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Friday, 7 December 2018

Mr John Alexander OAM MP
PO Box 6021
Parliament House
Canberra ACT 2600

Dear Mr Alexander,

RE: Inquiry into automated mass transit

Thank you for the opportunity to participate in the inquiry into automated mass transit. As an owner-operator of toll roads in Australia, Canada and the US, Transurban has a keen interest in technological advancements that may impact transportation in the near and long term.

Since we began operations with CityLink in Melbourne in 1999, the opportunities afforded by new technology have enabled us to improve traffic flows and safety on our roads, while also making it easier for customers to engage with our toll products. The impact of rapid technological change is evident in the current makeup of our business, which has transitioned from a traditional engineering workforce to one with almost 40 per cent employed in technology.

With regard to the inquiry's terms of reference, it is our view that the increasing sophistication of connected and automated vehicles (CAVs) and the growing uptake of electric vehicles, will transform transport and present huge benefits for road operators, motorists and other road users. However, the task of introducing CAVs and electric vehicles on to our roads is incredibly complex and and will involve rethinking how we plan, build, operate and fund road infrastructure. As a toll-road operator, relied upon by motorists to make one-and-a-half million trips in Australia each day, we are doing our best to understand the challenges ahead. By working with vehicle manufacturers, industry and government, we hope to make the transition to CAVs and electric vehicles as safe and efficient as possible for our customers.

One of the most pressing challenges presented by the uptake of electric vehicles, is the impact on Australia's current road funding model. Fuel excise currently contributes 52 per cent of total road-related revenue from all levels of government, but this revenue stream is declining at around 16 per cent each year due to increasing fuel efficiency. Declining fuel excise threatens Australia's ability to maintain old roads and build new roads, all of which will be required to cope with our rapidly growing cities and urban areas.

With this in mind, Transurban undertook the first real-world test of user-pays road charging in Australia, the purpose of which was to gauge motorists' understanding of the current road funding system and assess their attitudes toward and behaviours under various user-pays options. In our report, *Changed conditions ahead: the Melbourne Road Usage Study*, we found that when people understood the benefits of a user-pays model, they supported the case for change. Since running the trial program, we have continued to contribute to the progression of this issue and provided submissions to the Department of Infrastructure, Regional Development and Cities' Heavy Vehicle Road Reform.

Similarly, Transurban is proactively engaging with vehicle manufacturers, industry and governments to prepare for the uptake of CAVs on our roads over the coming decade. While the timeline to full automation is still debated, vehicles with partial-automation features are already driving on Australian roads, and will increasingly rely on connected infrastructure to operate safely. The National Transport Commission has been tasked by Australian transport ministers to deliver a roadmap of reform to enable conditionally automated vehicles to operate safely and legally on Australian roads before 2020, and full automated vehicles from 2020. Transurban is supportive of this national approach and has provided responses to the National Transport Commission at a number of stages throughout its reform program.

We are currently running trials of partially automated vehicles in Melbourne, Sydney and Brisbane to investigate how they respond to the road environment including lane lines, signs, roadworks, and other vehicles. A report on the first of our Melbourne trials was released earlier this year and highlights a number of challenges observed when automated vehicles are faced with a live road environment. We are also undertaking trials in NSW in partnership with the State Government and expect to release our report later this year.

The impact of technological change on transport is being investigated in parrallel by a number of governments and industry bodies across Australia – with both the public and private sectors having distinct but complementary roles to play in the implementation of this new technology. As Australia prepares for the uptake of CAVs and electric vehicles, it will be critical for new policies and regulations to be consistent across the states and territories, and structured in such a way as to encourage innovation while ensuring public safety. Transurban recently provided a submission to a similar inquiry held in Queensland by the Transport and Public Works Parliamentary Committee, in which we discussed our position on a variety of major transportation trends and provided a number of recommendations.

Please find enclosed copies of the *Melbourne Road Usage Study*, *Victorian CAV Trials Phase One – Partially Automated Vehicles*, and Transurban's response to the Queensland Transport and Public Works Parlimentary Committee Inquiry into Transport Technology, discussed above. We encourage the committee to consider the findings and recommendations within each document.

Transurban welcomes further discussion with the committee on matters discussed above. To arrange a meeting please contact Alison Crosweller, Government Relations Manager

Yours sincerely

Wes Ballantine
Group Executive, Victoria and Group Strategy

Transurban

CHANGED CONDITIONS AHEAD

THE TRANSPORT REVOLUTION AND WHAT IT MEANS FOR AUSTRALIANS

MELBOURNE ROAD USAGE STUDY
REPORT OCTOBER 2016

CONTENTS

FOR MORE INFORMATION VISIT
CHANGEDCONDITIONSAHEAD.COM

Congestion is the biggest thing we are facing in this city … More cars per family, more families, our population is growing dramatically and the roads can't handle it. So people have to think about how they use the roads more carefully.

Frank, Dandenong North study participant

FOREWORD

Australia is facing the demands of a growing and increasingly urbanised population. At the same time, our major road-funding source, namely fuel excise, is diminishing as we move to more fuel-efficient and electric vehicles.

As technology changes transport, we must consider how we want the future to look and determine the services and systems that can best support us; and we must start by getting the foundations right.

If our cities are going to continue to be among the most liveable in the world, we need a road-funding system that will grow with demand and is built on the principle of those who benefit, pay. This will allow us to invest in and use our infrastructure more efficiently, while providing an equitable revenue stream that is aligned with actual road use.

In 2016, Transurban completed the first real-world test of user-pays road charging in Australia. Conducted over 17 months, 1,635 motorists drove 12 million kilometres under a range of charging options. The study tested user-pays as an alternative to the current funding model and also trialled two demand-management charging approaches.

After seeing how participants behaved and listening to what they had to say, we believe that a usage-based road-charging system could work in Australia.

The study showed that moving to a user-pays system would likely generate a sustainable funding source that could meet our future infrastructure needs. It also indicated that a user-pays model could help manage demand through the use of charging signals to vary driving behaviours in congested geographies and at peak travel times.

Through a series of attitudinal surveys conducted over the course of the study, we saw a significant swing in participants' preference from the current system, which they initially knew little about, to a user-pays model. This shows that, by

After seeing how participants behaved and listening to what they had to say, we believe that a usage-based road charging system could work in Australia.

experiencing a different way of paying for their road use, participants could see the benefit of a direct and transparent user-pays model over the current system of opaque fees and charges.

For the purpose of this study, our road-usage charges were designed to reflect replacement of the current road-related expenditure. Lower or higher charges could be applied to amplify driving behaviours and therefore could help manage demand across road networks or address the needs of specific community groups.

In real-world implementation, the level of charges would depend on the objectives, which will be an important consideration for policymakers. A user-pays system offers that flexibility.

At Transurban, we constantly look for innovative transport solutions to improve the efficiency of our networks and ultimately the liveability of our cities.

Traffic congestion and the performance of the wider road network impact our ability to deliver on our value proposition for our customers, government partners, investors and the broader community.

We live and work in Australia's major cities and, like everyone else in the community, we want the best quality of life possible. Efficient transport networks are central to that proposition.

I would like to thank all of the participants in our study for giving up their valuable time and providing their insights. Most agreed to participate because they saw it as a way to contribute to finding better transport solutions for their communities.

They have given us what no amount of theory could – a genuine picture of Australians' views and behaviours when it comes to user-pays road charging. The insights they shared are detailed throughout this report.

We look forward to further discussion on how we can continue to make progress towards a fairer and more sustainable way to fund our roads.

Scott Charlton
CEO, Transurban

EXECUTIVE SUMMARY

Transurban's Melbourne Road Usage Study was the first real-world test of user-pays road charging in Australia.

The study captured the responses of 1,635 private light vehicle motorists from the Greater Melbourne region to five user-pays charging options. It was designed to meet three objectives:

- to gauge motorists' knowledge and understanding of our current road-funding system and assess their attitudes and preferences toward user-pays charging options.
- to understand motorists' behavioural responses to different charging and implementation options.
- to prove that technology is not a barrier to implementing a practical user-pays system.

Two road-charging models with distinct purposes were tested consecutively:

- **Usage-based model** – this model tested participant responses to a user-pays funding approach that is more transparent and sustainable as a funding source.

  Three usage-based charging options were tested: charge per kilometre; charge per trip; and flat rate (capped kilometres).

- **Congestion-based model** – this model tested how motorists responded to demand-management pricing signals to reduce road use in highly congested geographies or at peak travel times.

  Two congestion-based charging options were tested: cordon (area); and time of day.

THE STUDY IN NUMBERS

1,635	Melbourne motorists*
5	Charging options
1B	Data points recorded
1.2M	Trips recorded
12M	Kilometres of travel recorded
5,000	Participant surveys completed
4,500	Participant statements issued

** Includes 70 pilot group participants and 300 control group participants*

SUSTAINABLE FUNDING SOURCE

The study shows a user-pays road-funding model will work in Australia and can provide a sustainable, fair and flexible funding system that grows with demand.

60% PREFER A USER-PAYS SYSTEM OVER THE CURRENT SYSTEM

It shows that participants were open to trying a more direct and transparent way of paying for their road use and that the different charging options tried by participants did not impede their usual driving behaviours.

The charging options used in the study broadly reflect current levels of national road-related expenditure, and do not represent specific policy recommendations. Through raising or lowering the charging levels, particular behaviours could be amplified or, similarly, the needs of specific community groups addressed.

Of the usage-based options, the charge per kilometre was the most popular, potentially due to its simple and easy-to-understand nature, with 59 per cent of participants preferring it over all the options tested, compared with 21 per cent for the charge per trip option and 20 per cent for the flat rate (Figure 1).

Highlighting the power of information sharing and practical experience in building awareness, a series of attitudinal surveys conducted at key points throughout the study shows a considerable shift in participant preference towards a user-pays model over the current system of opaque fees and charges. At the start of the study, 85 per cent of participants were comfortable with the current funding system. However after experiencing alternative ways of paying for their road use, 60 per cent said they preferred a user-pays system (Figure 2).

> *"I hope what comes out of this study is that we see a change in road use patterns. I really do. It would be nice to give the people who have long commutes by car and don't have any other option a fair run at the road."*
>
> *Rob | Hampton*

FIGURE 1. PREFERENCES OF USAGE-BASED CHARGING OPTIONS (OF THOSE WHO PREFER USER PAYS)

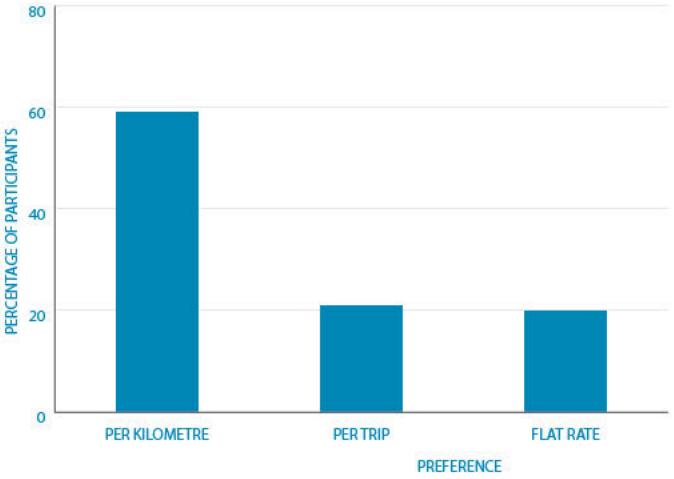
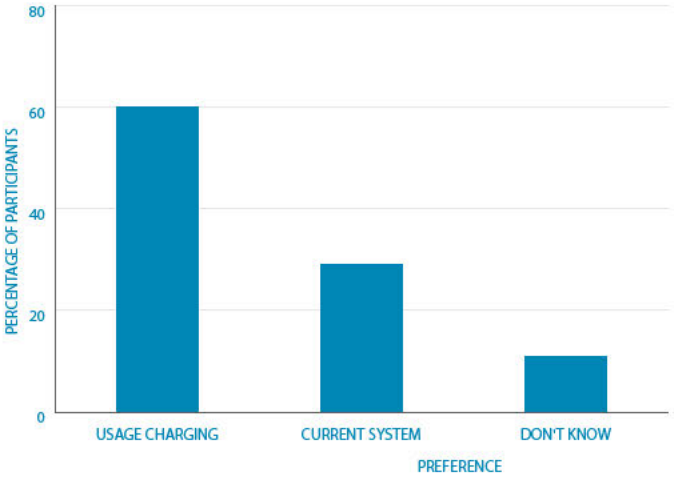


FIGURE 2. FUNDING SYSTEM PREFERENCES AFTER EXPERIENCING USER PAYS



MANAGING DEMAND

A user-pays funding system could also be adapted to assist with managing traffic across road networks through the use of pricing signals to modify behaviours in highly congested geographies or during peak travel times. This would add to the suite of tools available to policymakers to manage demand, including behavioural change initiatives, communication programs and the provision of alternative transport modes.

Only a small percentage shift in travel patterns is required to achieve peak spreading and make a considerable difference to the overall demand profile of the road network. Industry bodies have suggested that even a five per cent change in traffic levels during peak periods would increase traffic speeds by 50 per cent.[1] This variation is similar to the traffic flow changes commonly observed during school holiday periods.

CORDON CHARGING

The study showed that cordon charging could be effective in Australia as a congestion management tool, with a subset of participants reducing their road use within the central city during peak periods.

Of the 319 participants who completed trialling cordon charging, 51 per cent did not enter the cordon at peak times during the baseline period, with many not entering the area at all during the study. The group of participants who entered the cordon as part of their usual driving habits appeared to have reduced their weekly cordon travel by 10 to 15 per cent when driving under the cordon charging option.

Despite the observed downward trend for the participants who entered and travelled around the Melbourne CBD cordon, the road usage for the group in aggregate, including those who never entered the cordon, remained largely unchanged during the application of a cordon charge. This result supports the view that demand-management tools need to be specific and targeted to those who would respond to this charging signal.

While cordon charging was applied to the easily recognisable boundary of Melbourne's CBD (Figure 3) for the purpose of the study, cordon charging does not necessarily need to be limited to city centres. It also has application for other areas experiencing temporary or sustained congestion.

FIGURE 3. CORDON AREA

1 Kelly, J and Donegan P, City Limits, Melbourne University Press, 2015, page 172

TIME-OF-DAY CHARGING

In contrast, the time-of-day charging option applied one peak and one off-peak rate to all road usage regardless of location. The study's testing of behavioural responses to time-of-day charging showed no overall substantial change in participants' usual driving patterns when the option was applied. This does not necessarily mean that time-of-day charging would not have application in Australia, but rather, the charging signal needs to be clearer for users, and more specific in application before it can effectively address demand issues for targeted geographic zones or roads. Time-of-day charging has already been successfully implemented internationally.

OVERALL FINDINGS

Setting clear objectives for a user-pays system in Australia will underpin its effectiveness. The extent to which addressing congestion is prioritised alongside the restoration of a sustainable funding base for Australia's road networks will be an important consideration for policymakers.

The study demonstrates that a user-pays system could provide a sustainable funding source . It also demonstrates the flexibility a user-pays system could offer in enabling a wide range of price signal options to help manage demand. Furthermore, it shows that Australians are open to discussing user-pays as a viable alternative to the current system.

SYSTEM DESIGN

Study participants provided insights into several elements that need to be considered in the design and implementation of any new system, including:

- transparency and awareness
- choice
- fairness
- technology
- privacy and information security.

TRANSPARENCY AND AWARENESS

By trialling a direct and transparent way of paying for their road use, study participants became more aware of their driving behaviours. In line with results from national market research, participants had a low awareness of their road use with only 20 per cent accurately stating how many kilometres they drove or trips they made each week, month or year. By experiencing a user-pays system over the duration of the study, participants became more aware of their road use, with one in two reporting their awareness had increased (47 per cent).

Participants were three times more likely to look at the travel statements they received in the mail rather than visit the website to monitor their road use (94 per cent versus 31 per cent) and gained more information from that direct and proactive communication channel.

Through exposure to information, participants' understanding of the current road-funding system also increased by 23 per cent.

With this understanding came greater appreciation of today's challenges. Thirty-five per cent of participants who were uncomfortable with the current system said so because they believed the system should be user-pays. This contrasts with only 11 per cent for those who had not experienced a charging option.

While achieving an understanding of the current road-funding system was important for participants to recognise the need for reform, ultimately their awareness of their own road use only increased after they had experienced a more transparent system.

30% REPORTED CHANGING THEIR ROAD USE

CHOICE

Thirty per cent of participants said they changed their road use during the study. Participants who trialled the usage and congestion-based options reported greater use of alternative transport modes. Of those who provided details, 30 per cent said they had used more public transport; 23 per cent said they walked more; and five per cent said they cycled more.

Practical access to alternative transport modes emerged as a key factor in determining participants' ability and willingness to change their road use. Wider societal factors, such as flexibility in work hours, also played a role. Ensuring Australians can make genuine choices about how and when they use the roads will be critical in meeting the demand-management objectives of any new system.

FAIRNESS

Participants expected any new system would be fair for all users, including regional drivers, and would provide adequate protections for the vulnerable. They also expected that with the introduction of any new system, existing road-related charges would be eliminated and funding raised would be hypothecated into transport networks.

TECHNOLOGY

Participants showed openness to trialling new technologies, including in-vehicle GPS technology. Eighty-four per cent of participants were comfortable with the GPS devices used in the study and 82 per cent felt that the devices accurately measured their road usage.

84% COMFORTABLE WITH THE GPS TECHNOLOGY USED IN THE STUDY

These devices transmitted 16 locational and operational data-points every 60 seconds, amounting to one billion data points over the course of the study. More than 99 per cent of the confirmed travel data was considered valid.

Practical implementation measures, such as an agreed approach for telematics, software configuration, vehicle compatibility and device installation among many others, would need to be considered in the design and selection of technologies to achieve the scale required for a broad-based user-pays system.

PRIVACY AND INFORMATION SECURITY

While participants were generally comfortable with the technology system used in the study, they reinforced the importance of personal information security and protection in any system design. Sixty-three per cent of participants said they would be comfortable having the GPS device in their car indefinitely, while 13 per cent mentioned privacy and data security concerns. This highlights the need for further work towards solutions that are acceptable to the community as a whole.

The Melbourne Road Usage Study provides encouraging signs that Australians are ready to start talking about road-funding reform and willing to try a user-pays system. This openness is essential to moving Australia to a system that delivers:

- a sustainable funding base that provides fairness to all users
- flexibility to manage demand and traffic congestion.

It is clear that the path to reform needs to begin with building a common understanding of how motorists currently use and pay for roads, and we hope this study provides the first practical step in this process. The path ahead will be challenging, but we believe Australia has a unique opportunity to take advantage of the imminent arrival of new transport technologies as a catalyst for rethinking the transport system as a whole and creating a sustainable, fair and flexible funding future.

NATIONAL MARKET RESEARCH – KEY FINDINGS

To accompany the Melbourne Road Usage Study, Transurban commissioned national market research involving more than 2,200 Australians to form a national perspective on road funding and user-pays charging. Key findings of this research include:

- 88 per cent of respondents had little or no knowledge about our primary road-related funding sources, such as fuel excise and vehicle registration fees.
- 52 per cent thought that, in principle, paying for actual road use was a better way than the current system.
- 67 per cent would like to see governments take action on the issue of transport and funding reform. Many respondents indicated that they were keen to see road-funding issues start to be addressed now through trials or further research. They also wanted assurance that any proposed solution would be thoroughly researched and trialled successfully.
- The charge per kilometre was the preferred user-pays option, with respondents saying they thought this was a fair option as it was most directly associated with actual road use.
- 45 per cent were positive about cordon charging and 42 per cent were positive about time-of-day charging.
- With the introduction of any new system, respondents expected to see more public transport, hypothecation of funding into transport, protections for vulnerable groups and fairness for all road users.

THE TRANSPORT REVOLUTION

The invention of mass-produced automobiles was a defining feature of the 20th century. Cars drove social changes by reshaping our cities with road networks and increasing access to mobility, enabling considerable personal and commercial outcomes. For most of the last century, fuel excise was a suitable funding regime, providing a steady income stream based on motorists' fuel usage.

A century on, new technologies are triggering the largest revolution of the transport sector since cars replaced horses. The impact of this revolution will be far reaching.

INTRODUCTION

Electric, connected and autonomous vehicles and ride sharing are among the many transport innovations poised to enter the mainstream in the coming decade, and will fundamentally change the way Australians travel.

This new wave of transport technology promises opportunities for more efficient and safer mobility, significant reductions in greenhouse gas emissions, large-scale transport service integration and improved mobility options for the disadvantaged. Significantly, it also provides a tipping point for changing how we fund transport.

Our growing population and progressive urbanisation are challenging our transport system. Simultaneously, our ageing population is placing increasing demands on health, aged-care and other services, further stretching government budgets across a broad range of service provisions including infrastructure.

Vehicle manufacturers have continued to make progress towards a more sustainable future by improving the fuel efficiency of motor vehicles and, in more recent times, introducing hybrid and electric models. This important and commendable forward thinking will help protect the future of the environment, but, at the same time, highlights the imminent expiry of Australia's current fuel-sale-based funding stream.

How we fund road infrastructure must be central to discussions about Australia's transport future as this underpins many of the technology-based services to come.

$25 BILLION
TOTAL ROAD EXPENDITURE (2013–2014)

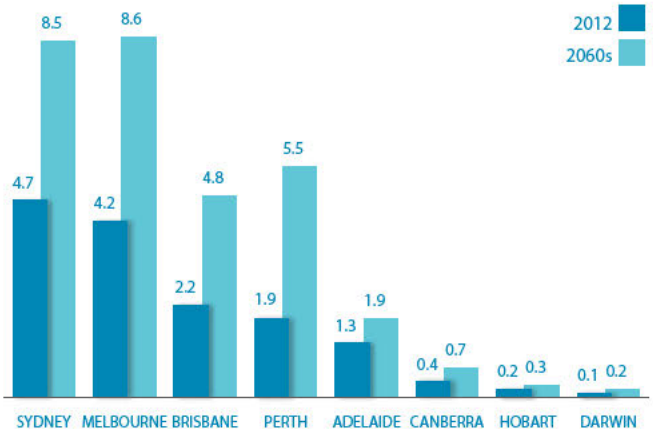
Source: BITRE Infrastructure Statistics Yearbook 2015

A proactive and holistic approach that systematically addresses future opportunities and challenges is crucial to finding effective and sustainable solutions for supporting Australia's growth and liveability.

AUSTRALIA'S CHANGING POPULATION

Australia's current population of 24 million is expected to grow to 30 million by 2030 and 40 million[2] by 2060. At the same time, our population is ageing. At current rates, the proportion of our population aged 65 years and over is expected to increase from 14 per cent today to 20 per cent by 2030 and almost a quarter of our population by 2060.[3]

FIGURE 4. AUSTRALIAN CAPITAL CITY POPULATION PROJECTIONS (MILLIONS)



Source: Australian Bureau of Statistics Population Projections, Australia, 2012 (base) to 2101, November 2013

Australia, like much of the rest of the world, is also becoming highly urbanised. With 80 per cent of employment based in cities, people are seeking homes closer to where the jobs are.[4] The proportion of our population living in capital cities is expected to grow from 66 per cent of the national population in 2011 to 73 per cent in 2061.[5]

In preparation, governments are continuing to invest in enhancing and expanding transport services as well as looking at creating regional hubs or multiple city centres to help ease pressures of population concentration. While these measures are expected to address some of the strains, transport demand will likely continue to grow, creating new challenges for our networks.

> *I think that it's not more roads, but more effective use of the roads we have.*
>
> *David | Burnley*

2 Australian Bureau of Statistics, Population Projections Australia: 2012 (base) to 2101, November 2013
3 Ibid
4 Grattan Institute, Mapping Australia's Economy: cities as engines of prosperity, July 2014, page eight
5 Infrastructure Australia, Population Estimates and Projections, Australian Infrastructure Audit Background Paper, April 2015

DECLINING FUNDING SOURCE

Fuel excise currently contributes 57 per cent of Australia's total road-related revenue (Figure 5). However, this revenue source has been decreasing steadily for years.[6] Despite growth in vehicle-kilometres-travelled, revenue raised from fuel excise in 2015 was less than that in 2001, in real terms.[7] The decline is largely driven by the introduction of newer and more fuel-efficient vehicles into the fleet. The expected growth in uptake of electric vehicles will likely further reduce fuel excise revenue. Recent CSIRO modelling highlighted the adoption of fuel-efficient and electric vehicles as key factors in reducing fuel excise revenue[8] (Figure 6).

The ongoing decline of fuel excise will present further challenges to government budgets. Australia's backlog of infrastructure projects has been estimated at up to $800 billion,[9] increasing the urgency of creating a more sustainable funding approach.

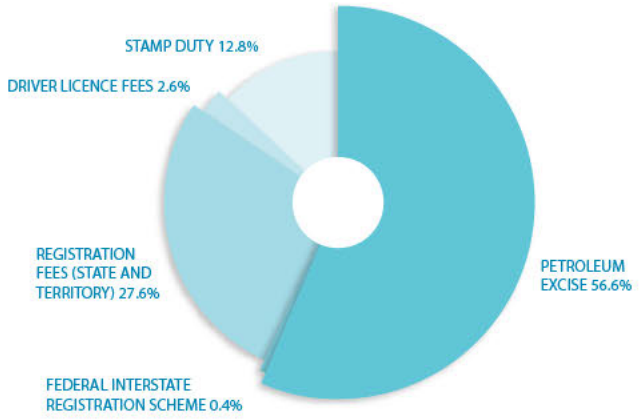
TOWARDS A FAIRER FUNDING SYSTEM

Fuel excise is sometimes described as a 'blunt' charging system. While there are exemptions in place for certain vehicle types and conditions (such as fuel for off-road driving), applying a standard rate per litre of fuel consumed means that vehicles taking the same road journey are charged differently, depending on their fuel efficiency. Motorists with less fuel-efficient and typically older-model vehicles are effectively being charged at a higher rate than those with more fuel-efficient and typically newer vehicles for equivalent usage of the road networks (Figure 7), raising equity concerns for the community as a whole.

To compensate for reductions in funding from fuel excise, state governments have progressively increased vehicle registration and licence fees.[10] With charges generally set at fixed rates, existing registration and licence fees also present equity challenges, with infrequent and low-demand motorists subsidising frequent, high-demand motorists.

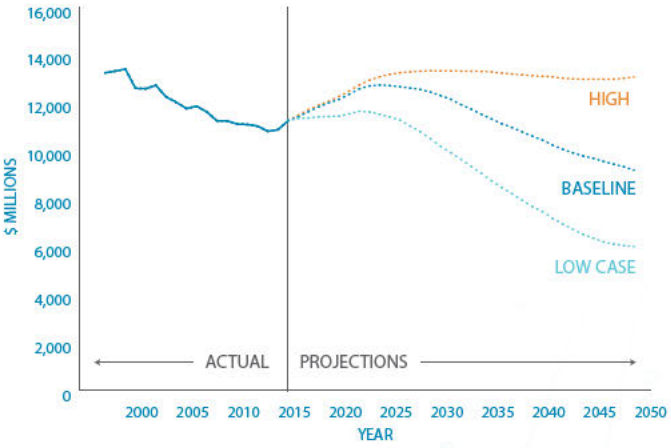
In the design of a sustainable and equitable funding system, a broad range of considerations will need to be taken into account. In the area of equity, the system needs safeguards and measures in place to protect vulnerable groups. A transparent system, based on the principle of those who benefit, pay, is a fairer way to fund road infrastructure.

FIGURE 5. 2013–2014 ROAD-RELATED REVENUES*



Source: Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015

FIGURE 6. AUSTRALIA'S DECLINING FUEL EXCISE REVENUE



Source: Transurban analysis; Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015; CSIRO (report for the NTC), Projecting future road transport revenues 2015–2050, May 2015

6 Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015
7 Ibid
8 CSIRO (report for the NTC), Projecting future transport revenues 2015 – 2050, May 2015
9 Infrastructure Partnerships Australia, Submission to Australia's Future Tax System Review Panel, October 2008
10 Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015

* Taxes and duties for specific purposes such as GST, fringe benefit tax, tolling revenue, luxury car tax or passenger vehicle customs duty and local government revenues from their own sources are not included.

GETTING THE MOST OUT OF EXISTING INFRASTRUCTURE

While introducing a sustainable funding source to meet our infrastructure needs is critical, we must also look for opportunities to use our existing transport infrastructure more efficiently.

Increasing congestion is impacting parts of Australia's urban road networks, with workday morning and afternoon peaks extending travel time, reducing journey time predictability and impacting productivity and the experience of road users.

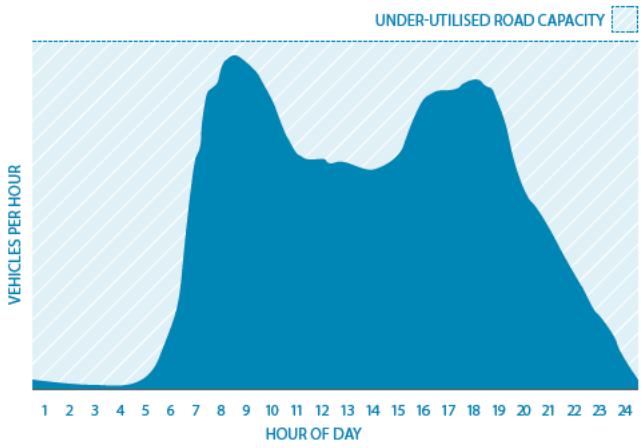
The economic cost of road congestion has been estimated at $13.7 billion in 2011 and is expected to grow to $53 billion by the 2030s.[11]

Congestion is not limited to road networks. Public transport systems also experience significant variations in passenger numbers during peak and off-peak periods.

Outside of peak periods, road networks are under-utilised (Figure 8). These inefficiencies present opportunities for easing congestion. A vast range of approaches to peak spreading, including price signalling, has been tried around the globe and implemented in some places.

Technology application and demand management represent an opportunity to improve traffic flow without necessarily building more physical roads or adding new lanes.

FIGURE 8. AUSTRALIAN CITY TRAFFIC PROFILE ON AN AVERAGE WORKDAY



Source: Transurban (2016) for illustrative purposes only

> *Something probably needs to be done, doesn't it, with the way the roads are, and with the way traffic is escalating all the time.*
>
> *Lenore | Bentleigh*

FIGURE 7: ROAD REVENUE CONTRIBUTIONS

Measure: 12,540km; Fuel excise: $0.396/L	2006 Holden Commodore*	2015 Toyota Corolla**	2016 BMW i3 (electric vehicle)
Fuel economy (L/100km)	10.9L	6.1L	0L
Litres of fuel used	1,367L	765L	0L
Annual fuel tax revenue contributions	$541	$303	$0
Annual vehicle registration fee***	$387	$297	$260
Total contribution to Australian road revenue	$928	$600	$260

Total annual travel of 12,540 kilometres is based on the average annual kilometres travelled by Melbourne Road Usage Study participants.

* 2006 Holden VE Commodore Omega 4-Speed Auto (Commodore was 2006 top-selling passenger vehicle in Australia).

** 2015 Toyota Corolla Ascent Hatch 7-Speed CVT (Corolla was 2015 top-selling passenger vehicle in Australia).

*** Vehicle registration fees vary between states and territories. Some states and territories also offer discounts for fuel-efficient vehicles and vary fee prices according to the vehicle weight.

Fees used here are based on the national average for each vehicle shown.

11 Infrastructure Australia, Australian Infrastructure Audit, 2015, page 32

INTERNATIONAL RESPONSES TO A CHALLENGING ISSUE

Declining revenue from fuel excise is not an issue specific to Australia. Across the world, cities, states and countries that rely on fuel taxes to fund roads and other transport infrastructure are now looking for alternative sources of revenue.

In addition, user-pays charging is also becoming an increasingly prevalent demand-management tool as governments and transport agencies look for ways to shift traffic out of excessively congested areas. Some governments, such as in London, use revenue raised from usage charges to fund new public transport projects, creating more alternative transport options for their communities.

Various countries, states and cities have already introduced, or are trialling, user-pays charging, using mass, distance, location and/or time dimensions to address specific issues such as:

- compensating for the additional road wear-and-tear caused by heavy vehicles and use of the road by transiting foreign heavy vehicles
- addressing funding shortfalls for transport infrastructure
- managing congestion in high-demand areas.

Figure 9 shows examples of how the international community is using user-pays charging models to solve specific issues.

Transurban is not alone in calling for change in the way Australian roads are funded. Independent government advisors, industry representatives, city strategy groups and motoring clubs have presented valuable perspectives on this important topic.

Effective progress is dependent upon the Australian community understanding the funding and congestion challenges we face and the need for reform. Doing so as a community will enable us to identify suitable and sustainable options that secure the prosperity and liveability of our country.

FIGURE 9. SUCCESSES IN OTHER JURISDICTIONS – A CLEAR FOCUS ON OBJECTIVES IS CRITICAL

NORTH AMERICA

1. **OREGON**
   Heavy vehicle charging scheme
   OreGo opt-in road usage charge program for light vehicles
2. **CALIFORNIA**
   Road charge pilot under way
3. **WASHINGTON, COLORADO, UTAH**
   Considering user-pays road pricing studies
4. **I-95 CORRIDOR COALITION**
   Proposed user-pays trial across four US states

EUROPE & U.K.

1. **LONDON, GOTHENBURG AND STOCKHOLM**
   Area/cordon charge implemented
2. **GERMANY, AUSTRIA, BELGIUM, CZECHIA, HUNGARY, POLAND, RUSSIA, BELARUS, SLOVAKIA AND SWITZERLAND**
   Heavy vehicle charge

ASIA/PACIFIC

1. **SINGAPORE**
   Location and time-of-day-based scheme in place
2. **NEW ZEALAND**
   Heavy vehicle charging in place since 1975
   Road-user charges in place for diesel light vehicles

POLICY OBJECTIVES

- Congestion management
- Road funding

INTRODUCING THE MELBOURNE ROAD USAGE STUDY

Transurban's Melbourne Road Usage Study was designed to capture field-tested information to equip policymakers with insights into how Australian motorists responded to user-pays road-charging options.

The study involved 1,635 private light vehicle motorists from Melbourne testing five user-pays charging options. It was designed to meet three objectives:

- to gauge motorists' knowledge and understanding of our current road-funding system and assess their attitudes and preferences toward user-pays charging options.
- to understand motorists' behavioural responses to different charging and implementation options.
- to prove that technology is not a barrier to implementing a practical user-pays system.

Conducted over 17 months, the study was undertaken in stages commencing with a detailed design stage. This incorporated a condensed pilot study with 70 participants testing the proposed methodology and technology. Findings from the pilot informed the design of the main study. Conducted over 12 months, the main study tested two road-charging models with distinct purposes:

- **Usage-based model** – this stage tested participant responses to a user-pays funding model that is more transparent and sustainable as a funding source.

  Three usage-based charging options were tested: charge per kilometre; charge per trip; and flat rate (capped kilometres).

- **Congestion-based model** – this stage tested how motorists responded to demand-management road charging that used pricing signals in highly congested geographies or at peak travel times to manage road use.

  Two congestion-based charging options were tested: cordon (area); and time of day.

For practical reasons, a rolling approach to the recruitment of participants and testing of the charging options was adopted.

Participants were recruited from three geographical zones within the Greater Melbourne region, which were reflective of the public transport options available at different locations.

Upon recruitment, in-vehicle GPS devices were installed in participants' cars and their usual (baseline) driving data was collected for a minimum of 35 days (not including the end-of-year holiday period). Following this, participants drove under one of the usage-based charging options. For the final stage, a group of participants was transitioned onto the congestion-based charging options.

A control group of approximately 300 participants did not experience any of the charging options and continued driving as usual throughout the study period. This group was used to adjust observed behavioural changes for seasonal and external factors that would have been experienced by all participants.

Quantitative data was collected via the GPS devices and analysed to understand potential behavioural changes as a result of the charging options. Additionally, qualitative feedback was captured through a series of surveys completed by participants at key points throughout the study.

In line with common market research practices, participants were provided a $100 gift card on joining the study. To simulate the financial impact of a real-world charging system as much as possible, virtual 'travel accounts' were created for each participant. By changing their road use, participants could be credited a maximum of $80 per month, which was accumulated and paid out at the end of the study.

Specialised technology was assembled to create an end-to-end system for the field-testing of road charging. This included integrating various components such as in-vehicle GPS devices, a billing system (based on the five charging options), payment processing, exception-handling, and customer management.

FIGURE 10. FIGURES USED IN THE STUDY'S CHARGING OPTION CALCULATIONS

$24B*	The total government road-related expenditure for 2012–13
240B*	The total kilometres travelled on all Australian roads in 2012–13
65M^	The estimated total number of trips taken on Australian roads each day

* *Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2014.*

^ *Transurban estimate, based on Road Usage Study pilot.*

MEASURING BEHAVIOUR UNDER A USER-PAYS SYSTEM

GPS devices were installed in the newest vehicle of each participant's household. These devices collected information such as the number of trips made; the start time and duration of each trip; and distance travelled and location covered.

In the first phase of the study, participants drove under normal conditions, to establish their baseline road usage. In order to obtain usual driving patterns to form the baseline, participants were not provided with any information about potential charging alternates upfront.

Once the baseline was established, participants were then asked to choose or were allocated a usage-based charging option and observations were made on how their behaviours changed, if at all. On completing this phase, a group of 675 participants was randomly allocated one of two congestion-based charging options and their travel data was compared against their baseline data to determine if any behavioural changes had occurred.

MEASURING ATTITUDES AND PREFERENCES TOWARDS A USER-PAYS CHARGING SYSTEM

Participants were surveyed at key points throughout the study to find out how their attitudes changed as they experienced road charging first-hand. Participants were surveyed on their:

- awareness of and attitudes towards road funding in Australia
- attitudes towards different user-pays charging options trialled in the study
- shifts in awareness and attitudes after experiencing user-pays, particularly in relation to perceived behavioural changes, knowledge levels, technology use and communication channels.

On completion of the study, participants were asked to complete a final survey by phone, with additional questions relating to the use of the GPS devices in their vehicles and their own assessment of any awareness and attitude shifts after experiencing road charging. More in-depth feedback on the study experience was also collected through selected participant focus groups and video diaries.

SETTING ROAD CHARGES

The charging levels set for the study were not intended to advocate for specific future road-charging levels or to indicate any form of policy recommendation. For the purpose of this study, the (then) current total government road infrastructure expenditure and national road usage estimates were used as the basis for charging calculations (Figure 10).

Simple, rounded charges were used for ease of explanation and participant understanding.

USAGE-BASED CHARGING OPTIONS

The usage-based charging options used units of measurement – trips and kilometres – to charge for road usage. Three usage-based charging options were available (Figure 11).

Participants were invited to choose their preferred charging option, and, where possible, this choice was accommodated. However, to ensure adequate sample sizes across all three charging options, some participants were allocated an alternate when their preferred option was fully subscribed.

FIGURE 11. USAGE-BASED CHARGING OPTIONS

Option	Charge
Charge per trip	$1 per trip. Vehicle movement is defined as a trip if the vehicle travels more than 100 metres after being stopped for at least five minutes
Charge per km	10c per kilometre
Flat rate	10c per kilometre for a capped number of kilometres, and 20c per kilometre for all excess kilometres

"Working in health care, I understand that research is a very important part of learning and discovery, so I felt being a part of road usage research might actually help long-term planning for Melbourne's roads."

Linda | Carrum Downs

CONGESTION-BASED CHARGING OPTIONS

Congestion-based charging options were based on the concept of using pricing signals to influence behaviour in high-use geographies or at peak travel times (Figure 12).

The charging levels for these options were based on distance travelled (kilometres) – the same as the charge per kilometre usage-based option – with adjustments to test specific pricing signals. For example, for the time-of-day charging option, the charge per kilometre was set at eight cents in off-peak times, half of the peak charge of 15 cents, to measure any propensity to change driving behaviour in the peak period.

Similarly, for the cordon-charge option, the charge was set at eight cents per kilometre any time plus a cordon area access charge of $8. This amount was chosen because it was comparable with similar charges internationally and was also benchmarked against other regular transport costs in Melbourne, such as public transport fares and parking fees.

The cordon area bordered the inner-city (Figure 13) as most Melbourne drivers are aware of the high-demand area in the CBD during peak periods. However, it could have been applied to any area that experiences congestion either on a sustained basis or temporarily at certain times of day.

Participants were randomly and evenly allocated to the cordon and time-of-day groups regardless of their driving activity in the baseline period. The control group was unchanged throughout the entire course of the study.

FIGURE 12. CONGESTION-BASED CHARGING OPTIONS

Option	Charge
Cordon (area)	8c per kilometre anytime plus $8 access charge per day to enter or move within a defined zone in inner-city Melbourne between 7am and 6pm, Monday to Friday
Time of day	15c per kilometre during peak hours (Monday to Friday, 7am–9am and 3pm–6pm); 8c per kilometre at all other times, with charges applicable in all areas

FIGURE 13. CORDON AREA

TRAVEL ACCOUNTS AND PIGGYBANKS

Participants were not required to contribute their own money to experience the road-charging options. To simulate the financial impact of a real-world charging system as much as possible, virtual 'travel accounts' were created for each participant. These accounts were used to simulate the experience of being charged for road use.

Travel account opening balances were calculated based on each participant's usual (baseline) road usage and the parameters of their specific charging option. As a participant used the roads, their road charges (calculated either by trip or kilometre and with/without a cordon charge applied) were deducted from their travel account.

At the end of each monthly billing period, if the participant did not change their road usage in line with the charging option being trialled, the account balance would be $0. At the start of each new billing period, the travel account was reset to the original opening balance. If the participant had reduced their road usage during the course of the billing period, the account balance would be in credit. Road usage exceeding the baseline amount would simply result in a $0 balance.

At the end of each month, any credit remaining in a participant's travel account was deposited into the participant's 'piggybank' (capped at $80 per month). Piggybank balances accrued and the totals were paid out to participants at the conclusion of the study.

Participants could keep track of their road usage via monthly travel statements (Figure 15) – similar to household account statements for gas, water or mobile phone services. An online portal was also available for participants to check their daily usage and access additional information (Figure 16).

FIGURE 14. PARTICIPANT SURVEYS WERE COMPLETED AT KEY POINTS THROUGHOUT THE STUDY

FIGURE 15. TRAVEL STATEMENTS WERE DESIGNED TO LOOK LIKE OTHER UTILITY STATEMENTS

FIGURE 16. AN ONLINE PORTAL, UPDATED DAILY, PROVIDED DETAILED INFORMATION ON PARTICIPANTS' ROAD USE

TECHNOLOGY

Creating a practical technology suite to support the field-testing of road-charging options involved assembling several technology components into an end-to-end system, which included:

- in-vehicle GPS devices
- a billing system (based on the five charging options), including a road-charging algorithm and simulated account balance
- payment processing
- exception handling
- customer management.

In-vehicle GPS devices are already in use in Australia and internationally. Public and private transport operators, emergency services, freight companies, fleet managers and insurance companies regularly use these devices to identify, locate and manage vehicle assets and driver performance. Private vehicle owners also use similar devices to monitor vehicle performance.

Two types of in-vehicle GPS devices (Figures 17 and 18) were used in the study to accommodate the wide range of models in Australia's existing vehicle fleet. These included:

- **OBD-II GPS device**

  The OBD-II (On-Board Diagnostics – Second Generation) GPS device was compatible with the majority of passenger vehicles in Australia (Figure 19). All vehicles sold in Australia since 2006 have an OBD port, usually located under the dashboard, and this is where the OBD-II device was installed. The OBD port is used by mechanics to run diagnostic and performance tests on vehicles during servicing. Once installed, the device is not generally visible to the driver. If a participant's vehicle required servicing during the study period, the device was simply removed and then reinstalled.

- **Plug-in GPS device**

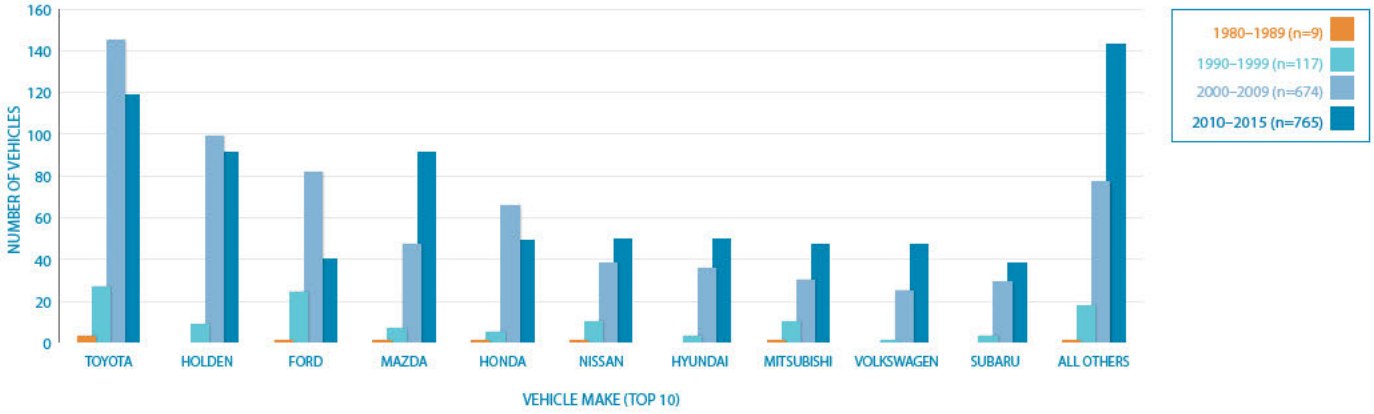
  For vehicles without an OBD port, generally those manufactured prior to 2006, a plug-in GPS device was used. The plug-in device included a power cable, installed via the vehicle's dashboard accessories port and a GPS antenna, placed on the dashboard for best reception. The plug-in device had an aesthetic disadvantage as its installation involved a visible cable.

The OBD-II GPS device was used in the majority of vehicles in the study (Figure 20).

FIGURE 17. OBD-II GPS DEVICES WERE INSTALLED IN POST-2006 VEHICLE MODELS

FIGURE 18. PLUG-IN GPS DEVICES WERE INSTALLED IN PRE-2006 VEHICLE MODELS

FIGURE 19. VEHICLES IN THE MELBOURNE ROAD USAGE STUDY



Devices were monitored to ensure they were properly installed and operational. If a device appeared to have been removed or had stopped transmitting trip data, follow-up processes were undertaken to make contact with the participant and look into the potential causes. Such occasions were limited and example causes included when the device was removed during servicing, and not reinstalled afterwards; when the vehicle had not been driven for an extended period; and, in rare cases, when the device was malfunctioning and required replacement.

In cases where the device was confirmed as not having been installed or working correctly for a known period during the study, appropriate exclusions were made according to agreed and consistently applied business rules. This ensured the analysis incorporated only valid travel data and time periods.

TYPE OF DATA COLLECTED

Both the OBD-II and plug-in devices were configured to capture only data specific to the study. Data collected was for two broad purposes, namely, to assess behavioural change and evaluate the performance of the GPS device (Figure 21). Sixteen data points were collected for every transmission from the GPS devices, which occurred approximately every 60 seconds.

Aggregating the raw locational data provided an accurate picture of how participants used the road networks. Figures 22, 23 and 24 on page 20, map the data points recorded for a select period during the study at a metropolitan, regional and state level.

FIGURE 20. PROPORTION OF PARTICIPANTS USING EACH TYPE OF DEVICE IN THE STUDY

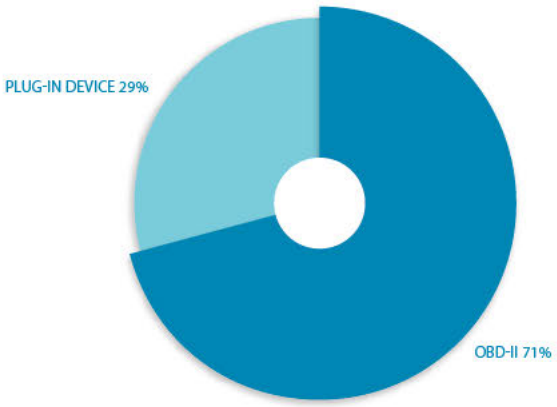


FIGURE 21. TYPES OF DATA TRANSMITTED

Participant travel data	Device performance data
• time of day at the start and end of each journey	• battery status and GPS connectivity
• distance travelled per journey and the duration of each journey	• if the device was attached, detached or moved to a different vehicle
• location (except in an area near the participants' home, which was masked for privacy reasons)	• if the ignition was on or off and if the vehicle was in motion or idling

DATA TRANSMISSIONS

FIGURE 22. MELBOURNE METRO LEVEL

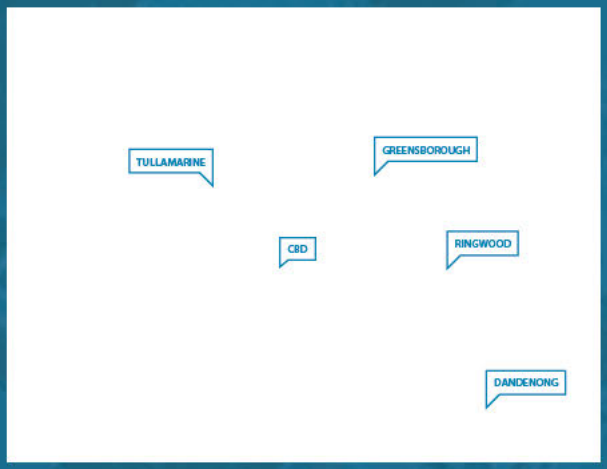


FIGURE 23. VICTORIAN REGIONAL LEVEL

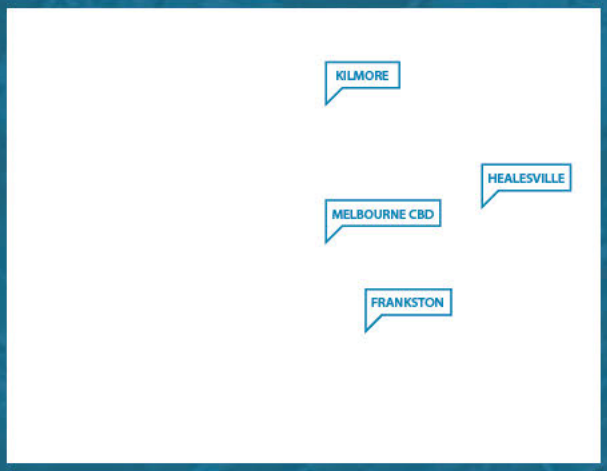
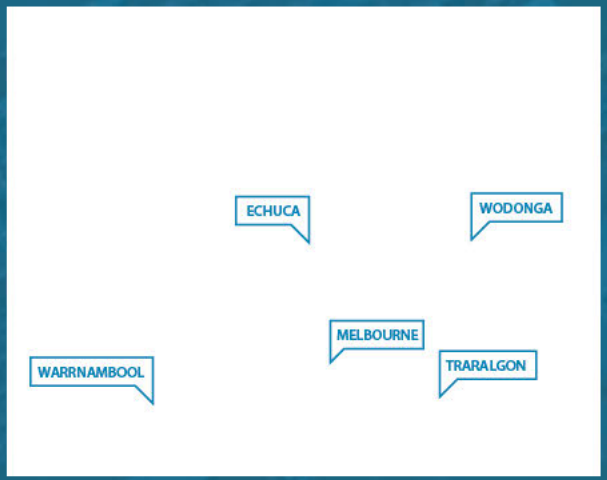


FIGURE 24. VICTORIAN STATE LEVEL



PRIVACY AND DATA SECURITY

Participants' privacy was of paramount importance. A range of security measures were put in place throughout the study to protect participant privacy.

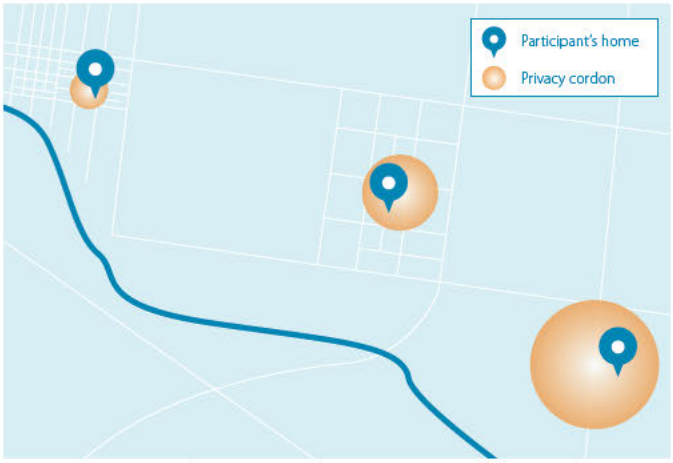
A privacy cordon was applied to an area around participants' homes; concealing the GPS coordinates when the participant's device entered the cordon, until the participant exited the privacy cordon again. Each privacy cordon radius varied based on the population density of the area with the participant's home not necessarily in the centre of the masked area, as illustrated by the circle (Figure 25).

To ensure the separation of participants' personal information from vehicle trip information, information access and identity controls were put in place for the study team.

Data security protections were also established to safeguard information collected during and subsequent to the study.

This study complied with the Australian Government's Privacy Act (1988) and the Association of Market and Social Research Organisations' Privacy (Market and Social Research) Code (2014).

FIGURE 25. ILLUSTRATION OF PRIVACY CORDON APPLIED TO MASK PARTICIPANTS' HOME ADDRESSES



NATIONAL MARKET RESEARCH

AUSTRALIA SAYS ...

Before road-funding reform can be progressed in Australia, the community needs to be brought into the discussion.

To help identify where this discussion should start, Transurban engaged independent market researchers to conduct both qualitative and quantitative research, including focus groups, online discussion groups and an online survey of more than 2,200 Australians. Respondents were representatively sourced from all Australian states and territories, covering both urban and regional areas. The research was conducted in accordance with the international quality standard for market and social research (ISO 20252).

Focus groups were designed to ensure diverse representation, and moderated by market research professionals in line with standard market research practice.

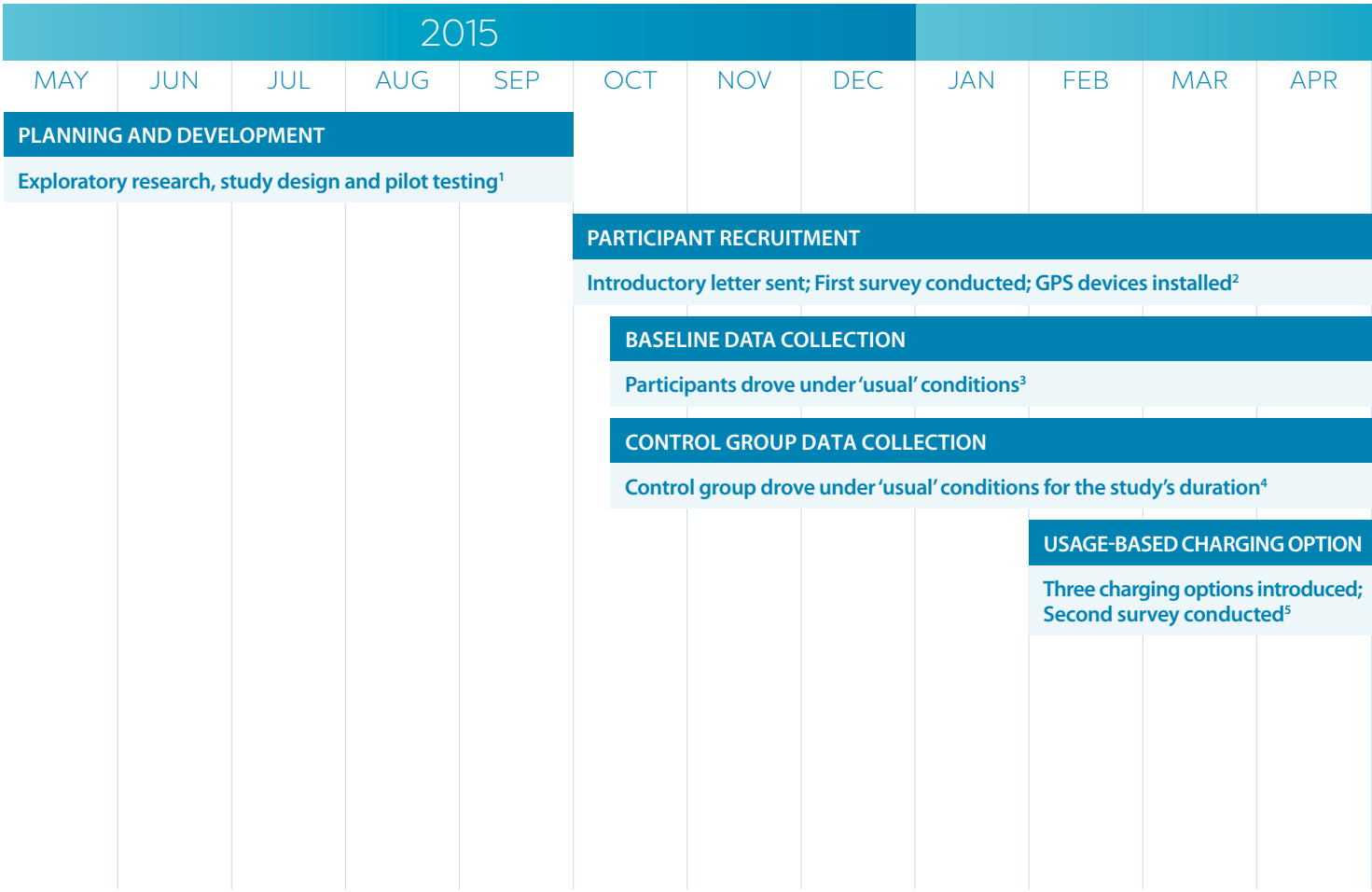
The online survey was conducted with respondents from across Australia, drawn from a professional market and social research panel.

The total sample size of 2,224 results in a maximum margin of error of +/-2.1 per cent at the 95 per cent confidence level.

The data set was weighted using population data from the Australian Bureau of Statistics' Census 2011 to ensure the findings accurately reflected the views of the Australian population.

Transurban's national market research reveals how the broader Australian community responded to the idea of road-charging reform in Australia. Some of these insights are included in the findings section of this report.

A STAGE-BY-STAGE GUIDE TO THE MELBOURNE ROAD USAGE STUDY



PLANNING AND DEVELOPMENT

1 Transurban designed and developed the Melbourne Road Usage Study in consultation with technical specialists. Exploratory research, focus groups, representative sampling design, technology development and pilot testing were conducted prior to the launch of the main study.

PARTICIPANT RECRUITMENT

2 An introductory letter was posted to target households, explaining that interviewers would be visiting households to invite residents to join the study.

Interviewers visited the targeted households to recruit participants. When a participant consented to join, interviewers recorded their vehicle information and household demographics, conducted a survey and installed a GPS device in his/her vehicle. A $100 gift card was provided to each participant as an incentive for joining. The control group was recruited at the same time.

BASELINE DATA COLLECTION

3 Each participant's usual (baseline) driving data collection commenced following the successful installation of a GPS device. A minimum 35 days of usual road usage data (with no charging options applied) was collected (not including the end-of-year holiday period).

CONTROL GROUP DATA COLLECTION

4 A control group of approximately 300 participants continued driving under usual (baseline) conditions for the duration of the study.

USAGE-BASED CHARGING OPTION DATA COLLECTION

5 Study participants were transitioned, via face-to-face interviews, onto a usage-based charging option. Three options were tested:

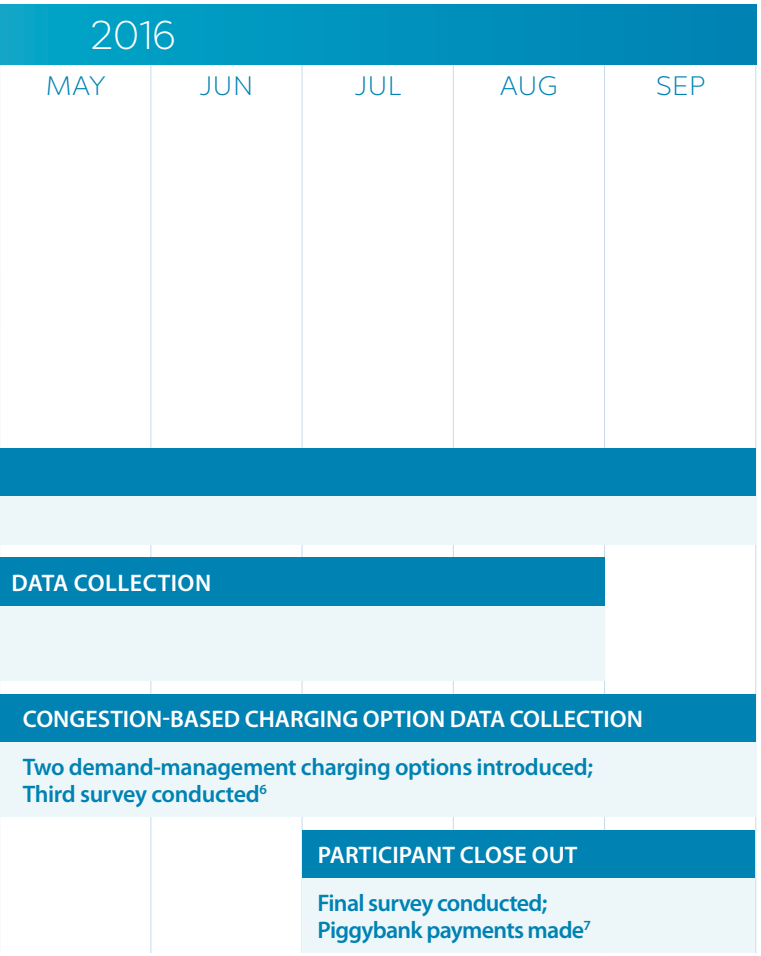
- **Charge per trip** – $1 per trip
- **Charge per kilometre** – 10c per kilometre
- **Flat rate** – 10c per kilometre for a capped number of kilometres and 20c per kilometre for all excess kilometres.

Study participants drove under one of these charging options for three months. Their road usage data was collected throughout this period. Participants also received monthly travel statements detailing their road usage and associated charges. Participants accrued piggybank credits when they reduced their travel.

A second survey was also conducted.

CONGESTION-BASED CHARGING OPTION DATA COLLECTION

6 675 study participants were transitioned, via face-to-face interviews, onto congestion-based charging options. Participants were assigned one of two options:



- **Cordon (area)** – 8c per kilometre plus a daily $8 cordon area access charge to enter or move within a defined zone in inner-city Melbourne from Monday to Friday, 7am to 6pm
- **Time of day** – 15c per kilometre during peak hours (Monday to Friday, 7am–9am and 3pm–6pm); 8c per kilometre at all other times, with prices applicable in all areas.

From this point, participants' road usage was charged according to their new charging option. A third survey was also conducted.

Participants drove under their new option for two months, and their road-usage data was collected throughout this period. Participants continued to receive monthly travel statements, this time detailing their road usage and associated congestion-based charges.

PARTICIPANT CLOSE OUT

7 On completion of the charging option phase, a final survey was conducted by phone. GPS devices were returned and total piggybank balances were paid to participants.

ANALYSIS AND REPORTING

Each participant's baseline data was compared with their usage and congestion data to identify road-usage behaviour changes. Survey responses were also compared to identify shifts in understanding and attitudes to road funding over time.

PARTNER ACKNOWLEDGEMENT

A multi-disciplinary team led by Transurban delivered the Melbourne Road Usage Study. This included social research and behavioural change professionals, technology and traffic modelling specialists, data technicians and statisticians.

This team included:

- **Concepts of Change**, behaviour-change and survey design consultants
- **Ctrack**, vehicle tracking systems supplier
- **Ipsos**, market and social research specialists
- **Optus**, telecommunications supplier
- **Symbolix**, analysis and statistical consultants
- **Newgate Communications**, communication consultants
- **Newgate Research**, market and social research specialists

In addition, a study reference group was established comprising federal and state government departments, industry bodies and motoring associations. Through regular engagement with the study team, the reference group provided valuable guidance that helped shape the study design and implementation.

Transurban thanks the 1,635 study participants for taking part in this landmark study and providing their perspectives on road funding, usage and charging.

STUDY DESIGN IN DETAIL

The study was designed with a staggered Before-After, Control-Impact structure to show differences in daily travel between participants driving under the charging options and a control group of approximately 300 participants. The control group's driving patterns were applied to the data collected from participants driving under the charging options, the "treatment groups", to enable necessary adjustments to account for variations in road use caused by seasonal impacts and other external factors.

The usage and congestion charging options were applied to the treatment groups consecutively to allow for assessment of both sets of data independently and to ensure the manageability of communications. In addition, the size of each treatment group was balanced to ensure adequate sample sizes across all charging options. Participant opt-out rates were monitored throughout the study to ensure minimum group sizes were maintained.

Detailed analysis and statistical modelling techniques were developed by Transurban's internal data specialists in accordance with guidelines from independent professionals.

As part of the participant sampling approach, a sample weighting matrix was developed to map participant responses against a response expected of the broader Melbourne population. Three dimensions were selected for weighting matrix alignment: number of household occupants, dwelling type and home ownership.

REPRESENTATIVE SAMPLING

The study sample was determined using stratification and a household cluster design using the Australian Statistical Geographic Standard (ASGS) to ensure that (as far as possible) every dwelling in Greater Melbourne had equal probability of selection.

Households were sampled from all listed private residences in Greater Melbourne; household selection was restricted to Statistical Area 1s (SA1s) with greater than 120 dwellings. SA1 is the second smallest grouping of households under the ASGS and typically ranges from 100 to 300 dwellings (or between 200 and 800 people).

Ninety SA1s were targeted for recruitment with a further 30 identified and held as reserves in case of non-response. This is known as household clustering, which involves choosing groups of households in the same neighborhood. Clustering offers efficiency in the field as field workers can approach multiple households for recruitment in a short period of time. However, it can come at a small statistical cost as households within a certain area may have similar behaviours. This potential effect was tested and accounted for using standard statistical techniques during the analysis phase.

The sample was segmented into three geographical zones to ensure adequate coverage and representation. The zones were defined at a Statistical Area 3 (SA3) level. The zones reflected distinct regions in Greater Melbourne related to the different access to public transport options experienced by Melburnians (Figure 26).

PILOT STUDY

The study design, sampling approach and targeted communication methods were tested and refined through a 70-participant pilot conducted prior to the full-scale study.

Field testing the methodology – from recruitment through to data collection and its findings – provided valuable insights that informed the design and operation of the study.

Data collected during the pilot study was excluded from the main study's data and analysis.

Within each target household, the most modern vehicle was chosen for the study participant. In a small number of cases (79) where the most recent vehicle was not available, the next newest vehicle was chosen.

The participant was the main driver of the targeted vehicle. Where households indicated during recruitment that there were joint main drivers, one was selected.

The configuration of the final treatment group was informed by a statistical power analysis suggesting a sample size of 300 in each treatment group would be required to optimise opportunity to detect a material change in behaviour that could be attributed to the charging option trialled, as well as a control group of 300 participants.

WEIGHTING AND CORRECTIONS

The demographic data gathered in the recruitment phase demonstrated that households in the study were broadly representative of the households of the Greater Melbourne region. Differences in demographics were addressed through weighting and post-stratification correction (using Australian Bureau of Statistics' Census 2011 as target values for home ownership, dwelling type and number of occupants).

Some slight differences in the participant demographics remained as an outcome of choosing the newest vehicle in each household rather than a random participant within a household. For example, the under-30 age class was under-represented, while full-time workers were slightly over-represented. There was also a minor over-representation of higher incomes and under-representation of lower incomes. The nature and small magnitude of these differences did not affect the strength of the statistical analyses.

FIGURE 26. PARTICIPANT ZONE BOUNDARIES

MELBOURNE ROAD USAGE STUDY GEOGRAPHIC ZONE DEFINITIONS

Zone One: inner-city suburbs with access to all modes of public transport, includes Balwyn 10 kilometres east of the CBD, Caulfield 12 kilometres south-east and Footscray 6 kilometres west of the city centre.

Zone Two: middle and outer suburbs with access to some modes of public transport, includes Frankston 40 kilometres south of the CBD, Dandenong 30 kilometres south-east of the city centre and Tullamarine 20 kilometres north.

Zone Three: outer regions with partial access to some modes of public transport, includes Mornington Peninsula approximately 80 kilometres south of the CBD, Bacchus Marsh 65 kilometres west, and Yarra Ranges approximately 60 kilometres east of the city centre.

BASELINE DATA COLLECTION

During the baseline period of the main study, participants drove with the GPS devices installed, but with no usage or congestion charges applied to their road usage. This baseline data was crucial to the study as it provided a means of comparing road usage behaviour under normal conditions and under the different charging options. A minimum of five weeks of baseline data was collected for each participant.

Figures 27 and 28 show the baseline data collected by trip and by average trip length for all participants. This data was compared against the estimated trips in the Victorian Integrated Survey of Travel and Activities 2012/13 (VISTA 2012/13) and found to be in reasonable alignment, with average daily trips of participants in the study just slightly lower than the 3.7 car driver trips per day for people in the Melbourne and Geelong regions.

FIGURE 27. PARTICIPANTS' AVERAGE NUMBER OF TRIPS PER DAY DURING THE BASELINE PERIOD

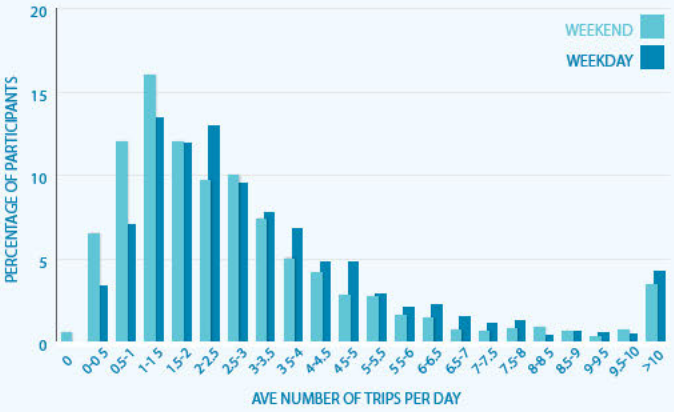
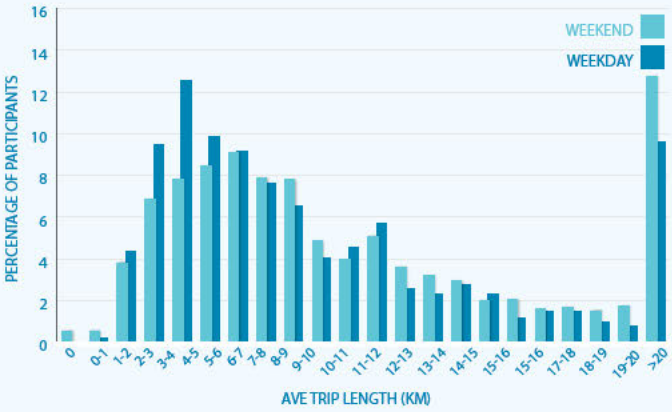


FIGURE 28. PARTICIPANTS' AVERAGE TRIP LENGTHS DURING THE BASELINE PERIOD



USAGE AND CONGESTION CHARGE DATA COLLECTION

Once a participant's baseline data was established, they were progressed into the charging-options stages. Data was collected to identify whether, and how, participants changed their road-usage behaviour under different charging options.

Three months of individual participant data was collected during testing of the usage-based charging options, and two months of individual participant data was collected during testing of the congestion-based charging options. Participants moved from one stage to the next on a rolling schedule. To complete testing within the study timeframes, recruitment for the congestion-based charging stage was concluded once the quota of approximately 300 participants for each charging option was reached.

ANALYSIS APPROACH

The main objective of the study was to characterise the behaviours, attitudes, understanding and preferences of Melbourne motorists towards different road-charging options.

Behaviour (travel patterns) and stated attitudes were compared across groups and before-after treatment using a mixed, general linear modelling approach. Analysis was undertaken by response variable (number of trips per day, average distance per trip or distance per valid travel day) and the individual factors potentially influencing the mean (such as treatment group, strata, and so on).

Weighted regression models were applied to the data in order to discount any impacts of a cluster effect due to the sampling approach used. That is, where households within a certain area may have more similar patterns than households of the broader region.

As is expected in non-compulsory research, not all participants completed final surveys within the study timeframes, and the number of participants included in the attitudinal results varies accordingly.

The study's analytical approach was designed in conjunction with independent specialists in statistics, market research and behavioural change. Aggregate-level analyses across sampling, weighting, and attitudinal and behavioural change were performed by these specialists to ensure the accuracy of the findings.

Beyond analyses undertaken at the aggregate level, more detailed examinations were undertaken to explore particular areas of interest. One example is the extended analysis undertaken to explore the behavioural differences (if any) across and within the different charging options. Notes have been included where analysis of behavioural and attitudinal results differed from the approach outlined in this section.[12]

PARTICIPANT ENGAGEMENT

An engagement approach was specifically designed for Melbourne Road Usage Study participants, to offer support and access to information through a range of channels.

The communications program was aligned to two broad objectives, namely, to ensure effective-yet-unbiased participant communication and to provide ongoing support for participants. The strategies used to achieve these objectives are outlined in Figure 29.

FIGURE 29. COMMUNICATION STRATEGIES

Effective, yet unbiased, communications	Support for participants
• to ensure baseline road usage data was not influenced by participant expectations or interpretations, initial communications made no mention of user-pays or other charging terminology	• to ensure participants could contact the project team quickly, reducing potential impacts on the data collection process, a staffed 1800 enquiries number, open from 8am to 8pm, seven days a week and an email address were established
• simple visual concepts such as easily recognisable icons and travel statements that are visually similar to other common household account statements were created	• an online portal where participants could find frequently asked questions and access more detailed information was also available with content updated daily

12 For example, refer to the direct and descriptive analysis for high change group on page 32 of this report.

The study used a two-way engagement approach to recruit and survey participants, to give participants opportunities to ask questions and provide direct feedback.

A comprehensive communications program was implemented throughout the study. Figure 30 broadly outlines the techniques used to engage with participants.

By the end of the study, participants had made 4,000 unique visits to the online portal, approximately 230 email enquiries to the study's participant-dedicated email address and 500 phone enquiries via the 1800 number. The most common contact types involved:

- providing information about their GPS device when requested
- asking for information about their role in the study – what was expected of them and what they could expect in the future
- providing updated personal details
- providing feedback on their study experiences.

FIGURE 30. COMMUNICATIONS PROGRAM

	Initial letter announcing program
	Three face-to-face surveys (at recruitment and the commencement of each charging option phase)
	Monthly travel statements, sent by post and email
	1800 enquiries line for participants to ask questions and for researchers to contact participants to investigate and resolve observed data and/or technology queries during the study
	Six focus groups held during the main study to gain insights into the success and impact of the communications and to recruit participants for video interviews
	Website content updated daily on participants' portals
	Final telephone survey

STUDY FINDINGS

Findings from the Melbourne Road Usage Study provide valuable insights into what motorists think about Australia's current road-funding system and reveal how motorists respond when roads are charged transparently and according to use under a range of charging options.

The findings suggest that a user-pays road-charging system could work in Australia and could provide a sustainable, fair and flexible system that grows with demand.

SUSTAINABLE FUNDING SOURCE – USAGE-BASED CHARGING OPTIONS FINDINGS

The first stage of the study tested three usage-based charging options, including a charge per kilometre, charge per trip and a flat rate, to determine whether a user-pays road-charging system could work in Australia by providing sufficient funding to meet our infrastructure needs.

Participants indicated their charging options preference through a series of attitudinal surveys. The surveys showed the charge per kilometre was the most popular and memorable option, and potentially, the easiest to understand.

Of the participants who preferred a usage-based system over the current system, 59 per cent preferred the charge per kilometre option compared with 21 per cent for the charge per trip and 20 per cent for the flat-rate option (Figure 31).

Seventy-two per cent of participants driving under the charge per kilometre option could recall that this was the regime they were driving under. Comparatively, only 64 per cent of participants driving under the charge per trip and 37 per cent of flat-rate participants could recall their particular option (Figure 32).

The number and nature of charging options to be made available would need to reflect not only the priority policy objectives but also practicalities of broad-based roll-out. Among the three example usage-based charging options used in the study, the charge per kilometre and charge per trip options are arguably more direct in nature than the flat-rate option which sets fixed usage amounts per billing period.

On the other hand, the flat-rate option could more easily cater for vehicles not equipped for GPS device installation by relying on periodic odometer readings, thus providing more practical choices across the diverse range of models in Australia's existing vehicle fleet. For the Melbourne Road Usage Study, all participants' vehicles did have GPS devices installed.

> *I was on a pricing plan based on kilometres which actually provided me with probably a better insight into my driving habits than I'd ever had before.*
>
> *Rob | Hampton*

> *For me, I would probably prefer the charge per trip option because I do a lot of kilometres, but I'm not stopping and starting a lot. Whereas someone who's doing a few kilometres but lots of trips would find the charge per kilometre option better. So I don't think there's a one-size- that- fits-all charging plan, unfortunately.*
>
> *Linda | Carrum Downs*

FIGURE 31. PREFERENCES OF USAGE-BASED CHARGING OPTIONS (OF THOSE WHO PREFER USER PAYS)

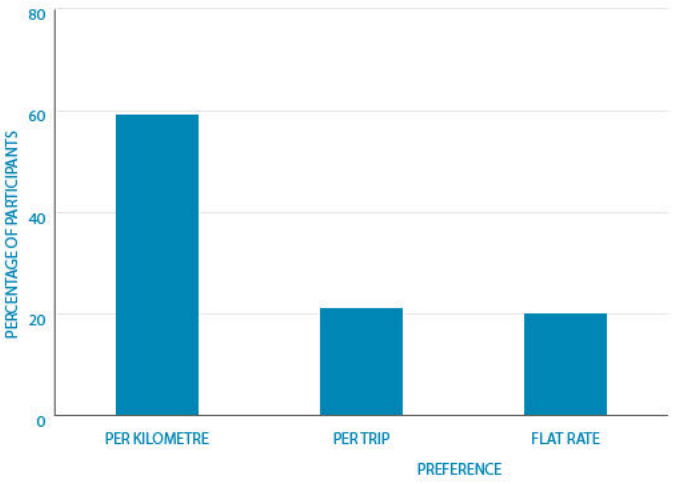
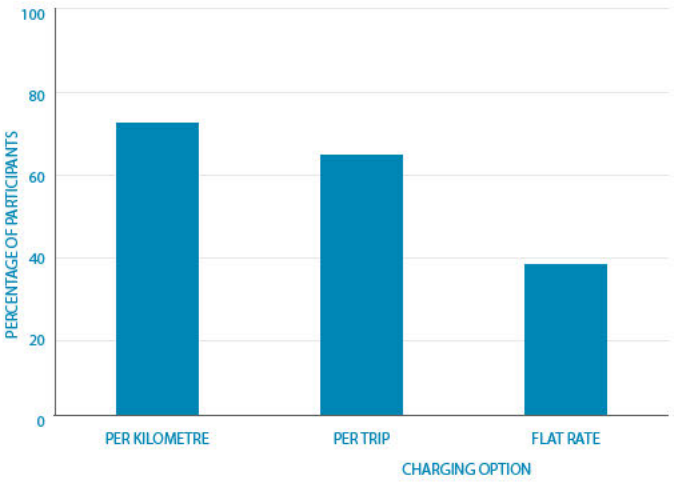


FIGURE 32. PARTICIPANTS' RECALL OF THEIR CHARGING OPTION



TESTING THE SUSTAINABILITY OF USER PAYS AS A FUNDING OPTION

The study showed that participants were open to trying more direct and transparent ways of paying for their road use and, after doing so, preferred a user-pays model over the current road-funding system.

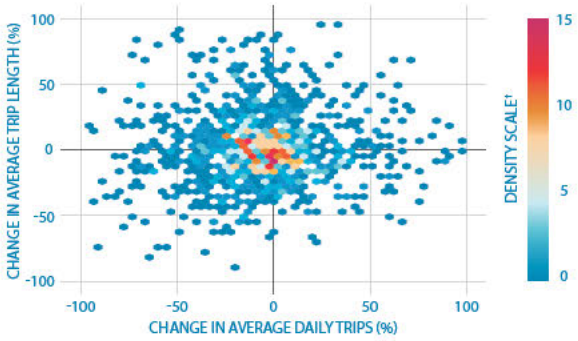
At an aggregate level, participants who trialled the usage-based charging options maintained largely consistent travel activities.* This suggests the charging options did not impede their usual driving behaviours.

> *I haven't been completely religious and regimented on vehicle usage. I have been conscious of it, but if I can avoid using the car I will.*
>
> *Cam | Whittlesea*

Figure 33 plots the degree of travel behaviour change exhibited by participants at an aggregate level. Changes are also analysed by control and the three charging options (Figures 34 - 37).

Travel behavioural change is shown as a percentage change in the average number of daily trips (horizontal axis) and the average trip length (vertical axis) made by participants, with the centre of the chart representing those who did not exhibit any change. The similarity in plot distribution across all groups of participants, control and charging options, suggests that the charging options did not substantially impede participants' usual driving behaviours.

FIGURE 33. CHANGE IN DAILY TRAVEL – ALL PARTICIPANTS



* Other than variations adjusted for factors not related to charging such as seasonality, in line with observation of control group behaviours.

† Density represents the number of participants who demonstrated similar behavioural changes

MEET BOB FROM ESSENDON – CHARGE PER KILOMETRE

Bob is a keen footy fan and a dedicated Essendon supporter. Bob mainly uses his car to make short trips across Melbourne, often to visit friends and family and to play golf. However, when he's travelling to the city, he takes public transport. Bob explains, "It's pretty hard to take a car into the city now. You don't really want to. I certainly don't. I either go by tram from the end of the street, or I drive the car down to the train station."

While driving under the charge per kilometre option and despite making "a conscious decision not to vary his driving at all", Bob reduced his overall driving and his overall trips. "When I saw my results, I thought, gee whiz, I've travelled less than what I estimated. It surprised me as I haven't altered what would be my normal type of driving habits."

"Price per kilometre seems the most logical way. You think about what you do and you can certainly change your pattern of what you do, or how you do it. Maybe you'll do three things in one trip rather than do three separate trips."

FIGURE 34. CHANGE IN DAILY TRAVEL – CONTROL GROUP

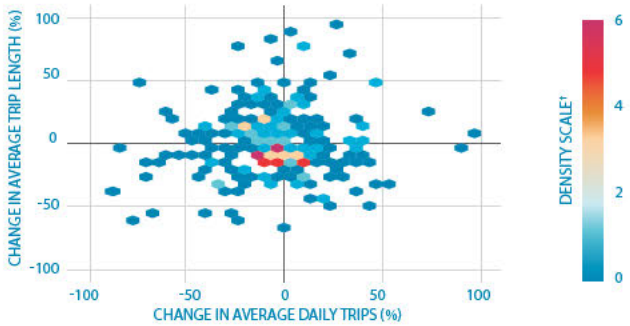


FIGURE 35. CHANGE IN DAILY TRAVEL – CHARGE PER KILOMETRE OPTION

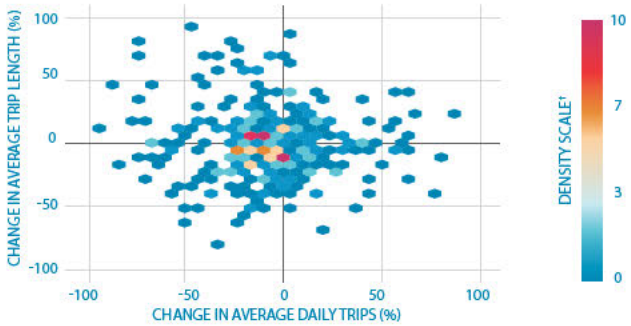


FIGURE 36. CHANGE IN DAILY TRAVEL – CHARGE PER TRIP OPTION

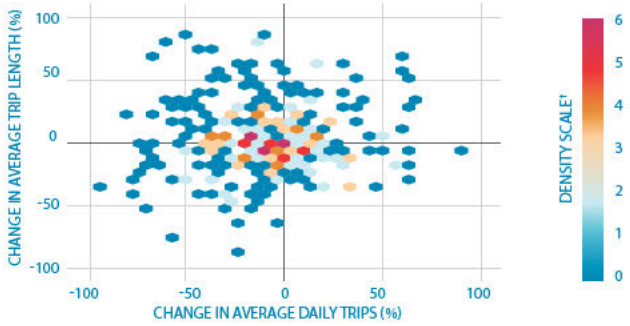
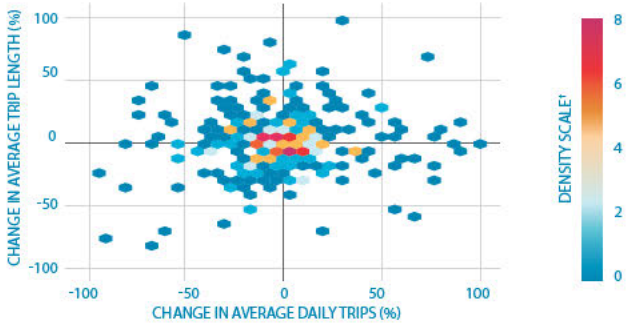


FIGURE 37. CHANGE IN DAILY TRAVEL – FLAT-RATE OPTION



ANALYSIS OF THE HIGH-CHANGE GROUP

Looking beyond the collective observations, descriptive analyses were undertaken to compare participants who exhibited high levels of change (either increased or reduced travel) with those who exhibited low levels of change (Figure 38), in order to identify any demographic distinctions across the two groups. Outliers – participants with the highest levels of change – were excluded from this process.

The analyses compared the high-change and low-change groups across common demographic factors such as age, income and household type. No substantial differences were found between the two behavioural groups (Figures 39, 40 and 41).

While no significant behavioural change was noted at an aggregate level, some differences were observed between the options trialled. While the road use of participants trialling the direct usage options – charge per kilometre and charge per trip – remained relatively aligned with seasonal traffic levels, participants on the flat-rate option have shown a tendency to increase the average number of trips taken per day.[13]

Further testing is required to confirm the trend and ascertain the particular factors causing these differences. Notably, only 37 per cent of those on the flat-rate option could correctly recall this as the option they were driving under. Potentially, participants who trialled the flat rate, which is a similar concept to a capped plan for a mobile phone, may have interpreted the charging option as unlimited travel.

> *I'm a little bit vague about how it transpired. But what's happened is I've been allocated so many kilometres per month. That's the baseline. Some months I go over it and some months I go under it.*
>
> *David | Forest Hill*

FIGURE 38. RANKING OF PARTICIPANTS' CHANGE IN TRAVEL

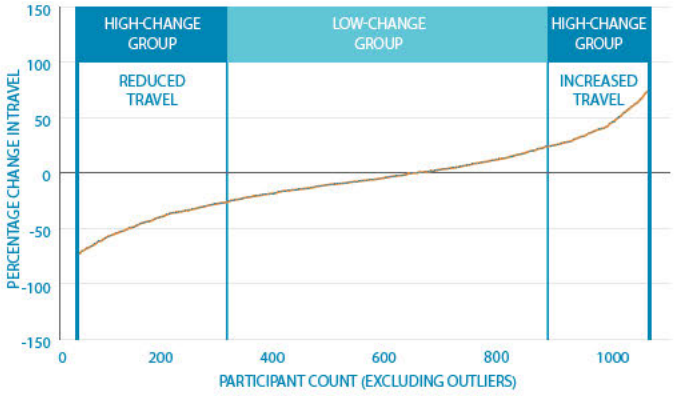


FIGURE 39. HIGH-CHANGE GROUP VS LOW-CHANGE GROUP – BY HOUSEHOLD TYPE

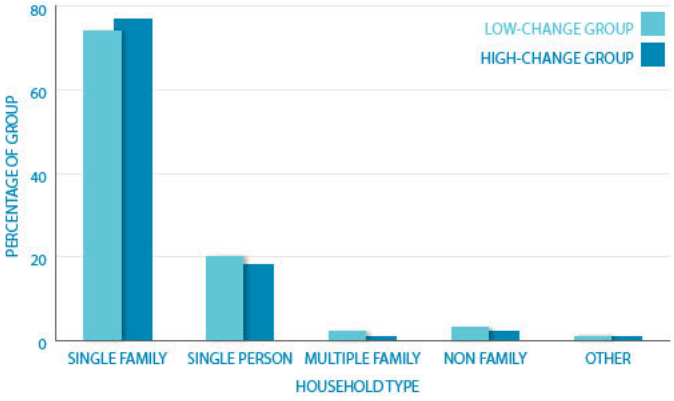


FIGURE 40. HIGH-CHANGE GROUP VS LOW-CHANGE GROUP – BY INCOME BRACKET

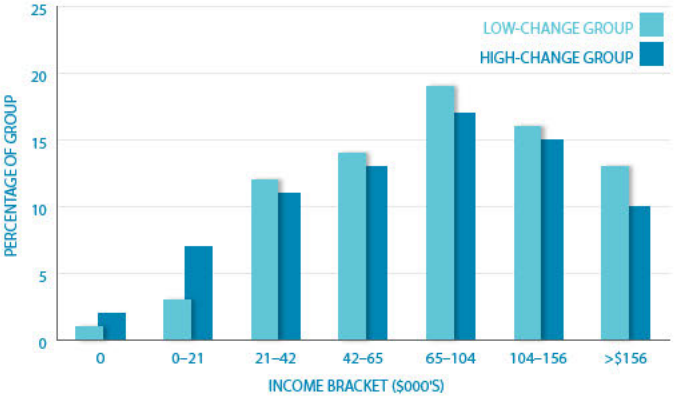
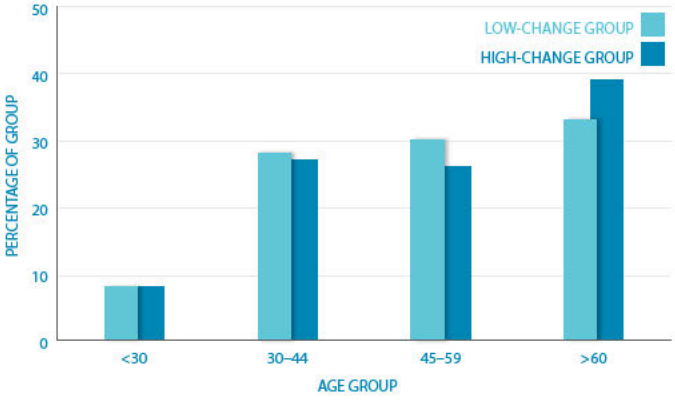


FIGURE 41. HIGH-CHANGE GROUP VS LOW-CHANGE GROUP – BY AGE GROUP



13 Relative to the control group and the flat-rate group's behaviour during the baseline period

MANAGING DEMAND: CONGESTION-BASED CHARGING OPTIONS FINDINGS

In addition to providing a sustainable funding base that grows with demand, a user-pays system offers the flexibility Australia needs to help manage traffic congestion through the use of price signals to modify behaviours in highly congested geographies or at peak travel times.

This would add an effective tool to the suite available to policymakers to manage demand, including behavioural change initiatives and communication programs, and the provision of alternative transport modes.

Only a small percentage shift in travel patterns is required to achieve peak spreading and make a considerable difference to the overall demand profile of the road network. Industry bodies have suggested that even a five per cent change in traffic levels during peak periods would increase traffic speeds by 50 per cent[14], similar to the traffic flow changes commonly observed during school holiday periods.

Building on the usage-based charging options, two congestion charging options – an area-based option (cordon charge) and a time-based option (time-of-day charge) – were tested.

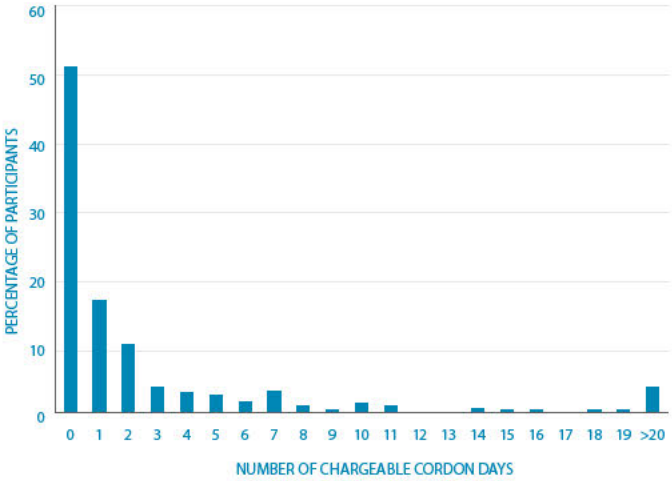
CORDON CHARGING

The study showed that cordon-charging could be effective in Australia as a congestion management tool, with a subset of participants reducing their road use within the CBD during peak periods.

Of the 319 participants who completed trialling cordon charging, 51 per cent did not enter the cordon in peak times during the baseline period (Figure 42), with many not entering the area at all during the study. The group of participants who entered the cordon as part of their usual driving habits appeared to have reduced their weekly cordon travel by 10 to 15 per cent.

Despite the observed downward trend for the participants who entered and travelled around the Melbourne CBD cordon, the road usage for the group at aggregate, including those who never entered the cordon, remained largely unchanged during the application of a cordon charge. This result supports the view that demand-management tools need to be targeted to deliver desired outcomes.

FIGURE 42: PERCENTAGE OF PARTICIPANTS WHO ENTERED THE CORDON AREA DURING THE BASELINE PERIOD



While cordon charging was applied to the easily recognisable boundary of Melbourne's CBD for the purpose of the study (Figure 43 on page 34), it does not necessarily need to be limited to city centres. It also has application for other areas experiencing temporary or sustained congestion.

Look, I think (congestion charging) is sort of fair, especially if it has an impact where it's reducing a lot of congestion … I think it's going to be, to some degree, maybe even inevitable in Melbourne … that's a bit of a gut feeling.

Trish | Burnley

(With the GPS devices) you have the capability of geo-fencing the whole, if you like, metropolitan area. So you can define what you call the Greater Melbourne area and say charges apply within these hours in this area. And outside, they don't apply. That would be a fairer way of doing it.

Rob | Hampton

14 Kelly, J and Donegan P, City Limits, Melbourne University Press, 2015, page 172

FIGURE 43. CORDON AREA TRAVEL DURING A DEFINED TIME PERIOD

FIGURE 44. PARTICIPANTS' COMFORT WITH CORDON-CHARGING AFTER EXPERIENCING THE OPTION

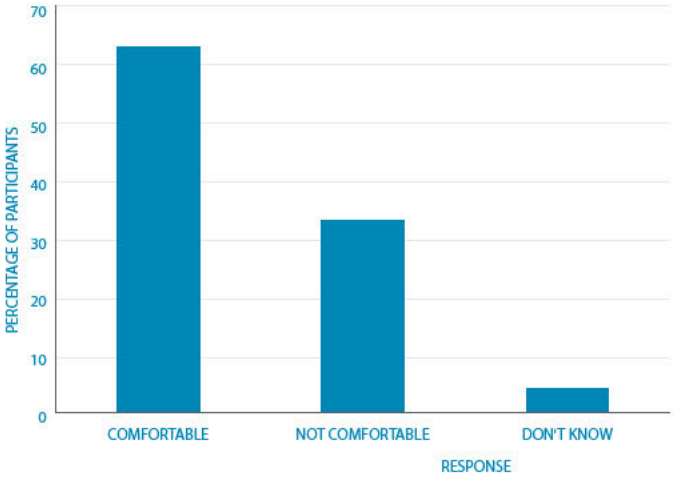


Figure 43 shows a summary of participant use of the cordon area during the baseline (represented by yellow dots) and charging (represented by blue dots) periods. Each dot represents the first transmission registered from the participant's vehicle within the cordon area during peak periods. Clusters are evident on arterial roads crossing the cordon boundaries as participants entered (or exited) the cordon area. Dots inside the cordon area show the vehicles that were already in that area when the first transmission was sent as they moved within the CBD.

Sixty-three per cent of participants who trialled the cordon charge said they would be comfortable paying for road use in this way (Figure 44).

63% WHO TRIED CORDON CHARGING SAID THEY WOULD BE COMFORTABLE PAYING FOR ROAD USE THIS WAY

The results suggest that even those who travel often into the cordon area could be supportive of this option if they see the benefits. Forty-nine per cent of those who travelled most often (more than six times in the treatment period) into the cordon area said they would be comfortable paying for their road use in this way - although this represents only a low number of participants. Of those who gave reasons for their discomfort with cordon charging as a permanent system solution, being worried about additional costs was the most stated (25 per cent).

TIME-OF-DAY CHARGING

Figure 45 shows the start time of trips taken by participants in the time-of-day charging option during the baseline period. At an aggregate level, analyses of behavioural change showed that participants' patterns and levels of road use in the presence of a time-of-day charge were largely consistent with those during normal driving periods. This result contrasts with the downward trends observed in the subset of participants trialling the cordon charge option.

51% WHO TRIED TIME-OF-DAY CHARGING SAID THEY WOULD BE COMFORTABLE PAYING FOR ROAD USE THIS WAY

In parallel with observing behavioural changes, the study also gathered information about participants' attitudes and preferences towards the charging options presented. Fifty-one per cent of participants who tried time-of-day charging said they would be comfortable paying for road use this way (Figure 46).

Further investigation is required to understand the factors that have contributed to the behavioural change and attitudinal observations. A hypothesis is that the time-of-day charging signal as applied in the study was not well understood by participants. Specifically, there were four different components for participants to remember on the time-of-day charging

FIGURE 45. TIME-OF-DAY PARTICIPANTS, TRIP START BY TIME OF DAY (BASELINE)

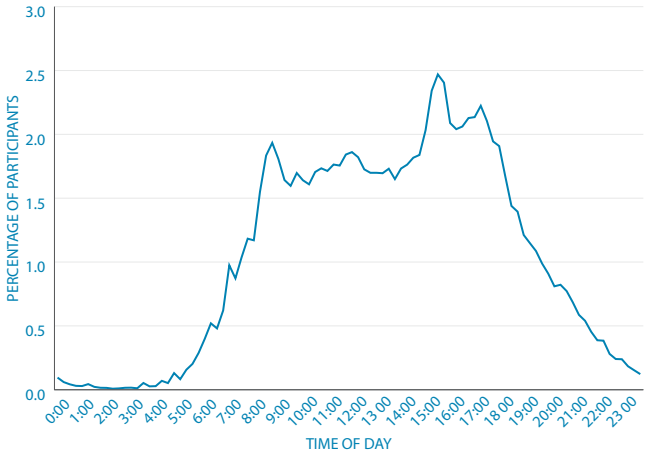
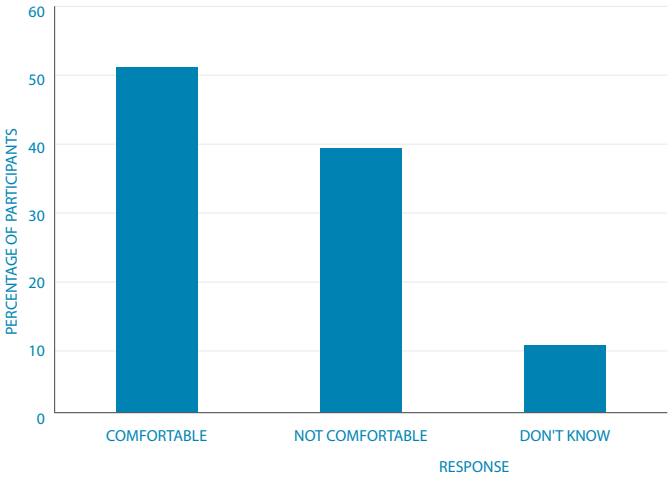


FIGURE 46. PARTICIPANTS' COMFORT WITH TIME-OF-DAY CHARGING AFTER EXPERIENCING THE OPTION



option – peak charge, off-peak charge, morning peak period and afternoon peak period. Only 27 per cent of participants could recall the peak charge associated with the time-of-day option, compared with 46 per cent recalling the cordon access rate in that charging option.

This does not necessarily mean that time-of-day charging would not have application in Australia, but rather, that the charging signal needs to be clearer for users, and more specific in application before it can effectively address demand issues for targeted geographic zones or roads. Time-of-day charging has already been successfully implemented internationally.

OVERALL FINDINGS

The behavioural and attitudinal testing conducted as part of the study demonstrated that a user-pays system can provide a sustainable funding source. It also demonstrates the flexibility a user-pays system could offer in enabling a wide range of price signal options to help to manage demand. Furthermore, it found that Australians are open to discussing this as a viable alternative to the current system.

Setting clear objectives for a user-pays system in Australia will underpin its effectiveness. The extent to which addressing congestion is prioritised alongside the objective of restoring a sustainable funding base for Australia's road networks will be an important consideration for policymakers.

EFFECTIVE APPLICATION OF CONGESTION CHARGING – TWO EXAMPLES

Internationally, different forms of congestion charging have been successfully applied to manage demand and achieve other policy objectives, giving an indication that it could be an effective mechanism for Australia.

Transurban's dynamically priced 495 and 95 Express Lanes in the USA, provide real-world examples of how pricing signals and technology can be used to manage demand, deliver consistent service levels for motorists and achieve other policy outcomes in the busiest transport corridor in the East Coast. Based on a sophisticated algorithm, the toll-price increases and decreases depending on traffic density and ensures a minimum average speed of 55 miles per hour and 45 miles per hour for the 95 and 495 Express Lanes respectively.

During peak periods, traffic speeds on the 95 Express Lanes are on average 40 per cent higher than on the adjacent general purpose lanes.[15]

Singapore has successfully used peak/non-peak incentives to help manage demand in conjunction with a geography-based charging signal. Despite its population growing by 140 per cent and rapid expansion of its national fleet, traffic volumes travelling into the city during morning peak hours are less now than in 1975, when road pricing was first introduced. The city also enjoys some of the world's highest peak-hour traffic speeds.[16]

15 Transurban Investor Day presentation, 2016
16 Menon, A.P. and Loh, N., Singapore's Road Pricing Journey – Lessons Learnt and Way Forward, Journeys, 2015 (https://www.lta.gov.sg/ltaacademy/pdf/J15Nov_p18Menon_SingaporesRoadPricing.pdf)

STUDY PARTICIPANTS DISCUSS CONGESTION

Participants flagged their concerns with congestion as a reason for joining the study, and the idea of road charging as a means for controlling congestion was also raised by participants.

Trish, a retired nurse who lives in inner-city Burnley, would like to see congestion addressed. She says she deliberately avoids driving in her area during peak periods or she'll get "stuck" in traffic. "I've learnt," she says, "I don't take my car into the city. I've had a couple of bad experiences when I thought I'd luck it and it went all pear-shaped. So I'm way over taking my car into the city." Unlike most participants, prior to the study Trish says she was already "fairly conscious of only trying to use my car when I needed it" through means such as instigating "car-free days", and riding her bike or walking to local destinations.

Trish agrees road charging has the potential to ease congestion. "Look, I think (road charging) is sort of fair, especially if it has an impact where it's reducing a lot of congestion … I think it's a good thing and I think it has been used in London and it's been quite effective or people are happy with it and it's changing people's behaviour. I think it's going to be, to some degree, maybe even inevitable in Melbourne … that's a bit of a gut feeling."

Trish also says public transport is an essential tool in easing congestion. "You've got to have at least some adequate or efficient infrastructure, particularly public transport."

Lenore, a retiree living in Bentleigh, agrees. "My pie-in-the-sky hope is that, eventually, public transport gets to the stage that it actually fits the bill or suits people," she says. "Whether you'd be able to get enough public transport to make sure people could do it reasonably, without being left on stations and without having to stand up from one end of the trip to the other, I don't know."

Rob is a project manager living in Hampton with his wife. Self-employed, Rob says he enjoys some freedom in how he travels during the week but he still encounters his share of traffic when attending 9am client meetings.

Participating in the study served as a wake-up call for Rob who says his participation prompted him to make lasting changes in how he uses his car.

"I think (the study) was really illustrative," he says. "Travelling at certain times, if you don't need to, you are actually just adding to the congestion. I can make a conscious choice to avoid doing that."

STUDY LIMITATIONS

The Melbourne Road Usage Study is the first real world test of user-pays charging in Australia. The study sought to offer valuable insights for policymakers, industry and communities in considering long-term changes to road funding to achieve objectives including funding sustainability, fairness and flexibility to respond to changing and growing transport demand.

Like any real-world trial, the study possesses a number of characteristics that limit its ability to fully reflect the conditions that would be present under an actual, system-wide user-pays system. Thus, the study may not detect the full range of corresponding behavioural changes that may materialise under a broad-based scheme.

While participants' behavioural responses are a key element of the findings, the study was not designed to shift behaviours towards specific outcomes – unlike a change management program that would typically accompany a wholesale policy change implementation. Rather, the study provided opportunities for motorists to consider their current driving behaviours and identify opportunities for change without targeted prompting.

For many participants, the incentive to change would likely be greater if they were paying for their road use rather than missing out on potential incentive dollars in their travel account. Known as 'loss aversion', the theory is that people are more likely to change their behaviours if they are faced with a potential loss rather than the incentive of a potential gain.

As the charging options were not applied across the entire road-user base, experiential outcomes in response to behavioural changes made by participants could not be simulated in the study. For example, participants choosing to incur a cordon charge did not experience an improved, less-congested driving experience, as the rest of the road users were driving under normal conditions without a cordon charge applied. This may have served to reduce the impact of positive reinforcement for participants for their behavioural change.

Finally, the relatively short duration of the study may not have allowed enough time for participants to consider how to factor changes to their road use into their routines and lifestyles. Similarly, the practical delivery of alternatives and valid choices such as new public transport alternatives, and flexible working hours and access to services typically take time to implement.

Interestingly, despite the limited changes observed at an aggregate level for road usage charges, 30 per cent of participants reported changing their road use. Further work is recommended to explore factors that contributed to the differences in perception (stated) and actual (observed) behavioural changes and testing of areas not covered by this study.

SYSTEM DESIGN

Highlighting the power of information sharing and practical experience in building awareness, a series of attitudinal surveys conducted at key points during the study showed a considerable shift in participant preference towards a user-pays model over the current system of opaque fees and charges.

At the start of the study, 85 per cent of participants were comfortable with the current system (Figure 47). However after experiencing alternative ways of paying for their road use, 60 per cent said they preferred a user-pays system (Figure 48).

Study participants provided insights into important elements in system design and implementation that warrant further exploration, including:

- transparency and awareness
- choice
- fairness
- technology
- privacy and information security.

These areas are explored in more detail throughout the following sections.

FIGURE 47. PARTICIPANTS' COMFORT WITH THE CURRENT SYSTEM BEFORE TRIALLING USER PAYS

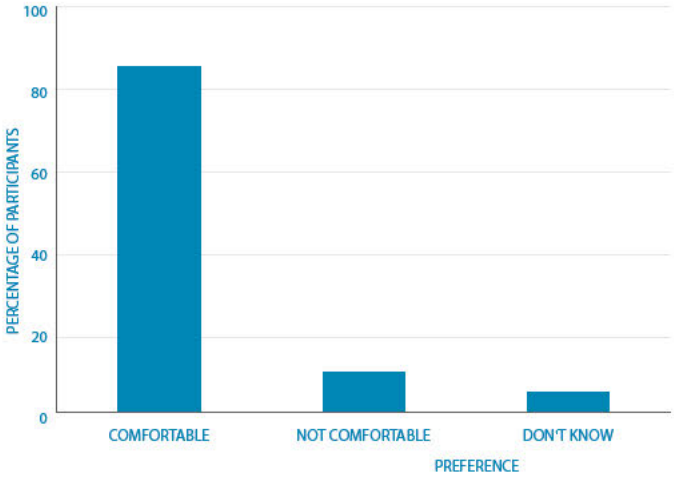
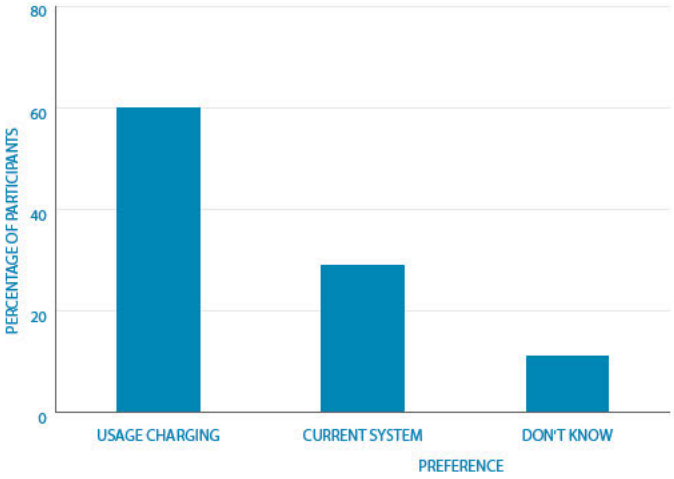


FIGURE 48. PARTICIPANTS' PREFERENCES IN FUNDING SYSTEM AFTER TRIALLING USER PAYS



NATIONAL MARKET RESEARCH

When presented with descriptions of the usage-based charging options trialled in the Melbourne Road Usage Study, research respondents preferred the charge per kilometre option. Respondents said they evaluated each option on its fairness. Specifically, they wanted all road users to pay their fair share.

The congestion-based charging options trialled in the study were appealing to respondents with 45 per cent of respondents positive towards a cordon charge and 42 per cent positive towards time-of-day charging.

In the qualitative research, where discussion was more in-depth, many noted that cordon charging would need to incorporate some element of time-of-day charging to address fairness. For example, respondents indicated that it did not seem logical to charge people for driving into the CBD at 3am.

"Where possible, I try and avoid driving during peak and will often stay late at work or come in early to do so. I like the idea that I might be able to be 'rewarded' with a discount for doing so. QLD"

FIGURE 49. PARTICIPANTS' AWARENESS OF CURRENT FUNDING SOURCES

TRANSPARENCY AND AWARENESS

In line with results from national market research, participants had limited awareness of their road use, with only 20 per cent accurately stating how many kilometres they drove or trips they made each week, month or year.

Through involvement in the study and experiencing a more direct and transparent way of paying for roads, one in two participants reported they became more aware of their road use (47 per cent), compared with just 11 per cent of those who did not try a user-pays option.

In addition, over the course of the study, participants' understanding of the current road-funding system increased by 23 per cent with a higher proportion of participants able to identify major road-funding sources (Figure 49). With this understanding came a greater appreciation of today's challenges.

Some participants indicated they were not comfortable with the current system of paying for their road use. When asked for their reasons, those who had experienced both the usage and congestion-charging options were more likely to say they believed the system should be user-pays (40 per cent), compared with those who experienced just a usage-based charging option (23 per cent) or had not trialled a user-pays option (11 per cent).

COMMUNICATION CHANNELS

For the main part of the study, two communication channels – a monthly travel statement and an online portal – were provided to participants. These both contained the same summary information about their travel and account balance. In addition, the portal provided further details on individual trips made by the participant, along with a history of their travel and previous charges incurred.

Participants engaged more with the travel statements, which were delivered to them directly by post, than the online portal. Eighty-six per cent of participants who experienced a usage-based option, and 94 per cent who experienced both a usage-based and congestion-charging option indicated that they read their statements. Comparatively, just 32 per cent of participants said they visited the online portal.

Through these channels, participants said they gained the most knowledge about the kilometres they had travelled. Figure 50 shows feedback from participants about the type of information they found the most useful. These results indicate that over time, engagement and awareness increased.

INSIGHT: AWARENESS LEADS TO OPENNESS TO CHANGE

Over time and with exposure to appropriate information, participants indicated that they became more aware of their road use. By experiencing a direct and transparent way of paying for their road use, participants became more engaged and showed openness to shifting to a user-pays system.

FIGURE 50. MOST USEFUL INFORMATION PROVIDED IN THE TRAVEL STATEMENTS.

	Participants trialling a usage-based charging option	Participants trialling usage and congestion based-options
Information about my kilometres	36%	48%
Information about my trips	26%	9%
Information about my piggybank	23%	21%
Nothing really	13%	11%
Other comments (e.g. information about their driving such as how much and for how long they drove)	22%	31%

* Participants could select multiple options

NATIONAL MARKET RESEARCH

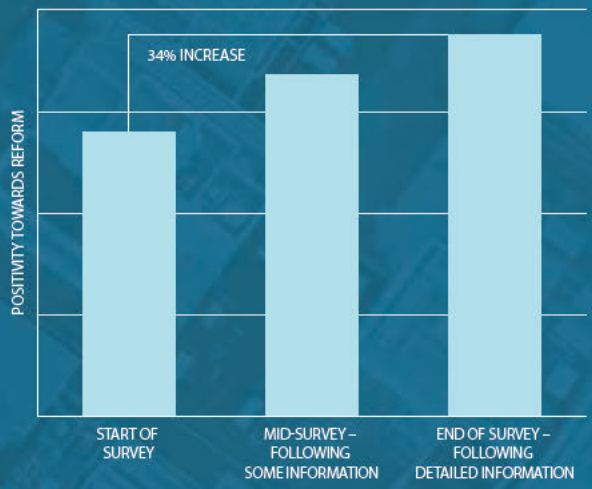
CHANGING ATTITUDES

Most Australians know how much it costs to fill their fuel tank, but our market research showed that 88 per cent of respondents have little or no knowledge about where their fuel money or vehicle registration fees go.

With such a low knowledge base, reform will need to begin with engaging the community to raise the level of understanding of today's funding approach and awareness of the need for change.

At the start of the market research, a small number of respondents felt positive towards road-funding reform. After reading information about the current situation, the number grew by 20 per cent. By the end of the exercise, the total number of respondents who felt positive about reform increased by 34 per cent (Figure 51).

FIGURE 51. IMPACT OF EXPOSURE TO INFORMATION ON POSITIVITY TOWARDS ROAD-FUNDING REFORM



Source: Newgate National Market Research, 2016

CHOICE

Practical access to alternative transport modes emerged as a key factor in determining participants' ability and willingness to change their road use. Wider societal factors such as inflexible work times were also notable considerations.

Study participants were recruited from three geographical zones within the Greater Melbourne region, reflective of the public transport options available at different locations. Some participants living in inner-city Melbourne (Zone One), with ready access to frequent and multiple public transport options, reported their ability to choose between multiple modes of transport as an enabler in modifying their road usage.

In contrast, some participants living further from the city centre (Zones Two and Three), where public transport access is generally more limited and/or infrequent, reported that a lack of practical alternative transport choices limited their ability to change their driving behaviours.

Thirty per cent of participants said they changed their road use during the study. Of those who provided details, 31 per cent of participants who had experienced both the usage-based and congestion-charging options said they had changed their road use by "using their car less". This is compared with those who experienced just a usage-based charging option (25 per cent) or no user-pays options (5 per cent). In addition, participants who trialled the usage and congestion-based options reported greater use of alternative transport modes (Figure 52). Of those who provided details, 30 per cent said they had used more public transport and 23 per cent said they walked more.

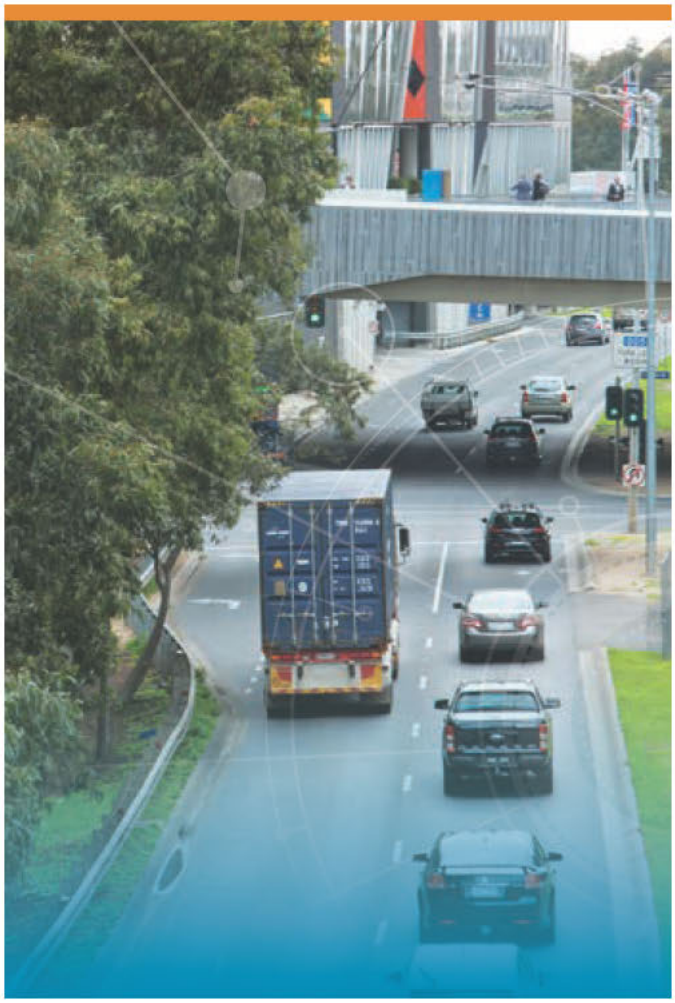
The higher reported use of all alternative modes of transport for participants involved in both phases of the study likely supports a common belief that habits take time and practice to change.

INSIGHT: DRIVING OFTEN UNAVOIDABLE

Study participants indicated that they often drove for reasons they saw as unavoidable. Access to alternative transport modes and wider societal factors such as inflexible work times impacted how they used the roads and their ability to change their behaviours.

FIGURE 52. REPORTED WAYS OF CHANGING CAR USE – ALTERNATIVE TRANSPORT MODES[17]

	Control group	Participants trialling usage-based options only	Participants trialling usage and congestion based-options
Used more public transport	0%	21%	30%
Walked more	2%	17%	23%
Cycled more	0%	1%	5%
Ride share/ car pool	0%	9%	7%
Went by taxi	0%	0%	1%



17 Participants could provide multiple answers to this question

The success of road-funding reform would be heavily dependent on an effective and integrated planning approach that takes into account charging options for roads as well as access to genuine and affordable transport alternatives.

Beyond the availability of public transport alternatives, wider societal factors such as standard work hours, school operating hours and retail opening hours also influence the amount of choice road users have in when and where they drive.

Study participants highlighted how the obligations of everyday life made driving a necessity, influencing their ability to reduce or change their driving while trialling user-pays charging options. Addressing these factors would require the coordinated efforts of multiple government and industry contributors. Ensuring Australians can make genuine choices about how and when they use the roads will be critical in meeting the demand-management objectives of any new system.

> *A lot of people wouldn't have much flexibility because they have to get to their job on time. But if you didn't have a job, or were a pensioner like me, then I suppose you're a lot more flexible.*
>
> *Zac | Doncaster*

STUDY PARTICIPANTS DISCUSS CHOICE

Participants interviewed for this report said that some flexibility was required before any changes in road usage were possible. For those who needed to be at specific places at specific times, change was difficult to accomplish. Those who worked long distances from their homes also found significant change challenging.

Cam, a train driver who lives in Whittlesea, said that driving to the station on his commute into work remained the best choice for him, as catching the bus would add an extra 40 minutes each way to his journey. Where it was practical, Cam did make changes in how he used his car. For example, he started grouping errands together to reduce his overall travel. In fact, he says this habit has stuck beyond the study period. "It's not only of benefit for the environment, but also for me as well," he says.

Linda from Carrum Downs says she also looked for opportunities to change, and where she had a choice, she did reduce her road use. Driving under the charge-per-trip option, she grouped multiple trips together to reduce the overall number; and under the time-of-day charge, she also looked for opportunities to change her driving in line with her charging option.

Linda said it was not possible to remove all travel during the peak charging period but she did try to limit it.

"I would stay at school longer than the usual drop-off time, to leave after 9am and save on that trip home. If I just socialised for 10 minutes, which doesn't cost anything, I could then travel home during the off-peak and save half the cost. But commuting to work, I didn't have that luxury. I couldn't say I'm not coming in until later because it's cheaper for me to come then."

FAIRNESS

Of participants who said they would be comfortable paying for roads in a new way, 15 per cent highlighted aspects relating to fairness that would need to be addressed in any future system.

When considering a real-life application of road-usage charging, study participants wanted to see benefits flow across the entire community and transport network. They said they wanted to see the existing road-related charges eliminated and the funding raised from road usage put directly towards transport projects and maintenance.

Participants reinforced the need for any new system to provide protections for vulnerable and disadvantaged community members. In considering differences between urban and regional road users, some noted that while regional Australians currently contribute to road funding via fuel excise and other charges, they see relatively little investment going into the roads they pay to use. Some living outside the inner city said they want to see their financial contributions provide benefits within their own communities.

Study participants imagined any new system would need to be fairer for all, with safeguards and measures to deliver enduring benefits for all the community, including:

- removing all current charges, including fuel excise, registration, licence fees and stamp duty
- putting funding raised towards construction and maintenance across transport networks
- taking a total transport network approach, including providing access to viable, efficient and cost-effective public transport alternatives for those in inner, middle and outer-urban areas and in regional Australia
- providing protection for the vulnerable in our communities
- looking at options for changing standard working hours and extending or changing essential services opening hours to create more freedom of choice in when and how people travel.

INSIGHT: DELIVERING FAIRNESS

Study participants expected any new system to be fair and equitable for all users. They also expected that other taxes would be eliminated to make way for the introduction of a user-pays system.

Taking the first steps in testing practical user-pays options, the study focused on motorists living in the Greater Melbourne region. Reflective of Melbourne's population demographics, the vast majority of participants lived in urban areas, with some living on the city fringes. This study acknowledges that any user-pays system could impact regional Australians in different ways to those living in cities. These impacts would need to be considered in the design and implementation of any new system.

> *If other charges were to be brought in such as dollars per kilometre, I believe then there should be rebates through other existing methods of funding roads at the moment. For instance it could be a discount in petrol prices or your car registration could be halved or something like that.*
>
> *David | Forest Hill*

> *Well, I think if you were paying money for each kilometre you drove then surely there would have to be some reduction in your registration I would imagine, otherwise it would work very well.*
>
> *Lenore | Bentleigh*

> *A user-pays system might be a little bit fairer. So the people that don't use their vehicles as often are not paying for those who use their vehicles a lot more.*
>
> *Cam | Whittlesea*

> *Road pricing is going to be a more direct cost for the road usage than the indirect costs and the indirect costs are going to disappear.*
>
> *Frank | Dandenong North*

STUDY PARTICIPANTS DISCUSS FAIRNESS

Participants who spoke in support of road-funding reform also wanted to know that any new system would be fairer than the current system, and that it would deliver tangible results.

Tohu works in the city and spends a lot of his weekends travelling around Melbourne to perform with his cultural group. He drives to work from Patterson Lakes most days, but says the train is also in close proximity to his office. Tohu says he likes the idea of offering a range of charging options to accommodate different driving requirements.

"I agree with having different varieties of (charging) plans available," he says. "Not everyone does the same as me. So with the other options available, you can use what's suitable for you and what's more beneficial for you."

He says any new road-charging system would need to be fully user pays, so those who drive infrequently get a fairer deal. "As long as it benefits all road users … (without impacting on) people who may not even have a car. They shouldn't be held responsible for road users. That's my view. I don't expect next door who doesn't use a car to cover my taxes."

Zac from Doncaster says he'd like to see other charges removed as part of implementing a new road-charging system. If other charges remained, he would be less enthused by the idea of reform.

"If they bring out pay-per-kilometre, they could take away the other various charges you have to pay for the maintenance of the roads, like registration and petrol – a decent amount of petrol tax," Zac says.

Meg, an airline worker from Essendon, would like to see more focus on public transport infrastructure spending, and less on roads.

"I get that people are wanting to get places quickly, and they might think getting on a freeway is the best way to do that. But for me, I'd prefer we concentrate more on public transport," she says.

Meg's interest in public transport stems from her concerns about the environment. "I wish everything would get a little bit more green," she says. "We all should have solar on the roof; we all should have wind power and all that stuff, you name it. More public transport so we're off the roads."

Meg also believes, if any new road-pricing system were introduced, changes to existing fees would be necessary. She suggests deducting usage charges from other road-revenue sources, such as council rates and would like to see fuel excise abolished.

"I have a strong view that if something like this (user-pays charging) did come into fruition, then all those other taxes need to be withdrawn – so user pays," she said.

NATIONAL MARKET RESEARCH

WIDER BENEFITS

Research respondents pointed out the need for a system that provided wide-reaching benefits for the whole community, including those living in regional Australia.

They also indicated consideration needed to be given to those who use public transport and those who would use public transport if it were accessible, as well as service operating hours and normal business hours.

Living in rural/remote Australia, we don't receive a good and fair return for our money from revenue for road funding. We pay the same fuel taxes, but haven't really seen any road repairs or upgrades in my area for quite a while. SA

Encourage more use of public transport instead of a whole bunch of cars with one person in each, all heading the same way. Carpool, people! QLD

We pay for the roads. General road funding comes out of our taxes. Petrol tax and road tax does not pay for our roads -they just contribute to general revenue - the big bucket the funding for everything comes out of. NT

I think you would need to see tangible outcomes. A ten minute reduction in the time to travel across town would be a good outcome… To have the main roads around the city flow quickly would be a good outcome. SA

Availability of USEFUL public transport needs to be factored in, too. Encourage me to drive less by providing alternate options that are USEFUL for me. ACT

If you don't have flexibility, then you are stuffed, basically. NSW

TECHNOLOGY

Advances in technology present solutions to enable a modern-day road-charging system. Creating a practical technology suite to support the field-testing of the road-charging options involved assembling several technology components that were fit for purpose. More work needs to be done to establish an operational and scalable solution that meets the needs of Australia's national vehicle fleet.

PARTICIPANTS' RESPONSE TO TECHNOLOGY

Participants showed openness to trialling new technologies, including in-vehicle GPS technology. Eighty-four per cent were comfortable with the device in their vehicle and many said they forgot about the device. In addition, 82 per cent of participants agreed that the GPS devices used in the study accurately measured their road usage (Figure 53).

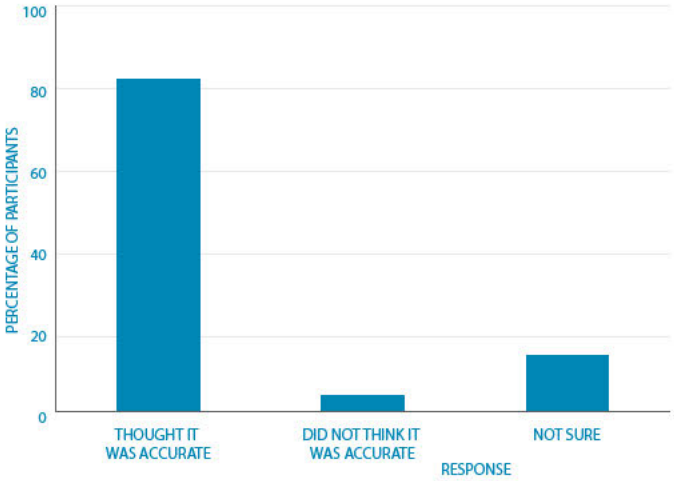
Of the two types of devices used, participants with the OBD-II installed felt more positively towards the device (87 per cent) than those with the plug-in device (76 per cent) (Figure 54). The plug-in device, which was used for (primarily older) vehicles that were not equipped with an OBD port, had visible wires and an antenna on the dashboard. The device's lack of aesthetic appeal likely impacted participants' positivity towards it. This device also presented a higher risk of inadvertent dislodgement. Participant feedback on the plug-in device included that it should be smaller, wires should be less visible and other installation or aesthetic factors.

Comments related to privacy matters are discussed in detail in the Privacy and Information Security section.

INSIGHT: TECHNOLOGICAL SOLUTION EXISTS

The study demonstrated that technology is not a barrier to the implementation of a usage-based charging system. The rapid progression of vehicle and infrastructure technology presents opportunity to explore practical considerations for widespread implementation.

FIGURE 53. PARTICIPANTS' VIEWS ON ACCURACY OF THE DEVICE



TECHNOLOGY PERFORMANCE

Regular GPS device screenings were conducted throughout the study to test the device performance and data validity. These screenings were designed to identify trip data that was invalid such as illogical trip durations and incomplete or inconsistent data. In line with participant expectations, 99.7 per cent of the confirmed travel data was considered valid.

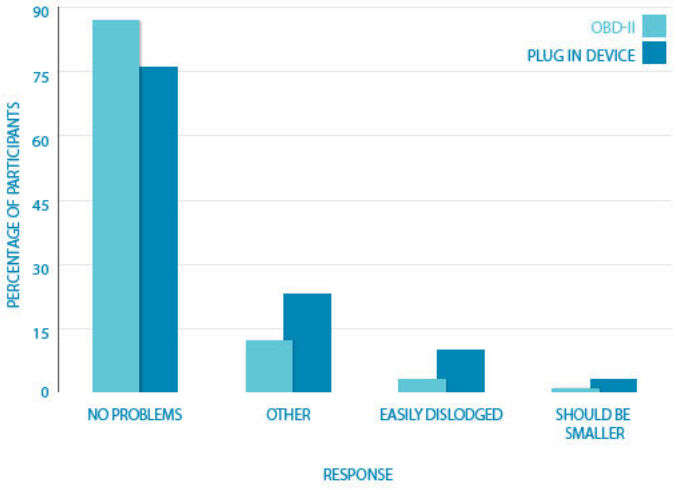
The screenings also identified when a device appeared to have been removed or stopped transmitting trip data. In these instances, follow-up processes were undertaken to make contact with the participant and ascertain the potential causes.

Only 0.3 per cent of devices (five devices) were found to be malfunctioning by the manufacturer, requiring replacement. Other device issues, which impacted only eight per cent of devices, related to installation or software configuration. Both of these results are within the expected norms of study conditions.

The study highlighted the types of logistical and practical considerations that will be important in a broad-scale implementation, such as:

- the positioning of the device in the vehicle
- embedding of the device by the manufacturer or approved installers to reduce installation issues
- adherence to the agreed communications protocol by all manufacturers.

FIGURE 54. PARTICIPANTS' COMFORT WITH THE GPS DEVICES USED IN THE STUDY BY DEVICE TYPE



In cases where the device was confirmed as not having been installed or working correctly for a known period of time, appropriate exclusions were made to ensure the study's analysis only incorporated valid travel data. For the purpose of the study, the amount of excluded data was 2.7 per cent of the total participant days.

Technology available today presents solutions that would enable a road-charging model to be implemented. Considerations such as choice, scalability and compatibility with a wide range of vehicles will require the cooperation of stakeholders in many sectors including automotive, technology and telecommunications.

"I've had the car serviced and the mechanic takes it out and I just plug it back in. It's easy; it's not a difficult device to have in the car.

Penny | Cranbourne West

My concern was connecting the actual unit into my car – would that affect my car's computer chip? That was my only issue, other than that it was fine. (After a few months there was) no impact in the car and I've had it for a few months now, I think.

Tohu | Patterson Lakes

I've got a (GPS) device attached to the vehicle. It doesn't seem to worry me. It's very small, it plugs into the cigarette lighter. It just does what it does, and I don't need to worry about it. I don't know how it works, the information's transmitted back to (the study administrator). They sort the account details out through the info they receive. They assured me that they would contact me if it wasn't working properly."

Meg | Essendon

PRIVACY AND INFORMATION SECURITY

While participants indicated that they were generally comfortable with the systems used in the study, they reinforced the importance of personal information security in any system transition.

Privacy is an issue that is top-of-mind for many Australians, especially in relation to the collection of their personal information and application of new technologies. Similarly, throughout the study, issues relating to privacy and data security were mentioned by some participants.

During recruitment, the majority of people who declined to participate in the study did not offer a reason for doing so. For those who did, four per cent mentioned concerns relating to privacy.

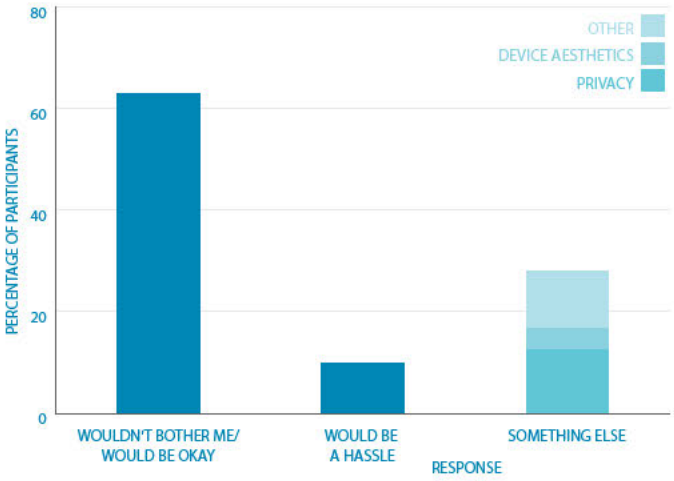
Following the practical experience of the study, 63 per cent of participants said they would be comfortable with the devices being in their car indefinitely (Figure 55), while 13 per cent noted that issues relating to privacy and information handling would need to be considered prior to the implementation of a broad-based system. Of the concerns raised, many were regarding data management and handling, and how participants' information may be used. Also of particular interest to participants was the collection of locational data.

While privacy and data handling matters are very important, with proper systems and procedures in place, they are manageable and could be addressed through considered system design. Collecting GPS coordinates is not a prerequisite for an effective user-pays system. For example, distance-based charging (such as the charge per kilometre option tested in the study) does not require locational data only the number of kilometres travelled. Similarly, under cordon charging, the system needs only to record that the vehicle entered the cordon area, not the location where this entry was made. The majority of in-vehicle GPS devices in use today have the flexibility to transmit only specified types of information, helping to address privacy and data security concerns.

INSIGHT: PRIVACY PROTECTIONS

Participants indicated they were generally comfortable with the technology system used in the study and reinforced the importance of personal information security in any system transition.

FIGURE 55. PARTICIPANTS' THOUGHTS ON HAVING THE DEVICES IN THEIR CAR INDEFINITELY*



** Participants could provide multiple answers*

While this discussion has focused on privacy and information security in relation to in-vehicle technology, other elements such as account and payment management, travel statements and website access are also important and will require consideration and administration.

> *(The GPS device) tracks where you are, it knows where you are. I think this system would be very good at eradicating vehicle theft because vehicles could be found very quickly through the system. So there's an added advantage in that, although a lot of people could possibly see that as a disadvantage.*
>
> *Frank | Dandenong North*

> *I didn't get in the car and think; all right we've got the little black box, its recording and all that. I just did (the driving) I needed to do. But it did make you think a little bit about how you used the vehicle.*
>
> *Cam | Whittlesea*

STUDY PARTICIPANTS DISCUSS THE IN-VEHICLE GPS DEVICES

Participants were generally comfortable with having a GPS device installed in their vehicle and, in some cases, were interested in seeing if the devices' functionality could be enhanced in the future. However, many also acknowledged the idea of having a tracking device installed in a private vehicle may concern some members of the community.

Garry, a theatre performer living in Ashwood, was one participant who saw further potential in the device.

"It's an interesting thing. In some respects, I find it could be a good tool if it could be linked to the police, somehow. So if you lose your car, it is being tracked. So you should know (where it is). But apparently, it was explained that option wasn't available during the study."

David, a counsellor living in Forest Hill, was similarly unconcerned by the technology used during the study.

"(The GPS device) has been quite convenient," he says. "I'm not very technical but I guess it transmits back to a depot. It would indicate how many trips we use, we go on, and what kilometres we travel and possibly even what time of the day it is. I'm not sure about that one. Some sort of tracking."

Sales rep David from Burnley said that while he wasn't thrilled at the idea of being tracked, he didn't find the technology an imposition once it was installed.

"I didn't notice the device from one day to the next," adding, "I had some problems with the engine management system and I asked them if that could be part of the problem. They assured me it was simply an inspection port … where they got information from the engine and no amount of interference could come from there. So it's irrelevant to me. I don't notice it. I'm not aware of it in the car."

For Simon, a volunteer firefighter, the idea of being tracked for the study was not as concerning as the potential time commitment involved in participating in the study.

"(The study recruiter and I) had a chat about (my participating), and what it was for and I thought 'Yeah, all right, It's not going to impact on me in any way'. So I thought, 'Look if they just want to track the car and get data then that's fine. It was a really easy study to do. They want to track the movements of my car, for whatever reason at the time. No extra stuff for me to do – and it's helping."

NEXT STEPS

It is clear that the path to reform needs to begin with building a common understanding of how road users currently use and pay for roads.

As in the case of most reforms, we appreciate the path ahead will be challenging. In spite of this, we have a unique opportunity to take advantage of imminent transport technology developments as a catalyst for creating a sustainable, fair and flexible funding future.

INFORMATION AND AWARENESS

The study showed that transparency of appropriate information and awareness building are key to generating community support for reform.

A practical measure could be to have fuel excise charges itemised on petrol and diesel dockets. Similar information-sharing measures could also be applied to registration and licence fee receipts. The Australian Automobile Association has advocated change of this nature and we agree. As an industry, we need to work together to improve the transparency of road-related charges.

We believe these potential measures could help raise Australian road users' awareness of the road-related charges they already pay, as well as the inequity and sustainability challenges inherent in the existing system. For our part, we will first look for ways to engage with our customers on this important topic.

CREATING A CLEAR PATH FOR REFORM

With all three levels of government involved in transport infrastructure funding and planning, a cooperative and collaborative approach to reform discussion is critical to long-term success. We believe that a staged approach to implementing reform, allowing the existing system to progressively phase out in parallel with the gradual introduction of the future model, would deliver an effective transition to a funding future that supports Australia's growth and changing needs.

In the area of heavy vehicles, the Council of Australian Governments, through the Transport and Infrastructure Council, has been making progress on the reform pathway. The ultimate aim of the initiative is to improve productivity by turning provision of heavy vehicle road infrastructure into an economic service where feasible.

We look forward to the creation of a practical framework at a national level that allows for the need to balance nationally-consistent objectives with state and local area-specific requirements.

SYSTEM DESIGN – FAIRNESS AND EQUITY

As our study participants highlighted, there are a number of areas that will require intensive investigation to ensure the fairness and equity of any new system. Part of this is in identifying the vulnerable groups within our communities and designing a range of suitable protections. In addition, deep understanding of the unique transport practices and needs of different road users, across metropolitan and rural areas of our country, will be crucial to developing informed views in system design.

TECHNOLOGY

With the arrival of new transport technologies, we have an opportunity to design and lay the foundations for the kind of transport system that will support our communities.

Transurban worked with industry specialists in designing and operating the practical technology and operations specifically used in the field-test of the Melbourne Road Usage Study. Our study participants provided positive indication that they are willing to try these new technologies and interact with road charging information, as long as they have adequate protection for information security and privacy.

The study demonstrated that technologies available today present solutions to support a broad-based user-pays road-charging system. Scaling up the capabilities and preparing for broad-based implementation will require the coordinated efforts of stakeholders in various industries including automotive, technology, and telecommunications to ensure appropriate standards and application for Australia.

NATIONAL MARKET RESEARCH

Two thirds (67 per cent) of market research respondents were interested in seeing government take action on transport and funding reform. Most respondents indicated that they believed responsibility for addressing the issue was spread across Australian local, state, and federal governments.

Many respondents indicated that they were keen to see road-funding issues start to be addressed now, through trials or further research. People wanted assurance that any proposed solution had been thoroughly researched and trialled successfully.

In the qualitative research, respondents indicated that examples of other countries dealing with similar issues increased their confidence in an alternate system.

CONCLUSION

As the first practical study into user-pays road charging in Australia, we believe the Melbourne Road Usage Study has delivered insights into how Australians would respond to a new road-charging model. The study has shown Australians are willing to try different ways of using and paying for roads.

The study positively demonstrated that a road-charging model based on user-pays could work in Australia. It showed a usage-based model could help address our funding challenges today and generate a sustainable funding stream that keeps pace with Australia's growing demand and enables investment in the networks we need for the future. An example of how a user-pays model could keep pace with road-usage demand is illustrated in Figure 56.

In addition, the study demonstrated the flexibility a user-pays system could offer in enabling a wide range of price signal options to help manage demand and modify behaviours, and in so doing, help address issues such as traffic congestion and optimising network usage. This would add an effective tool to the suite available to policymakers to manage demand, including change management and communication programs, and the provision of alternative transport modes.

Setting clear objectives for a user-pays system will underpin its effectiveness. The extent to which addressing congestion is prioritised alongside the objective of restoring a sustainable funding base for Australia's road networks will be an important consideration for policymakers.

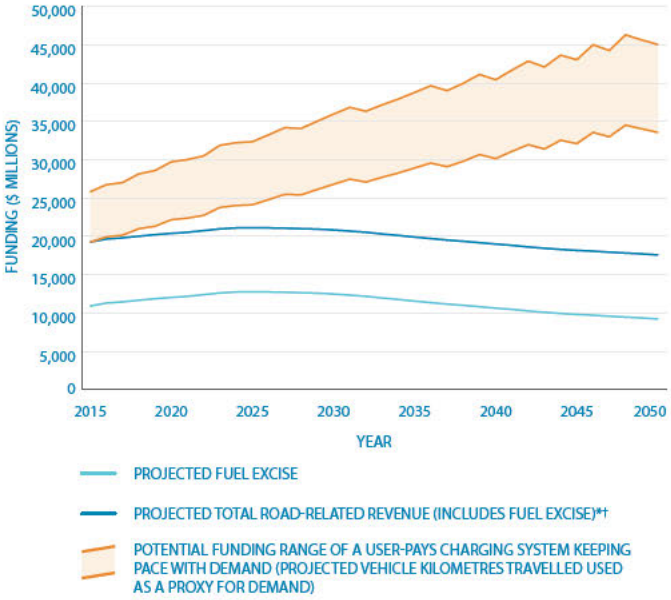
While the primary focus of the study was on road charging, the learning extended to other areas of infrastructure planning. The study highlights the need for a coordinated approach across the different modes of transport that provide Australians with the choice they need to initiate change.

Finally, the study emphasised the importance of bringing the wider community into the discussion. We believe the more time Australians have to understand the issues we face in transport, the more motivated they become to see change.

Through building an understanding of the challenges in the existing system and gaining first-hand experience in user-pays road-charging options, many of our participants developed an appetite for a funding future that is fair, flexible and sustainable.

As the study showed, Australians are willing to start talking about funding reform and we should all be ready to listen.

FIGURE 56. POTENTIAL FUNDING FROM A USER-PAYS SYSTEM COMPARED WITH EXISTING FUEL EXCISE



Source: Transurban analysis; Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015; CSIRO (report for the NTC), Projecting future road transport revenues 2015–2050, May 2015

** Taxes and duties for specific purposes such as GST, fringe benefit tax, tolling revenue, luxury car tax or passenger vehicle customs duty not included.*

† Assumes real revenues other than fuel excise remain constant.

"I've been driving now for 50 years and a lot has happened in those 50 years in terms of road usage. Melbourne is the world's most liveable city so I think to maintain that we've got to do something about our transport.

David | Forest Hill

The changes I've made to my driving patterns are going to be longer-term, even when this is over. It's something that I've now become aware of; do I need to add to the congestion on the roads? The answer is no, I don't."

Rob | Hampton

Transurban

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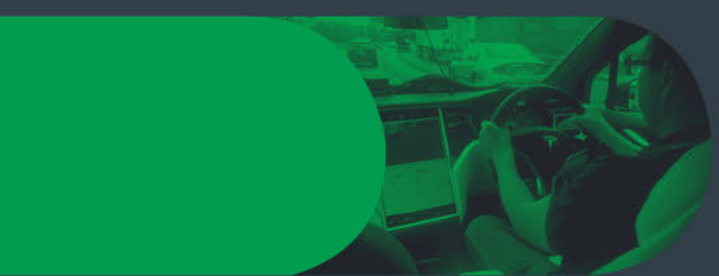
Transurban

Victorian connected and automated vehicle trials

Phase One—Partially automated vehicles

April 2018



In partnership with

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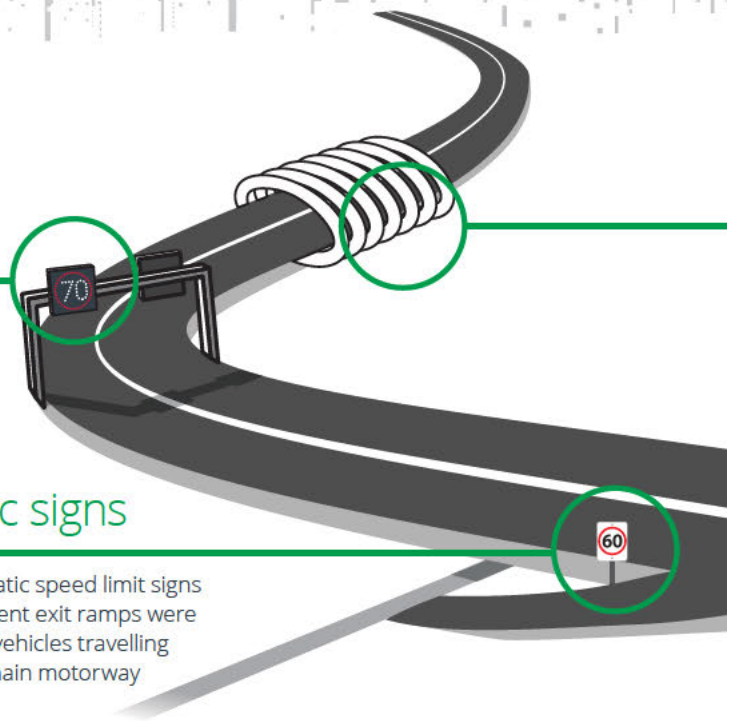
On-road findings

Electronic signs

- Electronic speed signs were challenging for some vehicles
- Signs on tunnel walls were rarely read correctly
- Flashing signs were read more reliably than other electronic signs
- Some specific sign types, locations and positioning were harder to read than others



Static signs

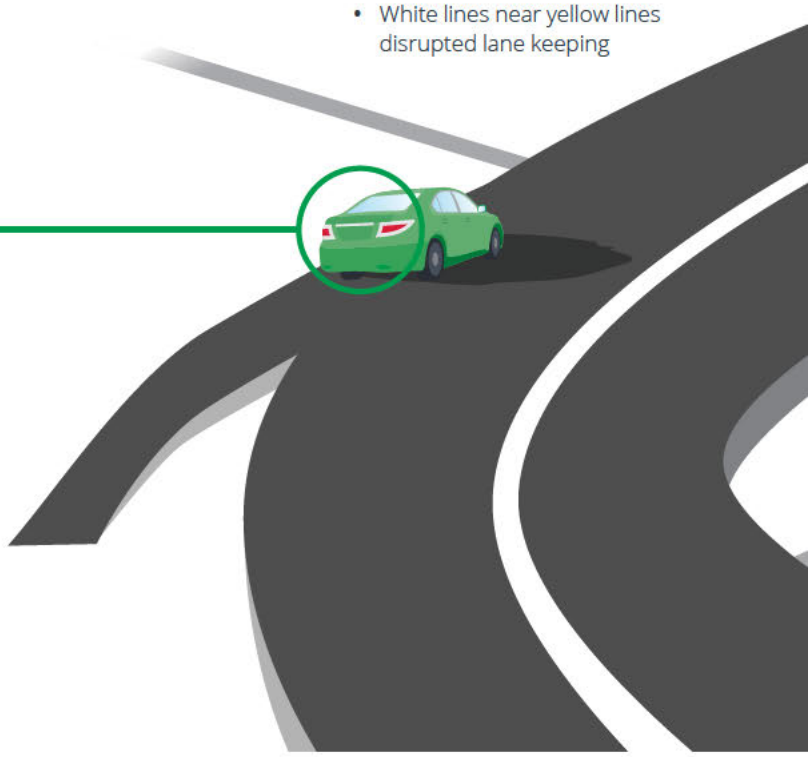
Some static speed limit signs on adjacent exit ramps were read by vehicles travelling on the main motorway

Roadworks

- Yellow lines were generally read well
- White lines near yellow lines disrupted lane keeping

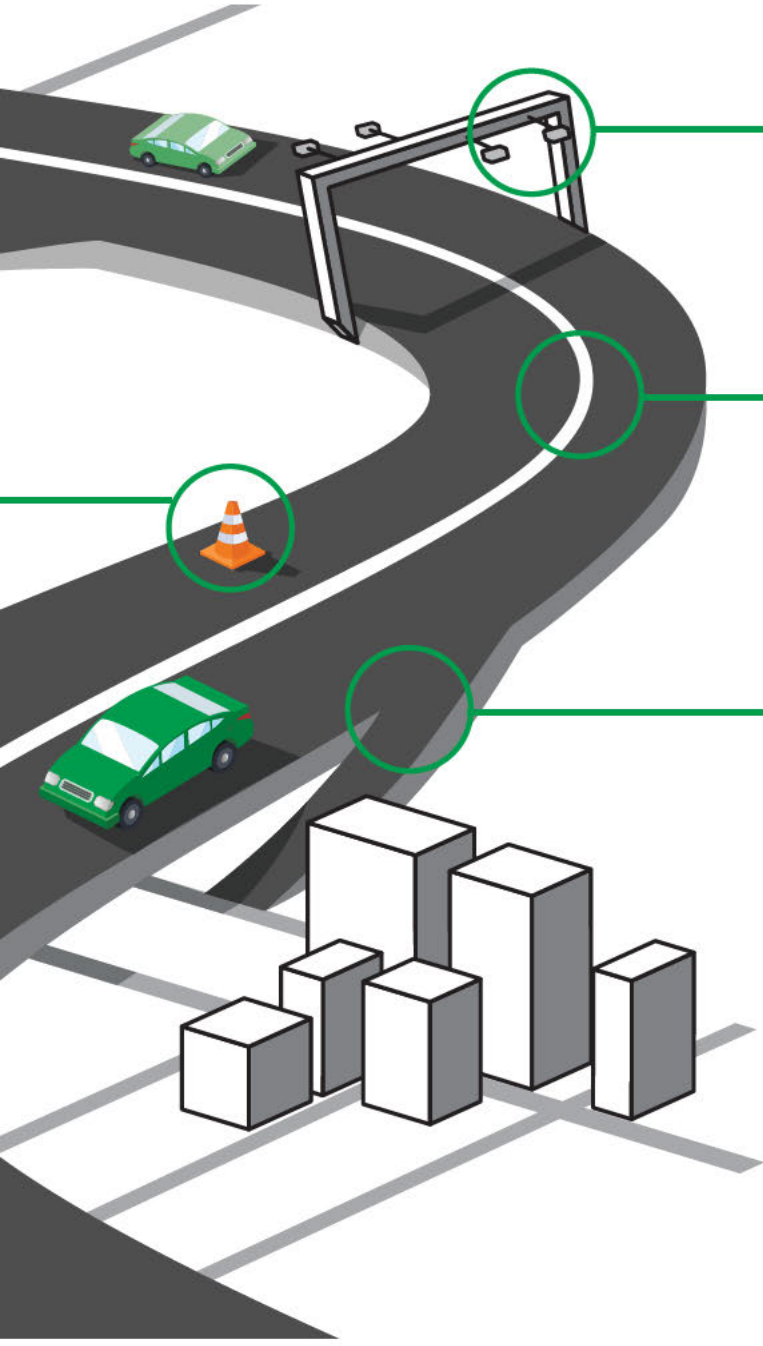
Other objects

Stopped/merging vehicles were not always detected



Sound Tube

CityLink's Sound Tube disrupted lane keeping and a vehicle's ability to determine speed limits



Toll point

Lane keeping was disengaged by gaps in line markings under toll points

Line markings

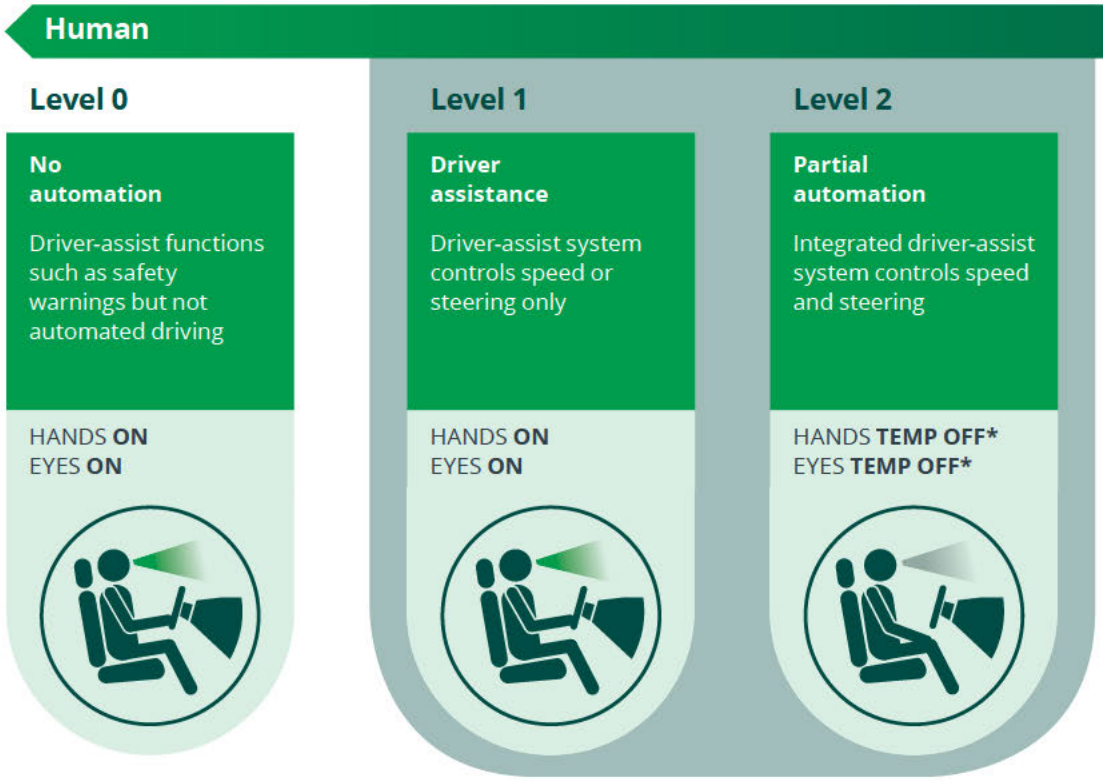
Lane keeping was sometimes disengaged when line markings changed

Exit ramp

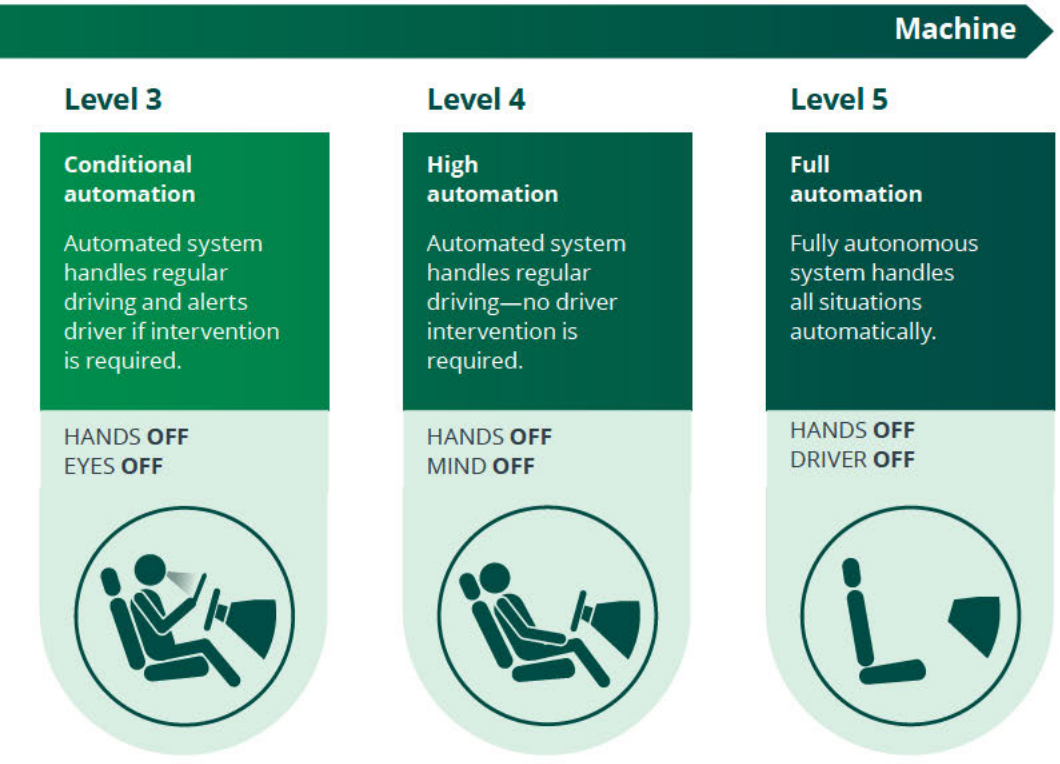
- Some vehicles followed solid line markings up exit ramps leading vehicles off the motorway
- Stationary vehicles at the end of exit ramps were not always detected

Contents

Phase One trials focused on levels 1 and 2 automation



*Technically possible although legality depends on jurisdiction.



Executive summary

Cars that can steer themselves, recognise speed limits and manage their speed are already driving on Australia's roads. However, much of our 50,000 kilometres of motorways was built decades ago and may not provide the best conditions for these new vehicles let alone be ready for the highly automated vehicles that are to come.

Transurban's trial of partially automated vehicles, the kinds already on our roads today, set out to understand the infrastructure changes that we may need to make now and over the next few years.

Launched in 2016, the trial is a partnership with the Victorian Government, VicRoads and the Royal Automobile Club of Victoria (RACV), with vehicles supplied by Audi, BMW, Mazda, Mercedes, Tesla and Volvo. This phase was the first of three planned phases. The second and third phases of the Victorian connected and automated vehicle (CAV) trial will explore higher-level automation features and connected vehicle communications. This phase recorded more than 6,500 observations from 12 vehicles on the Monash, CityLink and Tullamarine motorways in Melbourne.

The trial identified a number of challenges for vehicle manufacturers, infrastructure providers and regulators to consider and overcome in order to safely operate CAVs on the roads.

Some of the trial findings were unique to the Monash, CityLink and Tullamarine motorways and warrant further investigation. Detailed findings are discussed in the findings and recommendations section.

Some of the findings within this report will likely be addressed by new technology superseding the tested automation features. We will adopt the recommendations where practical changes to design, operation and maintenance can have real impact now. Where the findings were inconclusive, we will work with vehicle manufacturers to investigate further.

Alongside our on-road vehicle trials, we are also researching community attitudes towards automated vehicles. The first part of this research looked at their attitudes towards partial automation and showed there are still a number of barriers to the community's acceptance and adoption of automated driving.

With the technology moving so fast, it's important to monitor the type of vehicle features on the road as they evolve and are taken up by the community. The trial highlighted the importance of ensuring drivers are aware of how to use driver-assisted features safely. As automated vehicles become more commonplace, industry and government will need to build community understanding of the safe use of automated technology.

Key stats

- 4 trials
- 22 days over 4 months
- 46 trial sessions
- 118+ hours on the road
- 4,900 kms travelled
- 6 vehicle manufacturers
- 12 vehicles tested
- 6,500 observations

Phase One: Findings and recommendations

	Motorway	Finding	Recommendation
Lines: the stronger, the better	**Yellow lines visible during roadworks**	• Yellow lines were reasonably well read • Line contrast had a greater effect than colour, for example a solid white line among yellow lines disrupted lane keeping	• Where yellow lines are used, block out 'competing' lines, especially at transitions • Avoid leaving strongly contrasting white lines alongside yellow lines during roadworks • Revisit guidelines for line markings in roadworks, to provide clarity for contractors
	Changes in line marking under toll points	• Gaps in line marking under toll points disengaged lane keeping	• Paint lines beneath toll points
	Other changes in line markings	• Changes in line markings (solid-dotted, expansion joints, dual lines, gap due to lane add) sometimes disengaged lane keeping	• Evaluate impact of painting line markings over objects including expansion joints and drains • Investigate options for line marking treatments where lines change (solid to dashed) or disappear (lane added)
Pay attention next exit	**Line markings on exit ramps**	• Vehicles favour solid lines, and would sometimes follow a solid line up an exit ramp, rather than continuing along main motorway	• Revisit standards/guidelines for line markings at exit ramps. Consider step-out treatments if suitable • Where available, suggest drivers choose middle lane(s) when using lane keeping technology, if their vehicle is susceptible to these issues
	Stopped vehicles	• Sometimes vehicles did not detect vehicles stopped at the end of a ramp and did not slow down. This observation was not unique to exit ramps, but more frequent with particular ramp alignments	• Advise drivers of the technology's limitations through industry-wide awareness campaigns • Explore further with vehicle manufacturers and raise with Australasian New Car Assessment Program (ANCAP) • Consider adding warning signs further up ramp (for example, to advise vehicles to 'prepare to stop') • Explore longer-term options to alert vehicles on selected ramps and on other locations where queues may build up out of sight, through available connected vehicle communications • Await high-precision maps, so vehicles can better recognise ramps
Looking for a sign	**Electronic signs**	• Electronic speed signs were more challenging for some vehicles • Signs on tunnel walls were rarely read correctly • Flashing signs were read correctly and more reliably than constantly illuminating signs • Some specific sign types, locations and positions were more challenging to read than others	• Share data with vehicle manufacturers to refine Traffic Sign Recognition algorithms • Use different signs and change their position in future tunnels • Review sign height and positioning at problem locations, and design of new road furniture • Review and update electronic sign standards, if deemed necessary
	Static signs	• Static signs were read well, but sometimes vehicles read static ramp signs while travelling on main motorway	• Investigate options to ensure signs remain visible on ramp but less visible from main motorway
Urban design vs vehicle science	**Sound Tube**	• The CityLink Sound Tube art installation disrupted autonomous driving mode and disengaged lane keeping technology • Inside the tube some vehicles did not detect the correct speed limit, reading 80 km/h as 110 km/h or derestricted. The same vehicles read signs correctly before and after the tube • In one instance, a 'ghost' vehicle was detected where there was no lane	• Highlight to vehicle manufacturers and map providers to help identify cause • Once causes are understood, factor into future urban design wherever possible
Blinkered vision: CAVs can't see everything	**Other vehicles on the road**	• Vehicles travelling to the side of trial vehicles (for example, merging from entry ramps) may not be detected. Trial vehicles did not create gaps to allow merging vehicles into traffic	• Explore further with vehicle manufacturers • Where available, suggest drivers choose middle lane(s) when using automated driving features, if their vehicle is susceptible to these issues
	Other objects on the road	• Objects on roads may not be detected by CAV vehicles, including debris, stopped vehicles, people getting out of their vehicle (such as during an incident or breakdown), and roadworks equipment including traffic cones, plastic bollards, temporary and portable signs, and truck-mounted attenuators	• Educate drivers about the limitations of driver-assistance features to ensure they do not overestimate the capabilities of their vehicles

Preparing Australian roads for automated vehicles

Technology and massive population growth are transforming urban mobility. A new transport system that is more integrated, connected and automated is emerging. Many of the benefits of this new system will stem from the arrival of automated vehicles. These vehicles have the potential to improve road safety and efficiency, as well as deliver other social and network benefits.

While the timeline to full automation is hotly debated, the transition phase could last up to 20 years. It is important for road operators to understand the benefits and limitations of automated vehicles, including the impacts on infrastructure operation and maintenance.

Vehicles with partial automation features are already driving on Australian roads, and the emergence of more advanced vehicles is imminent. How quickly Australia can prepare its systems, regulations, infrastructure and communities for the arrival of CAVs will underpin their successful introduction.

Shifting the driving task from humans to vehicles is incredibly complex and touches all aspects of the transport industry. Existing rules for vehicle manufacture, insurance, road operations, and driving all need to be revised. This process will likely involve significant legislative change, and the development of new regulations and guidelines that ensure public safety and foster innovation.

Recent work by national bodies such as the National Transport Commission (NTC) has been critical to progressing these considerations. The NTC is currently working on a phased reform agenda to support the introduction of vehicles with automated driving systems (ADS) can be introduced from 2020.

The Victorian Parliament has passed legislation enabling trials of higher-level automation on Victorian roads, based on nationally approved guidelines.

Physically preparing Australia's roads for CAVs is also essential. In a recent assessment of 20 countries' preparedness for automated vehicles, Australia ranked 14th. We received the maximum score for the quality of our mobile networks but only average ratings for the quality of our roads, availability of 4G and the number of electric charging stations.[1]

Infrastructure upgrades generally require long lead times and come at significant cost. As a country we urgently need to understand if we have to retrofit Australia's almost eight million square kilometres of local and arterial roads and motorways with CAV-ready technology and infrastructure.

1 KPMG 2018, Autonomous Vehicles Readiness Index

Victorian CAV trials
Phase One

Phase One comprised two complementary programs: a series of on-road trials and a community research program.

During Phase One, on-road trials focused on identifying the:

- issues CAVs encountered while driving on the Monash, CityLink and Tullamarine motorways
- infrastructure changes we could and should make now and over the medium term.

Our four-month on-road trials involved 12 current model vehicles with partial automation features, sourced from six vehicle manufacturers. The broad range of vehicles helped us identify common themes—which, in turn, will help inform our future road upgrades and operations.

The trials were not about comparing vehicle models or features—vehicle manufacturers conduct their own tests before launching vehicles on to the market. While testing vehicles by manufacturers is commercially sensitive and generally not shared publicly, our research spans many vehicle types. We believe this makes the findings useful to both road operators and governments.

Our findings are available via our website: **cavs.transurban.com**

During Phase One, we also explored Australian's views about automated driving, and identified potential barriers to the adoption of CAVs in Australia. This understanding could help shape public education programs.

What we trialled

Phase One trialled current-model Audi, BMW, Mazda, Mercedes, Tesla and Volvo vehicles with partial automation features. While partially automated vehicles are already on the road, we expect the number to increase significantly over the next few years.

What is partial automation?

Technology installed in partially automated vehicles generally helps vehicles:

- steer themselves and stay in their lane (known as latitudinal control)
- manage their speed relative to other vehicles on the road (known as longitudinal control)
- recognise the speed limit.

Vehicle manufacturers highlight that current partial automation features are intended for driver-assistance only. They are not designed to automatically handle every scenario that may arise on the road.

Our trial looked at how vehicles with those features interacted with the motorway environment, including: speed signs, toll points, line markings, motorway artwork and architecture, entry and exit ramps, objects on the road, merging vehicles, different light and weather conditions, peak-hour congestion, and road works.

Partial automation features

Look out for these technologies as you make your way through the report.

Lane Keep Assist (LKA)
Reads lane lines and proactively intervenes with vehicle steering to ensure the vehicle stays in its lane.

Adaptive Cruise Control (ACC)
Building on standard cruise control functions, ACC sets a maximum speed, but may adjust speed based on distance to the vehicle in front.

Traffic Sign Recognition (TSR)
Camera technology detects and reads speed signs and displays them in the vehicle.

Minimal Risk Condition (MRC)
This refers to the way the vehicle reacts if, after multiple warnings, the driver does not take back control of the vehicle.

Implementations of these features vary across vehicles, for example in the range of speeds at which they function. Some of the trial vehicles allowed these features to be used in combination.

Victorian CAV trials
Phase One

How we ran the trials

Phase One included four trials which increased in complexity. These trials were run between August and November 2017 (refer to Figure 1).

Professional drivers from the state-of-the-art Australian Automotive Research Centre (AARC) testing facility drove the test vehicles, with observers from Transurban as passengers.

Trial vehicles completed circuits of the Monash, CityLink and Tullamarine motorways while drivers and observers recorded how the vehicle's automated features responded to road infrastructure.

Observations were corroborated by video footage from four cameras installed on the vehicle's front, rear and interior.

We collected more than 6,500 observations via this structured approach. Analysis of these observations helped us identify themes and issues warranting further investigation. We provided reports to participating vehicle manufacturers documenting the particular vehicles' responses – giving vehicle manufacturers the opportunity to assess their vehicles' recognition and reaction performance.

However as an infrastructure owner and operator, our focus was on identifying any issues common to multiple vehicles—as common issues were more likely to warrant future changes to motorway infrastructure.

While we present quantitative information, it is indicative only, and not statistically significant.

Technology is constantly changing and, after these trials concluded, some vehicle models may have been modified and may now behave differently. Conditions on the trial's motorways have also changed. Road works in progress during the trial are now complete.

Safety first

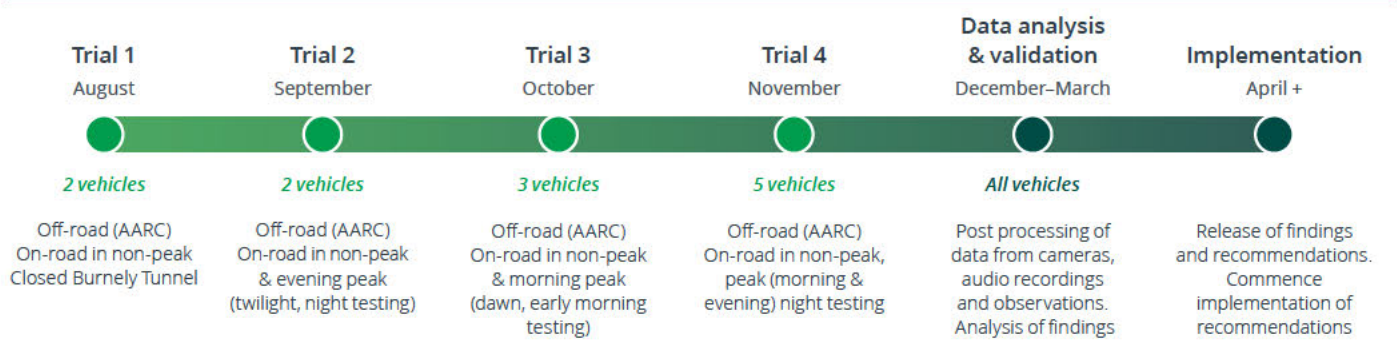
Each trial included safety and vehicle technology briefings followed by a driver familiarisation day at the AARC's closed track facility with the vehicle manufacturers. This gave drivers the opportunity to become familiar with activating and deactivating the automated features of each vehicle prior to testing in live-traffic situations.

The exclusive use of a closed test track also provided a safe, controlled environment in which the vehicles could be put into a Minimal Risk Condition.

This allowed us to gain a rare insight into how the vehicles would behave if a driver was to fall asleep or become medically incapacitated while driving using automation features.

Except for the MRC test, trial drivers had their hand on the steering wheel. They remained in control of the vehicle at all times.

Figure 1: Phase One timeline



Findings and recommendations

This section outlines key findings across lines, exit ramps, speed signs, motorway art and other objects and vehicles on the road which informed a number of recommendations. Some of the findings presented here relate to motorways in general. Some findings are toll-road focused, and some are specific (or even unique) to individual motorways.

Lines: the stronger, the better

Lane Keep Assist

Yellow line markings aren't that confusing

- *Yellow lines were reasonably well read*
- *Line contrast had a greater effect than colour, for example a solid white line amidst yellow lines disrupted lane keeping*

In Victoria, yellow lines are used over the standard white lines to temporarily shift traffic lanes and create room for road works. This means there can be two sets of line markings on the road, which can be confusing for drivers to navigate.

We expected the vehicles would find the yellow lines difficult too, and while lane keeping within yellow lines was less reliable than in white lines, the difference was not as significant as anticipated (refer to Figure 2).

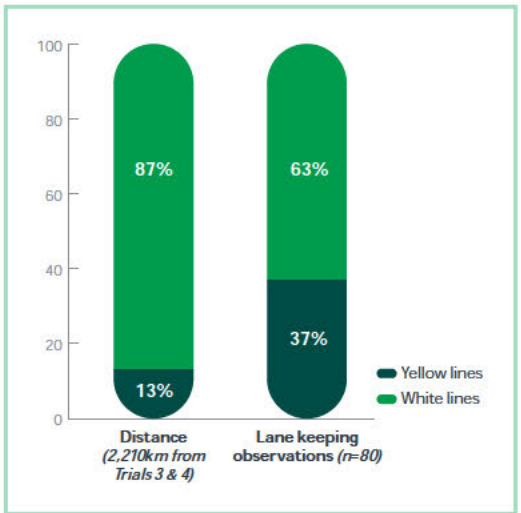
Roadworks related to the CityLink Tulla Widening Project and Monash Freeway Upgrade meant that sections of the trial route were marked with yellow lines. Vehicles navigated roadwork areas quite well, especially in instances where white lines had been blocked out at the transition to or from yellow lines.

While the lane keeping sometimes disengaged within the yellow lines, this was likely due to the number of changes to line markings in a roadworks environment, rather than the colour of the lines. Vehicles tended to follow the 'best' line based on contrast (for example, solid rather than dashed, wider, brighter, freshly painted, or continuous).

Recommendation

- *Where yellow lines are used, block out 'competing' lines, especially at transitions*
- *Avoid leaving strongly contrasting white lines alongside yellow lines during roadworks*
- *Revisit guidelines for line markings in roadworks, to provide clarity for contractors*

Figure 2: Proportion of lane keeping observations within roadworks with yellow line markings, relative to the proportion of distance travelled within yellow lines



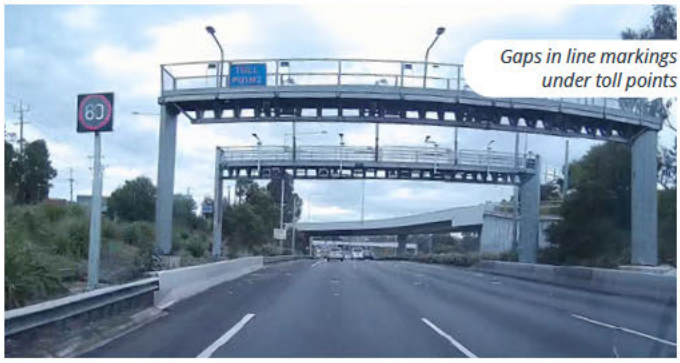
Gaps in line markings under toll points are confusing

- *Gaps in line marking under toll points disengaged lane keeping*

Short gaps in the line markings under the tolling gantries on CityLink are a legacy of an earlier toll operating system, however, advances in technology means the gaps are no longer necessary.

As expected, these gaps in line markings created challenges for vehicles, with lane keeping systems sometimes disengaging as lines disappeared under gantries.

Vehicles reacted to the change differently, with some simply carrying-on and waiting for lines to reappear and others shifting side-to-side hunting for lines to follow.



There was also a difference in the time (typically it was 0 to 10 seconds) until vehicles would re-engage their lane keeping after lines reappeared.

Recommendation

- *Paint lines beneath toll points*

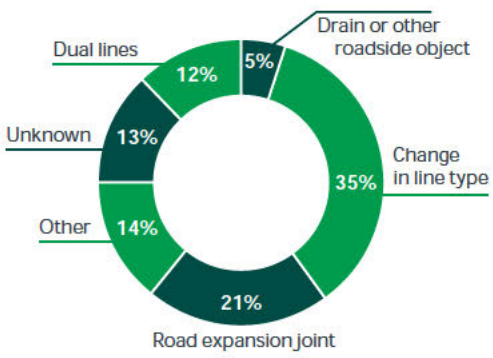
Disruptions to line markings are problematic

- *Changes in line markings (solid-dotted, expansion joints, dual lines, gap due to lane add) sometimes disengaged lane keeping*

In general, the lane keeping features, worked well where there were good quality line markings on the road. Although sometimes lane keeping disengaged for no apparent reason, most of the time clear factors triggered it.

The main causes for disengagements occurred due to: changes in line types (for example, solid lines changing to dotted lines), exit ramps, expansion joints, drains, dual lines, marks on the road, chevron markings at exit ramps and other roadside objects, such as roadwork bollards (refer to Figure 3).

Figure 3: Type and frequency of trigger causing lane keep assist system disengagement, excluding toll gantries (Trials 3 & 4—2,210km)

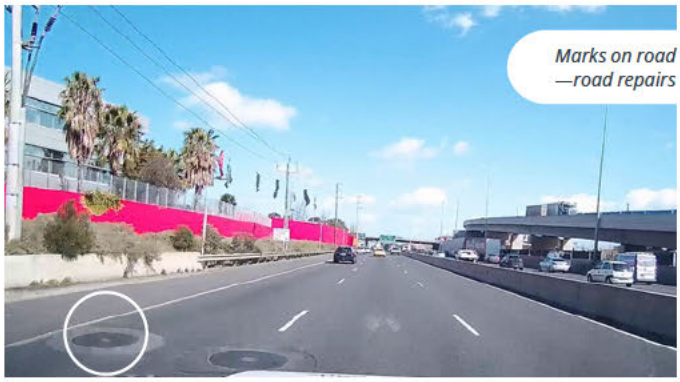


Lines can also be disrupted when a lane is added after merging traffic enters the freeway. When this occurs, the lane widens and the middle line does not appear until it is the full width of two lanes. In this instance, lane keeping sometimes disengaged.

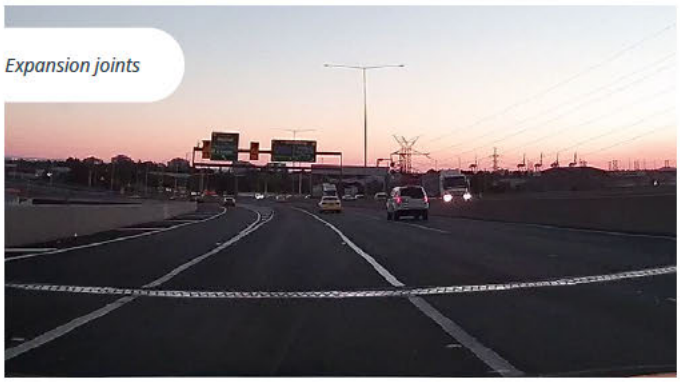
When lanes had a sharp curve, vehicles would not necessarily slow down as a driver would. This was unsettling for drivers, in some cases leading them to deactivate auto steering around sharp bends.

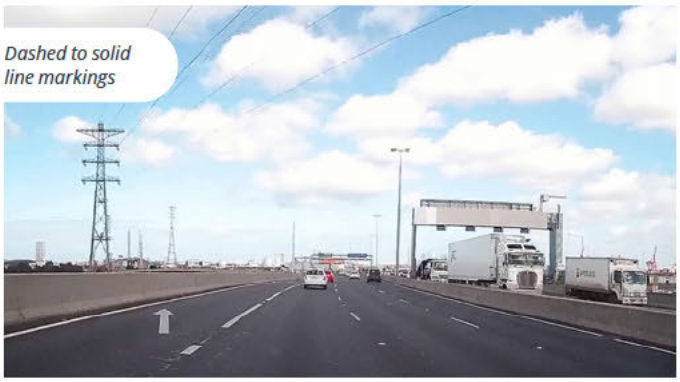
Recommendation

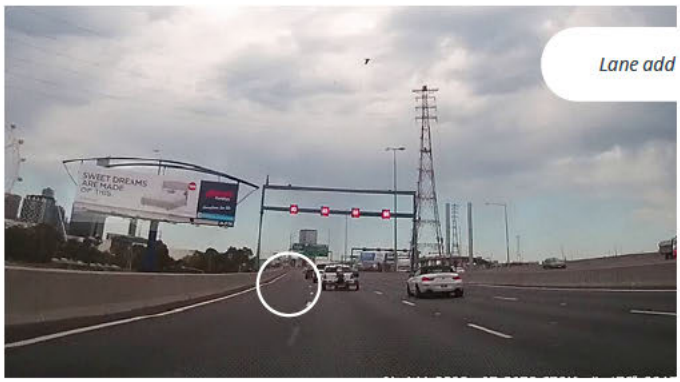
- *Evaluate impact of painting line markings over objects including expansion joints and drains*
- *Investigate options for line marking treatments where lines change (solid to dashed) or disappear (lane added)*


Marks on road
—road repairs


Chevrons


Expansion joints


Dashed to solid
line markings


Lane add


Dual lines

Pay attention next exit

Lane Keep Assist

Adaptive Cruise Control

Exit ramp line markings lead the way

- *Vehicles favour solid lines, and would sometimes follow a solid line up an exit ramp, rather than continuing along the main motorway*

At exit ramps, the solid line at the edge of the far left lane veers off the motorway as it follows the exit ramp, while a dotted line continues across the exit ramp lane marking the main motorway, which is consistent with current guidelines. Because lane keeping systems sometimes favour solid lines over dotted lines we found that vehicles in the left lane using lane keeping would follow the solid line marking and be led up the exit ramp rather than continuing along the motorway. If not anticipated, this behaviour could lead drivers to take the wrong exit or make last-minute swerves back on to the motorway.

Vehicles favour solid line up exit ramp

Recommendation

- *Revisit standards/guidelines for line markings at exit ramps. Consider step-out treatments if suitable*
- *Where available, suggest drivers choose middle lane(s) when using lane keeping technology, if their vehicle is susceptible to these issues*

Female, 36-40, VIC, CAV advocate

"My previous model car had ACC but would ignore and would not react if approaching a stationary object...But if I had not been aware of the limitations that could have been really nasty"

Stopped vehicles become camouflaged

- *Sometimes vehicles did not detect vehicles stopped at the end of a ramp and did not slow down. This observation was not unique to exit ramps, but more frequent with particular ramp alignments*

The end of motorway exit ramps typically intersect with other roads, causing vehicles to pause at give way signs or traffic lights.

In some cases, vehicles using adaptive cruise control (ACC) along an exit ramp did not seem aware of stopped vehicles at the end of the ramp and did not slow down as they approached those vehicles. At certain exit ramps such as at Toorak Road, Hawthorn East, this occurred frequently, across several different trial vehicles.

At times in other locations on the motorways vehicles using ACC did not seem to detect and slow down for a stationary vehicle ahead (for example, when driving in congestion or approaching stopped vehicles around a tight corner).

ACC systems rely on moving vehicles to identify and modify speed. If trial vehicles approached stationary vehicles without driver intervention, it is presumed that autonomous emergency braking (AEB) would have activated. However, the braking would have been severe and may have caused a collision.

The alignment and geometry of certain ramps may have made it difficult for CAVs to detect the movement of another vehicle along the ramp, though further investigation is required.

Recommendation

- *Advise drivers of the technology's limitations through industry-wide awareness campaigns*
- *Explore further with vehicle manufacturers and raise with ANCAP*
- *Consider adding warning signs further up ramp (for example, to advise vehicles to 'prepare to stop')*
- *Await high-precision maps, so vehicles can recognise ramps*
- *Explore longer-term options to alert vehicles on selected ramps and on other locations where queues may build up out of sight, through available connected vehicle communications*

Looking for a sign

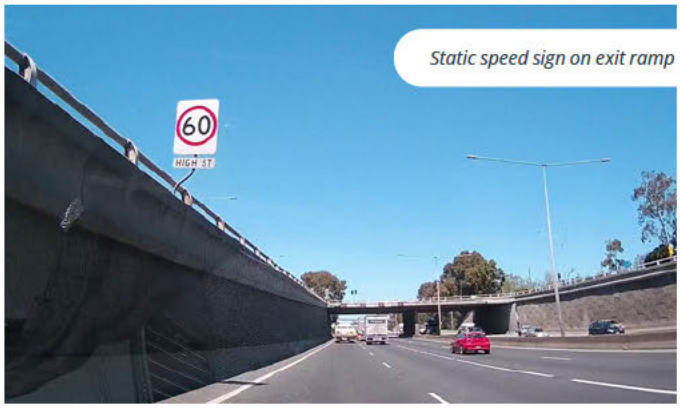
Traffic Sign Recognition

Most new vehicles have digital maps that specify the speed limit on a given section of road. Some partially automated vehicles also draw data from traffic sign recognition (TSR) features, which use cameras to read the physical speed signs as the vehicle drives past. Given Victorian motorways often use Electronic Speed Limit Signs (ESLS) with varying speed limits, this extra source of data is important as a road's speed may not be correctly reflected in the digital map.

Some of the trial vehicles had TSR which drivers used as guidance in manually setting or adjusting the vehicle speed. In many cases it was not possible to determine from the instrument panel, whether the vehicle used a digital map or TSR to determine the speed limit.

In our TSR analysis we noted vehicle responses when a vehicle passed a speed sign requiring a change in speed (for example, going from 60km to 80km). We excluded instances where a vehicle passed a sign showing the same speed displayed on the vehicle's instrument panel from our analysis because we could not tell if the vehicle had read the most recent sign.

As vehicle automation increases and vehicles begin adjusting their speed automatically, it is critical that vehicles can identify the correct speed.



Static speed sign on exit ramp

Most static signs are easily read

- *Static signs were read well, but sometimes vehicles read static ramp signs while travelling on main motorway*

As electronic signs are increasingly used to manage urban motorways in Victoria, static signs are becoming less common; although these still appear on exit ramps, and sections of road beyond managed motorway networks.

Static signs on, or near the motorway network were generally identified and read correctly and, in most cases, assisted the driver. However, there were some examples where vehicles driving on the motorway identified and read static signs on adjacent entry and exit ramps. In these cases the static signs applied to the ramp, not the motorway, resulting in a misinterpretation of the speed limit.

The placement, reflectivity and luminosity of static signs are guided by national standards, however guidelines may need to be revised to ensure the position of a sign does not create confusion for TSR systems.

Recommendation

- *Where possible, reposition signs to be visible on ramp but less visible from main motorway*

Electronic signs are challenging

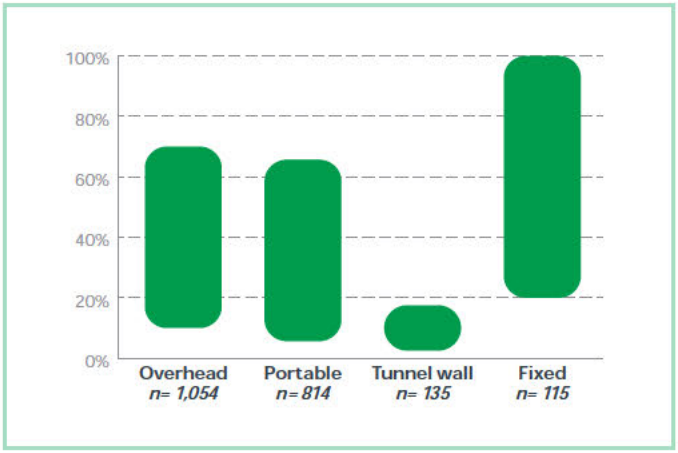
- *Electronic speed signs were more challenging for some vehicles*
- *Signs on tunnel walls were rarely read correctly*
- *Flashing signs were read correctly, more reliably than constantly illuminating signs*
- *Some specific sign types, locations and positions were more challenging to read than others*

Not all of the trial vehicles had TSR activated for use in Australia. Vehicles with TSR varied in ability to identify and correctly read the speed limit for most sign types across different vehicle manufacturers.

Sign positioning impacted a vehicle's ability to correctly identify and read speed signs. For example, road-side fixed signs were generally read better than overhead (gantry-mounted) or portable signs beside the road (refer to Figure 4).

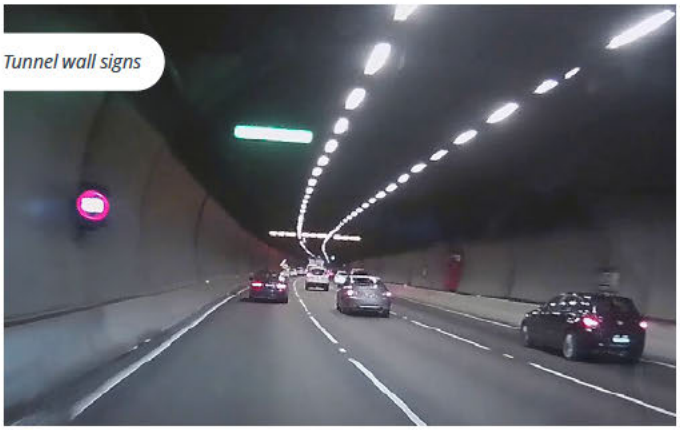
In CityLink's tunnels, ESLS are mounted on the tunnel walls rather than overhead to provide more clearance for higher vehicles. These signs are smaller than other ESLS and were especially challenging for vehicles to identify, regardless of the lane the vehicle was travelling in. Further analysis is now under way to determine whether size, positioning, LED refresh rate, pixel scanning, height and luminosity may be contributing factors.

Figure 4: Minimum and maximum rates across vehicle manufacturers of identifying and correctly reading speed limits, for different types of ESLS



Where signs were identified, there were several instances where they were incorrectly read. For example, 80 km/h was misread as 60 km/h, but also sometimes as 30, 40 or 100 km/h. While it is unclear why this happened, we are providing feedback to the vehicle manufacturers to allow them to refine their TSR algorithms.

The two concentric circles around the edge of an electronic sign, flash to draw attention to a speed limit differing from the normal limit in that location. On average, flashing speed signs were correctly read more often than solid or continuous signs. This was unexpected, as anecdotal industry feedback suggested that flashing signs were problematic (refer to Figure 5).


Tunnel wall signs

Portable electronic sign

Fixed electronic sign

Also, some specific sign locations seemed more problematic than others, but we had too few observations of each such location by the different vehicles to be sure, or to work out why this might have been the case.

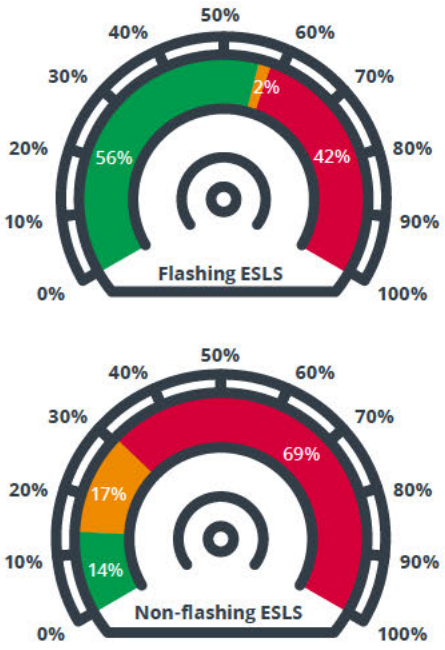
- Motorway-to-motorway interchange—the electronic signs on a gantry over a downhill motorway-to-motorway interchange ramp were read less accurately than other gantry-mounted signs. We are currently analysing if there is anything unusual about this location, such as ramp gradient or sign height, and whether these could be factors.
- Unusual gantry design next to billboard—another location where electronic signs were read less reliably was at a gantry with an unusual design, with a large billboard to the left of the gantry. It seemed as though vehicles had difficulty with TSR from the left lanes of the motorway, despite accurately reading the signs from the right lanes. We are currently analysing whether factors such as the structure of that gantry or location of the billboard have any impact on TSR performance.

Recommendation

- *Share data with vehicle manufacturers to refine traffic sign recognition algorithms*
- *Use different signs and change their position in future tunnels*
- *Review sign height and positioning at problem locations, and design of new road furniture*
- *Review and update electronic sign standards, if deemed necessary*

Overhead (gantry-mounted) ESLS

Figure 5: Non-flashing vs flashing ESLS



*Identified sign and read speed **CORRECTLY***
*Identified sign and read speed **INCORRECTLY***
***DID NOT** identify sign*

Urban design vs vehicle science

Adaptive Cruise Control

Traffic Sign Recognition

Sound Tube

- *The CityLink Sound Tube art installation disrupted autonomous driving mode and disengaged lane keeping technology*
- *Inside the tube some vehicles did not detect the correct speed limit, reading 80 km/h as 110 km/h or derestricted. The same vehicles read signs correctly before and after the tube*
- *In one instance, a 'ghost' vehicle was detected where there was no lane*

Sound Tube, a unique and iconic piece of motorway architecture, encases CityLink between Racecourse and Brunswick Roads.

The Sound Tube environment appeared to trigger a mix of behaviours across different vehicles, interfering with their ability to stay in their lane, detect other vehicles and determine the correct speed limit.

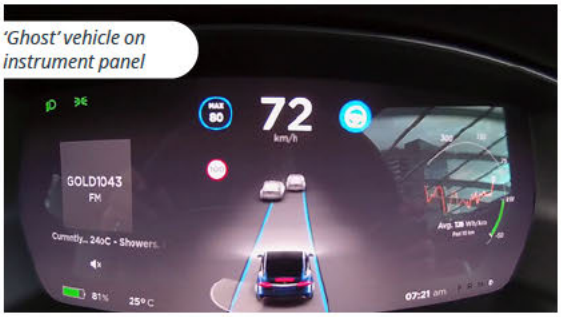
For instance, at certain points within the Sound Tube some vehicles identified the speed limit as 110 km/h or 'derestricted' despite having identified the correct limit beforehand and continuing to do so afterwards. This was an issue in particular in the left lane, southbound.

In another instance, a vehicle using ACC through the Sound Tube detected and braked in response to a 'ghost' vehicle that was not actually there. Various theories suggest the environment may be influenced by factors such as reflections from communication signals, electro-magnetic interference and unusual light and shadow patterns, but the cause is unclear.

We'll continue working with vehicle manufacturers and engineers to understand how the Sound Tube interacts with CAV technology.

Recommendation

- *Highlight to vehicle manufacturers and map providers to help identify cause*
- *Once causes are understood, factor into future urban design wherever possible*

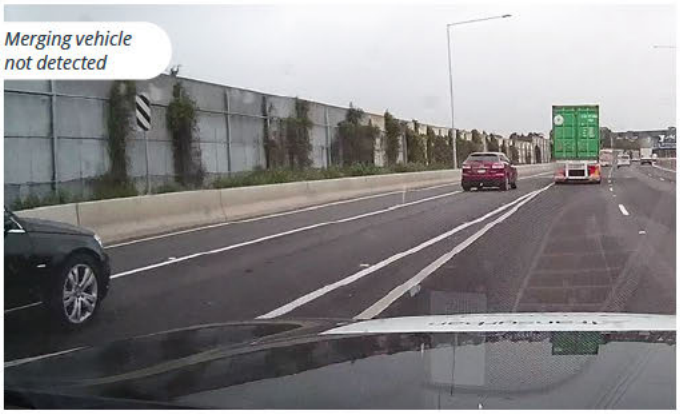


Blinkered vision: CAVs can't see everything

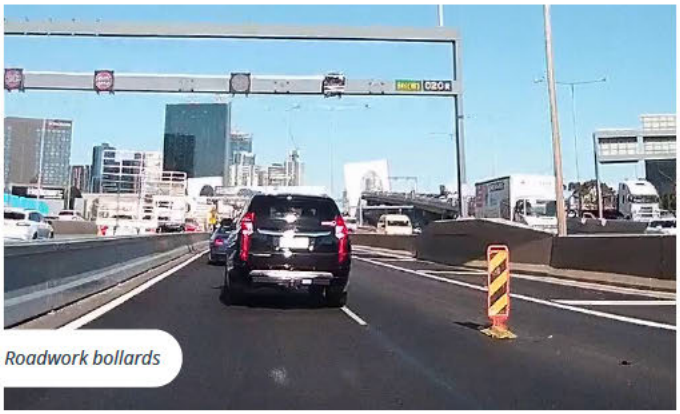
While we take care in ensuring our motorways are clear at all times, there are instances where other objects may be on the road. These may be planned for and controlled as is the case with roadworks, or unplanned and dangerous such as if material falls from a vehicle.

At this stage, vehicle manufacturers acknowledge that debris, people, and plastic bollards may not necessarily be identified by the current generation of partially automated vehicles.

Similarly, merging vehicles would not necessarily be identified by the current generation of these vehicles, which means that there would be no 'merging politeness' (speeding up or slowing down to allow the merging vehicle to enter the lane) displayed by the CAV vehicle on the motorway.



Merging vehicle not detected



Roadwork bollards

Other vehicles on the road

- *Vehicles travelling to the side of trial vehicles (for example, merging from entry ramps) may not be detected. Trial vehicles did not create gaps to allow merging vehicles into traffic*

Recommendation

- *Explore further with vehicle manufacturers*
- *Where available, suggest drivers choose middle lane(s) when using automated driving features, if their vehicle is susceptible to these issues*

Other objects on the road

- *Objects on roads may not be detected by CAV vehicles, including debris, stopped vehicles, people getting out of their vehicle (such as during an incident or breakdown), and roadworks equipment including traffic cones, plastic bollards, temporary and portable signs, and truck-mounted attenuators*

Recommendation

- *Educate drivers about the limitations of driver-assistance features to ensure they do not overestimate the capabilities of their vehicle*

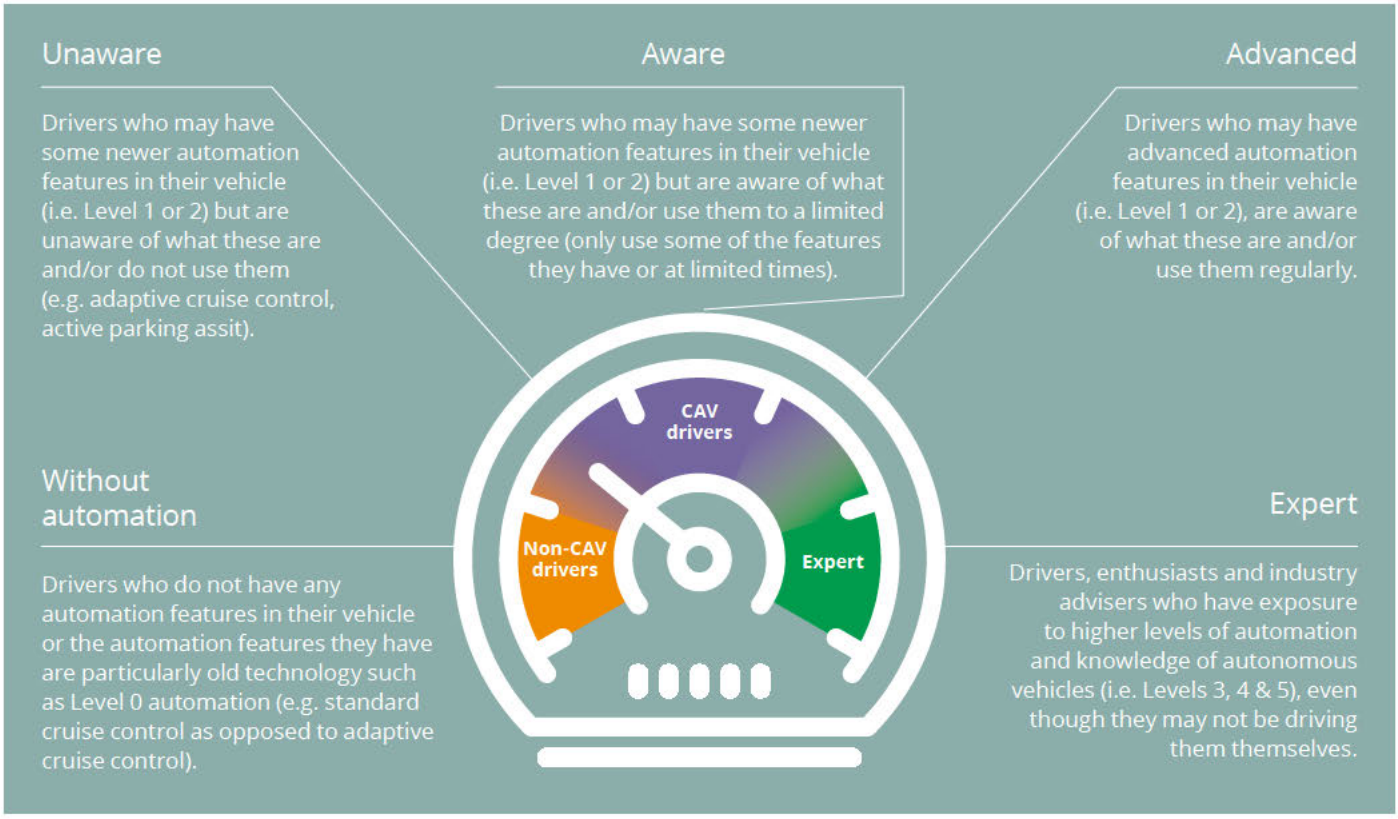
Community research

Community understanding of CAV technology is an important factor in its safe transition onto our roads.

Our community research program focused on community attitudes and perceptions towards partial automation, as well as the reasons why people may not accept, or be wary of increased automation on motorways.

The research activities took place in Victoria, New South Wales and Queensland with participants ranging from non-CAV drivers through to experts.

Figure 6: Research group comprised a spread of experience with CAVs



Research finding

Research participants found that driver assist features work best on motorways or clearly marked roads, with good double lane (minimum) roads and a speed limit of 80km and over

Attitudes to partial automation

205 A qualitative study involving 205 drivers, some already using automation and others not, contributed to a two-week online forum.

Our research showed that many people within the community have heard about autonomous vehicles, but there is still some confusion about how and when these features will reach them. They view the technology as having the potential to make roads safer, not just a way to make driving easier.

Despite being broadly aware of the inevitable change from human to autonomous driving, the community's understanding of partial automation features is low and there wasn't consistent language used when describing the technology.

As people try out driver-assistance features—typically in their own car—they generally feel more positively towards the technology and advocate its benefits to friends and family. So far this group has been quite small, comprising owners of new or luxury vehicles, but this may change as vehicles across all price points begin to offer these features in line with customer expectation and safety rating agency guidelines. Uptake of this technology has the opportunity to make our roads safer, but only if drivers are aware of the limitations such as those identified as part of our trial.

"I love all these gadgets and I reckon they have saved me from a bump or two over the last few years. I must admit though, they are only a help and are by no means infallible. The driver must read their car manual very carefully and be aware of what each system can do and, most importantly, what it can't do."

Male, 46-50, QLD, CAV advocate

"I especially love the adaptive cruise control—it makes me feel a lot safer and keeps me a safe distance from the car in front. I think all cars should have this then we wouldn't have people tailgating. Fewer accidents if we had to have it and we couldn't switch it off."

Male, 46-50, QLD, CAV advocate

"Anything to make it safer and easier to drive is a bonus and I would certainly use any new technology available."

Male, 51-55, VIC, CAV advocate

Barriers to adoption and acceptance

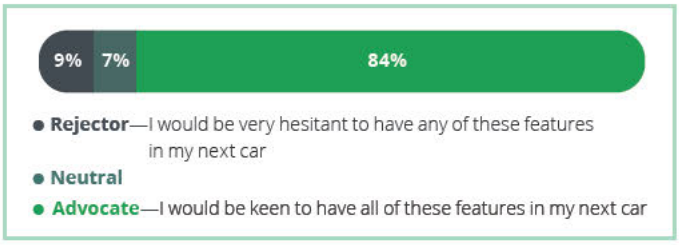
Eighty-four per cent of respondents were eager to have automated features in their next car. Nine per cent said they would be very hesitant and seven per cent were neutral. Across these groups, there was no significant difference between gender or age. Among the group who identified as 'very hesitant', five key barriers to adoption emerged.

536 Transurban customers responded to a survey that asked them about how they felt toward having automation features in their next vehicle.

9% Nine per cent of respondents profiled as 'very hesitant to automation features'.

40 From that subset, 40 participated in an online forum.

Figure 7: Results from screener survey re attitude toward automation features in next vehicle



"I have cruise control but it's not adaptive, I don't miss something I never had."

Male, 51-55, QLD, CAV advocate

Figure 8. Five key barriers to adoption

Fear of new technology	Many do not trust a computer to be better than a human	*"I'm not too sure about the park assist, adaptive cruise control & automatic braking as I'm probably too much of a control freak and not sure I would trust that the computer components would not malfunction."* **Female, 51-55, QLD, CAV rejector**
Potential impact on driving skills and behaviours	Fear of social change, decrease or loss in driving skills	*"I find the other mentioned features are creating lazy drivers. People no longer check their blind spots, or look in their mirrors and I often see people drift between lanes. It's dangerous and scary to think a new generation of drivers will know these features as standard."* **Female, 25-27, NSW, CAV rejector**
Overconfidence in one's ability	Feel there is no current need to use driver-assistance and to trust in own ability	*"I am a skilled driver and do not need these features to 'help'."* **Female, 25-27, NSW, CAV rejector**
The enjoyment of driving	Driving is more than just getting from 'A' to 'B'	*"I like DRIVING. I'm not sitting in the car, letting "something" else do the driving for me."* **Female, 46-50, NSW, CAV rejector**
Price/value	Want to buy most affordable car available, not interested in frills or special features	*"Great make them standard and raise the price of cars higher than ever. All these gadgets cost and cars are over priced already. I think I'll buy a horse."* **Male, 51-55, QLD, CAV rejector**

Conclusion

The trial has delivered a mixed set of findings, in some cases these findings led to clear recommendations, however others are inconclusive and require further investigation.

Throughout our trial we provided specific feedback to vehicle manufacturers, highlighting how automated driving technologies were challenged by specific motorway features for use in their on-going product development.

We thank the vehicle manufacturers for their ongoing co-operation and also acknowledge the technical support provided by ARUP.

It doesn't make sense to make all the recommended changes now. The development of vehicle technology is likely to outpace road infrastructure owners and operators' ability to make physical modifications to infrastructure. Some of the challenges identified in our trial could potentially be addressed in the longer term through more advanced connected vehicle communications (e.g. I2V/V2V communications) or high-precision maps. We are, however, making two practical changes now:

- line markings—paint lines under toll gantries
- tunnel wall speed signs—ensure a different sign type for future tunnels such as West Gate Tunnel.

We will also incorporate what we've learned in the design of new roads and how we operate them.

Some of our recommendations suggest changes to the standards and guidelines that are being used today. We will work with industry to ensure these feed into an ongoing review process, to improve national consistency and harmonisation.

Next steps

As vehicle technology continues to evolve, further trials will be important to measure how these developments address the road infrastructure challenges we identified. Our future trial program will include trialling:

- the same vehicles with newer automation systems to learn about improvements in these systems. Also, redoing trials after we have made changes to our infrastructure will allow us to assess the impact of those changes
- different vehicles to help us understand further issues and interactions not already identified from the trials to date
- additional roads more broadly across the network within Victoria and other jurisdictions, to help identify further findings specific to those road environments.

In the next phases of the trial program, we will build on the learnings from this first phase by introducing more highly automated vehicles and connected vehicle communications.

We look forward to sharing further details of these trials as they become available, and welcome further industry collaboration to accelerate the introduction of these important new technologies.

Glossary

AARC

Australian Automotive Research Centre

ACC

Adaptive Cruise Control—builds on standard cruise control functions and maintains a set speed and following distance to the car in front

ANCAP

Australasian New Car Assessment Program—it provides Australian and New Zealand consumers with independent vehicle safety information

CAV

Connected and automated vehicle

Driver-assistance features

Vehicle safety systems that assist drivers in some elements of driving, such as warnings and the emergency breaking

GPS

Global positioning system—high precision maps\3D maps which vehicles can compare against what their sensors 'see', to help pinpoint their exact location

I2V

Infrastructure-to-vehicle

Identify a traffic sign

Where a vehicle detects a traffic sign exists

LIDAR

Measurement of distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor

Line marking

Lines used on a road surface to provide guidance and information to drivers and pedestrians—commonly to delineate lanes

LKA

Lane-keep assist—reads lane lines and proactively intervenes with the steering of the vehicle to ensure that it does not unintentionally leave the lane

Map providers

Providers of digital maps to the vehicle manufacturers e.g. HERE Maps, TomTom, etc.

MRC

Minimal Risk Condition—this refers to the way the vehicle reacts if, after multiple warnings, the driver does not take back control of the vehicle

NTC

National Transport Commission

Radar

A system for detecting the presence, direction, distance, and speed of objects, by sending out pulses of radio waves which are reflected off the object back to the source

Read a traffic sign

Where a vehicle identifies and correctly reads the speed sign and illustrates the speed on the instrument panel

Sound Tube

Encasing CityLink between Racecourse and Brunswick Roads the Sound Tube is a unique and iconic piece of motorway architecture

Toll point/gantry

Elevated structure above the road which monitors vehicles underneath for billing purposes

TSR

Traffic Sign Recognition—camera technology that detects and reads traffic signs and displays them in the vehicle

V2V

Vehicle-to-vehicle

Transurban

QLD Transport and
Public Works Committee

Inquiry into Transport Technology

Transurban submission

September 2018

Traffic Management Centre, located at Transurban Queensland offices in Eight Mile Plains

Contents

Terms of reference

		SECTION WHERE ADDRESSED
A	Identify trends and changes in fuel type usage in the sectors of personal transport, freight transport and public transport, such as the increasing uptake of hybrid and electric vehicles	Section 4
B	Examine the readiness of the transport network for increasing electrification of vehicles in coming years	Section 4
C	Identify other emerging technological factors which will impact on transport networks into the future, such as driver aid technology and 'driverless car' technologies	Section 5
D	Examine how technology is affecting employment arrangements in the transport industry, particularly in the food delivery area	Not applicable

Section 1: About Transurban

Transurban Queensland in numbers


6
operating assets


1.6M
customers


2
upgrade projects


482
lane kilometres under management


5.6M
kilometres travelled per day


~470,000
trips per work day


~70,000
hours of travel time saved per work day in FY18


~280
employees


~1,000
traffic incidents managed monthly, includes breakdowns, out of fuel, debris clean up

Transurban welcomes the opportunity to make a submission to the Transport and Public Works Committee Inquiry into Transport Technology.

Transurban is an urban toll road developer and operator with 16 motorways across Australia and North America. Transurban has a 62.5 per cent ownership stake in Transurban Queensland, which operates six toll roads in Queensland.

These include AirportLinkM7, Clem7, Gateway Motorway, Go Between Bridge, Legacy Way Tunnel and Logan Motorway.

Transurban's role is to build the roads that cities need, making sure travel on these roads is as easy, quick and safe as possible. From traffic control operators and response crews working 24–7, to customer service experts developing new travel apps, and engineers designing and upgrading the roads, we're working to make sure cities keep moving not only today but well into the future.

Since beginning our operations with CityLink in Melbourne in 1999, the emergence and increasing power of technology has seen Transurban transition from a traditional engineering business to a substantial technology business, with almost 40 per cent of our workforce employed in technology.

The technology underpinning road infrastructure has been constantly developing and expanding to optimise traffic flow and create a better and safer experience for drivers. The installation of intelligent transport systems (ITS) on many roads has created 'smart' roads.

New roadside technologies such as coordinated ramp metering, lane-use management systems, variable speed limit signs, CCTV cameras, automatic incident, height and occupancy detection as well as travel-time information work together to help us get the best out of a motorway. All this is integrated into a central traffic management system that can apply traffic management plans, and in the future will be increasingly automated and coordinated with connected and automated vehicles.

As a long-term owner-operator of road infrastructure in Australia, we have a vested interest in monitoring new and emerging technologies that will impact road development, operations, maintenance, tolling products and customer service.

With the digitalisation of transport services and the imminent arrival of driverless vehicles, we are focusing on ensuring our business and road infrastructure is well equipped to manage this change.

Section 2: Overview

Electric and automated vehicles, mobility as a service and ride sharing are among the many transport innovations poised to enter mainstream life in the coming decade, transforming the way people move around cities.

These new transport technologies will bring opportunities for more efficient and safer mobility, significant reductions in greenhouse gas emissions, large-scale transport service integration and many more benefits that are yet to have been even contemplated.

Autonomous and electric vehicles will create efficiencies not yet seen on Australian roads—from journey planning that includes integration with public transport, to improvements in traffic flow born from communication links between vehicles travelling on the same road.

Australia needs to be ready to take advantage of these opportunities to ensure the benefits are delivered to the Australian community.

In the not-too distant future, electric and autonomous vehicles will be the standard vehicle seen on roads, not the exception. Before this can be realised, infrastructure and the community need to be prepared for the change.

Urban policy decisions made today will shape the evolution of mobility and transport usage over the coming decades and must consider new technologies as well as existing policies and systems that underpin transport networks and services in Australia.

In preparing for the change, we must consider the significant impact electric vehicles will have on Australia's current road funding model.

Fuel efficiency is already eroding the funding base for Australia's road infrastructure and will continue to decline as the uptake of electric vehicles increases.

Australia's transport challenges and opportunities are converging and gaining momentum, but the Australian public remains largely unaware of their existence.

The community needs to be engaged and informed about the reality of the situation confronting all of us so we can all start talking, with confidence, about practical solutions to facilitate the evolution of transport.

The impact of emerging issues in transport technology will have a direct impact on Transurban's operations.

In our response we have provided information on the technology trends that we consider will have major implications on transport and mobility over the next few decades, and examples of how Transurban is preparing for the change. Where relevant, we have provided recommendations for government to consider as part of the inquiry.

Image courtesy of Volvo Australia

Section 3:
Response to inquiry

The invention of mass-produced automobiles was a defining feature of the 20th century. Cars drove social changes by reshaping our cities with road networks and increasing access to mobility, enabling considerable personal and commercial outcomes.

A century on, new technologies are triggering the biggest revolution of the transport sector since cars replaced horses. The impact of this revolution will be far reaching.

Significantly, it also provides a tipping point for changing how we fund, build and maintain road infrastructure.

Our growing population and progressive urbanisation are challenging our transport system. Simultaneously, our ageing population is placing increasing demands on health, aged-care and other services, further stretching government budgets across a broad range of service provisions including infrastructure.

It is important that action be taken by government now to ensure the readiness of our communities for the transport revolution.

Our recommendations in support of this objective are contained in the table below and referenced throughout the report. Transurban welcomes further discussion with the Committee on matters included in this submission.

CORE AREA	RECOMMENDATIONS
1. Road-user charging	With the rapid advance in transport technology, governments should prepare to transition to an alternative funding model/s to support road infrastructure. A significant first step is under way with the Federal Government's Heavy Vehicle Road Reform (HVVR). The HVVR aims to establish a transparent, fair and efficient charging system that invests revenue into road infrastructure to meet user needs. The HVVR is only the first step in reform and we recommend the following should also be considered: 1. Government progress medium-term planning toward a light vehicle road-user charging scheme in line with the forecast growth in electric vehicle uptake. 2. Road-user charging frameworks are also designed to meet other transport objectives such as improving travel times and road utilisation. Transurban would be pleased to discuss the findings of our analysis in this area with the Queensland Government.
2. Connected and automated vehicles (CAVs)	CAVs are coming and will be on the road in the next decade. To ensure we are prepared for their introduction we recommend the Queensland Government, together with industry: 1. Conduct a community awareness campaign to build understanding of their safe use and automated features. 2. Conduct road trials now of automated technology to ensure road infrastructure is ready for the arrival of CAVs. We note the work that the Department of Transport and Main Roads and Transurban are undertaking in this space. 3. Keep pace with rapidly changing technology by creating a regulatory environment in which such trials can be implemented with ease and continue to conduct trials of the latest technology.
3. Mobility as a Service	Ultimately transport networks will become integrated with users moving seamlessly between different modes of transport. To ensure that the future of mobility is fair for consumers we recommend: 1. Introducing an assurance framework for transport network companies (e.g. Uber) to ensure fair and transparent charging for customers (e.g. charging tolls at the gazetted toll price). 2. Government provide public access to data from various modes of transportation and ancillary services in a single place so that mobility as a service providers can easily access the data. Relevant data includes information relating to on-street and off-street parking, live public transport data, fuel pricing and charging station availability. This will allow easy integration with software for cost, route and travel mode comparison. It will also facilitate innovation in the sector and ultimately provide choice to customers by creating a variety of service options and open platforms for payment solutions.

Section 4:
Electric vehicles

Transitioning Australia's fleet to electric vehicles will bring environmental and social benefits but for this to happen we need to ensure the community, infrastructure and regulatory environment are ready.

Australia's transition to alternative-fuel vehicles

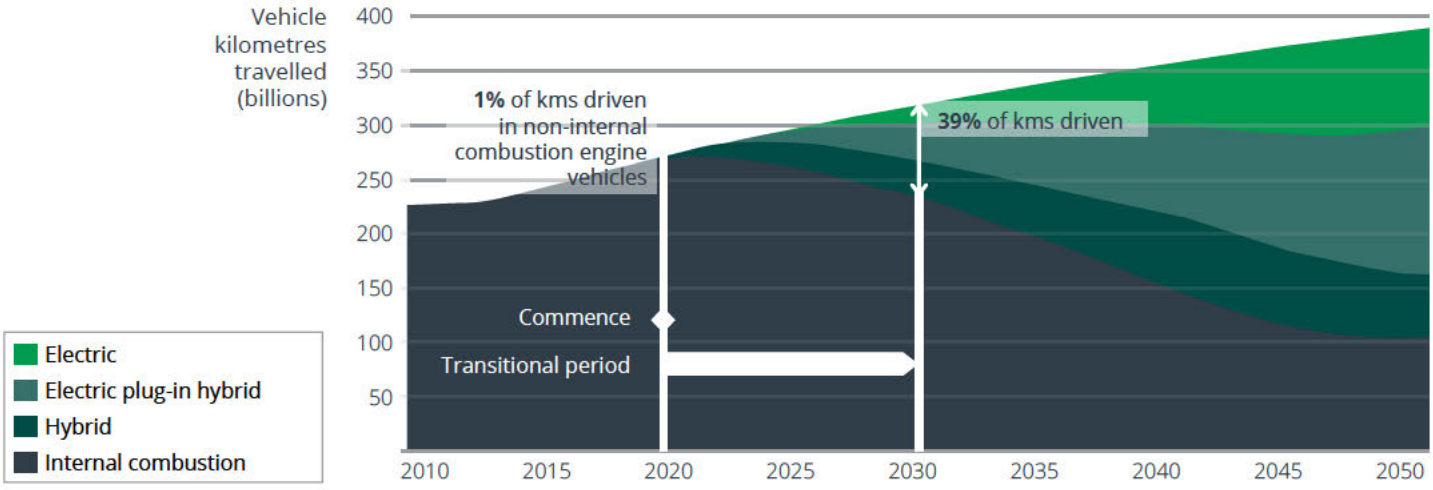
While uptake of electric vehicles in Australia has lagged behind global leaders such as China, Norway and Japan, there is growing momentum in the local market as consumers and governments recognise the benefits of electric vehicles and their inevitable role in future transport.

Electric vehicle sales increased by 67 per cent from 2016 to 2017 and now make up 0.2 per cent of the Australian market[1].

Looking ahead, total electric vehicles on the road are forecast to reach over 2.56 million or 13.2 per cent of total new Australian vehicle sales by 2036, moving to 13.63 million or 61.5 per cent of all new vehicle sales by 2050[2].

Figure 1 shows vehicle kilometres driven by conventional vehicles will soon peak and begin declining as electric and hybrid vehicles increase total share.

Figure 1: Adoption of electric vehicles



Source: Projecting future road transport revenues 2015–2050, May 2015; Transurban analysis

Air and noise pollution

Air quality is an important environmental measure for our roads. Specific regulations are in place for maintaining air quality within road tunnels and ensuring vehicle exhaust is appropriately diverted via tunnel ventilation systems. With zero tailpipe emissions, electric vehicles will improve air quality near all Australian roads.

Road traffic has been identified as the most common noise source in Victoria and is associated with reduced community amenity[3]. Electric vehicles are much quieter than conventional vehicles and will therefore improve amenity in communities across Australia. However, quieter vehicles may present a risk to vulnerable road-users such as pedestrians, motorbikes and road operation teams who may rely on vehicle noise to interact with the road environment.

[1] Electric Vehicle Council and ClimateWorks Australia 2018, The state of electric vehicles in Australia, Second report: driving momentum in electric mobility
[2] AEMO 2017, Electric Vehicles Insights, prepared by Energia
[3] Beyond Zero Emissions 2016, Zero Carbon Australia Electric Vehicles

Preparing roads for electric vehicles

As a road operator, we're considering how electric vehicles might impact how we design, build and manage our roads. We're working with industry experts to review the impact of electric vehicles on our roads.

The way we detect and respond to traffic incidents may change in order to address a growing electric vehicle fleet. For instance, lithium battery fires are expected to be high intensity and can take longer to extinguish than gasoline fires. In addition the potential release of toxic fumes may also require emergency services to wear self-contained breathing apparatus and use hoses that spray fog and special ventilation fans that push air out at a high velocity to protect bystanders downwind of the fire[4].

In instances where vehicles run out of fuel, mobile charging units will likely need to be made available along with charging stations at each breakdown bay.

As highlighted earlier, electric vehicles also emit less exhaust and are quieter which we would consider in the design and operations of roads into the future.

Erosion of fuel excise

Australia, like most countries, is currently reliant on a century-old funding system that will not survive the transport revolution.

Every year there are more fuel efficient and electric vehicles on the road. As depicted in Figure 2, the result is that fuel excise, which currently contributes 52 per cent of total road-related revenue from all levels of government, is declining at 16 per cent each year, and, in short, coming to an end[5].

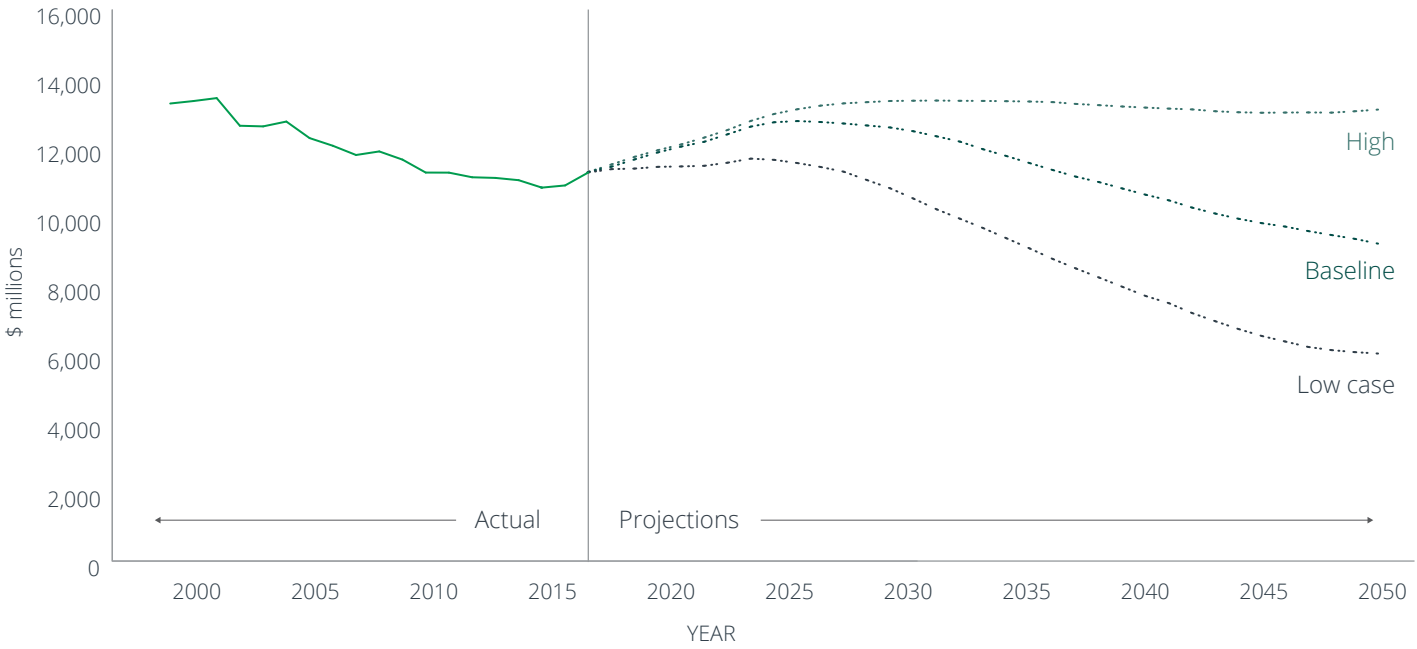
Australia needs to reform its road funding model to provide a fair and sustainable system that is built on a principle of those who benefit, pay. This will allow us to invest and use the infrastructure more efficiently and provide a revenue stream that is aligned with actual road use.

For many years, the need for road funding reform has been gaining momentum.

Nationally significant bodies such as Infrastructure Australia, the Productivity Commission, Bureau of Infrastructure, Transport and Regional Economies, the Australian Automotive Association and Infrastructure Partnerships Australia as well as the Henry Tax Review and Harper Review all advocated for change. These groups have highlighted Australia's demographic changes, stretched government budgets, declining fuel excise and the inequity of the current system as worthy triggers for reform.

While this groundswell provides impetus for change, without understanding Australians' views and behaviour towards road pricing systems, reform will always remain theoretical.

Figure 2: Australia's declining fuel excise revenue



Source: Transurban analysis; Bureau of Infrastructure, Transport and Regional Economics, Australia Infrastructure Yearbook 2015; CSIRO (report for the NTC), Projecting future road transport revenues 2015–2050, May 2015

[4] Tesla Model X Emergency Response Guide, available, < https://www.tesla.com/sites/default/files/downloads/2016_Model_X_Emergency_Response_Guide_en.pdf >
[5] Bureau of Infrastructure, Transport and Regional Economics, Australian Infrastructure Statistics—Yearbook 2017, available < https://bitre.gov.au/publications/2017/files/yearbook_2017.pdf >

Case study: Melbourne Road Usage Study

In 2016, Transurban conducted Australia's first real-world trial of broad-based user-pays road charging. The study was conducted in Melbourne over 17 months with 1,635 motorists travelling 12 million kilometres under a range of charging options.

The study tested user-pays models such as a charge per kilometre, charge per trip and flat rate charge as an alternative to the current system of fuel excise.

It also tested two demand-management charging approaches (time-of-day charge and cordon/area charge).

The Melbourne Road Usage Study findings suggested that replacing the current road funding model with a user-pays system could work in Australia, providing a sustainable, fair and flexible funding system that grows with demand.

The study found that 60 per cent of participants preferred a user-pays system after experiencing first-hand a more transparent way of paying for their road use.

Participants were open to discussing viable alternatives to the current system and highlighted the power of information sharing and practical experience.

The study was designed to offer valuable insights for policymakers, industry and communities in considering long term solutions to road funding and managing demand.

The results of participant preferences are shown in Figure 3 and 4 below. More information on the study is available at **changedconditionsahead.com** and the full report is attached (Appendix 1).

Figure 3: Preferences of usage-based charging options (of those who prefer user pays)

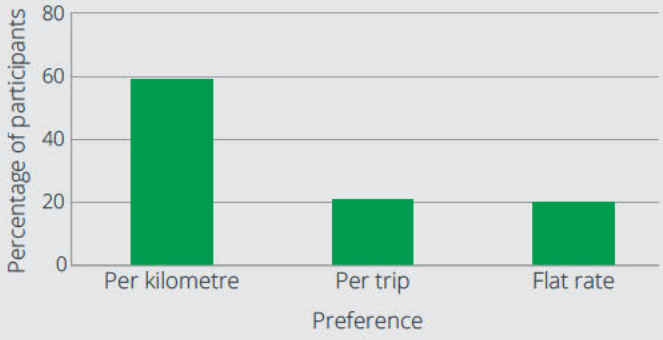
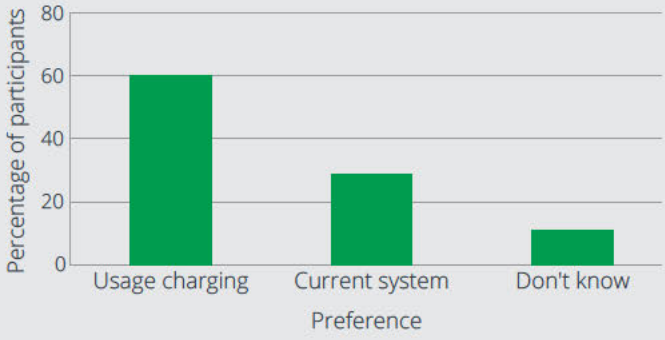


Figure 4: Funding system preferences after experiencing user pays



Recommendation 1—Road-user charging

With the rapid advance in transport technology, governments should prepare to transition to an alternative funding model/s to support road infrastructure.

A significant first step is under way with the Federal Government's Heavy Vehicle Road Reform (HVVR). The HVVR aims establish a transparent, fair and efficient charging system that invests revenue into road infrastructure to meet user needs. The HVVR is only the first step in reform and we recommend the following should also be considered:

1. **Government progress medium-term planning toward a light vehicle road-user charging scheme in line with the forecast growth in electric vehicle uptake.**
2. **Road-user charging frameworks are also designed to meet other transport objectives such as improving travel times and road utilisation. Transurban would be pleased to discuss the findings of our analysis in this area with the Queensland Government.**

Section 5: Trends

Connected and automated vehicles (CAVs), along with smarter roads and changing attitudes towards mobility offer the potential to improve the efficiency, safety and accessibility of our roads within the next 20 years.

Connected and Automated Vehicles

CAVs have the potential to significantly improve traffic flow, efficiency and safety across the road network. An estimated 90 per cent of road incidents are the result of human error.

Within the next 20 years we may see lane-use capacity increase as CAVs are introduced. Connected vehicles will be able to travel in 'platoons' with two or more vehicles travelling more closely together by communicating with each other to coordinate their acceleration and braking. Once penetration of CAVs reaches a threshold level, different approaches such as dedicated lanes could be considered to manage the coexistence of automated and manually-driven vehicles.

CAVs also have the potential to give sectors of the community who face mobility challenges, including older people and those with disabilities, access to new transport options.

Vehicles with partial-automation features are already driving on Australian roads, and the emergence of more advanced vehicles is imminent. How quickly Australia can prepare its systems, regulations, infrastructure and communities for the arrival of CAVs will underpin their successful introduction.

Shifting the driving task from humans to vehicles is incredibly complex and touches all aspects of the transport industry. Existing rules for vehicle manufacturers, insurance, road operations, and driving all need to be revised. This process will involve significant legislative change, and the development of new regulations and guidelines that ensure public safety and foster innovation. National bodies such as the National Transport Commission (NTC) are critical to progressing these considerations. The NTC is working with state governments on a uniform phased reform agenda to support the introduction of vehicles with automated driving systems.

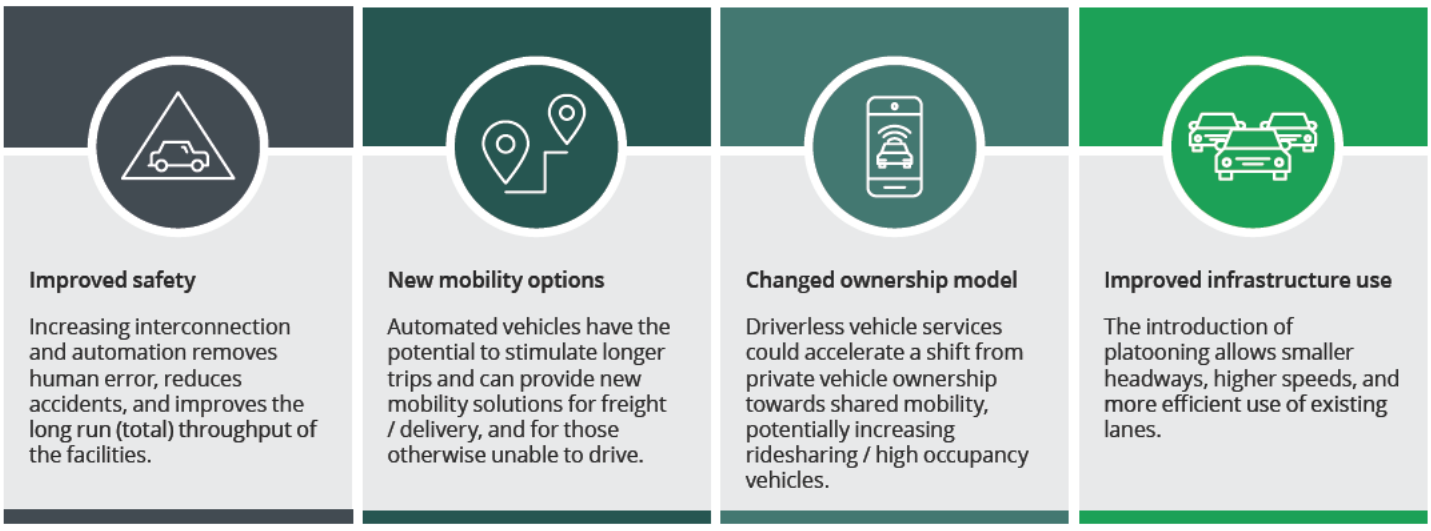
The uniform laws are expected to be introduced from 2020.

Physically preparing Australia's roads for CAVs will also be a substantial task.

In a recent assessment of 20 countries' preparedness for automated vehicles, Australia ranked 14th. Australia received the maximum score for the quality of our mobile networks but only average ratings for the quality of our roads, availability of 4G and our preparedness for the future electrification of vehicles[6].

Infrastructure upgrades generally require long lead times and come at significant cost. As a country we urgently need to understand if we have to retrofit sections of Australia's almost eight million square kilometres of local and arterial roads and motorways, which would benefit from CAV-ready technology and infrastructure.

Figure 5: CAVs will fundamentally change how we travel



[6] KPMG 2018, Autonomous Vehicles Readiness Index

Case study: CAV trials

Transurban has conducted trials in Melbourne, Sydney and the United States to understand how CAVs will interact with road infrastructure.

Transurban Queensland (TQ) is preparing to conduct trials in Brisbane, commencing October this year. The trials have two components, the first being to explore how partially automated vehicles (level 1 and 2) interact with the motorway network around Brisbane. The second component will look at reducing congestion using innovative approaches involving connected vehicle communications.

TQ has established a reference group of government and industry stakeholders to inform the development of the trials.

Interstate and international trials

Our CAV trials in Victoria looked at how partially automated vehicles react to the motorway environment including: speed signs, toll points, line markings, motorway artwork and architecture, entry and exit ramps, objects on the road, merging vehicles, different light and weather conditions, peak-hour congestion and road works.

The trial recorded more than 6,500 observations from 12 vehicles driving on the Monash, CityLink and Tullamarine motorways in Melbourne.

The trials provided valuable insights into what is needed to prepare our roads for an automated-vehicle future and highlighted some of the challenges vehicle manufacturers, infrastructure providers and regulators face.

Some of the issues for CAVS included:

- Line markings—disruptions to line markings, including gaps under toll points, sometimes led to lane-keep assist disengaging.
- Exit ramps—vehicles favoured solid lines, and would sometimes follow a solid line up an exit ramp, rather than continuing along the main motorway. While on the exit ramp, vehicles sometimes did not detect vehicles stopped at the end of a ramp and did not slow down.
- Speed signs—vehicles' ability to correctly read a speed sign seemed dependent on the sign type (electronic or static), location and position of the sign. Flashing electronic speed signs were read correctly more reliably than electronic signs that did not flash. Signs on tunnel walls were rarely read correctly.
- Other vehicles/objects on the road—vehicles travelling to the side of trial vehicles (for example, merging from entry ramps) were not always detected. Similarly, other objects on the road such as debris, stopped vehicles, roadworks, and temporary portable signs were not always detected.

The trial was run in partnership with VicRoads, Royal Automobile Club of Victoria (RACV) and vehicle manufacturers.

A similar CAV trial program was recently completed in partnership between Transurban, Transport for New South Wales (TfNSW), and the Roads and Maritime Services (RMS).

Trial data is being captured via our Australian-first, purpose-built app that tracks, records and measures all interactions between CAVs and road infrastructure. This app will also be used for Queensland-based trials.

The NSW trial will be followed by further testing of automated vehicle technology on urban and regional roads led by the NSW Centre for Road Safety.

In the United States, Transurban has partnered with the Federal Highway Administration (FHWA) and the Virginia Department of Transportation (VDOT) to use vehicle-to-vehicle and vehicle-to-infrastructure communications to demonstrate a combination of connected vehicle applications on our I-95 Express Lanes. These applications enable vehicles to safely drive more closely together in 'platoons'.

The partnership is studying how CAVs may improve safety and mobility by specifically testing electronics, information processing and communications technology to better understand the practical application of CAVs in a real-world environment.

It is clear from our work in this space that vehicle automation behaves differently on different road networks and it is essential to understand the issues unique to specific environments to ensure the safe introduction of CAVs.

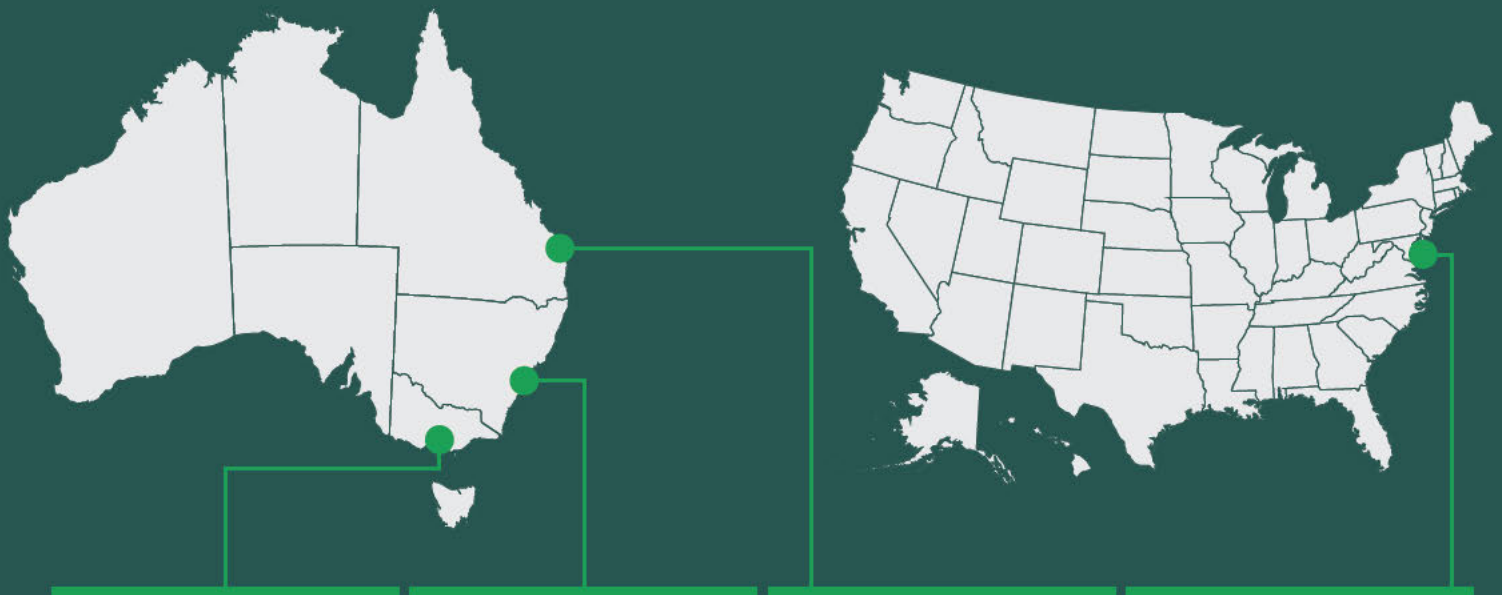
For more information on our CAV trials visit **cavs.transurban.com**

Recommendation 2—Connected and Automated Vehicles

CAVs are coming and will be on the road in the next decade. To ensure we are prepared for their introduction we recommend the Queensland Government, together with industry:

1. Conduct a community awareness campaign to build understanding of their safe use and automated features of CAVs.
2. Conduct road trials now of automated technology to ensure road infrastructure is ready for the arrival of CAVs. We note the work the Department of Transport and Main Roads and Transurban are undertaking in this space.
3. Keep pace with rapidly changing technology by creating a regulatory environment in which such trials can be implemented with ease and continue to conduct trials of the latest technology.

Figure 6: CAV expertise



VIC	NSW	QLD	Greater Washington Area
Multi-phase program in partnership with VicRoads, RACV and vehicle Original Equipment Manufacturers (OEMs)	Infrastructure audit in partnership with TfNSW, RMS and vehicle OEMs	Connected vehicle trials for level 2 automation Infrastructure audit and speed harmonisation	Connected vehicle trials in partnership with FHWA and VDOT

Market research: Community attitudes towards CAVs

As with each new wave of technological development, the uptake and success of CAVs will be guided by community awareness and acceptance.

While the technology is developing quickly, people need time to adjust to new behaviours especially when these involve handing control over to technology.

As a road operator with five million customers across Australia and 1.6 million in Queensland, we have a role in helping prepare the community for the impacts of new vehicle technology, so they feel safe during the period of transition to automated driving.

Alongside our on-road trials, we researched community attitudes towards automated vehicle technologies. We've started by looking at lower-level functionality and will work up to more advanced levels.

This research found 84 per cent of people would like to have partial automation features in their next vehicle. At the same time, 9 per cent of people were hesitant to change and 7 per cent were neutral. Across these groups there was no significant difference between gender or age.

Among the group that identified as very hesitant , five key barriers to adoption emerged.

- Fear of new technology—many do not trust a computer to be better than a human.
- Potential impact on driving skills and behaviours—fear of irreversible social change, decrease or loss in driving skills.
- Overconfidence in one's ability—some drivers feel there is no need to use driver-assistance due to trust in own ability.
- The enjoyment of driving—driving is more than just getting from 'A' to 'B'.
- Price/value to buy most affordable car available, not interested in frills or special features.

These results highlight some of the key challenges to the community adjusting to CAVs.

Government and industry will play a key role in helping prepare the community for the impacts of new vehicle technology, so they feel safe during the period of transition to automated driving.

Shared mobility

Products and services within the sharing economy are becoming more commonplace, leading some people to reassess whether they need to own a car themselves. Instead of owning a car, which can be expensive, people in urban and suburban areas might be better off accessing one when they need it through apps like GoGet or Uber.

The move away from car ownership and towards new shared models of mobility is reflected in the declining proportion of young people who hold a driver's licence. In Australia, the decline has been noted by motoring bodies such as the RACV, reporting that licensing rates for young adults aged 18 to 24 have decreased by 18 per cent since 2001, with over a third of Victorian adults aged 18 to 24 in 2016 not holding a driver's license[7].

Ride sharing and carpooling is likely to reduce the cost of travel and free up parking spaces, however it's unclear what the impact will be on net vehicle kilometres travelled.

A study of seven major US cities found a strong correlation between increasing ride-hailing and households reducing their number of vehicles[8]. While car ownership may decline, we could see a greater amount of kilometres travelled by a smaller fleet of vehicles.

Despite additional vehicle kilometres, it's expected that congestion could still be reduced by improvements in vehicle connectivity, ensuring vehicles are well coordinated with synchronised traffic flows.

Transurban encouraging ride sharing on the roads

Different transport choices, such as ride and car sharing, are gaining momentum as cities face increasing populations and demand for infrastructure.

The impact that carpooling would have on congestion and the environment is significant. But beyond this, widespread carpooling offers important social benefits too. Shared-vehicle services give users access to transportation on an "as-needs" basis, eliminating on-going costs of ownership.

In association with the Banksia Foundation, which promotes sustainability, Transurban has launched a challenge to encourage carpooling on Transurban toll roads in Australia. Through the Banksia Ignite Challenge, Transurban is calling for ideas that will significantly increase the use of carpooling on toll-roads.

As an incentive, the challenge has $15,000 prize money, with two runner-up prizes of $5,000 each. Transurban will choose one or more of the solutions to develop into a proof of concept.

Transurban already encourages ride-sharing on its roads in the United States.

In Washington DC, Transurban operates express lanes. These consistently deliver a predictable travel time, no matter what time of the day. They do this by changing the toll based on demand—a model called dynamic pricing . Motorists can drive on these lanes for free if their vehicle is classified as high occupancy , that is, with three or more occupants including the driver.

Travel and demand management options such as these will become increasingly accessible as mobility as a service applications become more widespread and sophisticated, integrating mobility service platforms.

Mobility as a Service

The service-based consumption of transport is disrupting and shaping the future of transport. Also known as 'mobility as a service' (MaaS), this new approach to accessing transportation services will have wide-ranging implications for the entire transport ecosystem, and how we integrate movements.

MaaS describes the shift towards providing customers with individually targeted travel options delivered in a convenient way, such as through a smartphone app. Service providers will package up transport options with real-time route information and online payment. This service will require providers to take a holistic view of the transport offering, combining public transport with car travel options. To do this, data from various modes of transportation must be accessible and developed in such a way that allows for integration and comparison within the transport network.

As technology develops and customer expectations of mobility services change, it will be critical for governments to facilitate innovation, especially by the private sector, by providing timely access to relevant public data sets.

As it stands, Australia's infrastructure data is fragmented. It assumes that travellers/commuters have already predetermined their time and mode of travel, and will source information regarding their trip accordingly. There are no data sets currently available that combine public transport options with traffic conditions and other services, which would provide travellers with a range of options.

The need for a national framework for public data sharing and accessibility is essential and Transurban is willing to assist government as this develops.

[7] RACV 2017, Young Adult Licensing Trends—2017 Update
[8] iMOVE, Smart shared mobility and potential implications for levels of congestion, available < https://imovecrc.com/news-articles/intelligent-transport-systems/smart-shared-mobility-implications-for-congestion/ >, accessed 14 August 2018

Case study: New digital platforms making mobility easier

Smartphones and apps have brought information, convenience and choice to everyday life and are credited with products and services becoming easier to access and increasingly tailored to customers' individual needs.

It's certainly true that mobile technology, among other things, has dramatically changed the way our customers interact with our products and business.

Since the introduction of electronic tolling, tags, known as e-Tags, have worked well for regular users. However, recent customer analysis indicated that 50 per cent of our customers are infrequent toll road-users, meaning they typically use our roads less than four times a year.

The research also told us that these customers want flexibility, control and easier ways to manage their toll road travel, with many just wanting to pay for their toll road use without committing to an account. While occasional toll road-users may not want to have an e-Tag in their car, most have a smartphone in their pocket.

To reach these customers and improve their experience we focused on the driver, rather than the vehicle, and created a new way to pay for tolls. LinktGO is a GPS-enabled mobile app that allows drivers to see their toll travel in real time and pay trip-by-trip using their smartphones, with no ongoing commitment.

LinktGO has built-in safety features that leverage a phone's core motion technology, suppressing notifications until the phone senses that the customer is no longer moving at speed. If the customer tried to access the app while driving they would find it temporarily disabled.

Customers can start driving just by registering their vehicle and a credit card to the app—no paperwork, no start-up costs and no tag needed.

Using LinktGO, customers pay trip-by-trip, with trip details and associated costs displayed in real-time and prompts to indicate when payment is due. Trips are recorded even if the phone battery dies or da connection is lost.

Transurban has also recently partnered with Melbourne City Council to trial integrating parking occupancy data into the LinktGO app to create a new parking feature. The feature allows customers t find available parking spaces and provides them information on current restrictions for each spot, suc as time limits. While the trial is still in its early days, initial customer feedback has been positive.

Recommendation 3—Mobility as a Service

Ultimately transport networks will become integrated with users moving seamlessly between different modes of transport. To ensure that the future of mobility is fair for consumers we recommend:

1. **Introducing an assurance framework for transport network companies (e.g. Uber) to ensure fair and transparent charging for customers (e.g. charging tolls at the gazetted toll price).**
2. **Government provide public access to data from various modes of transportation and ancillary services in a single place so that mobility as a service providers can easily access the data. Relevant data includes information relating to on-street and off-street parking, live public transport data, fuel pricing and charging station availability.**

This will allow easy integration with software for cost, route and travel mode comparison. It will also facilitate innovation in the sector and ultimately provide choice to customers by creating a variety of service options and open platforms for payment solutions.

Internet of Things

For a long time, roads have been dormant pieces of infrastructure made of bitumen and concrete. When technology is added, such as cameras and road sensors, they usually operate within closed local area networks—meaning information is transferred within a restricted network.

These types of devices and networks have helped shape the intelligent transport systems that have improved the safety and efficiency of our roads networks. However promising developments in Internet of Things (IoT) will likely lead to an increase in the prevalence and sophistication of Intelligent Transport Systems.

IoT refers to a network of "smart" physical devices embedded with technology that allows them to sense, process and transmit data to other devices in a connected network. It will see a proliferation of computing devices embedded into previously non-intelligent objects in all aspects of life.

For road infrastructure providers it means more information can be collected and processed through things such as road pavement and ventilation systems, water management systems, bridge monitoring systems, safe work zone sensors embedded in personal protective equipment, portable traffic management equipment, fleet management and incident response just to name a few. With the addition of predictive analytics this technology has the potential to increase safety, efficiency, and environmental performance of our roads.

According to Stanford University, "machine learning" is the science of getting computers to act without being explicitly programmed and it is the foundation for a whole host of new technologies that will impact on the future of transport such as CAVs, MaaS and IoT.

Beyond these major trends, the predicative analytics within machine learning could be used to enhance operations and maintenance of transport infrastructure. Machine learning might one day be used to predict infrastructure maintenance requirements, which could help improve safety on the roads by alerting maintenance teams when technology upgrades and/or replacements are needed.

Valerann road studs being installed

Case study: Developing IoT and machine learning capability through Smart Highways Challenge

Transurban operates two roads in Washington, Virginia—the 495 and 95 Express Lanes. Earlier this year we partnered with two startups on pilot projects aimed at improving traffic management and forecasting on our toll roads.

In partnership with Union through the Smart Highways Challenge, Transurban narrowed a pool of 87 international applicants to six finalists to participate in a three-month incubation program. Through that process, they identified and approved two technologies by Valerann and Revmax, which are now being piloted on the Express Lanes.

Valerann, an international startup, is developing smart, solar-powered road studs that have expanded visibility to detect traffic congestion, road incidents and surface conditions. The pilot technology aims to collect real-time data, report to roadway operations control centres, and has the potential to communicate with CAVs as the technology advances. The road studs are designed to help Transurban reduce both the detection time of road incidents and the response time to variable congestion to provide a faster, more fluid driver experience.

Revmax, a Brooklyn-based startup, is partnering with Transurban to study the ability to improve the accuracy of traffic forecasting using machine learning. Revmax's forecast tools will help Transurban plan its maintenance schedule and on-road resources such as the Virginia State Police and incident response service, Express Assist.

Section 6:
Future of transport

The nature, scale and timing of transport changes are difficult to predict but as these trends develop and reinforce each other, we anticipate a safer, more integrated and automated road transport network will emerge.

In the ideal transport future, passenger vehicles will be almost entirely automated, with certain motorways restricted to this mode of travel. These vehicles will reduce accidents by reducing and ultimately removing the impact of human error.

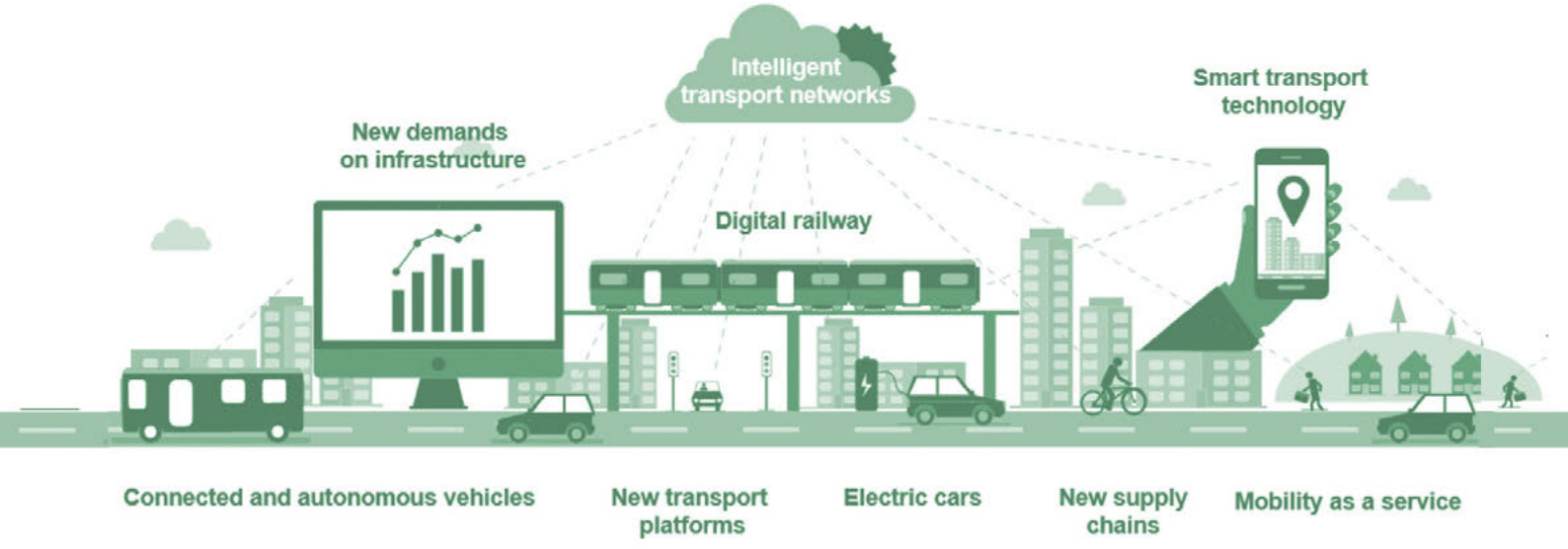
MaaS will be the predominant and affordable mode of personal travel, opening travel opportunities to new segments including elderly and disabled people. The advantages are particularly important for specific sectors of the community who face mobility challenges and cities needing to address "first mile" and "last mile" transportation gaps.

It's been estimated that shared, fully automated vehicles could lower the cost of personal mobility by 30 to 60 per cent relative to private vehicle ownership[9].

Beyond the reduced cost of travel the International Transport Forum, the transport policy think tank for the OECD reported that if shared taxis and taxi-buses were to replace private cars and scheduled buses in a city, congestion would be eliminated, traffic emissions cut by one third even without any new technology, and on-street parking places would become superfluous, freeing public space for other uses[10].

Similarly, automated-vehicle technologies will streamline the freight task by allowing real-time tracking and visibility across the supply chain and increase vehicle utilisation through vehicle platooning, and load-pooling—sometimes referred to as the "uberisation" of deliveries. In addition, developing technologies such as drones, droids and automated ground vehicles could provide innovative new solutions to last-mile delivery challenges.

This is an exciting time to be part of the transport industry as we see some of the most significant changes in the sector since cars first hit the road. We need to be prepared for the arrival of new technologies that will revolutionise the way we travel and Transurban is committed to working with government to help shape the framework for the future of transport.



Source: Atkins Acuity, available <atkinsacuity.com/viewpoint/intelligent-mobility-it-ready-private-investment>

[9] S. Bouton et, al. 2015, Urban mobility at a tipping point, McKinsey & Company, available at < https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/urban-mobility-at-a-tipping-point >, accessed 18 September 2018
[10] International Transport Forum 2016, Shared Mobility Innovation for Liveable Cities

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