling scenarios selected to represent each of the options in this analysis are:

Base Case Option

The Base Case option is a non-AEV option, where conventional vehicles continue to be operated on the network.

All existing modes of travel are still available, with no changes to the public transport network. Improvements to the road network are assumed, as documented by TransPosition.[26]

Option 1

Option 1 utilises the 'private car dominance' scenario modelled by TransPosition in 2017. This option assumes that all AEVs are privately owned with no increase in sharing beyond what currently exists. All existing modes of travel are still available, with no changes to the public transport network. [26]

Option 2A

Option 2A also utilises the 'private car dominance' scenario modelled by TransPosition. The difference between Option 1 and Option 2A is in ownership model of AEVs and not of travel itself, and as such modelling inputs are identical.

Option 2B

Option 2B was a custom scenario run by TransPosition in June 2018. It is based on the 'Optimal PT System' scenario developed in September 2017.

[28] Friedrich, B. 2016, *The Effect of Autonomous Vehicles on Traffic*, <https://link.springer.com/content/pdf/10.1007%2F978-3-662-48847-8_16.pdf>
[29] Levin, M. & Boyles, S.D. 2016, *A multiclass cell transmission model for shared human and autonomous vehicle roads*, <https://www.sciencedirect.com/science/article/pii/S0968090X1500354X>

This scenario assumes that all existing modes of travel are still available, with no changes to the public transport network. Although TransPosition's original 'Optimal PT System' assumes an increase in utility associated with rail services, Option 2B restores this utility back to align with that of the Base Case and Option 1.

A new mode type of 'Autonomous Carpool' has been added to this modelling scenario, which assumes that prices are subsidised until they match TransLink fares. Two alternative approaches to modelling the Autonomous Carpool mode type have been taken as a sensitivity, a core occupancy assumption of 2 passengers, and a sensitivity scenario where the occupancy of pooled vehicles is 5 passengers (to align with that projected for the 'PT Feeder' mode type).

Option 3A

Option 3A utilises the 'Optimal PT System' scenario developed in September 2017. This modelling scenario assumes that the attractiveness of rail services would be increased, reflected by an increase in utility. This has been used as a proxy for increased rail services as part of this economic appraisal.

TransPosition's scenario also assumed that limited use rail stations would be bypassed, and low-frequency bus services would be eliminated. These services are replaced with a new 'PT Feeder' mode type which represents an on-demand automated fleet service from any location to the nearest major public transport hub. These services are subsidised to TransLink fares to encourage take-up of public transport services.

Option 3B

Option 3B utilises a modified version of TransPosition's 'Line Haul PT' scenario, which incorporates a $10 cordon charge around the Brisbane CBD.

In this option, the majority of non-trunk public transport services have been replaced by 'PT Feeders' and 'AV Taxis', with public transport services limited to major line-haul transit services where high capacity is required.

4.2.3 Modelling projections

This section presents a visual summary of the transport modelling projections that were used as inputs into the economic analysis.

Figure 7: Projected person trips for each option

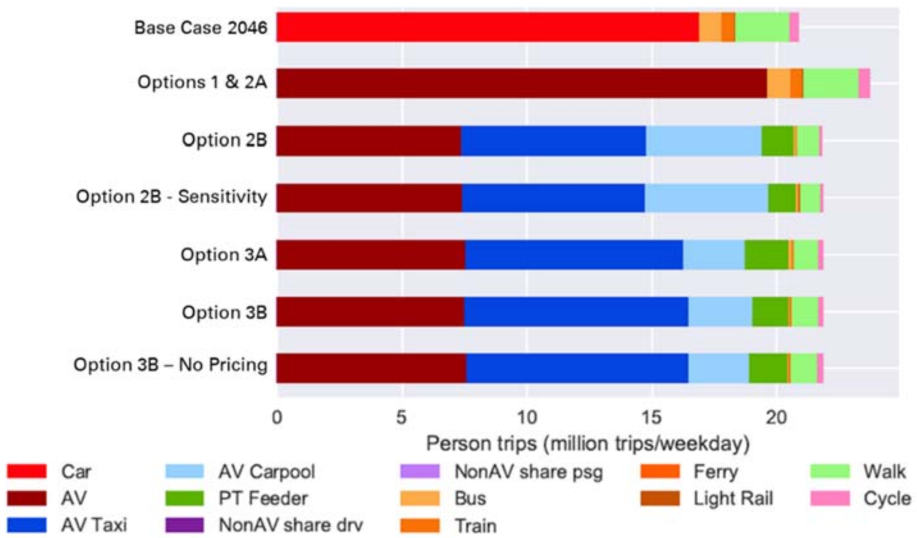


Figure 8: Projected average trip length (km) for each option

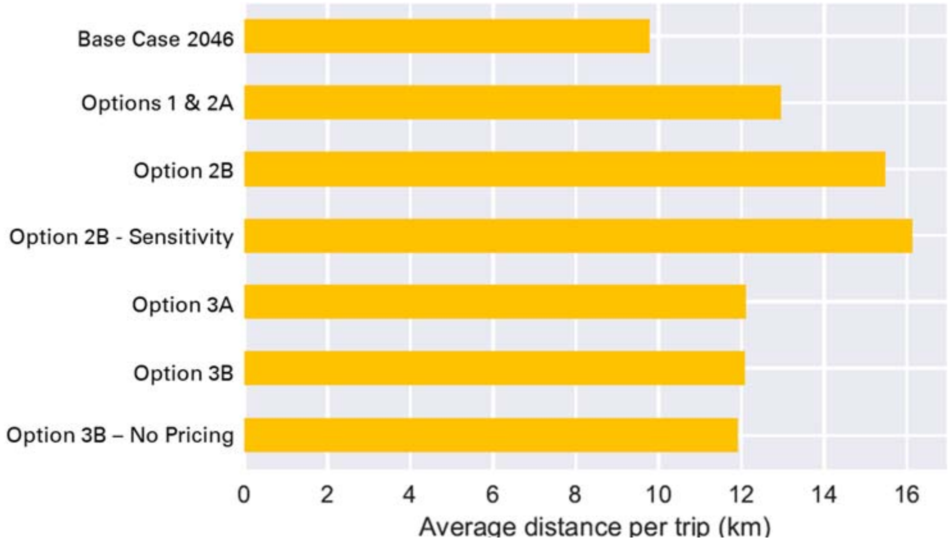


Figure 9: Average trip duration for each option

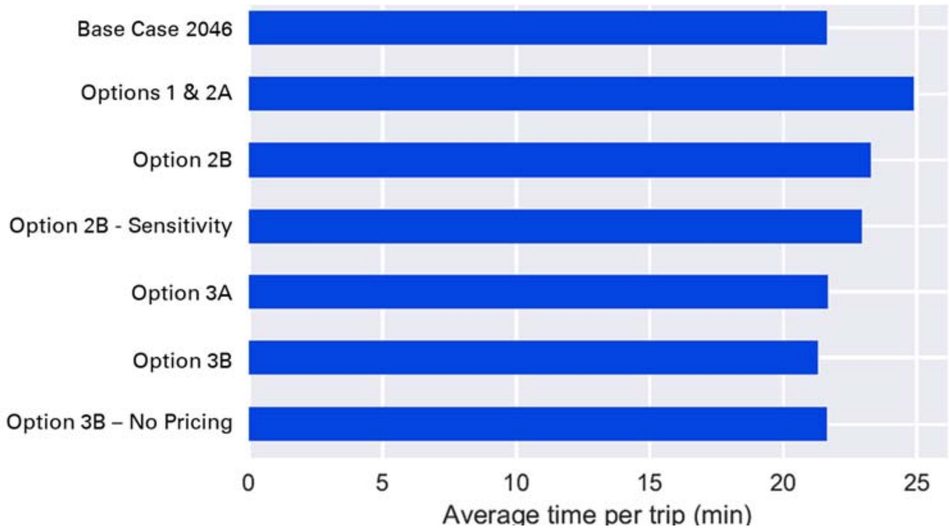
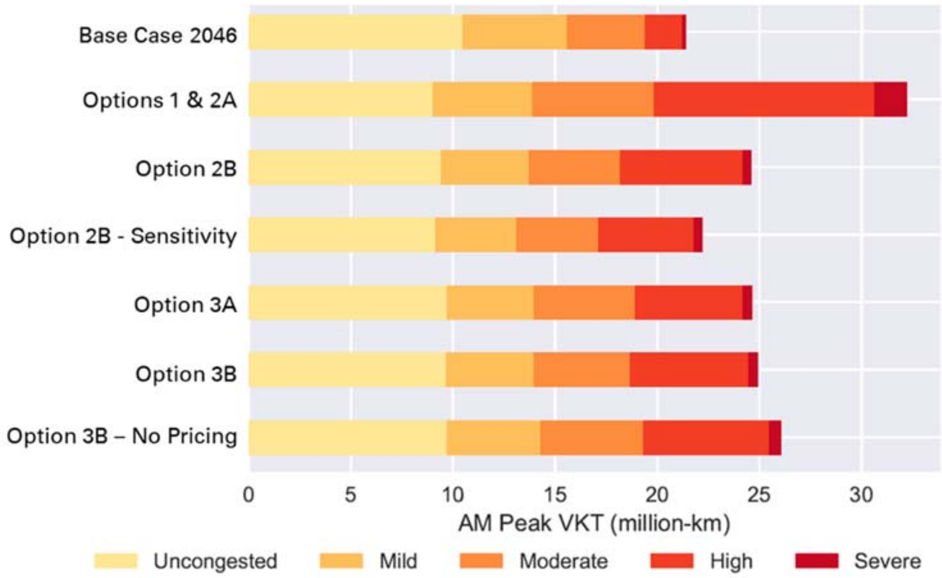


Figure 10: Projected congested VKT for each option



4.2.4 Considerations

Transport modelling of future scenarios inherently have a higher degree of uncertainty and error associated with them than current year scenarios. This is as a result of the compounding potential for error across interdependent input assumptions to the model.

The forecast year used by TransPosition for modelling each option was 2046, which at 28 years into the future introduces a high degree of uncertainty to the supporting analysis. This is particularly pertinent given only a single reference case is used to interpolate projections from, shifting this larger error back to forecast years that would traditionally have a higher degree of confidence.

The potential for these errors are introduced and compounded across inputs such as:

- Land use assumptions including geospatial distribution and density of population and employment;
- Transport network and service assumptions across future years, including the extent of upgrades beyond existing infrastructure and services;
- Pricing assumptions including cost of services, as well as behavioural aspects such as willingness to pay and value of time;
- Broader travel behaviour such as working habits, commuting trends, willingness to carpool and time of departure;
- Disruptions and potential changes to technology such as AEVs; and
- Errors in base year modelling expand as they are used to project further out.

This high degree of uncertainty necessitates that caution is used in interpreting the results of the economic and financial analyses which are dependent on transport modelling projections as key inputs.

Importantly, and recognising the inherent limitations of transport modelling in this context, the model underpinning this analysis was fit-for-purpose and provides valuable insight into the potential implications of the deployment and operation of AEVs.

4.3 Cost methodology

This section will outline the incremental costs included in the CBA, detailing the assumptions made.

All costs presented below are incremental to the Base Case option. This means that these are not the only costs that will occur over the assessment period, but are the additional costs beyond those incurred in the Base Case (non-AEV) option.

4.3.1 Option 1

As Option 1 is a 'do minimum' option with minimal intervention by Government, the only incremental costs are those associated with enabling the deployment of AEVs.

Administrative Costs

This item covers all policy and project development costs to develop the necessary legislation and regulation to enable the deployment of AEVs on Queensland roads.

The net undiscounted cost for this item is $45.0 million, cash flowed from 2020 to 2022, with $5.0 million in the first year and $10.0 million over the subsequent four years through to the first deployment of AEVs in 2025.

EV Charging Stations

This item includes the cost to the Queensland community to install charging stations for electric vehicles.

This analysis considers two main types of charging stations, the first being slow charging stations at the household level, the second being more expensive fast-charge stations for public use.

Household charging stations were assumed to cost $1,500 per unit, with the projected number of future households sourced from the Queensland Government Statistician's Office (QGSO).[30, 31]

The fast-charging stations were assumed to cost $26,667 for each unit, based on Jet Charge's recent deployment of 150 stations for $4.0 million in Australia funded by Jaguar.[32] These stations allow users to extend their driving range by 100km in 15 minutes of charging.[32]

This is at the lowest end of the range of costs for this infrastructure, with the Electric Vehicle Council reporting a common range of $70,000 to $180,000 per station.[30] The recent investment by the Queensland Government in the 'Electric Superhighway' of $3.0 million for 18 stations equates to $166,667 per station, however this higher cost also includes twelve months of free usage.[33]

Given that there is likely to be economies of scale in the widespread installation of charging stations, the lower cost observed in the Jet Charge installation was adopted for this analysis.

It was assumed that one public charging station will be required for every 25 vehicles on the road based on the upper range UK values reported by the Electric Vehicle Council.[30] This is a relatively high number of cars per station compared to current international experiences, however this is largely as a result of infrastructure being installed prior to the take-up of the electric vehicle technology by road users.

The combined cost for both household and public charging stations is assumed to be $6.7 billion, uniformly forecast over the period from 2025 to 2036.

Road Line Marking

To enable the effective deployment of Level 3 AEVs by 2025 it is assumed that line-marking will be required on Queensland roads to enable the new automated technology to more easily delineate lane edges. This is based on recent observations by Transurban in trialling AEVs on its network.[34]

A cost of $173.0 million has been assumed, based on $2.60 / m of line marking across the 33,352 km of Queensland state road network. These costs are assumed to be uniformly cash flowed over a five year period from 2023.

The state road network was used as a benchmark to develop cost estimates at an appropriate scale. While some sections of the state network is unsealed, other sections of the local government road network throughout SEQ would require similar treatment. The uncertainty associated with this and other cost items is considered as part of the sensitivity analysis in Section 4.5.4.

---

[30] Electric Vehicle Council, 2015, *Recharging the economy: The economic impact of accelerating electric vehicle adoption*, Table 4, <http://electricvehiclecouncil.com.au/wp-content/uploads/2015/05/Recharging-the-economy.pdf>
[31] QGSO. 2018, *Household and Dwelling Projections*,
[32] Renew Economy, 2018, *Jaguar plans big charger network ahead of I-Pace EV release* <https://reneweconomy.com.au/jaguar-plans-big-charger-network-ahead-of-i-pace-ev-release-67412/>
[33] Brisbane Times, 2017, *Electric car charging stations to be built across Queensland,* 27 July 2017 <https://www.brisbanetimes.com.au/national/queensland/electric-car-charging-stations-to-be-built-across-queensland-20170727-gxk16r.html>
[34] The Australian, 2018, *Autonomous cars: Gearing up for a driverless future*, April 3 2018, <https://www.theaustralian.com.au/business/technology/gearing-up-for-a-driverless-future/>

Vehicle-to-infrastructure communication costs are not included in this item. Investment in intelligent transport systems (ITS) is assumed to occur in the Base Case option, and as such is not included in the incremental analysis.

Digital Network Mapping

As AEVs become more prominent, and manually operated conventional vehicles declines, the way in which the road network is regulated will change from physical signs, to a digital GIS based network. This will require the development of a 'digital network map' that can be used by AEVs in safely navigating the road network, e.g. digitally coded stop lines and give way lines.

A cost of $10.0 million for the development and implementation of this asset and network mapping tool has been assumed, cash flowed uniformly over a four year period from 2022.[35]

Incremental Operating Costs

An allowance for maintenance and replacement of the above infrastructure items, particularly the electric vehicle charging stations has been included. This cost has been set at 10 per cent of the cumulative capital costs for charging stations each year. This reflects an expected average lifespan of 10 years for the charging station based on current technology.[36]

Road Maintenance Costs - See Section 5.2.8 for assumptions.

Terminal Value

Given that costs related to maintenance and replacement of infrastructure, such as charging stations, do not have an unlimited lifespan, a terminal value has been calculated to estimates the operating costs to perpetuity.

The method for calculation the terminal value is outlined in the equation below:

$$T = \frac{C\ (1+g)}{k-g}$$

Where:

T = Terminal value

C = Discounted operating costs in final year of calculations.

g = Growth rate of costs

k = Discount rate

With the core calculations undertaken using a thirty year assessment period from 2019, the discounted operating costs for the year 2048 were used for C.

Given this assumptions outlined for each cost item, there is no growth rate for operating costs at the final projection year of 2048, and the parameter 'g' is zero.

Summary of Cost Inputs

The figure and table below present the total undiscounted cost inputs to Option 1.

[35] This type of large scale integrated asset and regulatory mapping has few precedents in the transport sector. The scale of this cost item was selected based upon KPMG's understanding of similar digital based projects.
[36] Kettles, D. & Raustad, R. 2017, *Electric Vehicle Charging Station Technologies Analysis and Standards*, Electric Vehicle Transportation Centre, Florida Solar Energy Centre, University of Central Florida.

Figure 11: Option 1 Cost Profile

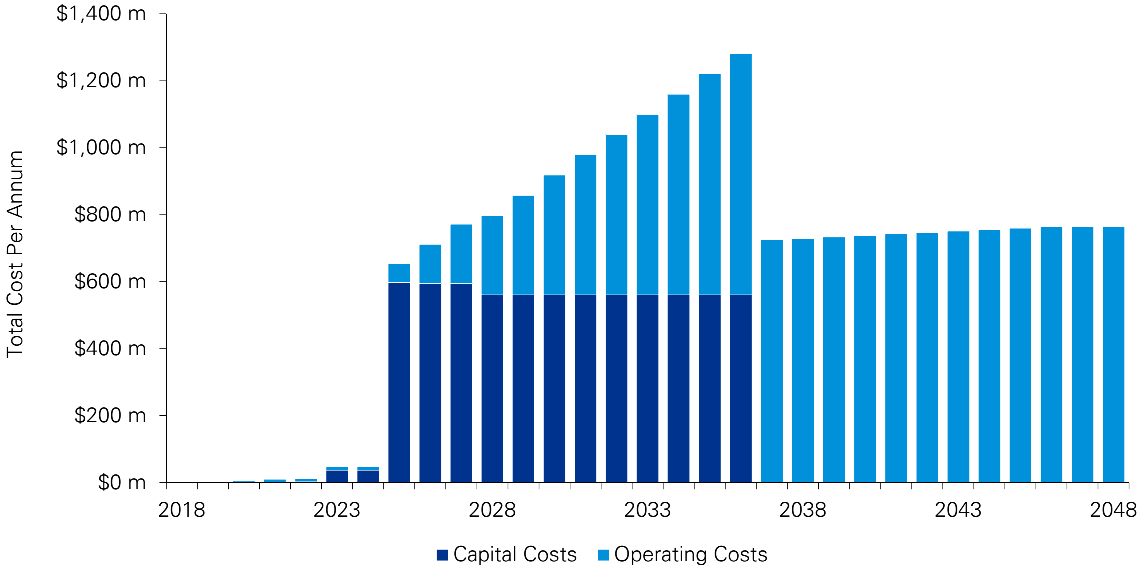


Table 2: Option 1 Cost Inputs

Year	Capital Costs	Operating Costs
Total	**$6,906 m**	**$13,678 m**

4.3.2 Option 2A

Option 2A is a fleet-owned predominately door-to-door service considers the items below, in addition to the cost items outlined in Option 1. Some cost items from Option 1 are included below as these have been modified from that presented in Section 4.3.1.

EV Charging Stations

This item includes the cost to the Queensland community to install charging stations for electric vehicles. This cost for construction of charging stations is assumed to be less when vehicles are operated by a fleet provider than when owned at a household level. This is due to the lower number of vehicles that are likely to be required under a fleet scenario to service the same level of travel demand.

To reflect this, the number of 'household' charging stations (i.e. slow charge) have been reduced to 25 per cent of that assumed in Option 1. This is to reflect the assumed level of car ownership as set out in Section 4.4.5.

The combined cost for charging stations is assumed to be $4.5 billion, uniformly forecast over the period from 2025 to 2036.

The revised capital costs for the electric vehicle charging stations result in reduced operating costs related to replacement over their lifespan as set out in Section 4.3.1, and subsequently a reduced terminal value for operating costs.

AEV Corridor Conversion

The cost of the dedicated AEV corridor conversion has been based upon the Smart Freeways project in Perth, Western Australia. A new Freeway lane is deployed by removing the emergency lane, and installing ITS technology. The Smart Freeways project is estimated to cost $47.0 million over a 5.2 km section of road.[37]

The sections of motorway in SEQ that are assumed to undergo this treatment in Option 2 are:

- Pacific Motorway (Gold Coast to Brisbane): 78 km
- Bruce Highway (Sunshine Coast to Brisbane): 105 km
- Gateway Motorway: 33 km
- Western Freeway / Centenary Motorway (Ipswich to Brisbane): 44 km
- Total (Both Directions): 520 km

The selection of these sections of motorway is for cost-estimation purposes only based on major arterial motorways. Detailed analysis and would be required to identify which routes would be required from a transport policy perspective.

The cost-input assumption for this work $2.4 billion, which is cash flowed uniformly over a five year period from 2030 when AEVs have a high adoption rate.

Conversion of On-Street Parking

This cost item is to reflect the conversion of on-street parking in the Brisbane CBD to additional pick-up and drop off bays to facilitate a fleet model.

There are currently 576 on-street bays in the Brisbane CBD, with a unit cost of $900, assumed to enable changed signage and line-markings.[38]

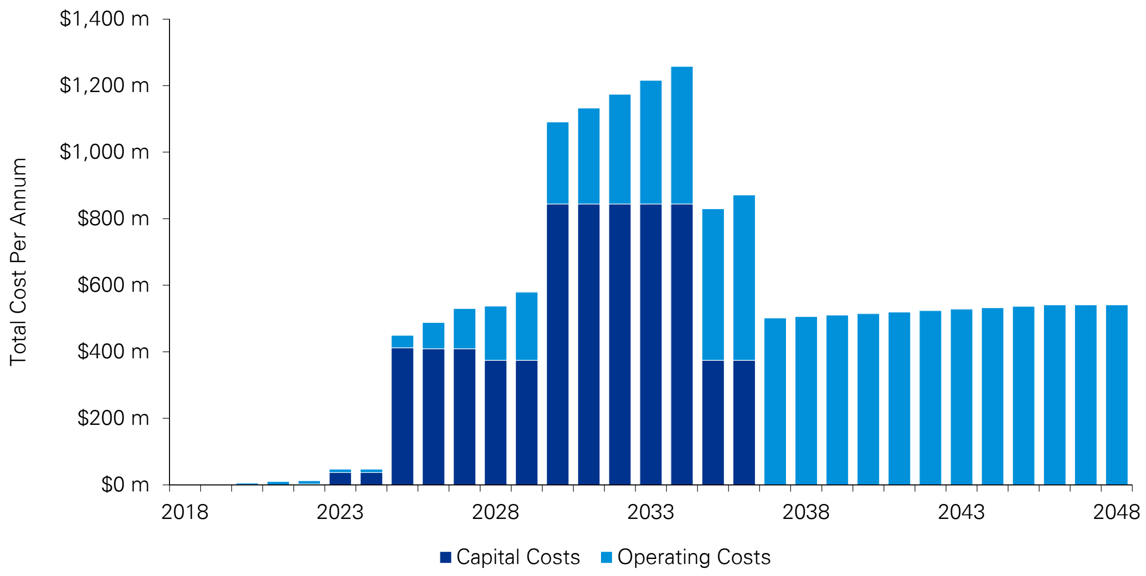
The cost assumption for this item is $518,400 in 2025 when the first AEVs are deployed.

Road Maintenance Costs - See Section 5.2.8 for assumptions.

Summary of Cost Inputs

The figure and table below present the total undiscounted cost inputs to Option 2A.

Figure 12: Option 2A Cost Profile



[37] MRWA, 2018, *Smart Freeways*, <https://project.mainroads.wa.gov.au/home/freeways/smartfreewaykwinana/>
[38] Brisbane Times, 2014, *Brisbane City Council's parking revolution*, 1 December 2014

Table 3: Option 2A Cost Inputs

Year	Capital Costs	Operating Costs
Total	**$7,025 m**	**$9,548 m**

4.3.3 Option 2B

Option 2B is a fleet-owned predominately door-to-door service that encourages increased car occupancy through dedicated infrastructure (e.g. high-occupancy vehicle lanes) and a pricing mechanism to encourage greater behaviour change. In addition to the items below, all of the cost items outlined in Option 1 are included in the cost of this option. Some cost items from Option 1 are included below as these have been modified from that presented in Section 4.3.1.

EV Charging Stations

This item includes the cost to the Queensland community to install charging stations for electric vehicles. This cost for construction of charging stations is assumed to be less when vehicles are operated by a fleet provider than when owned at a household level. This is due to the lower number of vehicles that are likely to be required under a fleet scenario to service the same level of travel demand.

To reflect this, the number of 'household' charging stations (i.e. slow charge) have been reduced to 25 per cent of that assumed in Option 1. This is to reflect the assumed level of car ownership as set out in Section 4.4.5.

The combined cost for charging stations is assumed to be $4.5 billion, uniformly forecast over the period from 2025 to 2036.

The revised capital costs for the electric vehicle charging stations result in reduced operating costs related to replacement over their lifespan as set out in Section 4.3.1, and subsequently a reduced terminal value for operating costs.

HOV lane conversion

A unit rate of $17,000 / km for conversion of existing lanes to a high-occupancy vehicle (HOV) lane (e.g. T2 or T3 lane) has been assumed based on TMR's Smarter Solutions Reference Guide.[39]

To estimate an approximate length of road network, the 102 km of network identified to form the Brisbane City Council's (BCC) 'Key Corridors' report has been adopted.[40] Although not all of the road in the BCC Key Corridors Performance Report will be suitable to be converted to HOV lanes, there are others not included in the reporting that would be, and as such the total length has been adopted as an indicative value for SEQ.

It is assumed that this item will cost $3.5 million, to be incurred uniformly over a five year period from 2024.

Road Pricing Infrastructure

To implement a cordon charge in the Brisbane CBD area, an allowance has been made for the installation of 40 gantries at a cost of $100,000 each based on the Smarter Solutions Reference Guide.[39] It is assumed that this item will cost $4.0 million in a single year at 2030.

[39] TMR, 2016, *Smarter Solutions Reference Guide*, Queensland Department of Transport and Main Roads
[40] BCC, 2018, *Greater Brisbane Key Corridors Performance Report*, <https://www.brisbane.qld.gov.au/traffic-transport/traffic-management/greater-brisbane-key-corridors-performance-report>

AEV Corridor Conversion - See Section 4.3.2 for assumptions.

Conversion of On-Street Parking - See Section 4.3.2 for assumptions.

Road Maintenance Costs - See Section 5.2.8 for assumptions.

Summary of Cost Inputs

The figure and table below present the total undiscounted cost inputs to Option 2B.

Figure 13: Option 2B Cost Profile

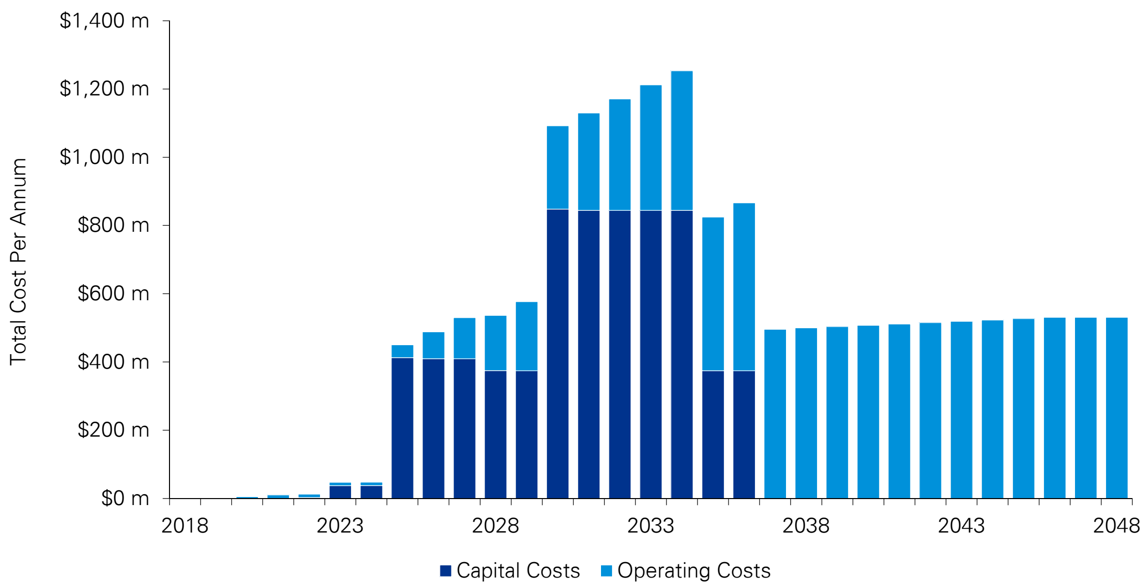


Table 4: Option 2B Cost Inputs

Year	Capital Costs	Operating Costs
Total	**$7,032 m**	**$9,415 m**

4.3.4 Option 3A

Option 3A assumes a fleet-owned AEV service that is incentivised to act as a feeder service to key public transport nodes through government subsidies. Option 3A encourages increased public transport usage by fast-tracking investment in public transport infrastructure and services along key corridors.

In addition to the items below, all of the cost items outlined in Option 1 are included in the cost of this option. Some cost items from Option 1 are included below as these have been modified from that presented in Section 4.3.1.

EV Charging Stations

This item includes the cost to the Queensland community to install charging stations for electric vehicles. This cost for construction of charging stations is assumed to be less when vehicles are operated by a fleet provider than when owned at a household level. This is due to the lower number of vehicles that are likely to be required under a fleet scenario to service the same level of travel demand.

To reflect this, the number of 'household' charging stations (i.e. slow charge) have been reduced to 25 per cent of that assumed in Option 1. This is to reflect the assumed level of car ownership as set out in Section 4.4.5.

The combined cost for charging stations is assumed to be $4.5 billion, uniformly forecast over the period from 2025 to 2036.

The revised capital costs for the electric vehicle charging stations result in reduced operating costs related to replacement over their lifespan as set out in Section 4.3.1, and subsequently a reduced terminal value for operating costs.

Public Transport Infrastructure

To reflect a sizeable investment by the Queensland Government in improving the public transport network across SEQ, the Metronet Project in Perth, Western Australia has been used as a reference.[41]

The Metronet Stage 1 Project is a $4.8 billion rail investment package, including the Forrestfield Airport Link, to be delivered over an eight year period.[42]

The assumption for this cost item is for $4.8 billion to be incurred evenly across an eight year period from 2025.

The Metronet program was selected as it is representative of a network wide infrastructure upgrade.

A sensitivity analysis has been undertaken on public transport expenditure in Section 4.5.4 assessing the likely impact of an increase of 100 per cent and 200 per cent of the estimated costs.

Public Transport Services

The NSW Government's 'More Trains More Services' program is used as a reference case to reflect a sizeable investment in rollingstock and services to make use of the additional capacity the above infrastructure investment allows.[43]

The assumption for this cost item is that $1.5 billion is invested over a four year period from 2025.

A sensitivity analysis has been undertaken on public transport expenditure in Section 4.5.4 assessing the likely impact of an increase of 100 per cent and 200 per cent of the estimated costs.

Additional Operating Expenditure

To reflect the addition ongoing operating expenditure that the above investment in public transport services and infrastructure will have, this analysis assumes an annual operating cost of $30.1 million as per the Cross River Rail business case.[44] This cost commences in 2025 and is ongoing over the life of the assessment period.

AEV Corridor Conversion - See Section 4.3.2 for assumptions.

Conversion of On-Street Parking - See Section 4.3.2 for assumptions.

Road Maintenance Costs - See Section 5.2.8 for assumptions.

Summary of Cost Inputs

The figure and table below present the total undiscounted cost inputs to Option 3A

---

[41] Metronet Stage 1 including FAL was selected as the reference case as this is a network expansion project in an urban environment. While Cross River Rail is of a similar scale in cost, this project is a unique project given the existing constraints including the Brisbane River which are not representative of other potential project locations.
[42] ABC, 2016, *Metronet first stage to be built within eight years, Labor says*, 15 December 2016 <http://www.abc.net.au/news/2016-12-15/metronet-first-stage-built-within-eight-years-wa-labor-says/8125362>
[43] TfNSW, 2018, *More Trains More Services* < https://www.transport.nsw.gov.au/projects/more-trains-more-services>
[44] Building Queensland, 2017, *Cross River Rail – Economic Analysis*, <http://buildingqueensland.qld.gov.au/wp-content/uploads/2017/08/Chapter-7.pdf>

Figure 14: Option 3A Cost Profile

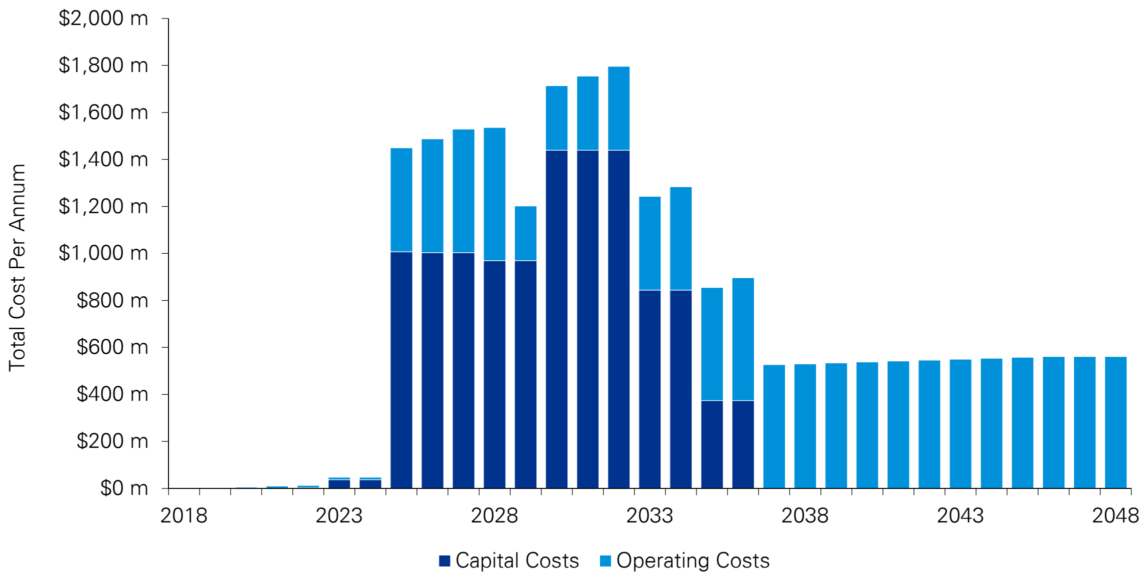


Table 5: Option 3A Cost Inputs

Year	Capital Costs	Operating Costs
Total	**$11,785 m**	**$11,647 m**

4.3.5 Option 3B

Option 3B assumes a fleet-owned AEV service that is incentivised to act as a feeder service to key public transport nodes through government subsidies. Option 3B encourages increased public transport usage through implementing a road pricing mechanism, deferring the need for investment in public transport infrastructure and services along key corridors until it is required to meet demand.

In addition to the items below, all of the cost items outlined in Option 1 are included in the cost of this option. Some cost items from Option 1 are included below as these have been modified from that presented in Section 4.3.1.

EV Charging Stations

This item includes the cost to the Queensland community to install charging stations for electric vehicles. This cost for construction of charging stations is assumed to be less when vehicles are operated by a fleet provider than when owned at a household level. This is due to the lower number of vehicles that are likely to be required under a fleet scenario to service the same level of travel demand.

To reflect this, the number of 'household' charging stations (i.e. slow charge) have been reduced to 25 per cent of that assumed in Option 1. This is to reflect the assumed level of car ownership as set out in Section 4.4.5.

The combined cost for charging stations is assumed to be $4.5 billion, uniformly forecast over the period from 2025 to 2036.

The revised capital costs for the electric vehicle charging stations result in reduced operating costs related to replacement over their lifespan as set out in Section 4.3.1, and subsequently a reduced terminal value for operating costs.

Public Transport Infrastructure

See Section 4.3.4 for assumptions, with this investment deferred eight years until 2033.

Public Transport Services

See Section 4.3.4 for assumptions, with this investment deferred eight years until 2033.

Additional Operating Expenditure

See Section 4.3.4 for assumptions, with this cost item deferred eight years until 2033.

Road Pricing Infrastructure - See Section 4.3.3 for assumptions.

AEV Corridor Conversion - See Section 4.3.2 for assumptions.

Conversion of On-Street Parking - See Section 4.3.2 for assumptions.

Road Maintenance Costs - See Section 5.2.8 for assumptions.

Summary of Cost Inputs

The figure and table below present the full undiscounted cost inputs to Option 3B.

Figure 15: Option 3B Cost Profile

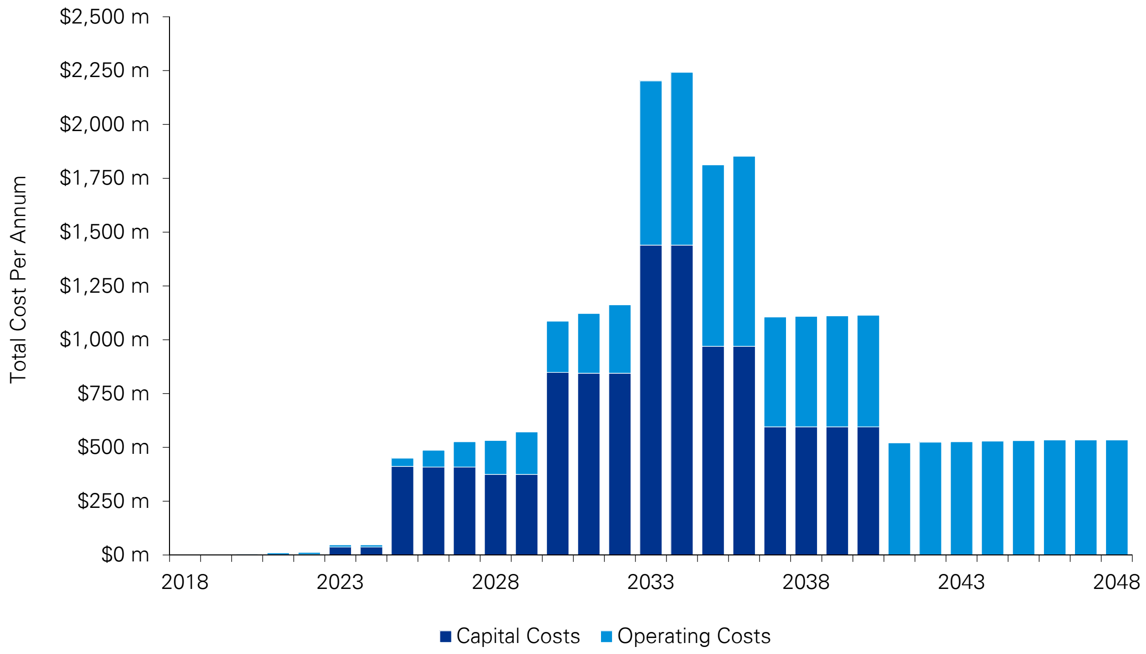


Table 6: Option 3B Cost Inputs

Year	Capital Costs	Operating Costs
Total	**$11,789 m**	**$11,050 m**

4.4 Benefit methodology

4.4.1 Value of travel time

When journey times are reduced for commuters and commercial travel, travel time savings are generated. Time savings associated with improvement in trip times can be quantified through the estimation of the user's time value.

The associated value of time (VOT) of each vehicle class and transit mode is applied to the modelled travel times for each scenario. The value of time parameters have been extracted from ATAP Guidelines PV2 Road Parameter Values and have been escalated from $2013 to $2017 using average weekly earnings (ABS cat 6302.0).

For the purposes of the analysis, travel to and from work is not considered a business use, and aligns with the private travel value of time as set out in ATAP.

The ATAP Guidelines PV2 Road Parameter Values specifies the value of travel time for passenger, business and freight and is documented in the below table.

Table 7: Value of Travel Time from ATAP Road Parameter Values

	TransPosition Vehicle Class	ATAP Vehicle Class	Value per occupant ($/per person/hour)	Freight Travel Time (Urban) $/vehicle-hour
Value of Time* ($2013)	Car, AV, AV Taxi, AV Carpool	Cars – Private	$14.99	-
	Car, AV, AV Taxi, AV Carpool	Cars – Business	$48.63	-
	Car, AV	4. Courier Van-Utility	$25.41	-
	CVM	7. Medium Rigid	$25.72	$4.15
	Public transport	9. Heavy Bus (Passenger)	$14.99	-
	CVH	12. Artic 6 Axle	$26.81	$42.06

**VOT values from ATAP are escalated by Average Weekly Earnings, Full-time Adult, Seasonally adjusted to $2017 for the analysis.*

The benefits realised from each option are dependent on the composition of the fleet across the network. As such, the modelled traffic outputs must be disaggregated to enable a robust assessment of the benefits.

While TransPosition's modelling accounted for rigid and articulated heavy vehicles through their commercial vehicle – medium (CVM), and commercial vehicle – heavy (CVH) classes respectively, a light commercial vehicle class was not directly modelled.

In order to disaggregate Transposition's light vehicle classes (AV and car) into private use, commercial use, and light commercial, statistics for Queensland were sourced from the Australian Bureau of

Statistics 'Survey of Motor Vehicle Use' (30 June 2016, Table 9) (SMVU). The table below provides a summary of the vehicle composition for Austroads Class 1-2 vehicle classifications based on SMVU data.

Table 8: Fleet composition from ABS Survey of Motor Vehicle Use

Vehicle Class (SMVU)	Cars (Private Use)	Cars (Commercial Use)	Light Commercial Vehicles (LCV)	Total
Proportion	57.3%	15.3%	27.3%	100%

Where travel demand for a particular travel or vehicle class differs between an option and the Base Case, the 'rule of half' is used as per the ATAP CBA guidelines.[45] In this instance, where travel demand in the option exceeds the number in the Base Case, the benefits allocated to new users is half of that of existing users. In instances where existing users experience increased travel times and costs, then new users are considered to have no benefit.

Travel times are calculated for active transport trips representing walking or cycling. As an 'unlinked' trips method was used in calculating benefits, many of these trips will be associated with an alternative mode such as accessing public transport. Where options improve in-vehicle accessibility (e.g. personalised AEV-services) a travel time saving will be experienced in net hours spent on active travel, which is presented as a benefit. This benefit represents less time spent accessing key public transport nodes or destinations, and does not represent a health benefit.

4.4.2 Vehicle operating costs

Vehicle operating costs (VOC) are the cost to the owner of operating a vehicle, and consists of basic running costs such as depreciation, fuel, repairs and maintenance. While vehicle operating costs are a well-established benefit stream within economic appraisal in Australia, the consideration of AEVs is not widely practiced. As such there is limited accepted guidance at either a national or state level for calculating the benefits associated with AEVs.

The primary difference in vehicle operating costs between conventional vehicles and AEVs that has been assumed for this analysis is in fuel / energy costs.

This analysis considers the following elements as part of the VOC calculations: fuel costs, maintenance costs and vehicle depreciation. All of these costs elements are calculated on a per vehicle kilometre travelled (VKT) basis.

Fuel Costs

Fuel costs for conventional vehicles are based on parameter values derived from ATAP, with the rate of fuel consumption adopted from Table 36 of the ATAP PV2: Road Parameter Values.

Fuel consumption is based on the equation C = A + B / V with the parameter values from ATAP set out in the table below:

[45] ATAP, 2018, *Cost-Benefit Analysis Guidelines*, Section 6, Available from: <https://atap.gov.au/tools-techniques/cost-benefit-analysis/7-step-6-estimate-user-benefits.aspx>

Table 9: Fuel consumption parameter values L/100km - Stop Start – Table 36 of ATAP PV2

Vehicle Class	A	B
Medium Car	8.8017	179.689
LCV	8.0758	226.185
Medium Rigid	28.5369	158.8351
Artic 6	75.4028	547.8857

The price of fuel for Brisbane was adopted from Table 1 of ATAP PV2: Road Parameter Values, and are set out in the table below. The fuel price indicated in the table is escalated by the Producer Price Index for Road Freight to $2017.

Table 10: Resource price of fuel - ATAP PV2

Fuel Type	Fuel Price (Brisbane) (2013)	Fuel Price (Brisbane) (2017)
ULP	97.7 c/L	100.4 c/L
Diesel	96.9 c/L	99.6 c/L

Similar to fuel consumption, energy consumption for AEVs is calculated on a per kilometre basis as outlined in the table below. A cost of 28 c / Kilo-watt hours (kWh) (excluding GST) was assumed based on market rates.[46]

Table 11: Energy usage of AEVs

Vehicle Class	Wh/km	Vehicle Example
Car	226	Tesla Model X[47]
LCV	262	Electric Van[48]
ECVM	636	IVECO Daily 50C Electric[49]
ECVH	1060	Daimler eTruck[50]

Maintenance Costs

Repairs and maintenance cost rates are adopted directly from Table 6 of ATAP PV2: Road Parameter Values and are set out in the table below:

[46] Australian Government, 2018, *Energy Made Easy*, Available from: <https://www.energymadeeasy.gov.au/offer-search/S/4000>
[47] Green Vehicle Guide, 2018, Available from: <https://www.greenvehicleguide.gov.au/>
[48] RMS, 2016, *Case Study: Battery Electric Distribution Van*, Available from: <http://www.rms.nsw.gov.au/documents/about/environment/air/case-study-battery-distribution-van.pdf>
[49] Lebkowski, A. 2017, *Electric Vehicle Trucks: Overview of Technology and Research*, Scientific Journal of Gdynia University
[50] Electrek, 2016, *Daimler unveils its first all-electric eTruck*, July 27 2016, <https://electrek.co/2016/07/27/daimler-etruck-first-all-electric-truck-125-miles-range/>

Table 12: Repairs and maintenance costs per km - ATAP PV2

Vehicle Class	Repairs and Maintenance Costs per Vehicle (c/km) ($2013)	Escalated Rates – Road Freight ($2017)
Medium Car	8.1	8.1 (CPI)
LCV	6.7	6.9 (PPI – Road Freight)
Medium Rigid	10.7	11.0 (PPI – Road Freight)
Artic 6 Axle	18.0	18.5 (PPI – Road Freight)

Depreciation Costs

Depreciation costs per kilometre have been estimated for each vehicle class based on average lifetime kilometres travelled and vehicle costs.

The average kilometres travelled for heavy commercial vehicles to depreciate to half of their initial sale value is assumed to be 650,000km. The average price for a new vehicle is assumed to be $200,000 for a medium rigid vehicle, and $270,000 for a heavy commercial vehicle.

The average number of kilometres travelled by a passenger car in a year in Brisbane is 10,500 km, with the average lifespan being 10 years.[51, 52] The average cost of a vehicle is assumed to be $27,994, based on ASIC's Money Smart website, and it is assumed that a vehicle depreciates to a third of its initial value over this period.[53]Based on the above, the unit rate of depreciation per kilometre used in the analysis is set out in the table below:

Table 13: Vehicle depreciation rates

Vehicle Class	Depreciation ($/km)
Car / LCV	$0.0601
Medium Rigid	$0.1538
Artic 6 Axle	$0.2115

4.4.3 Crash costs

The widespread deployment of AEVs is assumed to deliver significant improvements in road safety, and eliminate many fatal and serious injuries.

There is considerable uncertainty associated with estimating the likely crash reduction under an AEV future as the technology is in its infancy, and has not been deployed widely yet. For the purposes of this analysis, the research of Daniel Fagnant and Kara Kockelman from the Eno Center for Transportation in Washington DC has been adopted.[54]

[51] ABS, 2016, *9208.0 – Survey of Motor Vehicle Use, 12 Motnhs ended 30 June 2016,* Table 1, Available from: <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/9208.012%20months%20ended%2030%20June%202016?OpenDocument>
[52] ABS, 2018, 9309.0 - Motor Vehicle Census, 31 January 2018, Table 3, Available from: <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/9309.0Main+Features131%20Jan%202018?OpenDocument>
[53] ASIC, 2018, *Money Smart*, Accessed 22 June 2018, Available from: <https://www.moneysmart.gov.au/>
[54] Fagnant, D, Kockelman, K, 2013, *Preparing a Nation for Autonomous Vehicles*, Eno Centre for Transportation.

Fagnant and Kockelman estimate a crash reduction factor of 0.9 per AEV once the technology reaches 90 per cent take-up on the road network.[54] This aligns with observations that approximately 90 per cent of crashes on the network today can be attributed to human error such as fatigue, inattention or speeding.[55]

This has been implemented in the CBA by applying a crash reduction factor of 0.9 for the modelled year of 2046. Historic crash rates for severity types for SEQ have been calculated using crash data over the ten year period from 2007 to 2016.[56] These crash rates are presented in the table below, and were used in conjunction with projected vehicle kilometres travelled for each vehicle class from the TransPosition modelling.

Table 14: Crash rates and costs

Crash Type	Observed Crashes (2007 – 2016)	Crash Rate (Per Million VKT)	Crash Cost (ATAP - Table 16 of PV2: Road Parameter Values)^
Property Damage Only	20,450	0.118	$9,257
Minor Injury	14,475	0.084	$22,992
Medical	39,191	0.226	$22,992
Hospitalisation	32,744	0.189	$629,484
Fatality	1,146	0.007	$2,463,432
Total	108,006	0.623	-

**Crash costs in ATAP are $2013 and are escalated by CPI to $2017 for the analysis.*

Crash cost savings are projected linearly from the first year of benefits in 2026 through to 2046. To account for the slower rate of adoption of AEVs under Option 1 a ramp up period of ten years is incorporated, linearly increasing from 10 per cent of benefits in the first year of 2026 through to 100 per cent of benefits in the tenth year.

4.4.4 Environmental externalities

The inclusion of environmental externalities are an important part of an economic appraisal from a societal perspective. The impact of the options on the environment and broader community should be considered to internalise these environmental externalities into the decision-making process.

This analysis considers two environmental externalities; air pollution and greenhouse gas emissions. Other potential externalities such as noise, soil or water effects are typically only considered in a location specific context and are not considered as part of this analysis.

Air Pollution

Air pollution results from the emission of pollutants such as carbon monoxide through the inefficient combustion of fuel in conventional vehicles.

---

[55] NRSPP, 2018, *Human Error in Road Accidents, National Road Safety Partnership Program*, Online, Accessed 22 June 2018 <https://www.nrspp.org.au/resources/human-error-in-road-accidents/ >

[56] Queensland Government Data, 2018, *Crash data from Queensland roads*, Online, Accessed 22 June 2018, Available from: < https://data.qld.gov.au/dataset/crash-data-from-queensland-roads>

The recommended national guidance on calculating the impact of air pollution is the Austroads Technical Report AP T285-14: Updating Environmental Externalities Unit Values. Table 7.1 of this report indicates that "*air pollution is predominately an urban issue. The externality value is primarily a function of VKT and population distribution (which is largely associated with health impacts).*"[57]

The widespread deployment of AEVs will eliminate the emission of pollutants at the vehicular level, with all generation undertaken at centralised locations away from densely populated areas. While there will be some degree of impact on surrounding communities, the location and impact of these remote emissions is uncertain, particularly in the context of an increasing mix of renewable energy in power generation.

Given the emphasis placed on urban health impacts for this particular externality, this analysis only considers these costs for the Base Case option with conventional combustion engine vehicles.

The parameter values used in calculation of the Base Case costs are sourced from Tables 6.5 and 6.6 of Austroads Technical Report AP T285-14, and are presented in the table below. The values in the table below are then escalated to $2017 by CPI for the analysis.

Table 15: Air pollution parameter values from Austroads

Minimum urban externality values ($/1000VKT)				
Externality Type	**Car**	**LCV**	**CVM**	**CVH**
Air Pollution ($2013)	11.76	4.28	60.65	60.65
Air Pollution ($2017)	12.88	4.69	66.45	66.45

Greenhouse Gas Emissions

Unlike air pollution, greenhouse gas emissions have a global impact. Accordingly, the source of emissions is not of importance, rather the quantity and global warming potential of emissions. This CBA compares the volume of CO_2 equivalent gases emitted as a result of vehicle use on the transport network under each option.

The emissions from conventional vehicles for the Base Case option is calculated using ATAP parameter values, supplemented with International Panel for Climate Change (IPCC) values for CO_2 equivalency.

Fuel consumption is based on the equation $C = A + B / V$ with the parameter values from ATAP set out in the table below.

Table 16: Fuel consumption parameter values L/100km - Stop Start – Table 36 of ATAP PV2

Vehicle Class	A	B
Medium Car	8.8017	179.689
LCV	8.0758	226.185
Medium Rigid	28.5369	158.8351
Artic 6	75.4028	547.8857

[57] Austroads, 2014, *Technical Report AP T285-14: Updating Environmental Externalities Unit Values.*

The volume of fuel is then converted to the mass of emissions by product using ATAP parameter values (Table 17).

Table 17: Conversion ratio of fuel (L) to emissions (g/L) - ATAP PV2 Appendix B

Production Year	Fuel	CO_2	CH_4	N_2O	NOx	CO	NMVOC
2006	Petrol	2305.08	0.03	0.03	2.25	8.69	0.77
2006	Diesel	2698.14	0.033	0.099	2.747	1.275	0.681

These values are then converted into a CO_2 equivalent value for comparison purposes using conversion factors sourced from the IPCC.[58]

Table 18: Global warming potential - CO2 equivalency factors - IPCC

Time Horizon	CO_2	CH_4	N_2O	NOx	CO	NMVOC
100 Years	1	25	298	7	2	2

The mass of emissions per kilometre for AEVs is dependent upon the mix of renewables within the overall energy production sector. The table below presents the values that were adopted in this analysis.

Table 19: Greenhouse gas emissions (CO2 equivalent) of AEVs under 50% renewable generation

Vehicle Class	g/km	Vehicle Example
Car	105.0	Tesla Model X[59]
LCV	121.7	Electric Van[60]
ECVM	295.4	IVECO Daily 50C Electric[61]
ECVH	492.4	Daimler eTruck[62]

These values were derived by multiplying the reported Wh / km value for each vehicle by a projected kg / kWh of CO_2 equivalent.

The greenhouse and energy information for designated generation facilities was sourced from the Clean Energy Regulator for 2016-17.[63] Only production facilities within the National Energy Market

---

[58] IPCC, 2018, *Climate Change 2007: Working Group I: The Physical Science Basis*, Direct Global Warming Potentials <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html> and <https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-3-2.html>

[59] Green Vehicle Guide, 2018, Available from: <https://www.greenvehicleguide.gov.au/>

[60] RMS, 2016, *Case Study: Battery Electric Distribution Van*, Available from: <http://www.rms.nsw.gov.au/documents/about/environment/air/case-study-battery-distribution-van.pdf>

[61] Lebkowski, A. 2017, *Electric Vehicle Trucks: Overview of Technology and Research*, Scientific Journal of Gdynia University

[62] Electrek, 2016, *Daimler unveils its first all-electric eTruck*, July 27 2016, <https://electrek.co/2016/07/27/daimler-etruck-first-all-electric-truck-125-miles-range/>

[63] Clean Energy Regulator, 2018, *Electricity sector emissions and generation data 2016–17*

were considered, with kg / kWh of CO_2 equivalent calculated for both renewables and non-renewables.

This allowed a projected value of emissions for generation on the National Energy Market to be calculated if the Queensland Government's 50 per cent renewable energy target by 2030 is achieved. The projected value under a 50 per cent renewable scenario is 0.4646 kg / kWh of CO_2 equivalent.

To derive a value per gram the Austroads Technical Report AP T285-14: Updating Environmental Externalities Unit Values was used. The recommended parameter value on a per kilometre basis is presented in the table below.

Table 20: Greenhouse parameter values from Austroads

Minimum urban externality values ($/1000VKT) ($2013)	
Externality Type	**Car**
Greenhouse	5.62

The fuel consumption and emissions parameters were combined with the above to derive a cost per gram of $1.99 x 10^{-5} / g.

This price is equivalent to approximately $20 per tonne of CO_2.This value is slightly higher than the $18 per tonne that carbon was observed trading for in March 2018 under the Emission Reduction Fund.[64]

4.4.5 Car ownership costs

The deployment of AEVs will enable for a reduction in the number of vehicles purchased due to the potential for greater efficiencies in their use. At a household level, more households will be able to transition to owning a single car, with the one AEV able to transport multiple people if they travel at different times. Under a fleet ownership scenario, this advantage is extrapolated across an entire urban area, with a single car being used to service trips from users across the day.

This benefit has been estimated by calculating the difference in cumulative cost of purchasing vehicles within SEQ on an annual basis across each option.

This analysis calculates the expected number of vehicles to be purchased each year over the course of the evaluation period based on population growth. This value is based on a car ownership rate of 1.77 vehicles per household for Greater Brisbane based on the 2016 Census, the projected number of households to 2036 by the QGSO and an assumed average lifespan of ten years for a vehicle.[52]

AEVs are assumed to commence deployment from 2025, with full take-up by 2035. Under a private ownership model (i.e. Option 1) it is assumed that car ownership per household declines by 20 per cent to take advantage of the efficiencies in travel that AEVs present to users. This would see the projected number of cars in SEQ decline to 2.81 million by 2041 compared with 3.51 million under a non-AEV scenario.

Under a fleet model (i.e. Options 2A, 2B, 3A and 3B), the number of private vehicles declines to 25 per cent of value projected for non-AEVs. This assumption is based upon the maximum proportion of travel in a peak period in SEQ of 23 per cent from the South East Queensland Household Travel

[64] AFR, 2018, *Carbon price jumps in maiden run for Tony Abbott's emissions trading scheme*, 14 March 2018 <http://www.afr.com/business/energy/carbon-price-jumps-in-maiden-run-for-tony-abbotts-emissions-trading-scheme-20180313-h0xfhl>

Survey, with an additional 10 per cent allowance to account for maintenance and breakdowns in fleet vehicles.[65] The purchase of fleet vehicles commences in 2025, with full take-up assumed to be achieved over a ten year period through to 2035. This would see the projected number of cars in SEQ decline to only 878,000 by 2041.

The average cost of a vehicle is assumed to be $27,994, based on ASIC's Money Smart website.[53] For the purposes of this analysis, it is assumed that conventional vehicles cost the same as AEVs. While this is not currently the case, it is likely that any scenario that has widespread adoption of AEVs will see cost reductions through economies of scale in production, and require a price level to be affordable to households.

4.4.6 Parking repurposing

Once AEVs achieve widespread use, the value of car parking spaces will diminish allowing this land to be redeveloped for higher value purposes.

For the purposes of the CBA, the area of car parks in SEQ has been estimated from a Colliers International report which estimated the number of parking bays in the CBD as 25,633, with the number of workers as 117,817 in 2015.[66] This is equivalent to approximately 0.22 parking bays per worker.

This value has been used in conjunction with employee estimates from the QGSO for SEQ to estimate the number of bays across SEQ.

This estimate of approximately 360,000 parking bays is considered conservative as employees outside of the Brisbane CBD will likely require a higher rate of bays per employee due to reduced public transport accessibility in these areas.

An average area of each bay was assumed to be 5.4m x 2.6m as per Appendix 2 of the Brisbane City Plan (Transport, Access, Parking and Servicing Planning Scheme Policy).[67] An average value of land of $560 / m^2 was assumed.[68]

Given that the Base Case scenario is a non-AEV scenario, land designated for car parks in the Base Case still have value attached to them to support surrounding land use. As such the benefits assigned to the AEV options considers a 20 per cent uplift in the value of the land to reflect the repurposing for higher productive purposes.

The benefits associated with the repurposing of car park spaces have been uniformly distributed between 2030 (i.e. five years after initial deployment of AEVs) and 2041.

4.4.7 Terminal value

Given that many of the benefit categories outlined above do not have a limited lifespan, a terminal value has been calculated to estimates the benefits to perpetuity.

The method for calculation the terminal value is outlined in the equation below:

$$T = \frac{B\,(1+g)}{k-g}$$

---

[65] TMR, 2009, *Travel in South East Queensland: An analysis of travel data from 1992 to 2009*
[66] Colliers International, 2015, *The evolution of car parking – technology creating risk and opportunity*, available from: <https://trid.trb.org/view/1357499>
[67] BCC, 2000, *Transport, Access, Parking and Servicing Planning Scheme Policy*, Available from: <https://www.brisbane.qld.gov.au/sites/default/files/Appendix2_TransportAccess_PSP.pdf >
[68] SMH, 2017, *Melbourne land values surge while Sydney tops $1000 a square metre*, 24 October 2017

Where:

T = Terminal value

B = Discounted benefits in final year of calculations.

g = Growth rate of benefits

k = Discount rate

With the core calculations undertaken using a thirty year assessment period from 2019, the discounted benefits for the year 2048 were used for B.

As the furthest forecast year modelled was 2046, all undiscounted benefits in the years beyond this point were assumed to equal those calculated for 2046. Given this assumption, there is no growth rate of benefits, and the parameter ‘g’ is zero.

Benefit categories included in the terminal value calculations were value of travel time, vehicle operating costs, crash costs and environmental externalities.

4.4.8 Global assumptions

The table below outlines the core assumptions that were adopted in undertaking the CBA:

Table 21: Global assumptions for CBA

Type	Description	Assumption	Source
Evaluation parameter	Discount rate	7% real, with sensitivity at 4% and 10%	Infrastructure Australia
	Evaluation period	To perpetuity using terminal value. Core evaluation period of 30 years from 2019	ATAP Section 2.4 (T2 CBA)
	First year of full benefits	2025	Assumed first year of deployment of AEVs
	Annualisation factor	285.6 days per year	ATAP - Mode Specific Guidance – Table 7 of M1: Public Transport

4.5 Cost-Benefit Analysis

This section presents the results of the cost-benefit analysis (CBA) of each of the options and provides supporting discussion.

4.5.1 Options summary

The table below provides a concise description of the options assessed as part of the CBA:

Table 22: Description of options assessed in CBA

Option	Description
Base Case	AEVs are not deployed, and investment and regulation by Government is at existing levels.
Option 1	AEVs predominately privately owned by individual households.
Option 2A	AEVs predominately fleet owned in a door-to-door model with minimal government intervention.
Option 2B	AEVs predominately fleet owned in a door-to-door model with government pricing intervention to support higher rates of car-pooling.
Option 3A	AEVs predominately fleet owned, with government subsidisation of on-demand feeder services for public transport, and early investment in public transport infrastructure and services to drive mode shift.
Option 3B	AEVs predominately fleet owned, with government subsidisation of on-demand feeder services for public transport. Investment in public transport infrastructure and services is deferred, with a $10 CBD cordon charge implemented to drive mode shift.

For further description of the options refer to Section 4.2 for modelling assumptions and Section 4.3 for cost assumptions.

4.5.2 CBA results

The table below presents the core findings of the CBA:

Table 23: Summary of CBA results at 7 per cent discount rate

Option	Benefit-Cost Ratio	Net Present Value
Option 1 - Private Ownership	-1.7	-$21.5 bn
Option 2A - Fleet Ownership	-0.1	-$6.9 bn
Option 2B - Fleet Ownership (Subsidised Carpooling)	4.4	$21.7 bn
Option 3A - Mobility as a Service (Early PT Investment)	5.0	$39.6 bn
Option 3B - Mobility as a Service (Deferred PT Investment)	6.5	$45.7 bn

The results presented above are the outputs of the CBA which compared each option against a non-AEV Base Case. This involves measuring the difference in costs (e.g. travel time, crash costs, infrastructure investments, etc) between each option and the Base Case. Where reductions in user costs, such as travel time, are projected for an option compared with the Base Case, this is considered a benefit.

Option 3B presents the highest net present value (NPV) of $45.7 billion, as well as the highest benefit-cost ratio (BCR) of all options of 6.5 at a 7 per cent discount rate in perpetuity.

Option 3A has the second highest NPV of $39.6 billion, with a BCR of 5.0. Option 2B has a slightly lower BCR of 4.4 however the NPV is significantly less at a value of $21.7 billion.

The largest source of benefits across all options are car ownership savings associated with the reduced number of motor vehicles required to be purchased under a fleet model to service an equivalent travel demand. Crash cost savings associated with the improvements to road safety following the deployment of AEVs are also a significant source of benefit.

Options 1 and 2A result in a negative NPV as a result of increased congestion following the deployment of AEVs. The additional trips that were modelled for these options, combined with the trend to longer journeys as a result of lower modelled values of time results in increased travel times for existing car users. Similarly the higher vehicle kilometres travelled by car across all scenarios results in increased vehicle operating costs, where savings in fuel costs are outweighed by increased depreciation and maintenance costs for vehicles due to distance travelled.

Due to the degree of uncertainty, particularly relating to the future costs required to support these options, the focus should be placed on the magnitude of the benefits and the NPV in interpreting these results (as opposed to the BCR as a measure itself). The graphs below present a visual representation of the scale and source of benefits for each option. Further discussion on results is presented below, and detailed CBA result tables for each option are presented in Appendix B.

Figure 16: Benefits Composition Graph - Option 1

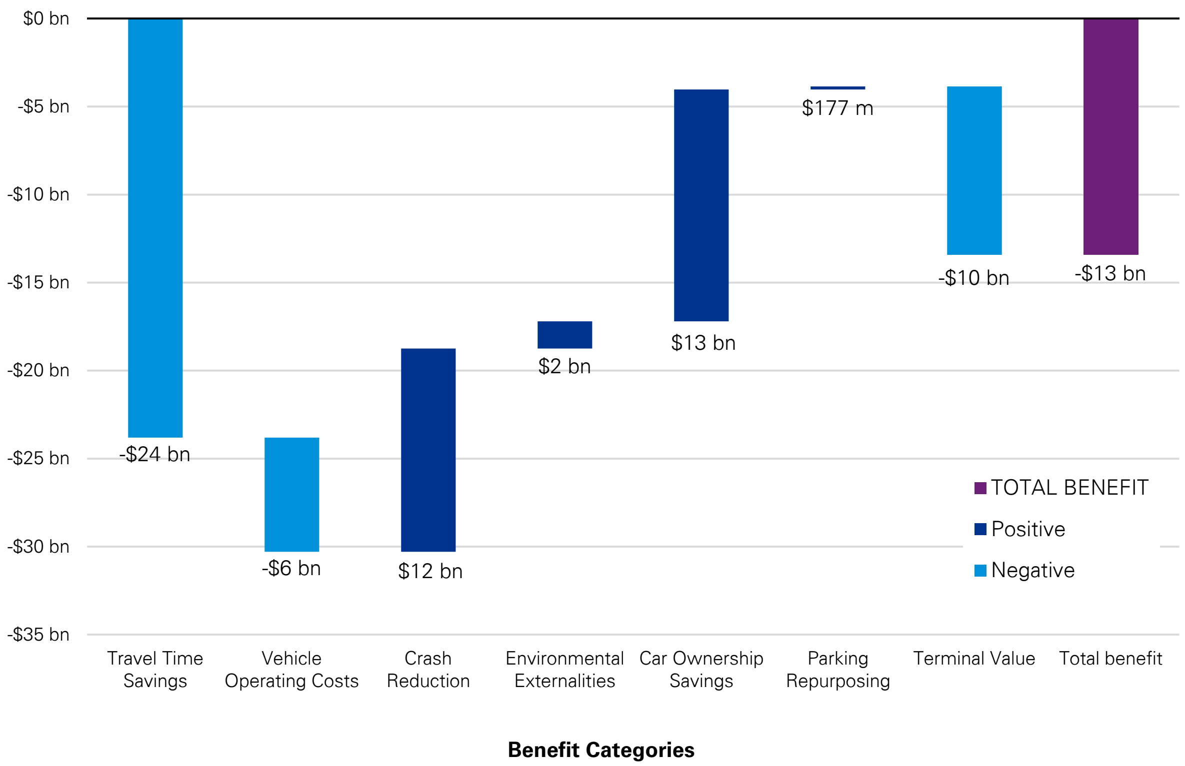


Figure 17: Benefits Composition Graph - Option 2A

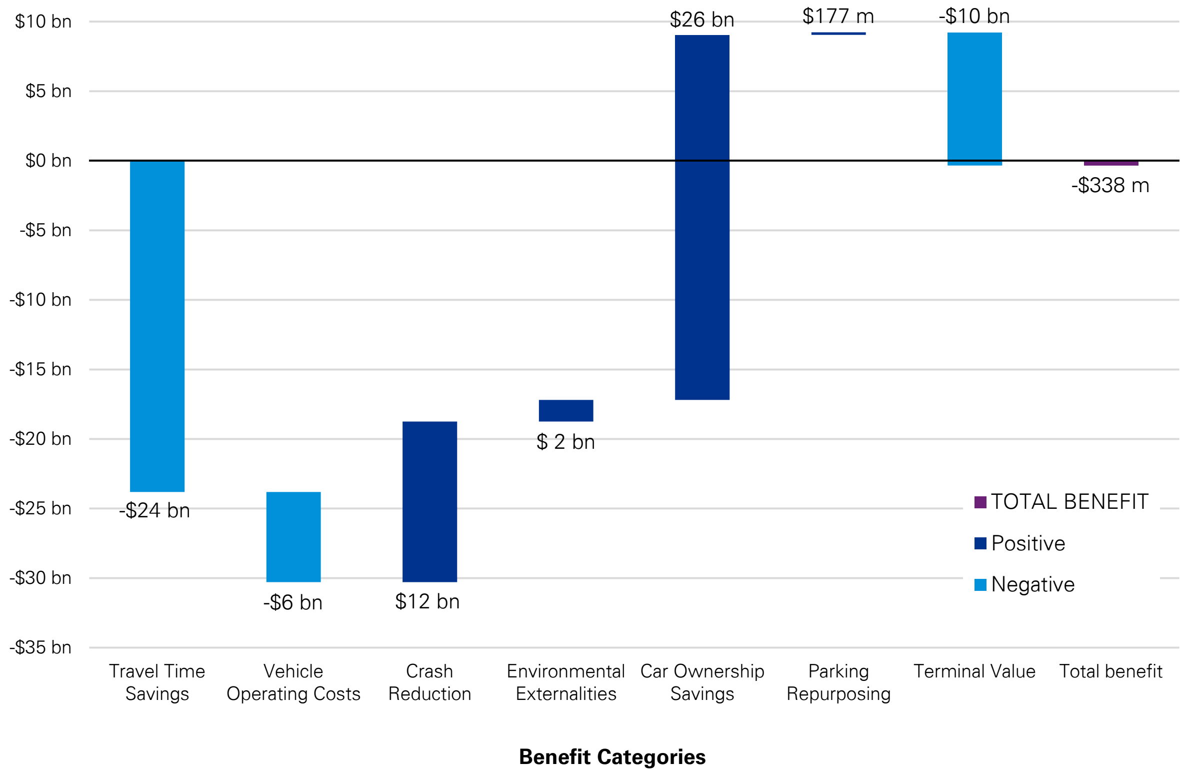


Figure 18: Benefits Composition Graph - Option 2B

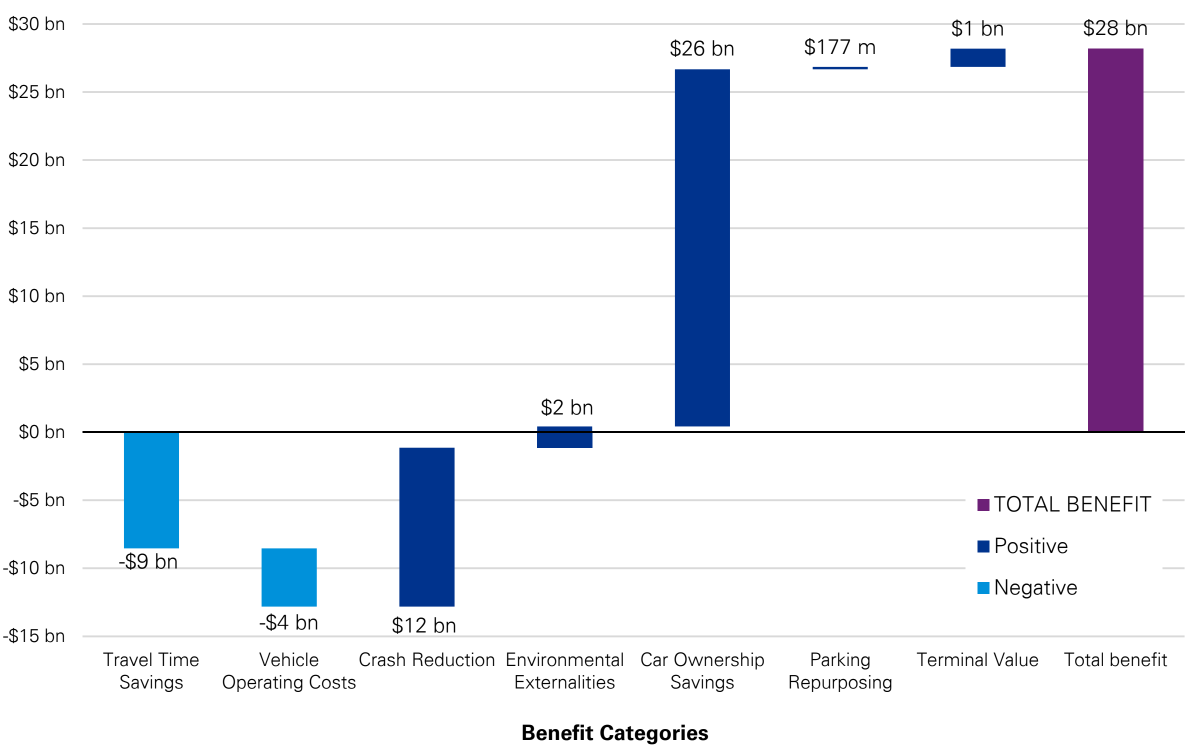


Figure 19: Benefits Composition Graph - Option 3A

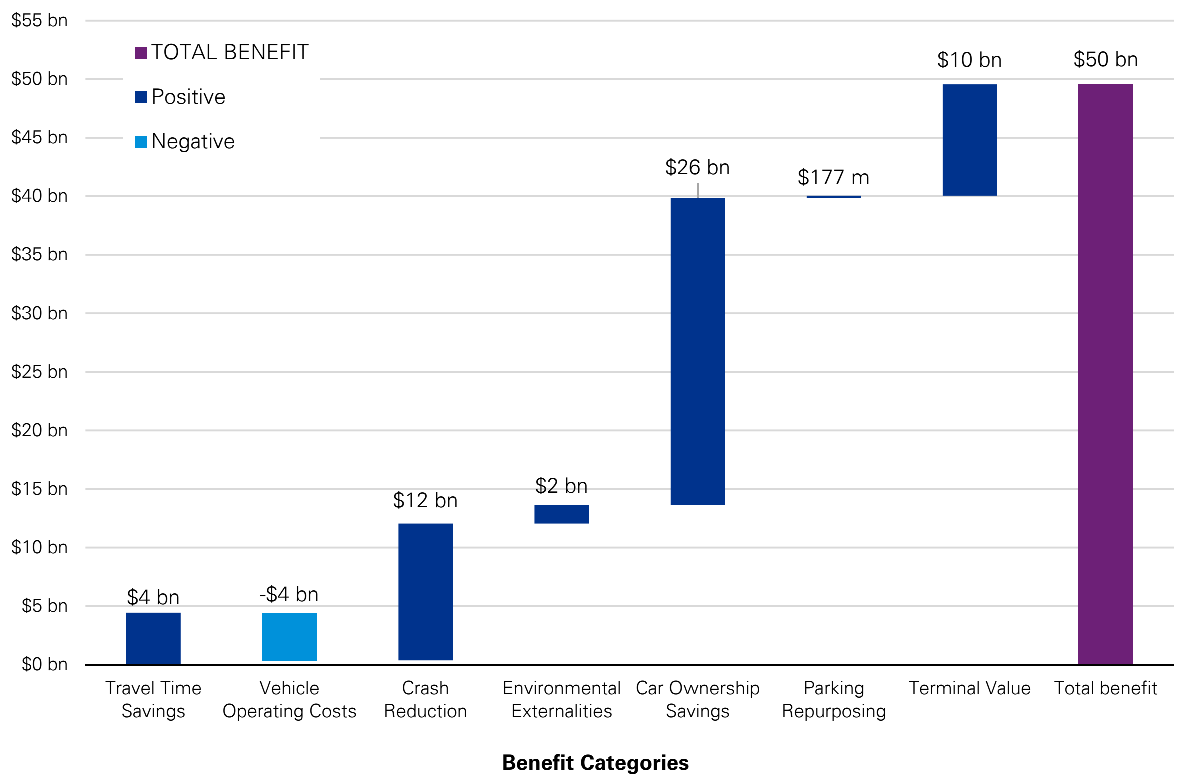
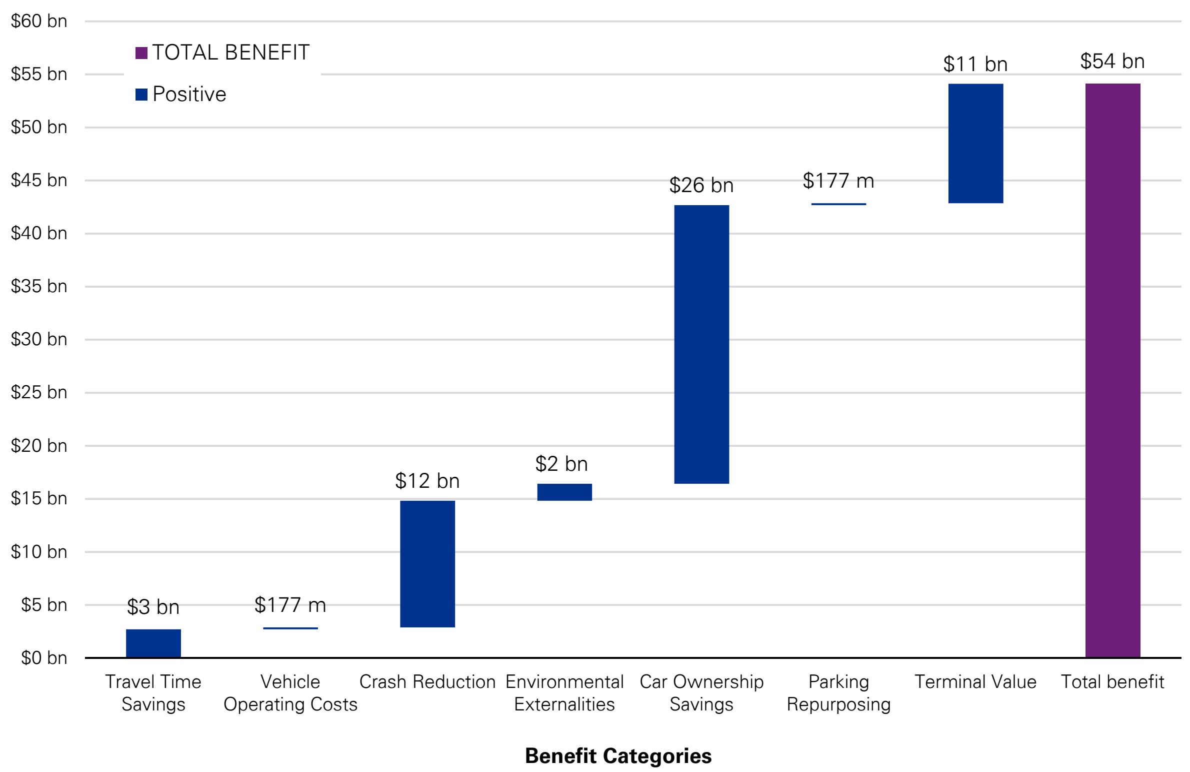


Figure 20: Benefits Composition Graph - Option 3B



4.5.3 Summary of analysis

The non-AEV Base Case scenario presents better travel time performance than either Options 1, 2A or 2B in which door-to-door AEV travel is the prevalent mode. This is a consequence of the increased number of trips induced by the increased accessibility offered by AEVs, with the additional demand outweighing the improved capacity offered by the technology.

Although Option 2A shows greater benefits relative to Option 1, these stem largely from the reduced number of vehicles that would be required to service the same level of travel demand under a fleet operated model. The fleet model greatly increases the utilisation of each vehicle, not necessarily through increased occupancy within individual trips, but through reducing the duration in which each car sits idle during the day.

The additional non-travel benefits associated with the technology in Option 2A (i.e. crash reductions, reduced emissions, and reduced ownership costs) are not sufficient enough to outweigh the reduced travel performance and investment required to deploy AEVs, resulting in a BCR below 0.

Option 2B exhibits a positive NPV and a strong BCR of 4.4, with increased occupancy in trips through a subsidised car-pooling service projected to deliver better performance than Options 1 or 2A. While Option 2B still exhibits increased congestion relative to the non-AEV Base Case, the higher rate of sharing compared with Options 1 or 2A reduces the impact of the additional travel demand projected as a result of AEVs.

The average all-day car occupancy of Option 2B was 1.6 compared with 1.3 or Options 1, 2A and the non-AEV Base Case.

Option 2B results in a positive NPV despite reduced travel performance compared with the non-AEV base case. Although travel time savings are normally critical in determining the success of transport initiatives, in this instance the benefits associated with reduced crashes and reduced car ownership outweigh the increased cost of congestion. Reducing car ownership costs frees up this sizeable household spending for other purposes.

Overall, this analysis suggests that if the efficiency of the technology deployed does not outweigh the travel demand it induces, then an approach of minimal government intervention in transport regulation and services will see increased congestion and a net negative impact on the Queensland economy.

This is further demonstrated through the results of Options 3A and 3B, which both show a strong positive return on investment. These options present with positive net travel benefits as a result of the more efficient use of the transport network by having on-demand transport services affordably shuttle people to public transport nodes along key transport spines.

Option 3B presents both the highest BCR as well as the highest NPV across all options. This is a result of deferring large infrastructure investment by using pricing and regulatory methods to drive travel behaviour changes once automated vehicle technology is deployed.

The pricing mechanism assumed under both Options 2B and 3B has a significant impact on the results of the analysis for these options. The economic costs associated with the implementation of a cordon charge are relatively low, while the travel benefits associated with these mechanisms is pronounced. This results in both a strong BCR and NPV for both of these options. The relative attractiveness of road pricing as a policy instrument is discussed in detail in Section 6.

The use of a subsidised on-demand fleet of AEVs, to replace infrequent feeder bus services and efficiently shuttle commuters to public transport nodes, boosts public transport mode share, and eases congestion. Both Options 3A and 3B result in a projected all-day public transport mode share across SEQ in excess of 10 per cent, compared with only 6 per cent under the private AEV ownership model of Option 1.

Option 3A increases investment in public transport services along key corridors to drive this shift, and achieves a higher projected mode share of 12 per cent in doing so. This results in increased travel time savings relative to Option 3B, although carries sizeable upfront infrastructure costs. Option 3B defers this investment through the use of a road pricing mechanism to drive travel behavioural change, delivering infrastructure and services once it is required from a capacity standpoint.

Both Options 3A and 3B present potential pathways to delivering Scenario 3, which as described in Section 4.1.3 is a MaaS model that supports the integration of AEVs with trunk public transport services along major spines to move large numbers of customers.

The strong BCR and NPV for both of these options indicates that this is the priority scenario to pursue in the context of the form of AEV technology assumed in the underlying transport modelling.

Section 6 will discuss the policy considerations associated with each of the priority Options - 3A and 3B.

4.5.4 Sensitivity analysis

A sensitivity analysis has also been undertaken to illustrate the high-level implications of uncertainty in this analysis. A sensitivity analysis demonstrates the effects of a change in analytical assumptions on key economic decision criteria including BCR and NPV, which is valuable in understanding which benefit streams are driving the CBA results.

The results of the sensitivity analysis for all options are presented below:

Table 24 - Outputs of the sensitivity analysis

Scenario		Option 1	Option 2A	Option 2B	Option 3A	Option 3B
Central Case	BCR	-1.7	-0.1	4.4	5.0	6.5
	NPV	-$21.5 bn	-$6.9 bn	$21.7 bn	$39.6 bn	$45.7 bn
1. Increased Occupancy of AV Carpool (2B Only) #	BCR	-	-	6.9	-	-
	NPV	-	-	$37.1 bn	-	-
2. Car Ownership Savings Omitted	BCR	-3.3	-4.1	0.3	2.3	3.3
	NPV	-$34.7 bn	-$33.1 bn	-$4.5 bn	$13.3 bn	$19.5 bn
3. Travel Benefits Omitted	BCR	4.4	7.5	7.6	4.9	5.9
	NPV	$27.5 bn	$42.2 bn	$42.5 bn	$39.0 bn	$41.1 bn
4. Both Car Ownership and Travel Benefits Omitted	BCR	2.8	3.4	3.5	2.3	2.8
	NPV	$14.3 bn	$15.9 bn	$16.2 bn	$12.7 bn	$14.8 bn
4. Total Cost + 100%	BCR	-0.8	-0.03	2.2	2.5	3.2
	NPV	-$29.6 bn	-$13.4 bn	$15.2 bn	$29.6 bn	$37.4 bn
5. PT Costs + 100%	BCR	-	-	-	3.7	5.2
	NPV	-	-	-	$36.1 bn	$43.7 bn
6. PT Costs + 200%	BCR	-	-	-	2.9	4.3
	NPV	-	-	-	$32.6 bn	$41.7 bn

This scenario uses outputs from a transport modelling scenario run by TransPosition which increases the average occupancy of automated carpool vehicles (subsidised AEVs) from the standard input of 2 to 5 people. This value was selected to align with the average occupancy of the PT Feeder mode in Option 3 which was assumed to be subsidised to the same cost (Translink fares) and was calculated as an output of the model.

In the central case results, car ownership cost savings represent the highest proportion of benefits. Excluding these from the analysis decreases the BCR and NPV of each option, however the order of results is maintained in terms of NPV.

Travel benefits are typically the primary reason for investment in transport initiatives as they often represent the majority of benefits. When travel benefits (including travel time savings and vehicle operating cost savings) are omitted from the analysis the BCR and NPV for Options 1, 2A and 2B increase significantly. This is due to the increased congestion and reduced travel performance that was projected by the TransPosition modelling for these scenarios. The BCR and NPV for Options 3A and 3B decline slightly as these options were projected to alleviate the congestion induced by the introduction of AEVs.

Given the uncertainty associated with the cost inputs for this analysis, a sensitivity analysis was undertaken by increasing all costs by 100 per cent. While this analysis saw the BCRs of Options 3A and 3B decrease, the relativity to other options remained the same and these two options still presented the highest NPVs.

A separate sensitivity analysis was undertaken to assess the impact of increasing the costs associated with improving public transport services and infrastructure. Two analyses were performed to assess a 100 per cent increase in costs, as well as a 200 per cent increase in costs. Both of these analyses demonstrated a decline in the BCR and NPV, however both Options 3A and 3B still present with NPVs higher than any other option even at a 200 per cent cost increase for public transport investment.

The sensitivity analysis highlights the relative degree of uncertainty implicit in the assumptions underpinning this analysis. The results vary significantly depending on the parameter benefit measures tested, and highlights the importance of further analysis to better understand the implications of AEVs on the value of travel time parameters and subsequently travel behaviour.

5 Financial appraisal

5.1 Overview

This chapter presents the results of a high-level financial analysis of Queensland Government revenue and expenditure under each of the options modelled. The analysis looks at the nature of the financial implications of the potential government actions that comprise the strategic options with respect to government revenue and expenditure, it does not provide a detailed comparative analysis of the options.

Unless otherwise noted the financial analysis is presented in state-wide terms due to the difficulty of accurately disaggregating state revenue into discrete regional areas (e.g. SEQ). While fuel excise is often cited as a revenue stream that will be impacted by the increased adoption of electric vehicles, it is a Commonwealth Government revenue source and as such will not be considered in this analysis.

Many of the revenue or expenditure items presented below use the strategic transport modelling provided by TransPosition as a key input to calculations. As described in the economic appraisal, the travel projections output by the model are dependent on a large range of factors including; land use changes, travel behavioural changes, future acceptance of flexible working arrangements, future infrastructure and service investment, and the form of future technologies.

Accordingly, there is a large degree of uncertainty associated with strategic transport modelling for future scenarios as a result of the interdependencies. An appreciation of this uncertainty should be held when interpreting the results of the financial analysis.

All results presented below are intended to inform policy-based decision making and should not be used in making future investment decisions.

5.2 Analysis results

5.2.1 Vehicle registration duty (Transfers)

Description of item and approach to analysis

Vehicle registration duty is paid whenever a new or used vehicle is registered, or ownership is transferred. The amount that is paid is dependent upon the type of vehicle that is being registered, and its 'dutiable value'.

A typical value for individual payment of $840 is assumed for a non-AEV (four cylinder), while a value of $560 is assumed for electric vehicles based on the Queensland Government online vehicle registration duty calculator.[69] The revenue is calibrated to the estimated actual revenue of $543.0 million reported for 2017-18 in Budget Paper 2 for the 2018-19 Queensland Budget.[70]

[69] Queensland Government, 2018, *Vehicle registration duty calculator*, Online, Accessed 15 June 2018, <https://www.qld.gov.au/transport/registration/fees/duty/calculator>

[70] Queensland Budget, 2018, *Budget Paper 2*

The approach undertaken by KPMG estimates the revenue sourced from private vehicle registration duty, and then scales this up to account for commercial vehicle registration based on the equivalent ratio for 2018. Private vehicle registration duty revenue is projected using an estimated number of car transfers each year. This value is based on a car ownership rate of 1.77 vehicles per household for Greater Brisbane based on the 2016 Census, the projected number of households to 2036 by the QGSO and an assumed average lifespan of ten years for a vehicle.[71]

The difference between the estimated revenue from private vehicle transfers and the reported revenue for 2017-18 from the Budget is assigned to commercial vehicle transfers, with this proportion between private and commercial vehicle revenue adopted for future year projections.

AEVs are assumed to commence deployment from 2025, with full take-up by 2035. Under a private ownership model it is assumed that car ownership per household declines by 20 per cent to take advantage of the efficiencies in travel that AEVs present to users.

Under a fleet model, the number of private vehicles declines to 25 per cent of value projected for non-AEVs. This assumption is based upon the maximum proportion of travel in a peak period in SEQ of 23 per cent from the South East Queensland Household Travel Survey, with an additional 10 per cent allowance to account for maintenance and breakdowns in fleet vehicles.[72]This would see the projected number of cars in South East Queensland in 2041 decline from 3.51 million under the non-AEV scenario to 2.81 million under a private ownership AEV scenario, or to only 878,000under a fleet ownership AEV scenario.

Two scenarios are considered for the fleet model, one in which the registration duty fees are retained as existing, and another in which the vehicle registration duty fees for privately owned non-AEVs increases once AEVs are deployed in 2025. This scenario, where increased registration applies to non-AEVs, has been identified as one potential policy lever through which Government can encourage the implementation of the fleet model.

The projected vehicle registration duty revenue under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 25: Financial impact of changes in vehicle registration duty across each option

Analysis Period	Non-AEV Base Case	Option 1	Fleet Options No registration change	Fleet Options Registration increase for private ownership
2018-19	$543 m	$543 m	$543 m	$543 m
2041	$1,448 m	$772 m	$241 m	$241 m
2041 Difference to Base Case	-	-$676 m	-$1,207 m	-$1,207 m
30 Year Total (2018-2048)	$34,288 m	$25,120 m	$13,932 m	$17,518 m
30 Year Difference to Base Case	-	-$9,168 m	-$20,355 m	-$16,769 m

[71] Jericho, G, 2017, *Australians still love buying new cars, even when wage growth is low*, 1 August 2017, The Guardian.

[72] TMR, 2009, *Travel in South East Queensland: An analysis of travel data from 1992 to 2009*

5.2.2 Motor vehicle registration (renewal)

Motor vehicle registration is an annual payment to renew the registration of an existing motor vehicle, for both commercial and private vehicles. Currently when registration renewals are paid a 'Traffic Improvement Fee' of $54.15 is collected.[73]

A typical registration renewal fee for a private 4-cylinder vehicle, excluding compulsory third party insurance, is $365, while the value for an electric vehicle was assumed to be $244 based on a single cylinder vehicle.[73]

The revenue is calibrated to the actual revenue of $1.8 billion reported for motor vehicle registration for 2017-18 by TMR. This value includes 'miscellaneous motor vehicle fees', as well as 'conditional registration fees'. For this analysis revenue from the 'Traffic Improvement Fee' is included which is an additional $221.0 million for 2017-18 as reported by TMR.

The projected revenue under each scenario is based upon the method for estimating the number of vehicles of each type (conventional and AEV), as well as commercial and private proportions of the revenue stream as outlined in Section 5.2.1.

The projected motor vehicle registration (renewals) revenue, including the 'Traffic Improvement Fee' under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 26: Financial impact of changes in motor vehicle registration (renewals) across each option

Analysis Period	Non-AEV Base Case	Option 1	Fleet Options No registration change	Fleet Options Registration increase for private ownership
2018-19	$2,066 m	$2,066 m	$2,066 m	$2,066 m
2041	$5,667 m	$3,121 m	$975 m	$975 m
2041 Difference to Base Case	-	-$2,546 m	-$4,692 m	-$4,692 m
30 Year Total (2018-2048)	$134,163 m	$90,052 m	$51,723 m	$65,756 m
30 Year Difference to Base Case	-	-$44,111 m	-$82,440 m	-$68,407 m

5.2.3 Driver licence fees

Drivers licence fees are charged on an irregular basis, ranging from annually to every five years depending on individual preferences. This analysis adopts an annual value of $45.38 based upon a three year licence costing $136.15.[74]

[73] TMR, 2018, *Quote for registration*, Accessed 25 June 2018, <https://www.service.transport.qld.gov.au/quoteforregistration/application/EnterQuoteType.xhtml?dswid=4824>
[74] TMR, 2018, *Licence Fees*, Accessed 25 June 2018, <https://www.qld.gov.au/transport/licensing/driver-licensing/fees>

This analysis assumes that there is 1.67 registered conventional vehicles (i.e. non-AEV) per licenced driver. This value was attained from the TMR based on the number of licence holders and registered vehicles as of August 2017.

The analysis is calibrated to the actual drivers licence fee revenue from 2017-18 of $164.0 million, and the estimate for 2018-19 of $170.0 million as provided by TMR.

The projected revenue under each scenario is based upon the method for estimating the number of vehicles of each type (conventional and AEV) as outlined in Section 5.2.1. This analysis only considers the likely impact of the introduction of AEVs on drivers licence fees, and does not consider varying rates of take-up in licencing across age groups.

The projected licencing revenue under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 27: Financial impact of changes in drivers licence fees across each option

Analysis Period	Non-AEV Base Case	Option 1	Fleet Options
2018-19	$170 m	$170 m	$170 m
2041	$454 m	$0 m	$0 m
2041 Difference to Base Case	-	-$454 m	-$454 m
30 Year Total (2018-2048)	$10,745 m	$2,881 m	$1,717 m
30 Year Difference to Base Case	-	-$7,864 m	-$9,028 m

5.2.4 Public transport farebox

Public transport farebox revenue represents the payments by public transport users through cash or electronic transfers based on the TransLink fare structure.

The projected public transport farebox revenue for SEQ is calculated on a per trip basis, calibrated to the actual revenue of $343.0 million for 2017-18 by the TMR, and an estimated revenue of $344.0 million for 2018-19.

Used in conjunction with trip numbers interpolated from the 2016 and 2046 transport modelling, this results in a unit rate of $1.62 revenue per trip. While this value is less than a standard single zone TransLink fare, it accounts for concessional trips such as those made by seniors and school students.

This unit rate was then applied to future projected trip numbers under each scenario. This includes the ‘PT Feeder’ vehicle class in the MaaS scenario for Options 3A and 3B.

The projected farebox revenue under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 28: Financial impact of changes in public transport fare revenue across each option

Analysis Period	Non-AEV Base Case	Option 1	Option 2A	Option 2B	Option 3A	Option 3B
2018-19	$344 m	$344 m	$344 m	$344 m	$344 m	$344 m
2041	$1,109 m	$1,098 m	$1,098 m	$1,390 m	$2,101 m	$1,584 m
2041 Difference to Base Case	-	-$10 m	-$10 m	$281 m	$992 m	$475 m
30 Year Total (2018-2048)	$25,517 m	$25,312 m	$25,312 m	$31,036 m	$44,994 m	$34,840 m
30 Year Difference to Base Case		-$205 m	-$205 m	$5,518 m	$19,477 m	$9,322 m

5.2.5 New road pricing revenue

Options 2B and 3B introduce road pricing mechanisms to drive the desired outcomes of their respective scenarios. This is modelled directly in Option 3B as a $10 cordon charge for the Brisbane CBD to encourage public transport usage, while in Option 2B a pricing mechanism is assumed as necessary to drive increased car occupancy.

Projected revenue from these options has been calculated using the projected number of car trips. This value is then scaled down by the proportion of trips that are work commute trips (27 per cent) from the SEQ Household Travel Survey, and the proportion of work trips into the Brisbane CBD (30 per cent) based on the 2016 Census.[65]

A scaling factor of 0.25 is applied to calibrate projected revenue in 2016 with that reported for the London congestion charge if an equivalent toll price was implemented.[75] This calibration factor is to account for the number of trips that occur within the cordon charge area given that modelling outputs do not contain geographic origin-destination information.

The projected road pricing revenue under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 29: Financial impact of changes in road pricing across each option

Analysis Period	Option 2B	Option 3B
2018-19	$0	$0
2041	$695 m	$680 m
30 Year Total (2018-2048)	$13,866 m	$13,583 m

[75] Badstuber, N, 2018, London congestion charge: why it's time to reconsider one of the city's great successes, The Conversation, 3 March 2018 <https://theconversation.com/london-congestion-charge-why-its-time-to-reconsider-one-of-the-citys-great-successes-92478>

5.2.6 Traffic infringement revenue

Traffic infringements, such as speeding fines, represents a sizeable revenue stream that is dependent upon human fallibility. The introduction and widespread adoption of AEVs should eliminate traffic infringements and the associated revenue through fines.

The actual revenue from Camera Detected Offence Program (CDOP) fines in 2017-18 was $166.0 million as reported by the TMR. An additional $42.0 million in traffic fines were collected by TMR in 2017-18, excluding fine revenue collected by State Penalties Enforcement Registry (SPER). This combined revenue was used to estimate a unit rate of $0.010 per vehicle kilometre travelled for non-AEVs.

The projected traffic infringement revenue under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 30: Financial impact of changes in traffic infringement revenue across each option

Analysis Period	Non-AEV Base Case	Option 1	Option 2A	Option 2A	Option 3A	Option 3B
2018-19	$239 m	$239 m	$239 m	$239 m	$239 m	$239 m
2041	$556 m	$0 m	$0 m	$0 m	$0 m	$0 m
2041 Difference to Base Case	-	-$556 m	-$556 m	-$556 m	-$556 m	-$556 m
30 Year Total (2018-2048)	$13,227 m	$4,612 m	$4,264 m	$4,136 m	$4,124 m	$3,881 m
30 Year Difference to Base Case		-$8,615 m	-$8,963 m	-$9,090 m	-$9,103 m	-$9,346 m

5.2.7 Subsidies to MaaS providers

Options 3A and 3B assume that automated fleet service providers will be subsidised by Government to offer costs equivalent to TransLink fare prices for travel to key public transport nodes.

To estimate the likely scale of subsidy required to achieve this, the current subsidy paid for public transport in SEQ has been adopted as the unit rate for trips.

As operating costs for public transport currently exceeds the farebox revenue, the Government pays an effective subsidy of $7.11 per trip based on the Service Delivery Statement for TMR from the 2018-19 Budget.

This unit rate is applied to the projected number of trips on the 'PT Feeder' mode type which represents the subsidised AEV fleet service to estimate the likely level of expenditure.

The projected subsidies to service providers under each alternative option is presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 31: Financial impact of changes in subsidies to MaaS providers across each option

Analysis Period	Option 3A	Option 3B
2018-19	$0	$0
2041	$2,565 m	$2,133 m
30 Year Total (2018-2048)	$43,719 m	$36,369 m

5.2.8 Road maintenance costs

While road maintenance costs are often perceived as being based on a scheduled timetable of regular works, increased loading and usage can increase both the frequency and costs of routine maintenance.

To estimate the projected changes in maintenance costs for each option, unit rates for road maintenance costs have been used in conjunction with the projected vehicle kilometres travelled.

The relativity of the parameter values was based on those presented in the Transport for NSW Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives.[76] These values are typically used for small scale road projects and as such a reduction factor of 0.1 was applied to account for both the larger scale of network being assessed, and the potential for reduced wear on road surfacing from AEVs.

Table 32: Unit rates for road maintenance

Vehicle Type	Maintenance Unit Rate (c/VKT)
Car	0.45
Rigid Commercial Vehicle	0.56
Articulated Commercial Vehicle	1.92
Public Transport Vehicle	1.05

The projected subsidies to service providers under each alternative option is presented in the table below.

Table 33: Financial impact of changes in road maintenance expenditure across each option

Analysis Period	Option 1	Option 2A	Option 2B	Option 3A	Option 3B
2041	$70 m	$70 m	$62 m	$63 m	$42 m
30 Year Total (2018-2048)	$1,195 m	$1,195 m	$1,062 m	$1,072 m	$716 m

[76] TfNSW, 2013, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives.*

5.2.9 Public transport operating costs

The introduction of AEVs has the potential to reduce the costs to Government associated with operating public transport by reducing staffing expenses.

The proportion of operating costs for public transport dedicated to on-road or rail operations (i.e. excluding customer interface, overheads, and infrastructure) is assumed to be 27.4 per cent based on research undertaken by the Independent Pricing and Regulatory Tribunal of NSW (IPART) in 2015.[77] Of this, only 27.6 per cent of the costs is attributable to the driver.[77]

Based on this it was assumed that 7.6 per cent of operating expenses for public transport could be reduced through the introduction of AEVs across all services. It was further assumed that all existing non-driver crews, such as guards, are retained to continue to provide services to passengers.

Expenditure was sourced from the Service Delivery Statement for the TMR from the 2018-19 Budget.

The projected operating expenditure for public transport under both an AEV and non-AEV scenario are presented in the table below. All figures are presented in nominal terms, with revenue indexed at an assumed rate of 2.5 per cent.

Table 34: Financial impact of changes in public transport operating expenditure

Analysis Period	Non-AEV Base Case	AEV Scenarios
2018-19	$2,789 m	$2,789 m
2041	$4,921 m	$4,550 m
2041 Difference to Base Case		-$372 m
30 Year Total (2018-2048)	$128,291 m	$121,910 m
30 Year Difference to Base Case		-$6,381 m

[77] IPART (2015), *Efficiency of NSW public transport services*, <https://www.ipart.nsw.gov.au/>

Summary

A high-level financial analysis of Queensland Government revenue under each of the options modelled was undertaken. A summary of the results of the analysis are presented in Table 35 below.

Table 35: Summary of projected changes to existing Queensland Government revenue sources

Analysis Period	Non-AEV Base Case	Private Ownership	Fleet Ownership	Mobility as a Service
2018	$3,421 m	$3,421 m	$3,421 m	$3,421 m
2041	$9,234 m	$4,992 m	$2,315 m	$2,800 m
2041 Difference to Base Case		-$4,242 m	-$6,547 m	-$6,433 m
30 Year Total (2018-2048)	$217,939 m	$147,976 m	$96,948 m	$106,092 m
30 Year Difference to Base Case		-$69,963 m	-$120,992 m	-$111,847 m

This table sums the projected revenue from vehicle registration duty, motor vehicle registration (renewals), drivers licence fees, public transport fare revenue, and traffic infringement revenues. No changes to registration rates are assumed beyond escalation at CPI. Potential revenue associated with road pricing is not included in this summary.

From the table above it is clear that if current revenue policies were to be held constant, Queensland Government revenue is likely to substantially decline when AEVs are deployed.

This decline in projected revenue largely stems from the reduced number of AEVs required to service the same level of transport demand impacting motor vehicle registration, particularly renewals. Motor vehicle registration in Queensland is higher than many other states in Australia, resulting in an increased sensitivity to reduced vehicle ownership.

The decline in revenue projected under fleet ownership models is more pronounced due to smaller fleet sizes compared with private ownership. Under a private ownership model it is assumed that car ownership per household declines by 20 per cent to take advantage of the efficiencies in travel that AEVs present to users. Under a fleet model, the number of private vehicles is assumed to decline to 25 per cent of the value projected for non-AEVs to meet peak period demand.

Revenue from traffic infringements as well as drivers licence fees are assumed to decline to zero once AEVs are fully deployed due to their driverless nature.

MaaS options are also assumed to incur additional expenditure in the form of government subsidies to fleet providers to support key public transport routes. The additional recurring expenditure assumed for these options couples with the projected decline in revenue to have a more pronounced fiscal impact.

It is worth noting however that the revenue generated under a feet ownership model may reduce the demand for road infrastructure over the short-term and provide an opportunity for the private sector to deliver road infrastructure in support of government mandates when required. This will reduce government expenditure on road infrastructure which will partially offset the decline in revenue. This is explored further in Section 7.2.3.1.

6 Policy considerations

While CBAs are a powerful tool in informing decision-making, they are only one of a range of measures used in policy analysis. In only considering economic impacts to the whole of society, CBAs can often mask important policy implications which can affect the feasibility of implementing each option.

This is particularly true for the transformative changes to travel behaviour and choices that are assumed under the options assessed in Section 4. This section will identify and discuss broader policy considerations surrounding each of the options considered for analysis.

Land use

One of the most important considerations that sits across all options evaluated in the analysis are the land use outcomes that each option facilitates. While the CBA considered land use to be independent of the transport network, service, and regulation, in practice land use responds to varying accessibility. This can be at a region wide level in terms of patterns of development, as well as at a local level where changes to accessibility for pedestrians can significantly impact the rates of use of retail and public space.

In terms of disruptive mobility technology, one of the modelling outputs for AEVS was an increase in length of travel both in terms of time and distance as a result of a shift in perceived value of time. While this in itself is no certainty, if realised it would likely have the effect of hastening the demand for urban sprawl. If people are content to travel longer, then some of the barriers to living in newer suburbs on the urban fringe are removed.

In the transport modelling provided, this trend of increased trip lengths and durations compounded with induced travel demand from people that were previously unable to, resulted in increased congestion. While this may result through individual preferences, and perhaps even be acceptable to regular commuters, any increase to congestion presents challenges to critical road users such as emergency service vehicles.

Options 3A and 3B which focussed on leveraging automated vehicle technology to support public transport nodes would boost the value of the land at these hubs. Although on-demand feeder services may broaden the effective range of train stations and decrease demand for residential development at these locations, the increased number of pedestrians would present increased commercial opportunities and attractiveness.

Car ownership

Scenarios 2 and 3 both assume that AEVs are primarily owned as part of a fleet service, with private ownership of vehicles declining as the new technology is adopted. This presents a considerable departure from what has been status quo since the post-war period, where the household car(s) presented the best form of accessibility to many people.

As discussed in Section 8, attempting to steer people away from behaviour that has been common across multiple generations can be difficult. This is particularly true when there are few incentive based policy instruments that can be used to drive the behaviour change.

Any regulatory or planning based changes to facilitate the shift away from private ownership are likely to incorporate restrictions to parking availability, either in terms of spaces at households or at destinations. The former would decrease the ease of car ownership, requiring residents to park on-street which can be difficult in dense inner-city areas, while the latter would decrease the utility offered by car ownership.

Regulation of parking is traditionally considered a local government matter, and although able to be guided through state planning objectives the implementation of these policies would be a gradual process with limited immediate impact.

Pricing could potentially be used as a lever through either a levy on parking, or through increased motor vehicle registration. Beyond the clear challenges associated with implementing a new broad based tax, pricing instruments introduce equity considerations for those that have limited alternative travel choices.

The existing personalised transport service options available to commuters in SEQ today have already increased considerably from what existed a decade ago. As these services become more affordable, and more reliable across the region the perceived value of car ownership will decline. Targeted policy measures aimed at increasing travel options for people through on-demand transport, particular outside of peak periods, will further decrease the value in privately owned vehicles.

Car pooling

Option 2B considered measures aimed at increasing the attractiveness of car-pooling as a mode of travel. The potential travel benefits associated with this commuting style has been well established, with HOV lanes already established across many parts of Brisbane in the form of T2 or T3 lanes.

Notably, these historical policy measures have often resulted in minimal change in travel behaviour, with several of the HOV lanes since restored to general use. Car occupancy has proven to be a difficult factor to change and will likely remain so without significant change in pricing signals.

Desire to share passenger cars contrasts with high occupancy in peak hour bus services. It is possible that the deployment of alternative vehicles such as on-demand minibuses or passenger vans may help to overcome this artificial barrier to car-pooling, and bridge the gap between passenger dense buses and low occupancy cars.

On-demand transport

Both Options 3A and 3B assumed that on-demand automated fleet services would be subsidised by government to provide shuttle services to key public transport nodes. In these options the improved accessibility offered by these on-demand services allowed low-frequency suburban bus services to be rerouted to deliver more high-frequency trunk services.

This is a policy that a number of cities across the world are now implementing, with ride-sourcing firm Uber recently proposing a partnership with the NSW Government to encourage train patronage, and reduce demand for commuter car parks.[78]

Where subsidised on-demand transport services are provided in addition to existing public transport services, there are few broader policy considerations for government. Using these subsidised services as an opportunity to rationalise bus services however presents a more challenging pathway. Beyond likely opposition from regular users to the removal of their traditional bus service, there are a range of social equity and accessibility considerations to address. Replacing traditional public transport with an on-demand transport service, particularly one with an online interface, may limit access to elderly citizens who may require additional assistance. Ensuring that the on-demand service provides appropriate levels of accessibility for those with disabilities is also critical.

[78] Daily Telegraph, 2017, *Uber has proposed the state government help it subside rides to train stations rather than build more commuter carparks*, 7 August 2017, <https://www.dailytelegraph.com.au/news/nsw/uber-has-proposed-the-state-government-help-it-subside-rides-to-train-stations-rather-then-build-more-commuter-carparks/news-story/eb117643f7ca7619ecbc1f8341f26779>

Although these concerns present challenges to policy makers, any shift to on-demand transport also presents opportunities to improve accessibility. This has been recognised by the National Disability Insurance Agency who have commissioned Melbourne University to undertake a trial where children with disabilities are offered a choice of transport modes, including Uber instead of a traditional bus service.[79]

While existing ride-sourcing companies have been incredibly successful in creating a consumer base across SEQ in recent years, on-demand travel is still a comparatively small mode type for general commuting. If a MaaS fleet based offering is the preferred scenario, then it is important to ensure that there are few impediments to people being able to take-up this option and forgo the need for a personal car.

Road pricing

Options 2B and 3B both returned strong BCRs, largely as a result of the use of a pricing mechanism. The introduction and operation of a cordon charge (or any other pricing mechanism) has a low cost associated with it, but has a significant impact on travel behaviour and consequently the travel benefits for road users. Road pricing also introduces a new revenue stream for government, either through ongoing user payments or sale of the tolling concession.

The benefits associated with such an approach are clear, however the evidence that not a single city in Australia has implemented such a policy highlights the lack of social licence that such a policy currently faces.

The likely strong public opposition to the introduction of a new road pricing scheme is not considered in the CBA, and underlines why such an appraisal tool should only be used as one of a number of means through which to inform decision-making.

Any such pricing mechanism would also require analysis of equity considerations, with a flat cordon charge as assumed in Option 3B for instance having a larger impact on lower income earners. Beyond reducing the disposable income for these households, a price to enter a key employment centre could act as a barrier to employment opportunities. A cordon charge would also impact all road users, regardless of whether or not commuters have a viable alternative choice of travel. Inner city based commuters for instance are more likely to have a broader range of travel choices (a product of greater accessibility, frequency and reliability of services) available to them than commuters in outer suburbs with limited public transport accessibility.

The opposition to road pricing is strongly linked to the low perceived costs that road users currently face. The introduction of a pricing mechanism under a fleet based model is likely to be easier for government, as these trips already have a perceived cost to users. Passengers who take existing on-demand transport for instance are already used to being charged for their journey.

This is evident through the recent attempt by the Western Australian Government's to implement a 10 per cent levy on Uber trips to fund buy-back of taxi plates.[80] While unsuccessful in their attempt to legislate the levy, it serves as an example that the traditional political obstacles to implementing road user charges are diminished when applied to fleet services.

There are potential competing policy objectives in such an approach. The introduction of a price or levy on ride-sourcing services would present a potential means of funding a subsidy to the same firms to make services to rail stations more attractive and boost patronage. At the same time, the introduction of any levy on ride-sourcing services would limit their attractiveness as an alternative to car ownership.

[79] ABC, 2017, *On-demand shuttle buses to move NSW commuters between home and train stations,* 16 August 2017 <http://www.abc.net.au/news/2017-08-16/shuttle-buses-to-help-nsw-commuters-get-to-train-stations/8811618>
[80] ABC, 2018, *Perth Uber and taxi levy hits dead-end as opposition MPs oppose new fare 'tax',* 16 February 2018, <http://www.abc.net.au/news/2018-02-15/perth-uber-and-taxi-levy-hits-dead-end-as-liberals-oppose-tax/9451100>

Mobility as a Service

The MaaS solution that underpins Options 3a and 3b is driven by the reconfiguration and integration of the transport system to promote multiple-seat journeys and reduce private vehicle ownership. This transport system change represents just one MaaS component and is complimented by the digital infrastructure and business platform to comprise the MaaS service model.

Inherently, the MaaS service model requires the involvement of both public and private sector stakeholders. While the development and operation of the digital MaaS platform (and some transport services) is anticipated to be led by the private sector, government oversight will remain important, particularly where there are key linkages, interdependencies and potential overlap with existing public transport system operations. In Queensland, government has an opportunity to define its roles and responsibilities which will shape the broker-government interface for MaaS in the state.

Notably, and importantly, the MaaS model described above can be delivered completely independently of the introduction of automated and electric vehicle technologies. In fact, a number of the benefits of this model can be realised now, with opportunities to enhance and increase the breadth of impacts once these technologies are introduced. Over the long term, there is significant opportunity for the convergence of emerging vehicle technologies with the current MaaS model.

The advent of AEVs has the potential to cause a shift in the MaaS model due to the significant reduction in the cost of transportation. Lower costs for the provision of public transport, and first and last mile, services may increase the scope and scale of the implementation of MaaS. This will increase the efficiency, reliability and most notably the reach of mobility services - an integrated public transport system will no longer be restricted to dense urban areas.

As a whole, the MaaS service model aligns to the Queensland Government's network optimisation principles and framework; MaaS aims to improve the efficiency of the current transport network by prioritising demand management and improvements to existing assets ahead of constructing new infrastructure. MaaS incorporates real-time network management and provides an alternative to private vehicle ownership while further improving the accessibility and use of traditional public transport modes.

7 Implications for planning and investment

The Queensland Government has a critical role in setting the policy direction for Queensland, and in ensuring that planning and investment decision-making maximises economic, environmental and social outcomes for Queenslanders.

Accordingly, there is an increasing need for Government to review current approaches to the planning, assessment and funding of transport infrastructure and services to identify where emerging trends and uncertainty can be better factored into decision-making. Given the future cannot be predicted, the key question for the Government is:

How can the Government appropriately preserve flexibility to maximise societal outcomes given uncertainty in the future?

To support Government in answering this question, there are a range of factors that need to be considered at each stage of the planning and investment lifecycles – these are described in detail below. Notably, this is not an exhaustive list, rather it should be used as a starting point to identify the range of questions and issues that the Government will need to consider over the short- and long-term.

7.1 Planning

7.1.1 Planning paradigm

Transport planning is critical in supporting the strategic policy direction of Government, and in guiding decision-making and investment.

As with policy, proactive and forward looking planning is important in guiding the development of our cities and regions, however the accelerating (and unpredictable) pace of change means that the traditional static planning paradigm is no longer best practice. There is a growing need for flexibility in planning; planning must be agile and responsive to sudden and unforeseeable change.

In this context, long term multi-modal transport (network, corridor, area, route and link) planning should remain a priority. However, in identifying long term planning objectives, it will be important to commit to shorter-term actions which can be reviewed and revised to respond to current circumstances. Measuring and monitoring performance will also remain a priority for Government.

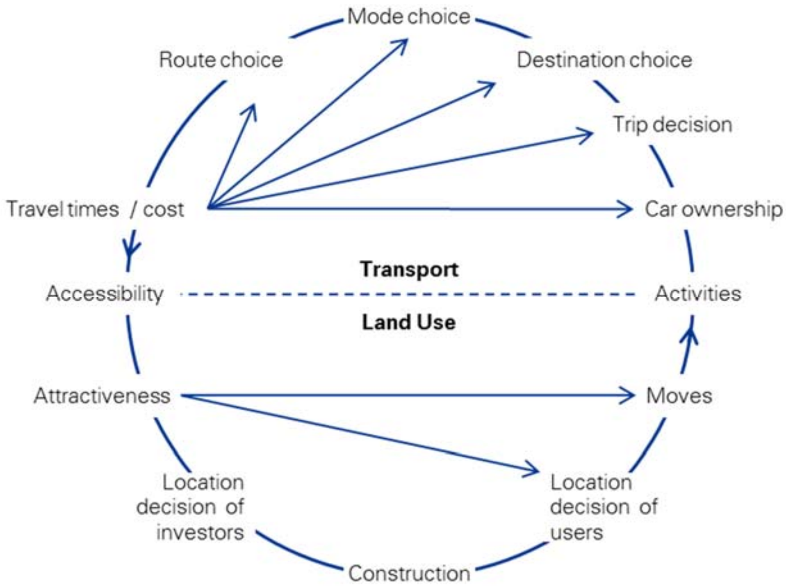
In addition to agile planning, scenario planning will be a valuable tool for government to identify and assess the transport priorities and needs under a range of possible and plausible futures. Scenario planning will assist in identifying the major drivers of change resulting from (and inducing) shifts in land use, technology and travel behaviour that will shape future transport requirements.

7.1.2 Integrated transport and land use planning

The integration between land use and transportation planning has always been recognised as a central feature of good planning, however in the face of significant mobility disruption this integration has never been more important.

As shown in Figure 21, transport and land use are interdependent, and the interaction between the two is defined by the how individuals inform or respond to choices regarding travel behaviour and/or where they choose to live, work and play.

Figure 21: Land use transport feedback cycle



The accessibility effects of AEVs have the potential to significantly change development patterns as increased mobility changes the cost and attractiveness of travel. AEVs can potentially alter the trade-offs that households make between where they choose to live and their daily mobility patterns. Accordingly, these factors should not be treated as exogenous in planning. Transport planning should be integrated with key land use planning priorities and policies to create a shared vision for cities and regions. Within this framework, strategic transport initiatives need to be conceptualised within the context of a preferred urban structure rather than a traditional approach where transport investment simply responds to demonstrated demand.

7.1.3 Transport modelling

Technology-driven trends have the potential to significantly change travel behaviour, however the uncertainty surrounding how this behaviour will change brings into question the appropriateness of modelling techniques used in assessing policy and investment decisions such as those explored in this analysis.

There is an opportunity to leverage more advanced modelling approaches such as land use transportation interaction (LUTI) or activity based modelling to better guide strategic planning and investment decision-making under uncertainty. These approaches help planners understand the land use impacts of investment/policy decisions, and/or the travel behaviour of individuals based on the nature and purpose of each journey. Understanding these interactions will provide a firmer evidence base to guide government investment in infrastructure, not just for transport but for the provision of social infrastructure e.g. schools, medical facilities etc.

CASE STUDY: Melbourne Activity and Agent Based transport Model (MABM)[81]

The Melbourne Activity and Agent Based transport Model (MABM) is a new strategic transport model for Melbourne. The model has been developed as part of Infrastructure Victoria's Managing Transport Demand research program. The model will analyse travel demand patterns for Melbourne now and in the future, and identify the potential impacts of various transport network demand management policy options.

How does it work?

Traditionally, strategic transport models in Victoria use a trip-based approach, which considers the characteristics of aggregated trip types. The MABM is different. It uses an advanced approach developed over the last 25 years by researchers. The MABM:

- **Puts the customer at the centre, person-based rather than trip-based** - the MABM represents each person in Melbourne and their daily travel plans, including when, where and how they will access their various activities. It also includes their demographic characteristics such as age, income and household composition.
- **Able to consider peak spreading impacts** - unlike traditional models, the MABM uses a continuous timescale. As congestion grows people tend to change the times that they travel to avoid congestion. This is known as 'peak spreading'.
- **Focused on plans and activities rather than journeys –** This means it can take into account constraints that are unique to individuals – for example if you need to take a car to work so you can pick a child up from school after work.
- **Able to model the impacts of future transport technology –** By considering the needs and constraints of individuals, MABM has a strong foundation and is uniquely placed to modelling the impacts of emerging travel technology.

The MABM is a significant first for Australia. Watch a demonstration of the model **here**.

7.1.3.1 Modelling considerations

In undertaking transport modelling, planners are required to make a number of assumptions regarding critical factors such as the future geospatial distribution of population and employment. Currently, Queensland Government population and employment projections are modelled without consideration of transport capacity or network constraints. For example, projections may forecast growth in employment in the CBD but not have the infrastructure or capacity to support access to these jobs. Incorporating these constraints into demographic forecasts will be important in better guiding planning and decision-making.

7.2 Investment decision-making

As highlighted, automated and electric vehicle technologies are evolving rapidly, and are likely to have complex and unpredictable effects on consumer behaviour. In the context of the rapidly changing transport environment, there should be a renewed focus on historical investment decision-making and analysis frameworks to incorporate this new risk and uncertainty. In order to do this, consideration should be given to:

[81] http://infrastructurevictoria.com.au/managing-transport-demand

- adjusting current parameters and methodologies used to measure these impacts in economic appraisal
- incorporating scenario analysis into investment appraisal
- using tools such as real options analysis
- alternative funding mechanisms
- alternative approaches to infrastructure delivery.

7.2.1 Economic parameters

The anticipated economic, environmental and social impacts of AEVs will have various likely implications for the economic parameters used in estimating the benefits of transport infrastructure projects.

As described in the economic analysis above, the following components of economic analysis are likely to be affected:

- The valuation of travel time savings may reduce for travellers in AEVs due to increased comfort and convenience, and opportunities to undertake productive activities;
- Vehicle operating costs (and therefore vehicle operating costs savings) may reduce due to lower whole-of-life costs of electric vehicles relative to internal combustion engine vehicles;
- Safety parameters are likely to change – vehicle accident rates per kilometre per road class are likely to decline;
- Environmental parameters are like to change with the widespread adoption of AEVs – rates of air pollution, noise pollution, and greenhouse gas pollution per kilometre are likely to decline;
- 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; 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.

Further to the above, further analysis should be undertaken to identify the potential role of an additional parameter or measure that accounts for uncertainty, and/or recognises the importance of maintaining flexibility.

To support best practice transport assessment, future economic appraisal would benefit from a nationally consistent set of parameter values that incorporate the impacts of AEVs – particularly capturing the uncertainty over the short term. Further research and analysis will need to be undertaken to establish these new parameters, and in some instances new methodologies may need to be developed. Importantly, these parameter values will need to be regularly reviewed and updated as AEVs are deployed and the benefits are realised.

7.2.2 Real options analysis

Real options analysis is an alternative approach to investment decision-making that addresses the potential shortcomings of conventional economic appraisal in effectively capturing uncertainty, and the value of flexibility in the assessment of future mobility disruptions.

Real options analysis incorporates the value of preserving the right to exercise an alternative course of action in the future – a critical consideration for identifying the implementation or investment pathway which maximises the benefits to society. Similar to financial options where a person can sell the right to execute a contract in the future at a fixed rate, real options considers valuation based on the decision makers right to alter a fixed course of action.

With respect to infrastructure decisions, there is inherent value in preserving flexibility which may be required in the future to deal with uncertainty surrounding technology systems, user behaviour or commercial outcomes. In this instance, the uncertainty surrounding the form and pathway of an autonomous transport future is clearly more uncertain than current typical investment decisions. Moreover, the pathway to an autonomous future is filled with many future choices and subsequent decisions which must be made by industry, government and transport network users. Defining future scenarios, and thus assuming the future state is certain for the sake of analysis, omits the very clear fact that the future course is uncharted.

Appendix C further explores how real options analysis can be used in the strategic assessment of future mobility options. The details provided may be useful in guiding future strategic planning and infrastructure or policy evaluation by Government.

7.2.3 Funding

The financial appraisal in Section 4.5.4 demonstrates that the introduction of AEVs is likely to disrupt the existing revenue model underpinning road funding and maintenance in Queensland. At the same time, transport is competing for limited funding, as the Government carefully manages the State's budget to maximise economic and social outcomes, while ensuring that the distribution among sectors delivers the most effective and efficient investment for the State.

There are a number of potential policy responses which may be employed to mitigate the projected financial impact of AEVs and to help fund transport expenditure. As described in Section 4, these mechanisms are also effective demand management measures. Notably, these are intended for discussion and consideration, and do not constitute a recommendation or endorsement of any of these policies.

Policy responses include:

- **Location specific road user charge:** Regulate demand within a defined geographic area. In this type of model, drivers are only charged when crossing the cordon boundary to enter or exit the designated area.

  For example, Stockholm and London's congestion charge zones.

- **Whole-of-network based road user charge:** Applied across the entire road network. In either partial or whole of network schemes, pricing may be applied uniformly across all vehicle classes, or differentially applied based on the type of vehicle, vehicle mass, distance travelled and/ or time of journey.

  Whole-of-network pricing is an advanced road pricing mechanism that can only be enabled once vehicles are equipped with advanced communication technologies such as GPS on-board systems. While it is not practical mechanism for the current fleet of conventional vehicles, the high levels of information and communication technologies that support AEVs will enable the introduction of whole-of-network pricing.

Within these high level responses there are a range of specific design components that will determine the impact on Government revenue (and congestion). Detailed financial analysis should be undertaken to better understand the funding options available to Government, and to further understand the timing considerations of implementation for such mechanisms. This analysis must take into consideration the different models of deployment for AEVs, which will determine to a large degree the ease of implementation for these funding mechanisms. For example, the deployment of a fleet model (whereby pricing is both dynamic and trip based) may reduce a number of the barriers to implementation, including physical infrastructure and community acceptance.

7.2.3.1 Infrastructure delivery

The advent of AEVs has the potential to change to role of government in the delivery and maintenance of transport infrastructure. Linked closely to the discussion regarding funding above, the commercial operation of a fleet model may open opportunities for further Private-Public Partnerships in the provision and operation of road infrastructure. The revenue generated under these models provides an opportunity for the private sector to deliver road infrastructure in support of government mandates. As a result, the ongoing role of government may shift towards brokering transport outcomes, responsible for monitoring system performance and operation to ensure safe, sustainable and efficient transport outcomes. Notably, government's role and focus on policy-setting and regulation will remain critical regardless of the deployment model.

There are likely implications of this change on the Queensland Government's current infrastructure investment program, and highlights the importance of reviewing existing planning and investment appraisal processes (as described above). In line with the objectives of the Government's strategic planning process, the investment decision-making process must be consider the long-term implications of individual investments within the context of the whole transport network, and the coordination of transport projects with broader infrastructure and policy initiatives.

8 Behavioural considerations

Public policy, particularly in transport, is often developed under the implicit assumption that people are rational decision-makers who assess all information available to them during decision-making, and subsequently make decisions that maximise individual and societal outcomes. However, in reality, decision-making actually departs from classic assumptions of rational, cost-benefit calculation, and is based on individual proclivities and limitations.

The study of cognitive science and behavioural economics has uncovered that these, seemingly irrational, behaviours actually occur in predictable patterns which can be categorised into a number of cognitive biases. In the case of travel behaviour and mode choice, individual's make decisions based on a range of factors including known information relating to cost and convenience, in addition to psychological factors such as perceived prestige, safety and privacy.

This has a number of consequences when consideration is given to how society will change their behaviours and adopt to the new mobility environment brought about by AEVs and related business models. As described in results of the economic appraisal, realising the benefits of new mobility requires society to reduce overall car ownership and embrace new vehicle technologies. The speed at which this change occurs hinges not only on technological and regulatory advances, but also on how quickly consumer expectations and behaviours shift.

By understanding key cognitive biases, Government is able to design solutions that respond to how people actually behave, to support the actions described in Section 4.1. While separate, these tools complement conventional policy initiatives (such as the provision of incentives, or restricting choice) by acknowledging the importance of choice in guiding and supporting behavioural change. Constructing choices and framing new mobility options in ways that encourage behavioural change will help ensure that the anticipated benefits of AEVs and subsequent changes in mobility patterns can be maximised.

8.1 Car ownership

Societal attitudes towards car ownership has the potential to be a significant barrier to the adoption of changes in mobility. For many, particularly in Western cultures, owning and driving a car is a rite of passage and a symbol of freedom and prestige. Car ownership is embedded in our identity, it provides independence, autonomy, and is associated with privacy and comfort.

In addition to the resistance that is likely to occur due to the aforementioned factors, there are a number of cognitive biases that will further increase an individual's reluctance to relinquish their personally owned cars, due in large to the value placed on existing assets and choices:[82]

- Individuals have a tendency to prefer avoiding a loss to acquiring a gain, unless this can be compensated by important rewards;
- Individuals have a strong preference for what we already own, regardless of the objective market value; and

[82] Kahneman, D., Knetsch, J., & Thaler, R. 1991. *Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias,* Journal of Economic Perspectives, 5(1), pp. 193-206.

- Because we overvalue current benefits (and undervalue potential gains), individuals favour the current state relative to alternative scenarios.

Further, the transition from privately owned to shared mobility is not a simple, equivalent trade between tangible products. Rather, the change is a direct substitution of a tangible product with an intangible service. This is a significant and unfamiliar adjustment, which is likely to intensify the resistant to change.

8.2 Adoption of Automated Electric Vehicles

While the transition to AEVs is likely to be incremental, the shift will be significant. By eliminating driver control, passengers will be required to fully trust the technology, and in the effectiveness and reliability of its performance. Apprehension towards the adoption of AEVs can be attributed to two risk-related cognitive biases.[83]

Firstly, individuals are usually poor at assessing risk, and have a heightened sense of risk when presented with something new and uncontrollable. Individuals perceive risk along two emotional dimensions – "dread risk" associated with a perceived lack of control whereby the consequences of an incident could be inequitable and severe, and "unknown risk" relating to hazards judged to be new, unobservable, and/or unknown to those affected. In the case of AEVs, the risk posed by the new technology is currently unknown to the consumer and users are required to trust the technology by relinquishing control.

As anticipated, based on current known and published information, there is a low level of trust for the safety of AEVs. This can be attributed to the fact that individuals can rationalise the risk of a car accident in a conventional vehicle by considering human fallibility caused by factors such as fatigue, distractions, or impairments caused by alcohol or drugs, while the non-discriminatory and chance event of a technology fault cannot be predicted or managed against. Preliminary findings from the Australian National Survey of Public Opinion about Automated and Driverless Vehicles, revealed that 78 per cent of respondents indicated that they were 'concerned' or 'very concerned' about the ability of AEVs to perform safely in all conditions.[84]

Secondly, individuals tend to overemphasise the likelihood of certain events by relying on information that immediately comes to mind, or is easily available. This effect is known as the availability heuristic, or bias. This heuristic is observed in common perceptions of catastrophic but statistically rare events. For example, in the instance that an AEV has a highly publicised accident, individuals may easily associate AEVs with high safety risk even though the occurrence is extremely rare. Importantly, media coverage of events such as these exacerbate this bias and further increase the resistance of society to change (see case study below).

[83] Tveersky, A., & Kahneman, D. 1975. *Judgement under uncertainty: Heuristics and Biases.* Science, 185(4157), pp. 1124
[84] Australia & New Zealand Driverless Vehicle Initiative, 2017, *Preliminary findings from the first Australian National Survey of Public Opinion about Automated and Driverless Vehicles.*

Case Study: Trust in Automated Vehicles[85]

In March 2018, a self-driving vehicle failed to avoid fatally hitting a pedestrian in Arizona during a test trial performed by Uber. The media interest and extensive coverage of the accident has increased the perception that AVs are unsafe, despite the probabilistic fact that AVs are safer than current conventional vehicles (due to the elimination of human error).

As anticipated, consumer confidence and trust in AVs has fallen since the accident. According to a survey by the American Automobile Association, following the accident, 73 per cent of drivers claimed they would be too afraid to ride in an automated vehicles, up from 63 per cent in late 2017. Notably, incidents of this nature are likely to increase the regulatory scrutiny over safety testing in AVs, and should in fact lead to enhanced safety outcomes.

8.3 Overcoming cognitive biases

Strong emotional attachments and cognitive biases are not simple to overcome. However, measures can be taken to carefully construct how information and choices are presented, which may help guide better decision-making and influence behavioural outcomes.[86]

In the context of new forms of mobility and the required behavioural changes, Government would benefit from developing an engagement strategy to inform government policy and messaging. There are a wide range of approaches available to Government to prompt behavioural change and guide this strategy, for example measures could include:

- Frame choices in the context of what an individual would miss by not changing behaviour or adapting, such as the annual amount saved on transport expenditure by giving up private vehicle ownership.
- Promote and market the aggregate impacts of a behaviour change over an expanded timeframe to demonstrate the magnitude of the anticipated benefits, such as the number of lives saved over a 10 year period following the adoption of AEVs.
- Customise messaging to compare desired behaviour changes of an individual (or household) to that of similar customers who live or work nearby, such as the additional amount of time a neighbour saves by using integrated public transport services through MaaS for their daily commute.
- Encourage the uptake of new mobility models by marketing them as the "social norm".
- Promote the fact that the benefits of reduced car ownership or AEVs can only be comprehensively realised if there is widespread behaviour change - every person counts.

While the interventions described above are intended to support and enhance the policy and investment decisions described in Section 4.5.3, they can be implemented in advance, and in isolation, of these decisions.

In fact, there is an opportunity to proactively engage with the community (prior to the introduction of AEVs) to work towards overcoming potential cognitive biases and barriers, particularly relating car ownership. This has the potential to generate some benefits now, while also supporting the future transition to new modes and forms of mobility. Accelerating the adoption of new technology has the potential to support the early realisation of benefits.

[85] American Automobile Association, May 2018, *Vehicle Technology Survey.*
[86] These strategies are based on the theory of "choice architecture", a concept originating from the research of psychology and cognitive behaviour by Richard Thalar and Cass Sunstein.

9 Looking ahead

As described through the narrative of this report, the introduction of disruption mobility technologies has the potential to deliver significant benefits to society. However, the degree to which these benefits are realised is dependent on the actions (or inactions) of Government and industry.

The economic analysis undertaken suggests that if the efficiency of automated vehicle technology does not outweigh the travel demand it induces, then an approach of minimal government intervention will see increased congestion and a net negative impact on the Queensland economy. While this analysis is preliminary in nature, the results indicate that there are gains from proactively planning, and highlights the opportunity ahead for Government to work together with industry to achieve a common vision.

With reference to the strategic options, the economic appraisal indicates that Options 3A and 3B will deliver the greatest return on investment in terms of net present value to the Queensland economy. These options present two alternative pathways to delivering approximately the same transport outcome for SEQ – Mobility as a Service.

As highlighted throughout this report, achieving the desired future transport outcome has implications for the functions of TMR as a department, and the policy direction guiding transport planning and investment in Queensland. While Option 3A and 3B achieve a relatively equivalent outcome, they are underpinned by disparate policy positions. Option 3A leverages incentives to motivate behaviour change through the provision of greater choice and higher quality of services, while Option 3B uses disincentives through pricing mechanisms. This poses a challenge to policy-makers, who will be required to re-evaluate Queensland's policy platform in the context of future disruption.

9.1 Recommendations

Based on the analysis, and with reference to the broader transport and technology trends explored within this report, there are a series of recommendations Government may wish to consider. Importantly, these recommendations do not constitute policy or investment decisions. Rather, they are intended to guide further analysis that will provide a strong evidence base to support the Queensland Government in effectively responding to emerging technological disruptions.

Recommendation 1: Undertake further analysis into the preferred option.
1(a). Refine economic assumptions and modelling As indicated in this report, there were a number of limitations resulting from the economic assumptions and parameters underpinning the transport modelling. To support any future economic appraisal it is recommended that: • the model is tested with user defined input data and model parameter values which support the testing of different variables (e.g. vehicle occupancy under a fleet model); • and the modelling assumptions are further refined.

Recommendation 1: Undertake further analysis into the preferred option.

1(b). Undertake a strategic-level real options analysis

It is recommended that TMR undertake further strategic analysis, leveraging the principles of real options analysis, to articulate the full range of decision pathway/s (implementation pathways) available to Government to achieve Scenario 3.

The decision pathway/s should identify the incremental or "staged" actions (e.g. policy or investment initiatives) Government could take to support the achievement of Scenario 3. These pathways should be tested against different potential future uncertainty scenarios to identify how Government can effectively preserve the flexibility to adapt to emerging technology and future changes in network demand over the long-term.

The Queensland Government, in partnership with Data61, have defined a series of future uncertainty scenarios for Queensland transport. These scenarios provide a useful and pragmatic strategic setting that could be used to support this analysis.

Where appropriate, complementary studies being undertaken by TMR (such as the MaaS Roadmap and the Automated Freight modelling) should also be incorporated into this analysis.

The results of this strategic real options analysis should provide guidance to TMR regarding what actions are of immediate priority, and are appropriate for detailed investigation over the short-term.

1(c). Assess feasibility of short-term actions.

Based on the outcomes from 1(a), it is recommended that TMR evaluate the feasibility of the identified priority actions, and where required, refine the geographic scope for potential implementation or delivery.

1(d). Undertake a detailed financial analysis to better understand the potential financial impact of AEVs to Government under Option 3.

It is recommended that TMR undertake further, more detailed, financial analysis to estimate the potential impact of AEV uptake (in alignment with the assumptions underpinning Option 3, and the outcomes of Recommendation 1(a)) on long-term Queensland and local government revenue flows and long-term government expenditure.

As indicated by the outcomes of the high-level financial analysis in this report, the impact of AEVs is likely to require governments to reconsider the viability of current revenue arrangements, and to consider where new policy responses may be required.

Recommendation 2: Assess implications of emerging vehicle technologies in rural and regional areas.

2(a). Undertake strategic analysis to assess the implications of emerging vehicle technologies in rural and regional areas.

It is recommended that TMR undertake a strategic analysis to assess the implications of emerging transport technologies in rural and regional areas, in addition to identifying the unique service models and strategic opportunities that exist for the deployment of this technology.

Combined, the rural / regional and urban analysis provides Government with a whole-of-state overview of the impact of emerging technologies and subsequent mobility disruptions.

Recommendation 3: Develop a communications and engagement strategy to promote travel behaviour change.
3(a). Develop a communications and engagement strategy to promote travel behaviour change. It is recommended that TMR develop a communications and engagement strategy which focuses on measures targeted at overcoming potential cognitive biases that may inhibit the full realisation of the benefits of emerging technology and new forms of mobility. This strategy should identify both short and long term actions, with the intention of promoting positive behavioural change prior to the introduction of AEVs. As appropriate, components of this strategy should be integrated into the Queensland Transport Strategy (QTS) communications and engagement plan.

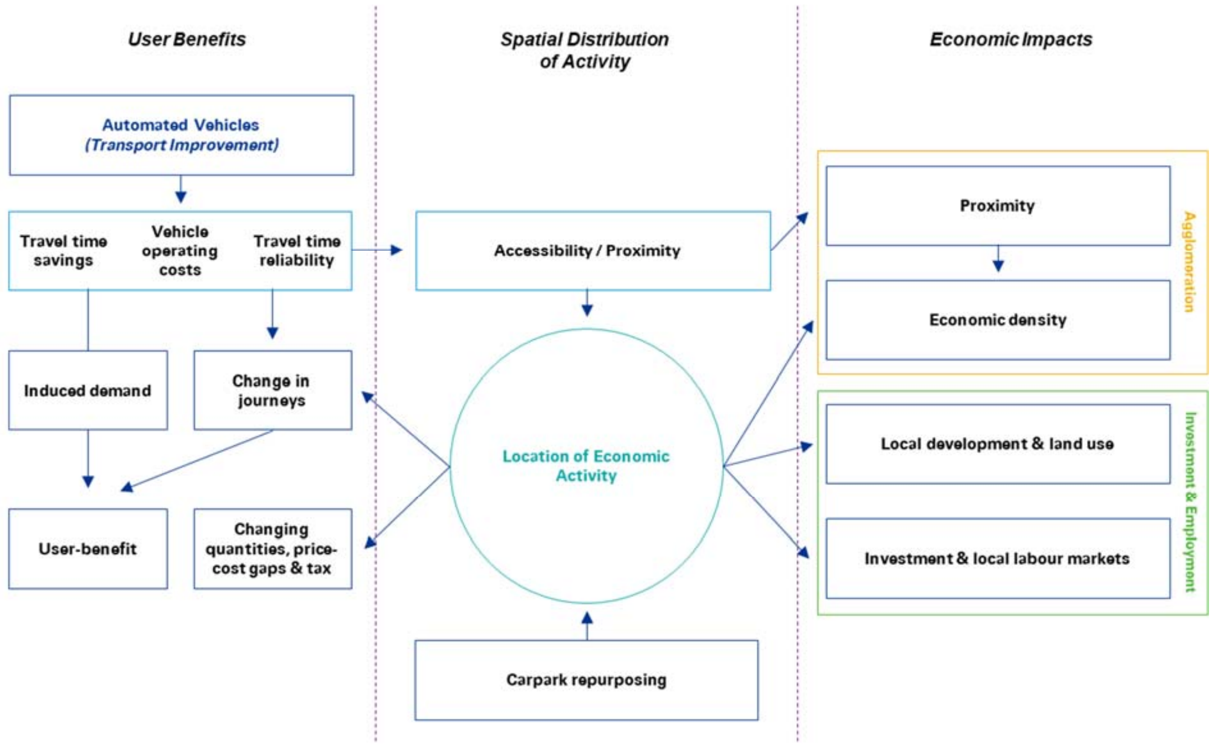
Recommendation 4: Investigate opportunities to promote consistency in transport planning and investment appraisal for initiatives significantly impacted by uncertainty.
4(a). Evaluate existing transport planning framework and guidelines. It is recommended that TMR evaluate existing planning frameworks and guidelines to identify where opportunities exist to better factor in future uncertainty. Consideration should be given to providing further guidance regarding the required timing and recommended process for undertaking the interim review/revision of long-term plans. **4(b). Undertake further research to define a consistent approach for the assessment of transport investments.** It is recommended that TMR further investigate opportunities to define a consistent approach for the appraisal of transport initiatives under uncertainty. Consideration should be given to developing further guidance regarding the economic parameters to be used in economic appraisal, and the modelling requirements that underpin transport analysis.

Appendix A: Economic impact of transport

Transport has a fundamental role in driving productivity, growth and prosperity within an economy. It is an enabler of spatial interactions, improving the accessibility and connectivity between employment and residential nodes. Improvements to transport (through infrastructure, services or technology) reduces the cost of connectivity and costs of production, and promotes greater economic and social activity. It also expands the productive capacity of an area by increasing available resources and allows individuals, firms and industries to operate more efficiently by enhancing the productive capacity of existing resources.[87]

The interplay between the direct and indirect impacts of transport on the economy is summarised diagrammatically in Figure 22 below.

Figure 22: Direct and indirect economic impacts of transport



[87] Munnell, A. H., 1992. *Policy Watch: Infrastructure Investment and Economic Growth.* Journal of Economic Perspectives, 6(4), pp. 189-198.

Appendix B: Detailed CBA results

Option 1 Results

	Benefits/Costs	Discount Rate		
		4%	7%	10%
	BENEFITS			
1	**Car: Private Use**	**-$21,607 m**	**-$11,942 m**	**-$6,892 m**
	Travel Time Savings	*-$14,295 m*	*-$7,901 m*	*-$4,560 m*
	Vehicle Operating Costs	*-$7,312 m*	*-$4,041 m*	*-$2,332 m*
2	**Car: Business Use**	**-$14,341 m**	**-$7,926 m**	**-$4,575 m**
	Travel Time Savings	*-$12,388 m*	*-$6,847 m*	*-$3,952 m*
	Vehicle Operating Costs	*-$1,953 m*	*-$1,080 m*	*-$623 m*
3	**Light Commercial Vehicles (Class 1-2)**	**-$15,046 m**	**-$8,316 m**	**-$4,799 m**
	Travel Time Savings	*-$11,554 m*	*-$6,386 m*	*-$3,685 m*
	Vehicle Operating Costs	*-$3,492 m*	*-$1,930 m*	*-$1,114 m*
4	**Rigid Heavy Vehicles**	**-$2,983 m**	**-$1,649 m**	**-$952 m**
	Travel Time Savings	*-$2,529 m*	*-$1,398 m*	*-$807 m*
	Vehicle Operating Costs	*-$454 m*	*-$251 m*	*-$145 m*
5	**Articulated Heavy Vehicles**	**-$767 m**	**-$424 m**	**-$245 m**
	Travel Time Savings	*-$2,244 m*	*-$1,240 m*	*-$716 m*
	Vehicle Operating Costs	*$1,478 m*	*$817 m*	*$471 m*
5	**Public Transport Vehicles**	**$690 m**	**$381 m**	**$220 m**
	Travel Time Savings	*$690 m*	*$381 m*	*$220 m*
	Vehicle Operating Costs	*$0 m*	*$0 m*	*$0 m*
6	**Active Transport**	**-$752 m**	**-$415 m**	**-$240 m**
	Travel Time Savings	*-$752 m*	*-$415 m*	*-$240 m*
7	**Other Benefits**	**$6,525 m**	**$16,869 m**	**$13,335 m**
	Crash Reduction	*$21,521 m*	*$11,548 m*	*$6,620 m*
	Environmental Externalities	*$2,883 m*	*$1,547 m*	*$863 m*
	Car Ownership Savings	*$21,132 m*	*$13,165 m*	*$8,592 m*
	Parking Repurposing	*$287 m*	*$177 m*	*$112 m*
	Terminal Value	*-$39,298 m*	*-$9,568 m*	*-$2,853 m*
8	**TOTAL BENEFITS**	**-$48,281 m**	**-$13,421 m**	**-$4,147 m**
	COSTS			
9	Operating Expenditure	$6,165 m	$3,584 m	$2,176 m
10	Capital Expenditure	$4,296 m	$3,081 m	$2,251 m
11	Terminal Operating Value	$5,891 m	$1,434 m	$438 m
12	**TOTAL COSTS**	**$16,352 m**	**$8,099 m**	**$4,865 m**
	COST-BENEFIT ANALYSIS			
13 = 8/12	BCR	-2.95	-1.66	-0.85
14 = 8-12	NPV	-$64,632 m	-$21,520 m	-$9,012 m

Option 2A Results

	Benefits/Costs	Discount Rate		
		4%	7%	10%
	BENEFITS			
1	**Car: Private Use**	**-$21,607 m**	**-$11,942 m**	**-$6,892 m**
	Travel Time Savings	*-$14,295 m*	*-$7,901 m*	*-$4,560 m*
	Vehicle Operating Costs	*-$7,312 m*	*-$4,041 m*	*-$2,332 m*
2	**Car: Business Use**	**-$14,341 m**	**-$7,926 m**	**-$4,575 m**
	Travel Time Savings	*-$12,388 m*	*-$6,847 m*	*-$3,952 m*
	Vehicle Operating Costs	*-$1,953 m*	*-$1,080 m*	*-$623 m*
3	**Light Commercial Vehicles (Class 1-2)**	**-$15,046 m**	**-$8,316 m**	**-$4,799 m**
	Travel Time Savings	*-$11,554 m*	*-$6,386 m*	*-$3,685 m*
	Vehicle Operating Costs	*-$3,492 m*	*-$1,930 m*	*-$1,114 m*
4	**Rigid Heavy Vehicles**	**-$2,983 m**	**-$1,649 m**	**-$952 m**
	Travel Time Savings	*-$2,529 m*	*-$1,398 m*	*-$807 m*
	Vehicle Operating Costs	*-$454 m*	*-$251 m*	*-$145 m*
5	**Articulated Heavy Vehicles**	**-$767 m**	**-$424 m**	**-$245 m**
	Travel Time Savings	*-$2,244 m*	*-$1,240 m*	*-$716 m*
	Vehicle Operating Costs	*$1,478 m*	*$817 m*	*$471 m*
5	**Public Transport Vehicles**	**$690 m**	**$381 m**	**$220 m**
	Travel Time Savings	*$690 m*	*$381 m*	*$220 m*
	Vehicle Operating Costs	*$0 m*	*$0 m*	*$0 m*
6	**Active Transport**	**-$752 m**	**-$415 m**	**-$240 m**
	Travel Time Savings	*-$752 m*	*-$415 m*	*-$240 m*
7	**Other Benefits**	**$33,239 m**	**$29,952 m**	**$19,626 m**
	Crash Reduction	*$21,521 m*	*$11,548 m*	*$6,620 m*
	Environmental Externalities	*$2,883 m*	*$1,547 m*	*$863 m*
	Car Ownership Savings	*$47,846 m*	*$26,248 m*	*$14,883 m*
	Parking Repurposing	*$287 m*	*$177 m*	*$112 m*
	Terminal Value	*-$39,298 m*	*-$9,568 m*	*-$2,853 m*
8	**TOTAL BENEFITS**	**-$21,567 m**	**-$338 m**	**$2,144 m**
	COSTS			
9	Operating Expenditure	$4,298 m	$2,498 m	$1,517 m
10	Capital Expenditure	$4,275 m	$3,012 m	$2,160 m
11	Terminal Operating Value	$4,170 m	$1,015 m	$310 m
12	**TOTAL COSTS**	**$12,744 m**	**$6,525 m**	**$3,987 m**
	COST-BENEFIT ANALYSIS			
13 = 8/12	BCR	-1.69	-0.05	0.54
14 = 8-12	NPV	-$34,310 m	-$6,863 m	-$1,843 m

Option 2B Results

	Benefits/Costs	Discount Rate		
		4%	7%	10%
	BENEFITS			
1	**Car: Private Use**	**-$11,845 m**	**-$6,547 m**	**-$3,778 m**
	Travel Time Savings	*-$7,409 m*	*-$4,095 m*	*-$2,363 m*
	Vehicle Operating Costs	*-$4,436 m*	*-$2,452 m*	*-$1,415 m*
2	**Car: Business Use**	**-$7,606 m**	**-$4,203 m**	**-$2,426 m**
	Travel Time Savings	*-$6,421 m*	*-$3,549 m*	*-$2,048 m*
	Vehicle Operating Costs	*-$1,185 m*	*-$655 m*	*-$378 m*
3	**Light Commercial Vehicles (Class 1-2)**	**-$8,165 m**	**-$4,513 m**	**-$2,604 m**
	Travel Time Savings	*-$5,988 m*	*-$3,310 m*	*-$1,910 m*
	Vehicle Operating Costs	*-$2,177 m*	*-$1,203 m*	*-$694 m*
4	**Rigid Heavy Vehicles**	**-$2,291 m**	**-$1,266 m**	**-$731 m**
	Travel Time Savings	*-$1,586 m*	*-$877 m*	*-$506 m*
	Vehicle Operating Costs	*-$705 m*	*-$389 m*	*-$225 m*
5	**Articulated Heavy Vehicles**	**$894 m**	**$494 m**	**$285 m**
	Travel Time Savings	*-$663 m*	*-$366 m*	*-$212 m*
	Vehicle Operating Costs	*$1,557 m*	*$860 m*	*$497 m*
5	**Public Transport Vehicles**	**$2,598 m**	**$1,436 m**	**$829 m**
	Travel Time Savings	*$3,403 m*	*$1,881 m*	*$1,086 m*
	Vehicle Operating Costs	*-$805 m*	*-$445 m*	*-$257 m*
6	**Active Transport**	**$3,224 m**	**$1,782 m**	**$1,028 m**
	Travel Time Savings	*$3,224 m*	*$1,782 m*	*$1,028 m*
7	**Other Benefits**	**$78,326 m**	**$41,012 m**	**$23,044 m**
	Crash Reduction	*$21,762 m*	*$11,677 m*	*$6,695 m*
	Environmental Externalities	*$2,922 m*	*$1,568 m*	*$874 m*
	Car Ownership Savings	*$47,846 m*	*$26,248 m*	*$14,883 m*
	Parking Repurposing	*$287 m*	*$177 m*	*$112 m*
	Terminal Value	*$5,509 m*	*$1,341 m*	*$480 m*
8	**TOTAL BENEFITS**	**$55,134 m**	**$28,194 m**	**$15,646 m**
	COSTS			
9	Operating Expenditure	$4,242 m	$2,467 m	$1,499 m
10	Capital Expenditure	$4,280 m	$3,016 m	$2,163 m
11	Terminal Operating Value	$4,091 m	$996 m	$304 m
12	**TOTAL COSTS**	**$12,614 m**	**$6,478 m**	**$3,966 m**
	COST-BENEFIT ANALYSIS			
13 = 8/12	BCR	4.37	4.35	3.94
14 = 8-12	NPV	$42,521 m	$21,716 m	$11,680 m

Option 3A Results

	Benefits/Costs	Discount Rate		
		4%	7%	10%
	BENEFITS			
1	**Car: Private Use**	**-$2,861 m**	**-$1,581 m**	**-$913 m**
	Travel Time Savings	*$1,061 m*	*$587 m*	*$339 m*
	Vehicle Operating Costs	*-$3,922 m*	*-$2,168 m*	*-$1,251 m*
2	**Car: Business Use**	**-$128 m**	**-$71 m**	**-$41 m**
	Travel Time Savings	*$920 m*	*$508 m*	*$293 m*
	Vehicle Operating Costs	*-$1,048 m*	*-$579 m*	*-$334 m*
3	**Light Commercial Vehicles (Class 1-2)**	**-$1,084 m**	**-$599 m**	**-$346 m**
	Travel Time Savings	*$858 m*	*$474 m*	*$274 m*
	Vehicle Operating Costs	*-$1,942 m*	*-$1,073 m*	*-$619 m*
4	**Rigid Heavy Vehicles**	**-$2,741 m**	**-$1,515 m**	**-$874 m**
	Travel Time Savings	*-$1,986 m*	*-$1,098 m*	*-$633 m*
	Vehicle Operating Costs	*-$755 m*	*-$417 m*	*-$241 m*
5	**Articulated Heavy Vehicles**	**$310 m**	**$172 m**	**$99 m**
	Travel Time Savings	*-$1,232 m*	*-$681 m*	*-$393 m*
	Vehicle Operating Costs	*$1,543 m*	*$853 m*	*$492 m*
5	**Public Transport Vehicles**	**$2,398 m**	**$1,326 m**	**$765 m**
	Travel Time Savings	*$3,639 m*	*$2,011 m*	*$1,161 m*
	Vehicle Operating Costs	*-$1,240 m*	*-$685 m*	*-$396 m*
6	**Active Transport**	**$4,765 m**	**$2,633 m**	**$1,520 m**
	Travel Time Savings	*$4,765 m*	*$2,633 m*	*$1,520 m*
7	**Other Benefits**	**$111,884 m**	**$49,191 m**	**$25,546 m**
	Crash Reduction	*$21,787 m*	*$11,690 m*	*$6,702 m*
	Environmental Externalities	*$2,929 m*	*$1,572 m*	*$876 m*
	Car Ownership Savings	*$47,846 m*	*$26,248 m*	*$14,883 m*
	Parking Repurposing	*$287 m*	*$177 m*	*$112 m*
	Terminal Value	*$39,036 m*	*$9,504 m*	*$2,972 m*
8	**TOTAL BENEFITS**	**$112,544 m**	**$49,556 m**	**$25,757 m**
	COSTS			
9	Operating Expenditure	$5,685 m	$3,545 m	$2,324 m
10	Capital Expenditure	$7,441 m	$5,379 m	$3,952 m
11	Terminal Operating Value	$4,329 m	$1,054 m	$322 m
12	**TOTAL COSTS**	**$17,455 m**	**$9,979 m**	**$6,598 m**
	COST-BENEFIT ANALYSIS			
13 = 8/12	BCR	6.45	4.97	3.90
14 = 8-12	NPV	$95,089 m	$39,577 m	$19,159 m

Option 3B Results

	Benefits/Costs	Discount Rate		
		4%	7%	10%
	BENEFITS			
1	**Car: Private Use**	**$1,522 m**	**$841 m**	**$485 m**
	Travel Time Savings	*$1,118 m*	*$618 m*	*$357 m*
	Vehicle Operating Costs	*$403 m*	*$223 m*	*$129 m*
2	**Car: Business Use**	**$1,077 m**	**$595 m**	**$343 m**
	Travel Time Savings	*$969 m*	*$536 m*	*$309 m*
	Vehicle Operating Costs	*$108 m*	*$60 m*	*$34 m*
3	**Light Commercial Vehicles (Class 1-2)**	**$941 m**	**$520 m**	**$300 m**
	Travel Time Savings	*$904 m*	*$500 m*	*$288 m*
	Vehicle Operating Costs	*$37 m*	*$20 m*	*$12 m*
4	**Rigid Heavy Vehicles**	**-$2,507 m**	**-$1,385 m**	**-$800 m**
	Travel Time Savings	*-$1,760 m*	*-$973 m*	*-$562 m*
	Vehicle Operating Costs	*-$746 m*	*-$412 m*	*-$238 m*
5	**Articulated Heavy Vehicles**	**$638 m**	**$353 m**	**$204 m**
	Travel Time Savings	*-$929 m*	*-$513 m*	*-$296 m*
	Vehicle Operating Costs	*$1,567 m*	*$866 m*	*$500 m*
5	**Public Transport Vehicles**	**$1,072 m**	**$593 m**	**$342 m**
	Travel Time Savings	*$2,121 m*	*$1,172 m*	*$677 m*
	Vehicle Operating Costs	*-$1,049 m*	*-$580 m*	*-$335 m*
6	**Active Transport**	**$2,490 m**	**$1,376 m**	**$794 m**
	Travel Time Savings	*$2,490 m*	*$1,376 m*	*$794 m*
7	**Other Benefits**	**$119,627 m**	**$51,229 m**	**$26,244 m**
	Crash Reduction	*$22,247 m*	*$11,938 m*	*$6,844 m*
	Environmental Externalities	*$2,989 m*	*$1,604 m*	*$894 m*
	Car Ownership Savings	*$47,846 m*	*$26,248 m*	*$14,883 m*
	Parking Repurposing	*$287 m*	*$177 m*	*$112 m*
	Terminal Value	*$46,258 m*	*$11,263 m*	*$3,511 m*
8	**TOTAL BENEFITS**	**$124,860 m**	**$54,121 m**	**$27,913 m**
	COSTS			
9	Operating Expenditure	$5,084 m	$2,989 m	$1,828 m
10	Capital Expenditure	$6,591 m	$4,392 m	$2,997 m
11	Terminal Operating Value	$4,118 m	$1,003 m	$306 m
12	**TOTAL COSTS**	**$15,793 m**	**$8,383 m**	**$5,131 m**
	COST-BENEFIT ANALYSIS			
13 = 8/12	BCR	7.91	6.46	5.44
14 = 8-12	NPV	$109,067 m	$45,739 m	$22,783 m

Appendix C: Real options analysis

As highlighted throughout this report, the transport sector is facing increasing disruption, and investment decision-making is being undertaken in the face of significant uncertainty and risk.

While the risk associated with uncertainty is captured in conventional economic appraisal through the application of scenario testing, sensitivity analysis and the use of higher discount rates, these techniques do not account for the value of flexibility, or inform decision-makers on the best option to reduce uncertainty in investment outcomes. In this context, real options analysis can be viewed as an effective mechanism to assess investments through the lens of uncertainty, and most importantly flexibility.

Notably, real options analysis is not currently widely used in the strategic assessment of transport investments, however is gaining traction as a useful and pragmatic approach to decision-making. Real options analysis is often seen as a valuation and evaluation tool, but real options analysis also has effective applications within strategic planning.

The following discussion highlights some of the key features that should be considered in undertaking a strategic-level real options analysis to further evaluate Options 3a and 3b, as identified in the recommendations of this report. The objective of the strategic real options analysis described here is to identify the courses of action available to Government and to highlight where pursuing decisions, or taking certain actions, precludes Government from achieving future outcomes.

Types of real options

There are a number of different types of real options, however in the context of transport decision-making and mobility disruptions there are two primary options which apply: option to delay/defer; and option to stage.

- The *option to delay* describes the ability to delay investment until new or additional information is acquired. This enables a more informed future decision, potentially avoiding a mistake from premature investment.
- The *option to stage* describes the ability to stage the implementation of an investment. This introduces a series of decision points into the evaluation process, allowing incremental decisions to be made once there is greater certainty. At each decision point decision-makers have the option and flexibility to continue, wait or even abandon the project/program depending on new information.

Capturing uncertainties

In the context of the emerging trends detailed earlier, there are a range of external uncertainties which may impact on the need for, or the ability to implement, a planning direction or investment decision. Importantly, uncertainties are not the same as risks and subsequently cannot be mitigated to neutralise their effect.

At the present time, based on information currently known and available, uncertainties include:

- Demographics, including the rate of growth and geospatial distribution of the population
- Changes in the spatial distribution of jobs incl. increases in teleworking

- Design and function of new vehicles – e.g. speed, headways and capacity (seats)
- Speed of technological development of automated vehicles
- Rate at which automated vehicles will enter the market
- Consumer adoption of automated vehicles
- Future policy, legislative and legal controls.

These uncertainties can be categorised into those that impact on the demand for transport infrastructure, and those that impact on the timing of the deployment and adoption of automated vehicle technology.

The Queensland Government, in partnership with Data61, have undertaken extensive research and analysis to define a series of future uncertainty scenarios for Queensland transport. These scenarios provide a useful and pragmatic strategic setting that could be used to support this real options analysis.

Decision-trees

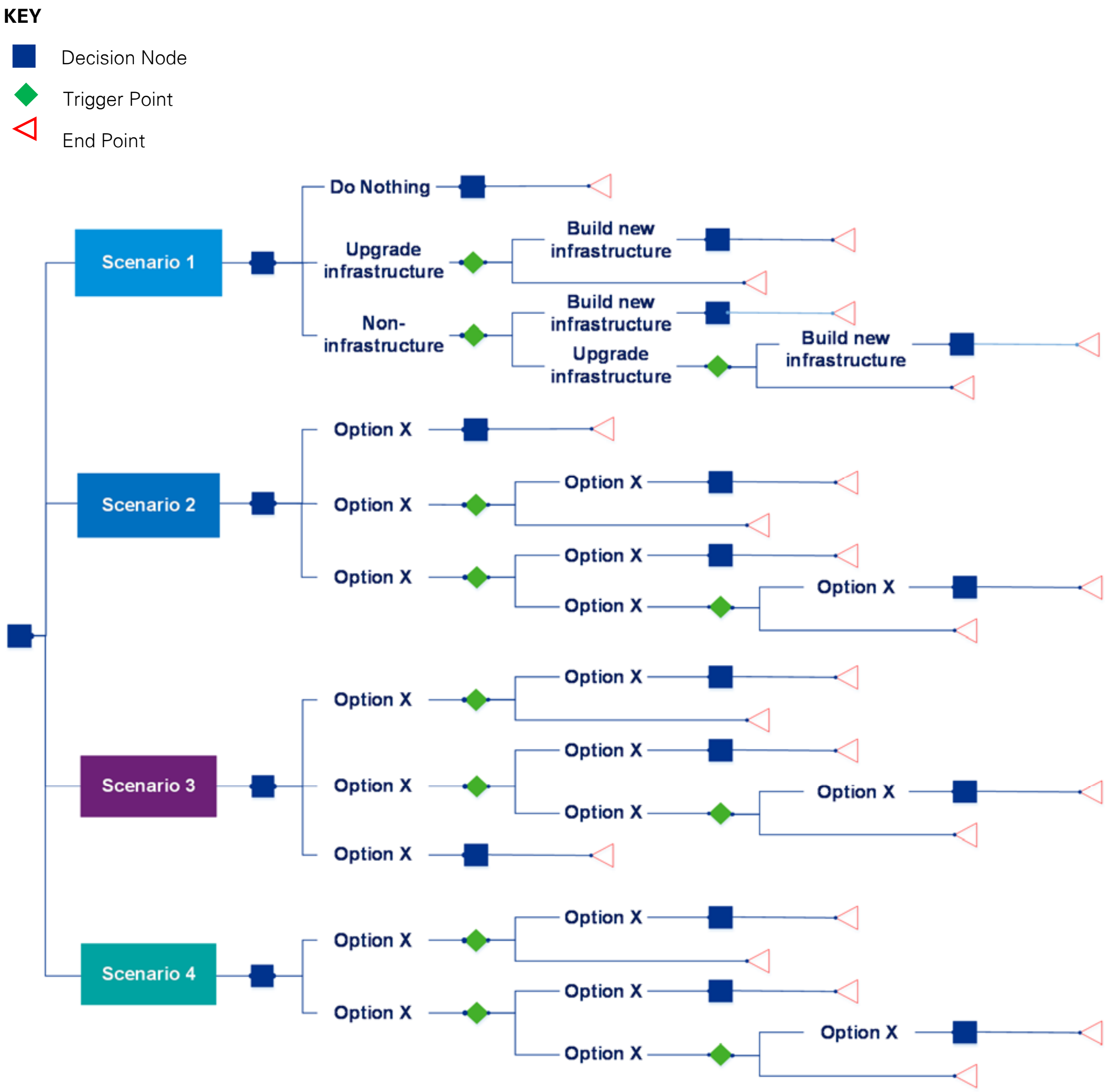
The development of a detailed decision-tree provides a visual representation of the possible outcomes of a series of related choices and courses of action available to Government under different scenarios. Each branch represents a possible decision, while choices are made at key decision "nodes". The decision to pursue a choice is determined at "trigger" or threshold points, whereby certain characteristics such as the introduction of technology, or demand levels, indicate the need for action. Accordingly, in developing a decision-tree, consideration should be given to the appropriate staging of actions, and the choices available that provide flexibility when further action is required.

It is important to note that choosing the 'do nothing' option now does not guarantee that all options will be available in the future. In fact, from a strategic perspective, taking a wait and see approach may lead to suboptimal outcomes as the opportunity to guide a course of action may be lost.

The example decision-tree below illustrates how the analysis would work from a conceptual viewpoint, whereby the decision-pathway changes depending on the uncertainty scenario (Figure 22). The sequencing and nature of future decisions (as defined by the decision-tree) will be different, depending on the uncertainty scenario being tested.

Using the Data61 scenarios as an for example, the Government may wish to purchase and operate a small fleet of on-demand transport services to support the transition to an integrated feeder ("last and first mile") service under scenario "CL", where mobility patterns are concentrated but the level of technological transformation is high. Under this scenario, the cost efficiencies generated as a result of the technology is not significant enough to support the commercial introduction of these services, as would be anticipated under scenario "CH" where mobility patterns are concentrated and the level of technological transformation is high.

Figure 23: Example Decision-Tree



"Points of no return"

Real options analysis is not only about making an investment decision, it is about gaining a better understanding of the options available now, and in the future, that will ensure the actions taken by government yield the maximum outcomes for the community.

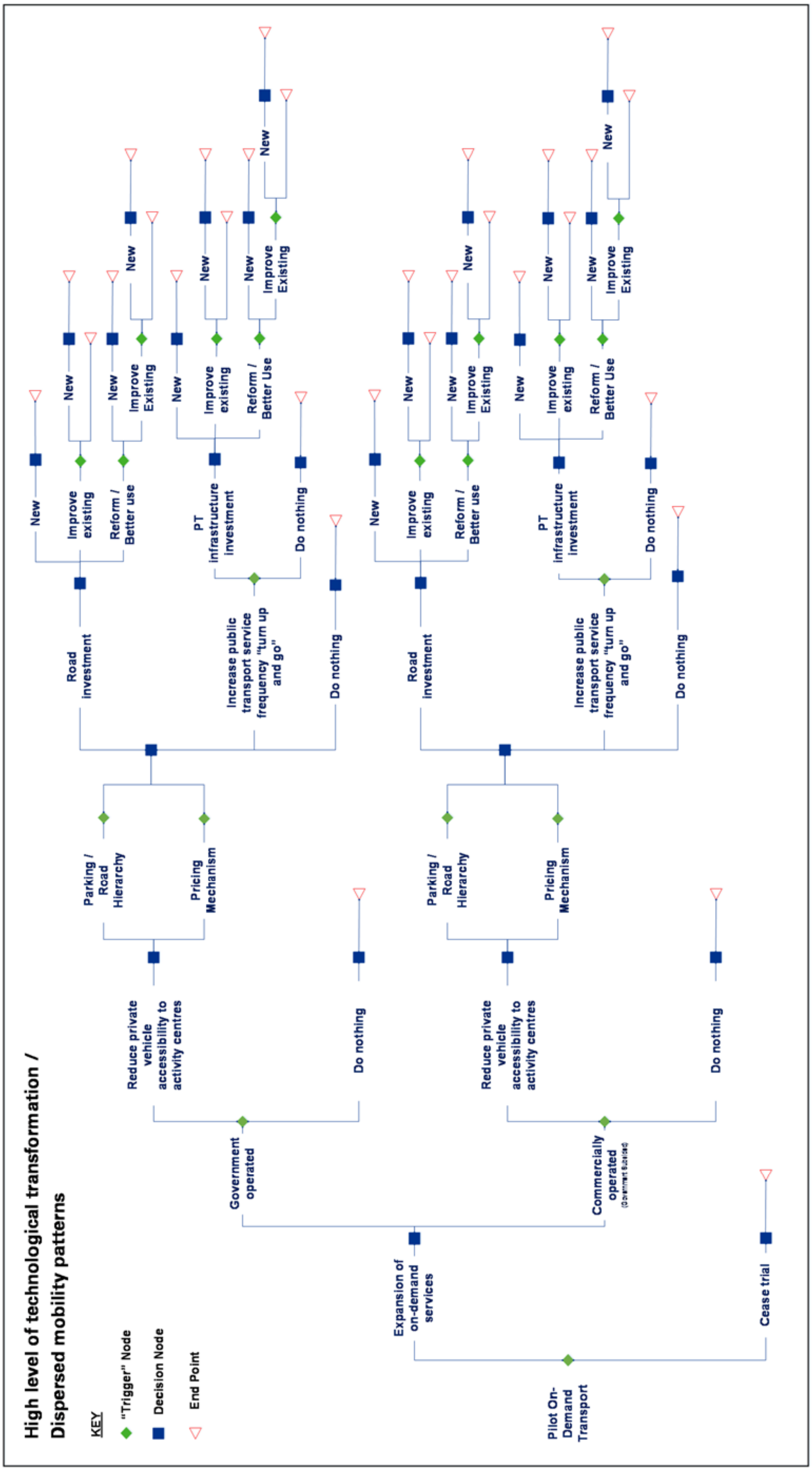
Under each scenario, and within each decision, there are a number of options that form "points of no return". These refer to decisions which lead towards a certain course of action, preventing or restricting the future option or flexibility to follow a different path – this may be both physically, in terms of nature of a transport network change, or due to the political implications of a decision.

In the context of Options 3a and 3b, the following decisions can be considered "points of no return", a number of which can be identified in the strategic-level decision-tree excerpt provided overleaf (Figure 23). The examples provided here are indicative only, and do not represent a comprehensive or complete analysis.

"Point of no return" could include:

- AEVs are deployed under a private ownership model (in contrast to fleet, or mixed ownership model)
- Government purchases early models of AEVs and upgrades the existing public transport fleet with automated vehicles.
- Significant changes are made to the current public transport system, including the redistribution of bus routes or substitution of conventional buses for demand responsive transport services
- Large scale capital investment into road infrastructure, particularly, at the expense of public transport investment
- Pricing initiatives.

Figure 24: Example Decision-Tree – Mobility as a Service



Contact us

Paul Low
National Leader - Infrastructure, Government and Healthcare
+61 7 3233 9771
plow@kpmg.com.au

Jon Frew
Engagement Lead – Infrastructure, Government and Healthcare
+61 7 3225 6821
jfrew@kpmg.com.au

Maddison Hoey
Engagement Manager - Infrastructure, Government and Healthcare
+61 3233 3236
mhoey@kpmg.com.au

kpmg.com.au