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Introduction

The place of congestion and crowding forecasts in the 2019 Audit

The *Australian Infrastructure Audit 2019* (the Audit) applies a user lens to the challenges and opportunities facing the Australian infrastructure sector over the next 15 years and beyond. The Audit considers affordability, access and quality of infrastructure assets and services and the experience of users from across the country.

The purpose of the Audit is to determine the current and future expectations of Australia's infrastructure networks to cater for existing and projected demand. In doing so, the Audit identifies key challenges and opportunities that our networks face now and into the future.

This technical report summarises the results of detailed transport network modelling undertaken by Veitch Lister Consulting on behalf of Infrastructure Australia for the 2019 *Australian Infrastructure Audit*. The modelling was undertaken for the nation's six largest urban conurbations. A conurbation is defined as an extended urban area. In the case of this report it applies to Australia's six largest capital cities and the neighbouring satellite cities and regions. These range from close to 6 million residents in the combined Sydney, Hunter and Illawarra regions, to 450,000 people living in the ACT and Queanbeyan. The assessment reports outcomes for a 2016 base year and forecasts the systems' performance in 2031.

A key finding of the Audit is that the experience of infrastructure services varies greatly for communities based on where they are located. Urban transport networks are no different.

Within our fast growing cities, Sydney, Melbourne, Brisbane and Perth, congestion is a major barrier to quality of life and economic prosperity of our communities. Our economy is urbanising, as the growth of some industries locate in large cities, particularly Sydney and Melbourne. Around 70% of Australia's economic growth occurred in capital cities between 2000–01 and 2015–16, an average growth rate of 3.2% per year.[1]

Australia's population is also highly urbanised. About 59% of our population live in our four largest cities, with 40% of Australia's population living in the two cities of Sydney and Melbourne.

Transport is critical to how our cities function and is an enabler of economic activity, leisure and social interactions. Our transport networks are critical to the movement of people, workers and business, as well as the movement of goods, from farms and factories to ports and shop fronts. Our urban transport networks are nationally significant infrastructure assets.

This report also highlights the challenges posed by congestion in our smaller cities and regional centres. Congestion challenges in Adelaide, Canberra, Geelong, the Illawarra, the Central Coast, the Gold Coast and the Sunshine Coast are less significant than in their neighbouring capital cities. However, the inter-city connections between fast growing cities and their smaller satellites are amongst the most significant in terms of the impacts of the total cost of delay on an individual transport corridor.

Public transport services are also most prolific within fast growing cities, smaller cities and regional centres. This paper allows an examination of the capacity of existing networks and the coverage of existing networks. The report highlights that, in the future, public transport networks generally have less capacity constraints than road networks. However, constraints are emerging on some networks causing reduced access to public transport.

The impacts of congestion in rural and remote areas are less economically significant. However, this does not undermine the impacts of persistent local congestion to the lives of people that experience it regularly. The cost of delay for businesses in rural and remote areas is not modelled, however Infrastructure Australia acknowledges it can be significant and has sought to acknowledge these issues within the Audit.

In our cities, Australians rightly expect affordable, accessible and reliable transport networks, to meet our daily needs. Too often our transport infrastructure falls short of these expectations. Congestion, crowding and delays make travel more unpredictable and expensive. This causes stress and detracts from what we value about our vibrant cities.

Infrastructure Australia has developed a national evidence base to diagnose these challenges and help in assessing the health of transport infrastructure and services, today and tomorrow, across Australia's largest and fastest growing cities.

This report adds to the evidence base established by the inaugural 2015 Audit. It goes further in enriching our understanding of the day to day workings of our urban transport infrastructure. For instance, this Audit addresses the increasingly important issue of public transport crowding. It also introduces new measures of urban Australians' access to essential health, education and employment opportunities. This shows where infrastructure serves people's needs, and where improvements are required.

This new approach reflects that urban transport itself has become more complex, is faced with more challenges and opportunities. Our expectations of physical access within our cities has evolved rapidly, as have expectations around immediate, 24/7 digital connectivity to information, entertainment, services – and to each other. Australia's urban population has also been growing twice as fast as other areas,[2] this changes the way people live and work.

Looking ahead, Australia's population is ageing and growing. Our urban transport infrastructure will have to meet the challenge of servicing new and growing markets, with tight constraints over funding and in a changing climate where extremes of weather are more frequent. Planning roads and public transport to address these challenges, and make the most of emerging opportunities, will be critical to Australia's continuing quality of life and productivity over the next 15 years and beyond.

It is not the role of the Audit to identify the reform or project solutions to address the network constraints identified by this modelling. Instead, the Audit informs a broader work program for Infrastructure Australia. The annual Infrastructure Priority List identifies projects and initiatives to address infrastructure constraints, while the 2021 Australian Infrastructure Plan will identify a reform pathway. Infrastructure Australia welcomes submission on the issues identified in this paper to inform the development of these future documents.

In this report

This report provides an overview of the strategic transport modelling undertaken by Veitch Lister consulting in order to inform the *Australian Infrastructure Audit 2019*.

- *Setting the scene: Australia's changing urban travel task* presents the Audit's headline forecast of the impact that a growing urban population will have on road travel demand, network congestion and reliability in our capital cities. The section also briefly surveys the broader social, economic, environmental and technological forces that both present challenges to and open opportunities for dealing with this growth in urban mobility.
- *Methodology: Notes about the transport modelling for the Audit* summarises the modelling approach and its value. It identifies where strategic transport modelling techniques could usefully be strengthened.
- *Australia's most congested and delay-affected roads, today and tomorrow* overviews the worst-performing road corridors in urban Australia. It provides a collective 'top 10' of the most congested corridors based on two major metrics. To represent the impact of congestion on users, roads are ranked according to the proportion of an individual driver's trip duration spent in congestion, currently and what is forecast for 2031. To represent the collective impacts of congestion on the broader community, road corridors are also ranked according to total hours of vehicle delay experienced by all users, currently and as forecast for 2031.
- *The Congestion and crowding in our cities* sections provide the principal content for this report and are an input into the *Australian Infrastructure Audit*. Existing (2016) and forecast (2031) road congestion, public transport crowding and social infrastructure access outcomes are detailed for six regions (conurbations):
  - Sydney, the Hunter and Illawarra
  - Melbourne and Geelong
  - Brisbane, the Gold Coast and Sunshine Coast
  - Greater Perth and the northern Peel region
  - Greater Adelaide
  - The ACT and Queanbeyan.
- Finally, *Future of modelling* discusses the limitations of strategic transport models and points to potential new opportunities and directions for future work in this space.

2

Setting the scene

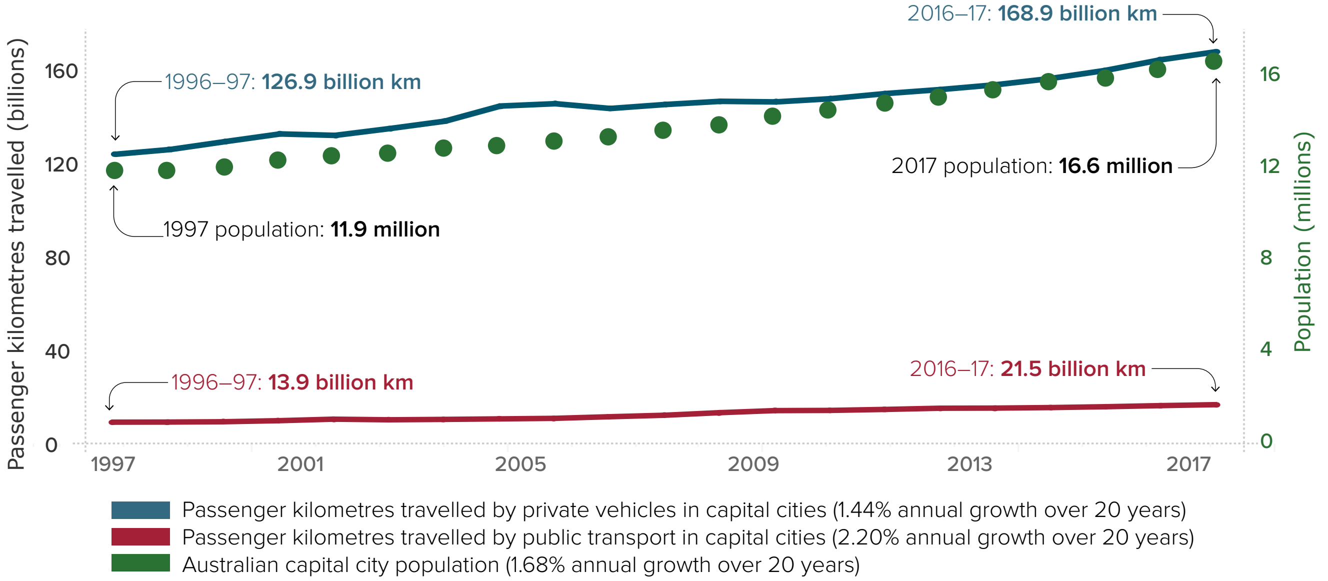
Australia’s changing urban travel task

2.1 More people, more cars, more journeys

Australia is home to more than 25 million people. In the last 10 years, Australia’s population has grown by 4 million, nearly twice as many new Australians than the previous decade. Much of Australia’s population growth has happened in our major cities – particularly the two largest, Sydney and Melbourne.

With more people living and working in Australia’s cities, the nation’s urban transport task has grown substantially. The demand for good roads and efficient public transport is greater than at any time in our history, and the need to improve these networks ever more pressing. Between 1996–97 and 2016–17, passenger kilometres travelled on Australian cities’ public transport networks increased by over 50% (Figure 1). Passenger kilometres on our cities’ roads also grew during that time,[3] but by a lower rate.

Figure 1: Population growth vs passenger kilometres travelled, by public transport and private vehicles in all capital cities, since 1996–97



Source: Bureau of Infrastructure, Transport and Regional Economics (2018), Australian Bureau of Statistics (2018)[4]

Despite this higher rate of public transport patronage growth, Australia's roads today remain the dominant means of travelling around our cities. While Melbourne and Sydney are unsurprisingly home to Australia's most congested roads, other capital cities have also seen their road network performance worsen in the last five years, due to population growth and other changes in travel demand.

2.2 The costs of road congestion and crowding in our largest cities

As illustrated in both the 2015 and 2019 Audits there is a well-established understanding of the economic costs of urban road congestion in Australia.

This Audit measures the effects of increased public transport use on crowding in Australia's largest cities. This is done using a new metric relating to the cost of public transport crowding (sometimes referred to as overcrowding or crush-loading). This factor reflects the discomfort and inconvenience that people experience when having to use a heavily loaded train, tram, bus or ferry.

Assumptions about the monetary value of time to individuals are used in this Audit to calculate the total costs of both road congestion and public transport crowding. The value of time is a commonly used factor in transport economics, reflecting the theoretical amount that people would be willing to pay to save time by avoiding delay and speeding up their travel.

The cost of public transport crowding is measured by applying a time penalty to journeys that are made under crowded conditions. A 10-minute journey spent in a public transport vehicle that is carrying a load approaching its crush-laden capacity translates into a three-minute penalty for each seated passenger and a 10-minute penalty for each standing passenger. To arrive at a total cost-of-crowding dollar value, the summed time penalty for all passengers is then multiplied by people's value of time.

The costs of road congestion are the most significant component of transport costs impacting users and the economy of Australian cities. These costs are calculated by multiplying the total delay hours (time people spend in traffic due to delay) by value of time (assumed financial values for times, split by private traveller, business traveller, light commercial vehicle and heavy commercial vehicle). While quantitatively very small relative to the cost of road congestion, public transport crowding is a major and likely growing challenge for Australia's largest cities. It promises serious future impacts on liveability for all our largest cities, with Melbourne the most affected.

Figure 2 and Table 1 show the total costs of road congestion and public transport crowding in Australia's six largest capital cities and neighbouring satellite cities, in 2016 and, as a projection, by 2031. For that year, this Audit's estimate is shown for comparative purposes alongside the estimate for 2031 that was included in the 2015 Audit.

The estimated totals are:

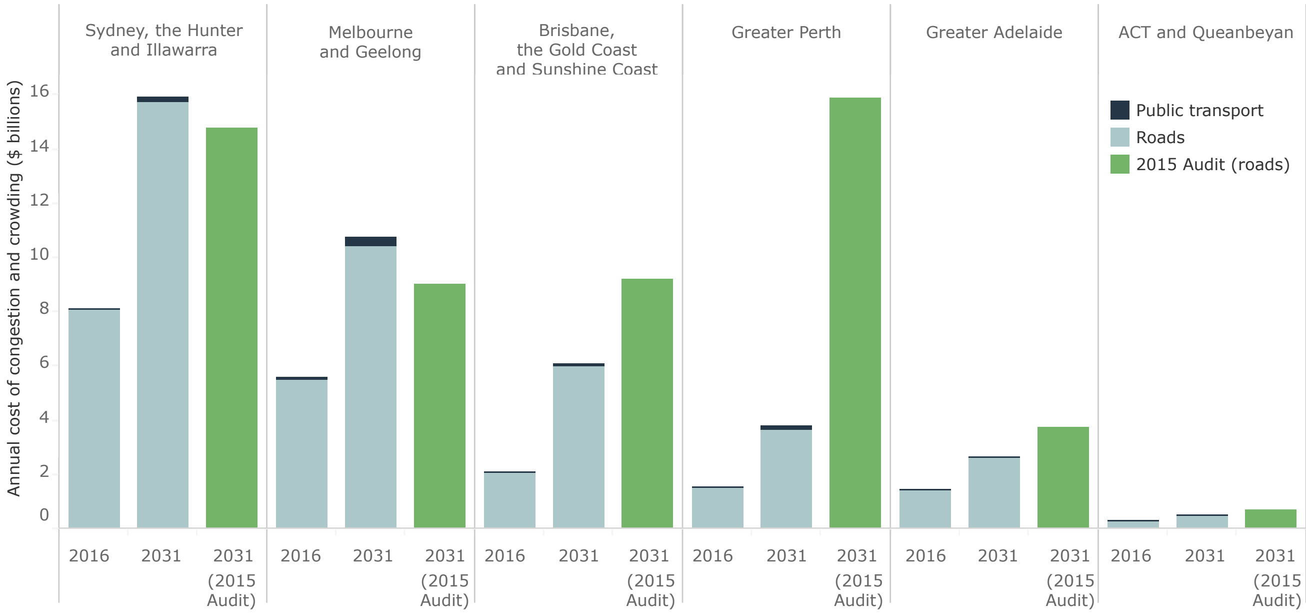
- 2016 total annual cost of road congestion: $19 billion, public transport crowding: $175 million
- 2031 forecast total annual cost of road congestion: $39 billion, public transport crowding: $837 million
- 2031 (from the 2015 Audit) forecast total annual cost of road congestion: $53 billion, public transport crowding: not measured.

The 2015 Audit estimate was based on the projection of each city's population that was in use at that time. The changes in population inputs has lead to marked variation between the 2015 Audit and the 2031 estimates for some cities. Perth is the subject of the largest difference, with the 2015 Audit having used population projections developed at the height of Western Australia's mining boom. The principal reasons for this and other variations between forecasts for 2031 are further explored in Methodology.

It is important to note that there are other ways of measuring the costs of congestion than the approach illustrated in Figure 2. One commonly cited metric is the Bureau of Infrastructure, Transport and Regional Economics' (BITRE) *avoidable social cost of congestion*. While this metric is very useful, it is based on a fundamentally different methodology to that employed for the Audit.

BITRE's metric measures the net social benefit that would be obtained if network management or pricing schemes were introduced to achieve optimal traffic levels. Key to this metric is the assumption that there will

Figure 2: The cost of road congestion and public transport crowding, 2016 and 2031



Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[5]

Table 1: The cost of road congestion and public transport crowding, 2016 and 2031

Model area	Cost	2016 ($ millions)	2031 ($ millions)	2031 ($ millions) from 2015 Audit
Sydney, the Hunter and Illawarra	Public transport crowding	68	223	N/A
	Road congestion	8,038	15,693	14,790
Melbourne and Geelong	Public transport crowding	75	352	N/A
	Road congestion	5,485	10,379	9,006
Brisbane, the Gold Coast and Sunshine Coast	Public transport crowding	14	90	N/A
	Road congestion	2,084	5,969	9,206
Greater Perth	Public transport crowding	17	159	N/A
	Road congestion	1,525	3,620	15,865
Greater Adelaide	Public transport crowding	1	4	N/A
	Road congestion	1,444	2,619	3,747
ACT and Queanbeyan	Public transport crowding	1	8	N/A
	Road congestion	289	504	703
Total	Public transport crowding	175	837	N/A
	Road congestion	18,865	38,784	53,317
	Congestion and crowding	19,040	39,621	N/A

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[6] always be some delay when driving. Ours is never the only car on the road, and traffic lights must sometimes be red. It recognises that achieving free-flow conditions at all times of the day is impractical and would require excessive expenditure on infrastructure. Instead of comparing congested to free-flow traffic conditions, BITRE's metric estimates the cost of a city's level of traffic not achieving economically optimal traffic levels. A detailed description of BITRE's methodology is available on their website.[7]

Some jurisdictions also estimate the cost of congestion on their road networks. The Queensland Department of Transport and Main Roads has developed a methodology which calculates the cost of excessive congestion on the network. This comprises of the cost of delay, vehicle operating costs and externalities, for vehicles travelling at less than 70% of the posted speed limit for motorways and less than 55% for arterial roads.[8] Similar to BITRE's methodology, the focus is on excessive congestion rather than on achieving free-flow conditions.

The cost of the congestion affecting each of the capital cities illustrated in Figure 2 is not just a result of the relative mismatch that each experiences between the supply of and the demand for roads or public transport. It is also a function of the absolute size of their population. In other words, the total estimated cost of congestion and crowding for each city is heavily influenced by the number of people living there – and, by extension, by how many public transport or car trips are undertaken.

Given this, it is to be expected that Sydney, Australia's largest city, should have the largest congestion bill, and Canberra the lowest. That doesn't necessarily mean that, on average, an individual Sydneysider spends more time driving or standing on the bus than an equivalent Canberran. It simply means that due to the larger population, more Sydneysiders are exposed to congestion or crowding of one kind or another.

However they are measured, congestion and crowding do not only frustrate the daily commuter. They also compromise Australia's productivity by making the movement of freight slower and more unpredictable, choking our exports, damaging the performance of public transport, and turning our cities into less pleasant places to live, where it is simply harder to access daily needs.

2.3 Two-speed cities

Digging deeper into how the growth of Australia's cities is impacting transport, we can see a story of spatial variation across as well as between our cities. Urbanisation is happening at a different rate for different cities and, within each city, in ways that deliver different accessibility outcomes for the urban centre and the urban edge.

As a city's population expands, the associated growth in higher-paid job sectors such as financial and professional services is concentrated in dense employment centres. In Australia's largest cities these locations are mostly historic CBDs served by established radial public transport systems. In some newer employment centres, such as Sydney's Macquarie Park, more recent growth in jobs density has warranted investment in new major public transport links.

In contrast, the location of traditionally lower-paid sectors such as retail, hospitality and other human services is tied to where customers and clients live. The working hours for these sectors are similarly aligned to the times when their customers want to access shops or services. This results in the spatial dispersal of jobs, and the temporal (variation over time) spread of commuting to and from these jobs, in ways that make them hard to reach with effective public transport. At its worst, the most disadvantaged in terms of their income are also the least advantaged in the commuting transport choices available to them.[9]

Adding to its implications for worsening income inequality, urban transport disadvantage risks also having a gendered impact.[10] The increasing rate of workforce participation by women in Australian cities is weighted towards the more dispersed types of employment outlined above. Women are also relatively more likely than men to undertake trip-chaining as part of their journey to and from work that is typically easier to do by car than public transport. For example, even if their workplace is accessible by public transport, young and, especially, single mothers may need a car for the childcare drop-off and pick-up.

These effects are magnified as housing affordability decreases. The choice of where to live becomes constrained to outer urban areas. Here housing costs may still be high relative to what was experienced by previous generations, but wages are lower and transport distances and costs often higher.[11]

While not explicitly modelled, the results of both audits should be interpreted as reflecting increased future levels of congestion likely leading to peak spreading. This situation occurs where an increasing amount of people travel outside the traditional rush hour, resulting in longer periods of congestion in the morning and evening periods, over a larger portion of the network.

Peak spreading may happen because of a need to travel further, and by car, to find work, or because shift work hours require it. Regardless of its causes, it often represents people's only response to a land use and transport challenge typical of growing cities.

2.4 The promise and reality of new technology

We live in an age of disruption where every day delivers news of technological innovations to solve transport problems. In practice, predicting the future is no easier for urban transport than for any other aspect of Australian daily life.

Transport users in Australian cities already take for granted many technology-driven changes that were unforeseen by all but their keenest observers, even at the time of the 2015 Audit. These changes are well illustrated in the context of Figure 3. New transport technologies are working in alignment to deliver the full range of an individual's personal access needs as part of a 'mobility as a service' package.

Very few of the transport technologies in Figure 3 were in standard use in Australian cities 15 years ago. Today nearly all of them are, albeit to varying degrees. Autonomous and connected vehicle technology has not yet advanced to the point of 'Level 5', defined as the machine driver operating to the same level as a human driver in all conditions. However, the Audit acknowledges some analysts have identified Level 4 autonomous technology could be commercially available in passenger vehicles around 2025, while Level 5 may be available from around 2030. Infrastructure Australia acknowledges that predicting the timing of the arrival this technology is challenging and uncertain.

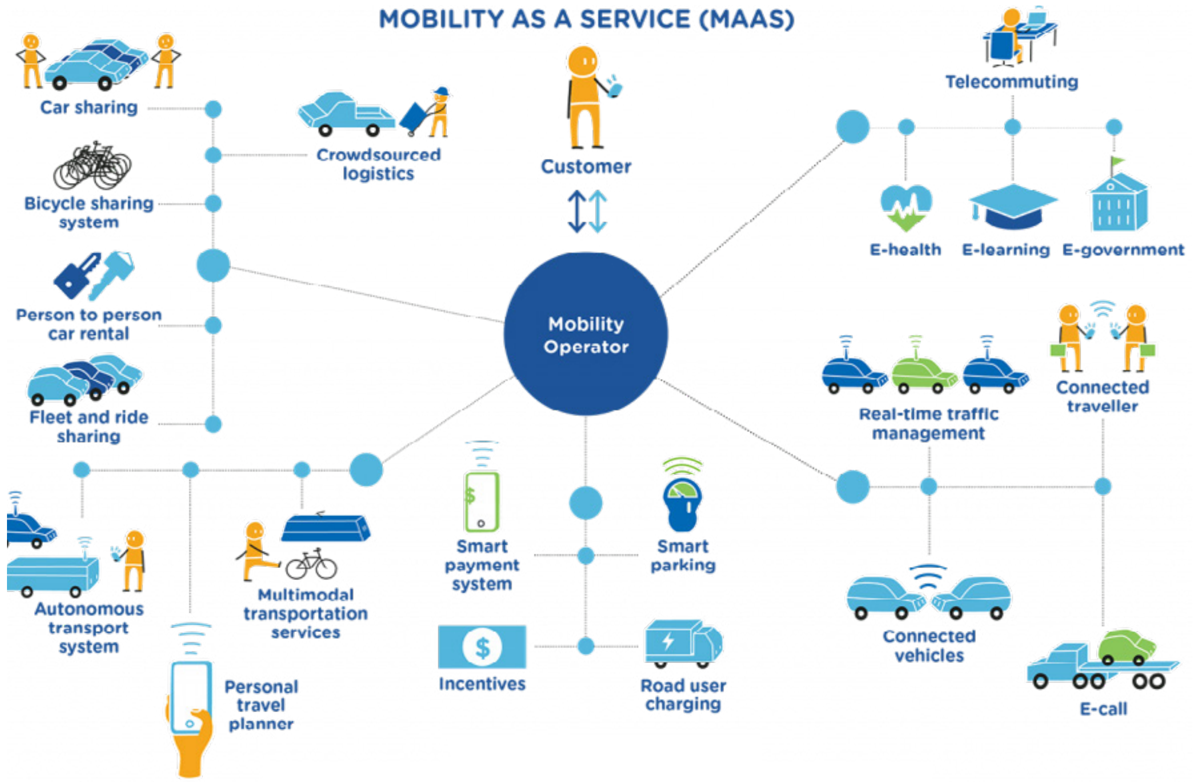
In comparison to many world cities, Australia has lagged in the adoption of transport technologies. Electric cars and buses, for instance, have been most quickly adopted in markets where there have been incentives from governments trying to improve urban air quality. For Australia, there is significant uncertainty about the rate of uptake. By 2025, between 6% and 36% of new fleet sales are estimated to be electric vehicles, depending on the level of government intervention.[12]

A consequence of slower uptake is that some benefits of electric vehicles, not directly related to local air quality but potentially more important for our cities, have yet to be realised. These include the potential advantages of electric vehicle propulsion systems for built-up city streets impacted by the noise of diesel trucks and buses.

On the other side of the ledger, governments responsible for ensuring the availability of power-generation as well as transport network capacity will face some big new challenges when integrating electric vehicles. Electricity generation or network infrastructure may need to increase substantially to service the recharging requirements of an electric fleet. In terms of public revenues, if a transition is not managed well, a shift away from petrochemical transport power could leave a shortfall in fuel excise revenue, which is channeled into consolidated revenue.

Although it is uncertain which technologies will be most widely adopted, and by when, it is clear that technological change will continue to have an impact on how people choose to move around our cities.

Figure 3: Transport technologies working together to deliver 'mobility as a service'



Source: Transport for NSW (2018)[13]

2.5 What customers want and expect

The digital economy is changing the way people travel, and what we expect from our journeys.

Ridesharing, which has been enabled by smart devices, is one example of a customer-focused transport product that responds to user preferences. The popularity of ridesharing is growing in Australia,[14] while potentially having wide network impacts. The degree to which ridesharing either helps or hinders dealing with urban congestion depends how it is introduced and managed.

Operating in a balanced regulatory environment, ride-share services can complement traditional bus services in extending the first and last mile reach of mass transit. This would be advantageous to the outer suburbs of Australia's geographically spread-out cities. Here the distance between radial rail lines increases as density reduces. In this setting a minibus rerouted in real time in response to demand might provide customers with an attractive late evening last mile connection to home from their mass transit service. This could be competitive with park-and-ride, and more effective than a fixed local bus route operating every 30 or 60 minutes.

In contrast, congestion could actually be made worse if ridesharing products are allowed to cannibalise mass transit patronage and occupy scarce CBD kerb space with passenger pick-ups and drop-offs. In this situation, government can find itself the operator of last resort for the most disadvantaged citizens.

Another potential instance of personalised transport products creating new impacts on transport networks is connected to the popularity of internet shopping. This can lead to increased congestion on city centre streets and kerbs in the middle of the day (i.e. between peak periods) due to a proliferation of light commercial delivery vehicles. Emerging evidence from global cities shows a link between this symptom and customers' expectations around the speed of receiving their online orders.[15] For many city centre workers, it is simply more convenient to receive a delivery at their workplace than for this to be delivered to an empty home.

Most people travelling to work on any given public transport service in any Australian city will be engaged with their smartphone or other connected device. If they are using this to work or to undertake some otherwise personally valued activity while travelling, then their in-vehicle time previously costed as a lost opportunity will need to be assessed in a new light.

More broadly, the continuing importance of personal health and well-being to transport customers will show up more and more in the value attached to walking or riding a bike as part of the daily transport routine.[16]

2.6 Balancing the expectations in an ageing and changing natural environment

In common with other dimensions of the Australian urban economy, the future story for transport in our cities looks like one of 'doing more with less'. This means stretching scarce funds further, and squeezing more people and goods through transport corridors where capacity is increasingly constrained by the value of urban land for alternative productive purposes.

As our population ages, transport will not be immune to the reduction in the number of taxpayers able to help fund the services required by older people. In fact, this ageing risks impacting road congestion and public transport crowding in other ways than just by reducing the nation's tax base.

One important role for driverless vehicles will be to meet some personal mobility needs for older Australians. Until then, however, this group of drivers will continue to be at higher risk of suffering death or serious injury from a crash than any other age group.[17] Governments' current responses to this risk include requiring periodic driving competence or medical clearance. A potentially growing group of older Australians unable to drive will demand additional public transport services. Their travel needs may include multiple short local trips. Demand is likely to be strongest during the peak shoulder and between-peak periods when, at least under existing pricing models in most of our larger cities, older Australians are incentivised to travel.

The increased number of working-age Australians employed to provide care outside a nine-to-five working day to an expanding cohort of older people will also add disproportionately to the growth of road use outside traditional peaks. For those shift-working carers whose dispersed workplace is their client's home or other community-based housing, rather than in a dense urban centre, public transport travel will struggle to compete with driving for directness and speed.

While somewhat balancing the ageing profile of the population, efforts to grow and diversify Australian cities' export markets by focusing on the higher education and inbound tourism sectors will also create more demand for public transport services, again and especially outside peak periods. Compared to other demographics, international students and tourists are relatively unlikely to want to own or use a car during their time in an Australian city.

In terms of the natural environment, the potential contribution of transport to emissions associated with climate change or local pollution is forecast to get worse before it gets better in Australia. Transport emissions are projected to increase steadily over the next 15 years at least, as a simple function of population and economic growth. From 2025 onwards, cars' share of transport emissions is expected to start to fall, due to improvements in vehicle efficiency and the larger (if overdue) uptake of electric vehicle technology.[18] A gradual shift towards low or zero-emission propulsion systems that can service motorised personal transport needs more cheaply than internal combustion engines will benefit people both inside and outside vehicles. The latter group will benefit from reduced localised amenity, emission and noise impacts.

However, these gains will be more than offset by steady growth in heavy vehicle emissions as the rising demand for consumer goods results in increased freight volumes, including goods imported through the major ports located in our largest cities.[19]

At the level of the individual public transport passenger in any Australian city, a more extreme climate will make air-conditioned and weather-sensitive design a universal requirement for vehicles and interchanges. This will have implications for public transport operating costs. Especially in the inland urban growth areas that in some of Australia's largest cities are not reached by any sea breeze and are exposed to more extremes of hot weather, transport will have to play its part in mitigating urban heat island effects.

3

Methodology

Notes about the transport modelling for the Audit

Transport models demonstrate and compare insights into the consequences of policy and project decisions. A professionally designed and operated transport model, fed with high-quality raw material in the form of variable datasets and fixed assumptions, is a powerful instrument in the larger urban planning toolkit.

Transport modelling has provided critical information for this Audit – on urban road congestion, as in 2015, but also for the first time on public transport crowding. The following sections on congestion and crowding in our largest cities focus on the findings of transport modelling undertaken by Veitch Lister Consulting.

This section addresses the strengths and limitations of transport modelling, briefly describes the transport model and associated assumptions used for the Audit, and notes the factors that have resulted in some of the Audit's transport modelling conclusions varying from previous forecasts or current expectations.

3.1 Transport modelling as a tool

In the context of a truly national Audit, a single strategic transport modelling approach provides a unique way of comparing diverse localities, transport interventions and timeframes based on consistent principles. Used in conjunction with, but not afforded more importance than, other forms of qualitative and quantitative research, transport modelling offers decision-makers an element of objectivity.

This objectivity is maximised when a transport model is applied in a consistent way to different networks in order to illustrate the effects of loading additional demand onto an existing or assumed future infrastructure network. This type of application can powerfully illustrate the worst-case impacts of background population growth encountering a business-as-usual network, however these are not necessarily the most likely.

For strategic purposes, the usefulness of transport modelling is further enhanced by its being based on forecast future scenarios that test both transport and non-transport factors. This can reduce the risk of demand projections simply extrapolating forwards from past or current travel habits. Forecast-based scenarios can help us to identify a choice of different growth pathways and the possible transport policy and investment responses for each.

On that basis, while the Audit's transport modelling may provide an evidence base for future decision-makers to consult when making investment choices, it will never be the sole source of information used. Infrastructure Australia recognises that its modelling describes just one version of many possible transport futures for Australian cities. Other futures involve a range of technological, policy or regulatory interventions that will need to be defined before they can be modelled. If infrastructure projects or other actions are proposed based on the transport modelling that informs this Audit, their progress should depend on much more detailed planning, options development and analysis.

3.2 About Zenith transport models

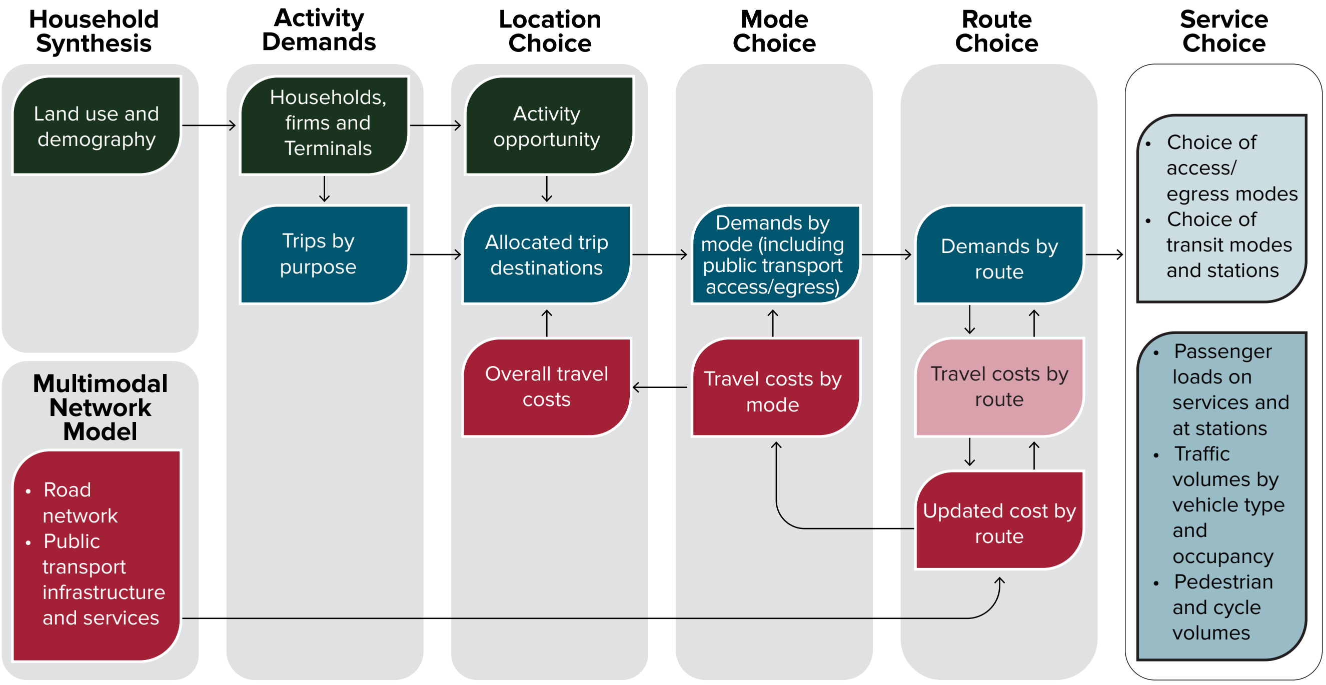
The type and scale of transport models vary from relatively simple intersection models used to predict the local traffic impacts of individual developments, to city-wide strategic models that aim to provide information on likely future conditions across metropolitan regions.

The Zenith family of transport models belongs to this class of strategic tools.[20] At the heart of Zenith models, the 'engine' that predicts the likelihood of a certain choice of travel route, time or mode is driven by behaviours that have been identified and calibrated through household travel surveys and validated using traffic counts and public transport passenger surveys. These relationships have been regularly updated over the past 18 years.

Zenith models aim to simulate all travel undertaken by households, businesses and visitors in the modelled region during an average weekday in the forecast year. Based on land use and demographic change scenarios, the models account for the level of participation in a range of activities across the region and the frequency of travel to them, as well as the choice of destination, mode and route.

The key stages in the Zenith transport modelling process are illustrated in Figure 4.

Figure 4: Representation of Zenith transport modelling process



Source: Veitch Lister Consulting (2019)[21]

3.3 What the modelling assumes

Modelling urban transport futures requires a wide range of assumptions to be made about what transport choices will be available to people in the future, what infrastructure will exist, and where people will choose to live and work.

In modelling road congestion and public transport crowding for Australian cities in 2031, the Audit assumes a 'do minimum' scenario in terms of new infrastructure, technology choices and policy settings.

What this means is that the 2031 scenario for each city only includes new projects that are under construction, under procurement, or were the subject of a public funding commitment from all relevant governments at the time of the transport modelling (between July and September 2018). It is important to note that some of the latter projects fall outside the relevant government's budget forward estimates horizon. This means that some of the projects assumed for 2031 forecast purposes may not yet be fully funded. Additionally, some bus routes have been expanded to include basic services in greenfield housing developments to provide a basic level of service in the model. It is assumed that this will occur in line with governments' past practice to support the development of new suburbs.

The scenario assumes no changes to transport technology, vehicles' fuel efficiency, or the real cost of fuel, tolls and public transport fares. The cost of car parking, however, is assumed to increase by 1.5% per annum to 2031 due to constraints on its supply.

3.4 What the modelling tells us

This transport modelling forecasts what each city's different transport user groups will experience from their roads or public transport in 2031. The modelling produces both demand and performance metrics for road use (individual drivers and commercial operators), public transport (rail, tram, bus and ferry passengers) and active transport (people walking and bike riding).

For road users, performance is measured using these traditional network modelling benchmarks:

- Volume / capacity ratio (VCR). This indicates the quantity of traffic relative to a road's capacity. When a link is modelled as operating at a VCR above 1.0 it is forecast as being used by more vehicles than it was designed to accommodate under theoretical free-flow conditions
- Average speed travelled on a section of road over the modelled time period
- Total hours of delay experienced by all vehicles using the road corridor during the modelled time period.

Additionally, these road and public transport user-oriented metrics have been included for the first time in the 2019 Audit:

- The duration and percentage of journey time spent in road congestion
- The total minutes of delay per single vehicle
- The time spent by a public transport passenger travelling on a crowded train, bus or tram
- Spatial variations across each city in residents' accessibility from their home to hospitals, schools and childcare (mapped as the average travel time to access this social infrastructure) and to employment (mapped as the percentage of total regional jobs that can be reached within 30 minutes).

How motorists and public transport users should read the maps

While the maps contained in this report are technical in nature, non-technical readers can apply the following simplified approach to reading the congestion and crowding maps in each city chapter.

For motorists:

- Roads marked in green have a low VCR. These roads will generally be perceived as travelling at or near signposted speeds – not delayed by other vehicles.
- Roads marked in yellow, with a medium VCR, imply some congestion with travel speeds over 50% of the signposted speed.
- Roads marked in red, with a high VCR, indicate heavy congestion with travel speeds under 50% of the signposted speed.

The thickness of the line indicates the volume of traffic, not the degree of congestion.

For a public transport users:

- Transport corridors (bus, tram or train) with a low VCR are indicated in green. These corridors will generally be perceived as having low public transport crowding – passengers can find a seat.
- Yellow corridors indicate a medium VCR, and infer higher levels of crowding, with passengers unable to find a seat and being forced to stand.
- High VCRs, shown in red, indicate uncomfortable levels of crowding, with additional passengers unable to board, and therefore needing to wait for a following service.

The thickness of the line indicates the volume of passengers, not the number of vehicles or the level of crowding.

3.5 Variations between the 2015 and 2019 Audits

Infrastructure Australia acknowledges that strategic transport modelling delivers results which can be very sensitive to changes in underlying assumptions and inputs. The change in the costs of congestion as reported by Infrastructure Australia's 2015 and 2019 Audits highlights the imprecise nature of forecasts using population or employment projections as well as the potential limitations of strategic transport modelling. For most cities, the two geographic areas used to calculate change in population and cost of congestion are identical.

As previously illustrated (Figure 2) this Audit's projected cost of road congestion in Australia's six largest capital cities and the neighbouring satellite cities and regions is about $14.5 billion lower than was calculated in 2015. Much of this difference is due to changes in the design of the transport model between the two audits, and in population and employment forecast inputs used as inputs to the model, however some variation is also the result of enhancements to the model's capability.

The impacts of changes in inputs

Perth is the subject of the largest difference, with the 2015 Audit having used population and employment projections developed at the height of Western Australia's mining boom. This means that population projections for 2031, used in the 2015 Audit, were 19% higher than those used for the 2019 Audit. As a result, Perth's forecast of congestion in the 2015 Audit was significantly higher than the 2019 forecast. Table 2 represents the variations in the forecast costs of congestion between the audits.

Table 2: 2031 costs of road congestion for VLC modelled conurbation

Model area	2015 Audit ($ millions)	2019 Audit ($ millions)	Difference
Greater Perth	15,865	3,620	-77%
Brisbane, the Gold Coast and Sunshine Coast	9,206	5,969	-35%
Greater Adelaide	3,747	2,619	-30%
ACT and Queanbeyan	703	504	-28%
Sydney, the Hunter and Illawarra	14,790	15,693	6%
Melbourne and Geelong	9,006	10,379	15%

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[22]

The forecast costs of congestion have also decreased for Brisbane, the Gold Coast and Sunshine Coast, the ACT and Queanbeyan, and Adelaide. For Brisbane and Canberra, population forecasts have decreased by 2% and 8% respectively since the 2015 Audit. For Adelaide, population forecasts have remained stable. Detailed quantitative information on some of these variations is included in city-specific sections of this supplementary report. Table 3 provides a summary of the differences in projected population inputs between the 2015 and 2019 Audits.

In the 2019 Audit, population and employment inputs were updated to reflect the 2016 Census. Travel costs and transport networks were also updated. Of particular significance was the observed reduction in fuel price between 2011 and 2016. This was based on a structural decrease observed in fuel retail prices collected by the Australian Competition and Consumer Commission.

Another point of difference is that employment forecasts in the 2019 Audit are based on projected levels of employment self-containment within each Local Government Area which recognise the structure planning of local authorities and the longer-term infrastructure and development planning by each state government.

Table 3: 2031 projected population used as inputs to the VLC modelling

Statistical area	2015 Audit	2019 Audit	Difference
Perth GCCSA	3.3 million	2.6 million	-19%
ACT and Queanbeyan	610,000	560,000	-8%
Brisbane GCCSA, Gold Coast and Sunshine Coast	4.5 million	4.3 million	-2%
Adelaide GCCSA	1.6 million	1.6 million	0%
Sydney model area	7.3 million	7.5 million	2%
Melbourne GCCSA and Geelong SA4	6.2 million	6.4 million	4%

Source: Veitch Lister Consulting (2019)[23]

The impacts of changes to models

The strategic model has also resulted in changes to the 2019 Audit's outputs. For instance, the largest single contributor to the decreased forecast cost of road congestion in Brisbane, the Gold Coast and Sunshine Coast, and Adelaide has been the recalibration of the transport model based on actual journey-to-work data from the 2016 Census. This recalibration has resulted in the number of road trips increasing in length but decreasing in number, thereby subtracting from the disproportionate impact, modelled and forecast in the 2015 Audit, of additional vehicles being added to already congested roads.

The inputs of a new methodology

Both audits attempt to place an estimated dollar value on the cost of road congestion. In addition, the 2019 Audit also forecasts economic costs for the crowding experienced by passengers on the public transport network. This new component aims to more accurately identify the cost of travelling under heavily crowding conditions on public transport services. In general, these crowding costs are less significant compared to road congestion costs.

Both audits use a similar approach to developing network assumptions that assumes only projects with funding or significant levels of political commitment will be completed by 2031. All cities in the 2019 Audit include major projects that were not modelled in the 2015 Audit.

3.6 Limitations of transport modelling

The Audit's transport modelling is affected by limitations shared to some extent by all high-level, strategic modelling exercises.

Of these, one of the longest-recognised relates to temporal coverage. The modelling in this Audit is based on the traditional AM and PM commuting peak periods within a generic or typical weekday. The modelling also includes off-peak time periods but does not account for weekend travel. This limitation is important because the pattern of travel on weekends can vary significantly from weekdays, and in our major cities weekend traffic is increasingly a problem.

In terms of Australia's future urban population, the modelling is based on the latest projections provided by State and Territory governments at the time of modelling. We have taken this approach in order to be as closely aligned as possible with the assumptions in other jurisdictional planning tools. External and internal migration flows are subject to policy settings and economic conditions, therefore population forecasts are susceptible to change. For instance, the Western Australian resources boom resulted in elevated population growth figures for the State in 2015. The most recent population projects for the State are less pronounced.

The implications of technological changes, like the introduction of connected and autonomous vehicles, cannot yet be reliably addressed by strategic transport modelling. Due to the significant uncertainty about the pace and impact of transport innovations, the Audit's modelling assumes no change by 2031 to existing transport technologies.

Of significance for cities subject to greenfield development pressures, strategic models tend to be less accurate in predicting transport outcomes for outer urban areas than they are for established suburbs. The newer the urban area – with these generally being located at the fringe of the city – the larger its geographic travel zones generally are, in order to capture enough population for the model to operate meaningfully. This means that, when access to jobs and social infrastructure is being assessed, the distance needing to be travelled to reach such opportunities from homes dispersed across large outer urban travel zones cannot be modelled as precisely as for the residents of the dense travel zones that capture established suburbs. Acknowledging that the impact of any decision about transport systems is ultimately measured in its impact on people's day-to-day life choices and activities, Infrastructure Australia has commissioned modelling of the differing existing and forecast future levels of access to social infrastructure across major cities.

Results indicate how proposed transport projects, in combination with broader economic and demographic trends, directly affect the ways in which people get to work and other important services. The modelling is intended to show high-level accessibility trends in each conurbation, and is not designed to forecast these outcomes at a suburb level. A principal reason for this limitation relates to the size of the travel zones that, in the model, provide the points at which modelled trips begin and end.

Ultimately no model can represent or predict all the factors affecting people's real life, end to end experience of getting from A to B. The newer the urban areas, which are generally located at the fringe of the city, the larger the zone covering it must be in order to capture a large enough population for the model to operate. This means that the distance needing to be travelled to reach a job or other service from a home in a new urban area cannot be modelled as precisely as for residents in established suburbs.

Additionally, the model cannot always accurately capture all factors affecting people's real life, such as finding a car park or walking to and from stops as part of a short public transport trip. However, it can ask the right questions. Finding the best solutions to the congestion and crowding challenges highlighted by the Audit calls for more detailed analysis, and for the exploration of a wide range of possible interventions in response to such questions.

3.7 In brief: future of modelling

The final chapter in this report discusses the limitations of strategic models in more detail and points to potential future directions and opportunities for model development. The chapter is a high-level overview of strategic metropolitan modelling and does not provide a detailed review or critique of specific models.

Specifically, *Future of modelling* looks at these issues and opportunities:

- Scope and purpose of existing models
- New mobility and the implications of new technology for modelling
- Data consistency, and practical challenges for modelling
- The transparency of assumptions
- The role of scenarios
- New and emerging datasets
- New and emerging models.

4

Australian cities' most congested roads

The impacts of congestion for motorists

In every one of the six cities analysed in this Audit there are road corridors that experience congestion, at peak times, on at least some sections of the corridor.

Infrastructure Australia has used a range of customer-focused metrics to identify the worst-performing roads in each of our major cities, both as experienced by an individual driver and in terms of total delay costs to the community at large.

Addressing the first of these, Table 4 and Table 5 show the ten most congested roads in Australian cities during the AM peak, for 2016 and 2031 respectively. The measure that is used to identify the corridors where a driver is most impacted is 'share of total journey time due to congestion'. This states the percentage of a driver's trip duration that is calculated as being spent in traffic congestion. In addition, the average accumulated minutes of delay experienced by each driver is shown.

Table 4: Ten most congested roads in Australian cities, 2016 AM peak

National rank	City	Corridor name (including origin / destination)	Travel direction	Corridor length (km)	Share of total journey time due to congestion	Delay per vehicle (mins)	Cost of congestion for a car	Cost of congestion for a heavy commercial vehicle
1.	Sydney	Artarmon to Sydney Harbour Tunnel via Gore Hill Freeway / Warringah Freeway	S/B	4	81%	16	$4.42	$19.03
2.	Sydney	Ashfield to Sydney CBD via City West Link / Anzac Bridge	E/B	9	69%	22	$6.08	$26.17
3.	Sydney	Narraweena to Chatswood via Warringah Road	W/B	12	68%	26	$7.18	$21.41
4.	Brisbane	Ipswich Motorway to Indooroopilly via Centenary Highway	N/B	10	68%	18	$4.97	$30.93
5.	Sydney	Hornsby to Parramatta via Pennant Hills Road	S/B	16	67%	34	$9.39	$28.55
6.	Sydney	Westmead to Strathfield via M4	E/B	12	67%	17	$4.69	$40.45
7.	Sydney	Artarmon to Surry Hills via Pacific Highway / Sydney Harbour Bridge / Cahill Expressway / Eastern Distributor	S/B	11	67%	20	$5.52	$23.79
8.	Sydney	Strathfield to Haberfield via Parramatta Road	E/B	4	67%	9	$2.49	$20.22
9.	Melbourne	Airport to city via Tullamarine Freeway	S/B	17	67%	24	$6.63	$10.71
10.	Sydney	Haberfield to Broadway via Parramatta Road	E/B	7	66%	18	$4.97	$21.41

Note: N/B, S/B, W/B and E/B represent northbound, southbound, westbound and eastbound, respectively.

Source: Veitch Lister Consulting (2019)[24]

Table 5: Ten most congested roads in Australian cities, forecast 2031 AM peak

National rank	City	Corridor name (including origin / destination)	Travel direction	Corridor length (km)	Share of total journey time due to congestion	Delay per vehicle (mins)	Cost of congestion for a car	Cost of congestion for a heavy commercial vehicle
1.	Sydney	Artarmon to Sydney Harbour Tunnel via Gore Hill Freeway / Warringah Freeway	S/B	4	84%	19	$5.25	$22.60
2.	Melbourne	Craigieburn to Metropolitan Ring Road via Hume Freeway	S/B	18	77%	39	$10.77	$46.40
3.	Brisbane	Ipswich Motorway to Indooroopilly via Centenary Highway	N/B	10	76%	26	$7.18	$30.93
4.	Sydney	Mount Druitt to Westmead via M4	E/B	13	75%	25	$6.90	$29.74
5.	Sydney	Liverpool to Sydney Airport via M5	E/B	28	74%	49	$13.53	$58.29
6.	Brisbane	Helensvale to Beenleigh via Pacific Motorway	N/B	26	73%	37	$10.22	$44.02
7.	Sydney	Ashfield to Sydney CBD via City West Link / Anzac Bridge	E/B	9	73%	27	$10.22	$32.12
8.	Melbourne	Gisborne South to Tullamarine Freeway via Calder Freeway	E/B	31	72%	51	$14.08	$60.67
9.	Sydney	Artarmon to Surry Hills via Pacific Highway / Sydney Harbour Bridge / Cahill Expressway / Eastern Distributor	S/B	11	72%	25	$7.46	$29.74
10.	Brisbane	Beenleigh to city via Pacific Motorway	N/B	35	71%	53	$14.64	$63.05

Note: N/B, S/B, W/B and E/B represent northbound, southbound, westbound and eastbound, respectively.

Source: Veitch Lister Consulting (2019)[25]

The impacts of congestion for Australia's productivity

In addition to customer-oriented measures of congestion for the busiest sections of roads, Infrastructure Australia has calculated which extended road corridors experience the greatest cumulative total of delays to all vehicles using them during the modelled period.

This metric provides a high-level indication of the collective cost of congestion to the broad community, in counterpoint to its impact on individuals. Table 6 and Table 7 show these impacts, expressed as total delay hours, for the AM peak period in 2016 and 2031 respectively.

Road congestion is expected to increase in all Australian cities between 2016 and 2031. From the user's perspective, the worst roads to drive on in 2016 were freeways or major arterial roads radial to a major employment CBD. The same is forecast to be true in 2031, the main difference being that outwards urban expansion and employment being more dispersed will by then have moved 'the end of the traffic jam' further out from each city centre.

For example, the worst congestion of Sydney's M4 is forecast to reach from Westmead in 2016 to Mount Druitt in 2031. For Melbourne, congestion will extend north from the airport corridor as far as Craigieburn, along the Hume Freeway that services the city's northern growth corridor. In Brisbane, an outer section of the Pacific Motorway, between Helensvale and Beenleigh, is forecast to be even more congested than the section between Beenleigh and the city.

Similarly, for road corridors ranked according to total hours of vehicle delay, the main change between the location of the worst corridors for 2016 and 2031 is in the distance from the CBD or other major centre that congestion forms. In this case, what is even more significant is the near-doubling of total delay hours that the 'top 10' for 2031 represents when compared to 2016.

These outcomes are forecast to come about despite the significant investment in road projects in Australian cities. As at 2016, most of Australia's worst congested roads were in Sydney. By 2031, due to strong population growth, Melbourne and Brisbane will also be home to several more of our 10 worst roads for traffic congestion.

As with road congestion, the patronage – and crowding – of train, tram, bus and other public transport services is also forecast to increase to 2031 in line with urban population growth despite substantial investment in new public transport infrastructure and services.

Table 6: Ten most delay-affected road corridors in Australian cities, 2016 AM peak

National rank	City	Corridor	Direction	Total delay (hours)	Cost of congestion (daily)
1.	Melbourne	West Gate Freeway / Princes Freeway corridor	E/B	10,800	$218,000
2.	Melbourne	Princes Freeway / Monash Freeway corridor	W/B	8,500	$172,000
3.	Sydney	Central Coast to Sydney corridor (M1)	S/B	6,200	$165,000
4.	Sydney	South Coast to Sydney corridor (A1)	N/B	5,800	$134,000
5.	Melbourne	Princes Highway / Monash Freeway corridor	W/B	5,300	$105,000
6.	Sydney	Liverpool to Sydney Airport corridor (M5)	E/B	4,900	$109,000
7.	Sydney	Mona Vale to Sydney Olympic Park corridor (A3)	S/B	4,900	$104,000
8.	Brisbane	Beenleigh to city corridor (Pacific Motorway)	N/B	4,800	$95,000
9.	Perth	Kwinana Freeway corridor	N/B	4,600	$91,000
10.	Melbourne	Metropolitan Ring Road (western section) (M80)	S/B	4,400	$85,000

Note: N/B, S/B, W/B and E/B represent northbound, southbound, westbound and eastbound, respectively

Source: Veitch Lister Consulting (2019)[26]

Table 7: Ten most delay-affected road corridors in Australian cities, forecast 2031 AM peak

National rank	City	Corridor	Direction	Total delay (hours)	Cost of congestion (daily)
1.	Melbourne	West Gate Freeway / Princes Freeway corridor	E/B	16,800	$334,000
2.	Melbourne	Princes Freeway / Monash Freeway corridor	W/B	15,900	$311,000
3.	Brisbane	Beenleigh to city corridor (Pacific Motorway)	N/B	11,700	$235,000
4.	Sydney	Central Coast to Sydney corridor (M1)	S/B	9,600	$257,000
5.	Brisbane	Helensvale to Beenleigh corridor (Pacific Motorway)	N/B	9,300	$189,000
6.	Sydney	Liverpool to Sydney Airport corridor (M5)	E/B	9,200	$198,000
7.	Perth	Kwinana Freeway corridor	N/B	8,600	$169,000
8.	Melbourne	Metropolitan Ring Road (western section)	S/B	8,500	$173,000
9.	Sydney	South Coast to Sydney corridor (A1)	N/B	8,400	$206,000
10.	Melbourne	Calder Freeway corridor	E/B	8,200	$160,000

Note: N/B, S/B, W/B and E/B represent northbound, southbound, westbound and eastbound, respectively.

Source: Veitch Lister Consulting (2019)[27]

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