Australian Government

Infrastructure Australia

June 2019

# Urban Transport Crowding and Congestion

## The Australian Infrastructure Audit 2019

Supplementary report

Infrastructure Australia is an independent statutory body that is the key source of research and advice for governments, industry and the community on nationally significant infrastructure needs.

It leads reform on key issues including means of financing, delivering and operating infrastructure and how to better plan and utilise infrastructure networks.

Infrastructure Australia has responsibility to strategically audit Australia's nationally significant infrastructure, and develop 15 year rolling infrastructure plans that specify national and state level priorities.

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# Acknowledgement of Country

Infrastructure Australia acknowledges the Traditional Custodians of Australia, and pays respect to their Elders past, present and emerging. We pay respect to their continuing connection to land, and the continuation of their cultural, spiritual and educational practices.

In preparing for the future of our infrastructure, we acknowledge the importance of looking beyond the immediate past to learn from Aboriginal and Torres Strait Islander's unique history of land management and settlement, art, culture and society that began over 65,000 years ago.

# Table of contents

# List of tables

## 9. Greater Adelaide



## 10. The ACT and Queanbeyan

# List of figures

Higher resolution versions of maps shown in this report, and other technical material, will be available on our website www.infrastructureaustralia.gov.au.

## 2. Setting the scene



## 3. Methodology



## 5. Sydney, the Hunter and Illawarra



## 6. Melbourne and Geelong

## 7. Brisbane, the Gold Coast and Sunshine Coast



## 8. Greater Perth

# Chair's foreword

Road congestion and public transport crowding are among the most common sources of frustrations for Australians living in our fast-growing cities. From Sydney to Perth, congestion and crowding are on the rise, and their impacts on quality of life and productivity are significant.

This supplementary report to the 2019 *Australian Infrastructure Audit* provides a snapshot of congestion and crowding in in 2016, based on the population and transport networks of our six largest capital cities and their satellites at that time, as well as a projection of what congestion and crowding could look like in 2031.

The future the report paints is one of growing congestion costs and public transport crowding, driven by a growing population. Almost 60% of Australians now live in our four largest cities and these cities are also growing quickly, with 72% of national population growth occurring in these cities alone over the past ten years.

As a result of future growth, without continued action, the combined cost of road congestion and public transport crowding is forecast to double to $39.6 billion by 2031. However, it is important to note that this vision of the future is unlikely to emerge, as it is built on a scenario in which investment in infrastructure stops and policy reform does not continue, while the population continues to grow.

While this future is unlikely, it does present a burning platform for governments to continue to invest in new infrastructure, for industry to grow its capacity to respond, and for the community to support continued reform.

Since the modelling for this report was completed, the Australian Government, as well as states and territories, has made further commitments to fund transport projects within our largest cities, as well as lowering permanent migration by 30,000, incentivising migrants to settle in regional Australia, and enhancing population planning. As this modelling was completed in September 2018, the new projects and population settings announced after that time are not included in the modelling for the report. The impacts of these projects and reforms are therefore not reflected in the modelling results.

As we move into a period of heightened construction activity and the subsequent commissioning of new projects, it will be important to consider not only the end state of construction, but how our cities continue to function during delivery. The notion that the construction of our cities will ever be finished is misplaced. Our cities will continue to grow and change, and the need for new investment and reform will continue.

While investment in transport infrastructure, particularly in Sydney and Melbourne, has increased significantly over recent years, continued investment and reform will be required to ensure these cities can accommodate growing populations and economies into the future.

Our research highlights that while recent investment has eased congestion on some transport corridors, continued and sustained investment will be required to relieve congestion on a citywide scale. However, to be effective, new investment must be well targeted to where challenges are likely to emerge in the future. This will likely involve linking transport and land-use planning and improving decision-making tools to ensure they can account for future trends in technology and consumer preferences.

This report supports the 2019 *Australian Infrastructure Audit* in identifying the challenges and opportunities our urban transport networks could face in maintaining our quality of life and productivity into the future.

We welcome your input in helping to define the reforms and investments that will address the challenges and harness the opportunities identified in this report. We will be taking submissions in response to both documents, and I encourage you to respond.

**Julieanne Alroe**
Chair, Infrastructure Australia

1

# 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

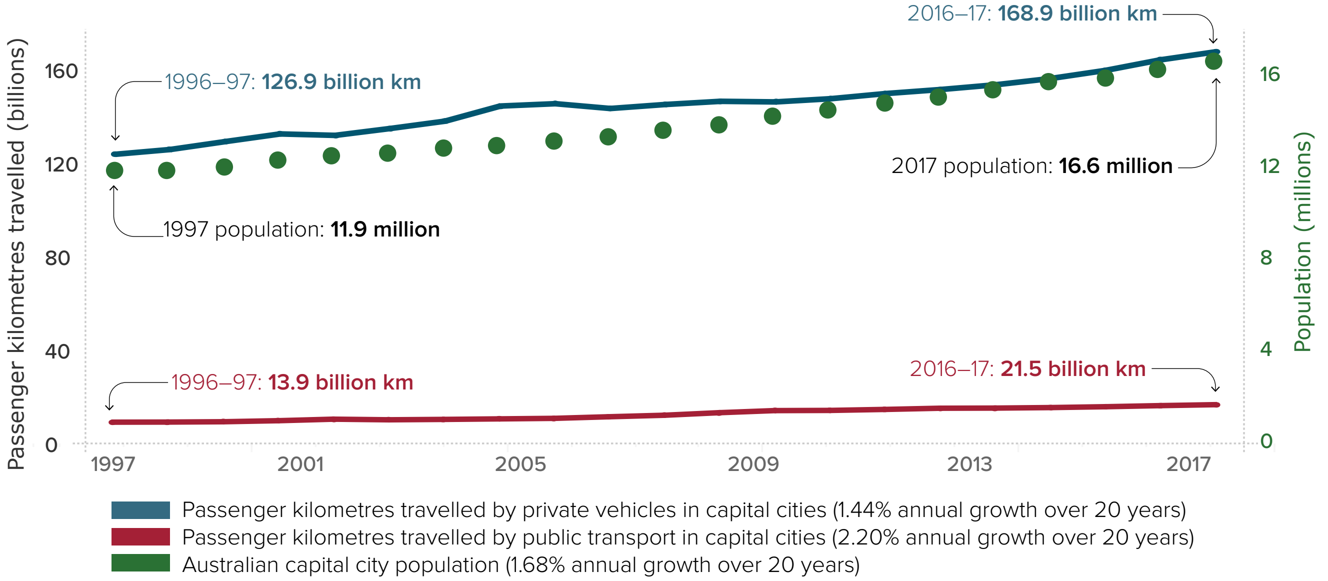
## Australia's changing urban travel task

### 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:

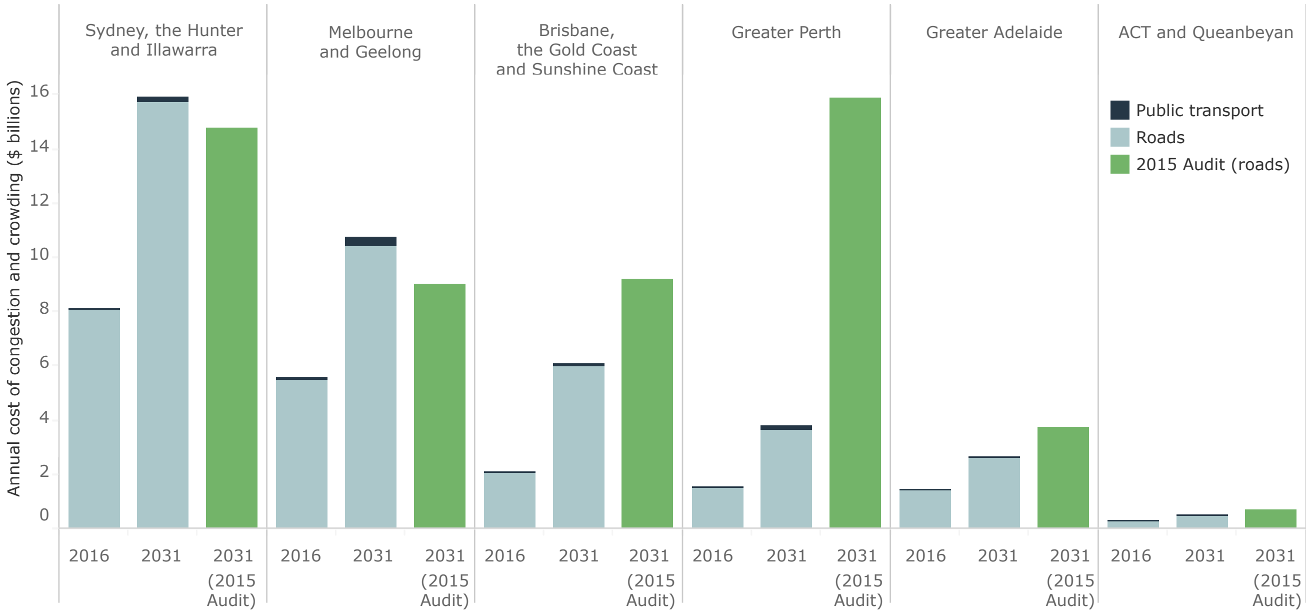
- 2016 total annual cost of road congestion: $19 billion, public transport crowding: $175 million
- 2031 forecast total annual cost of road congestion: $39 billion, public transport crowding: $837 million
- 2031 (from the 2015 Audit) forecast total annual cost of road congestion: $53 billion, public 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.

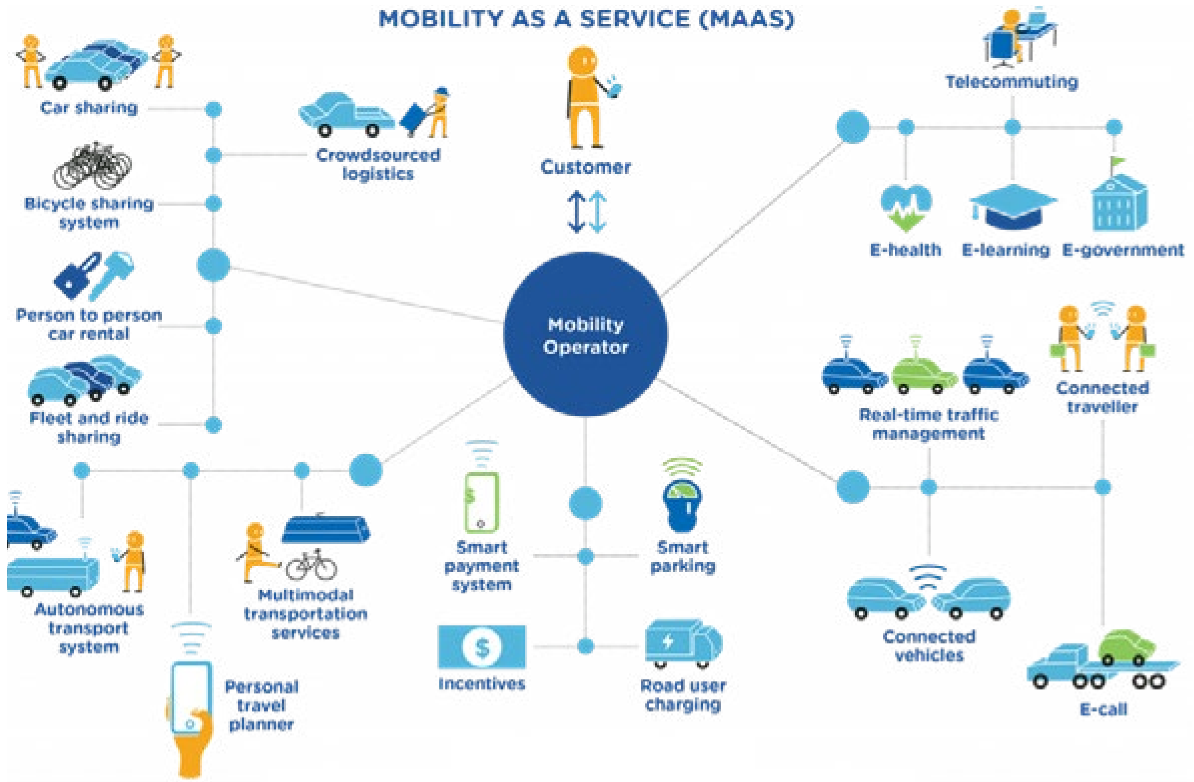
In comparison to many world cities, Australia has lagged in the adoption of transport technologies. Electric cars and buses, for instance, have been most quickly adopted in markets where there have been incentives from governments trying to improve urban air quality. For Australia, there is significant 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.

# Methodology

3

## 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

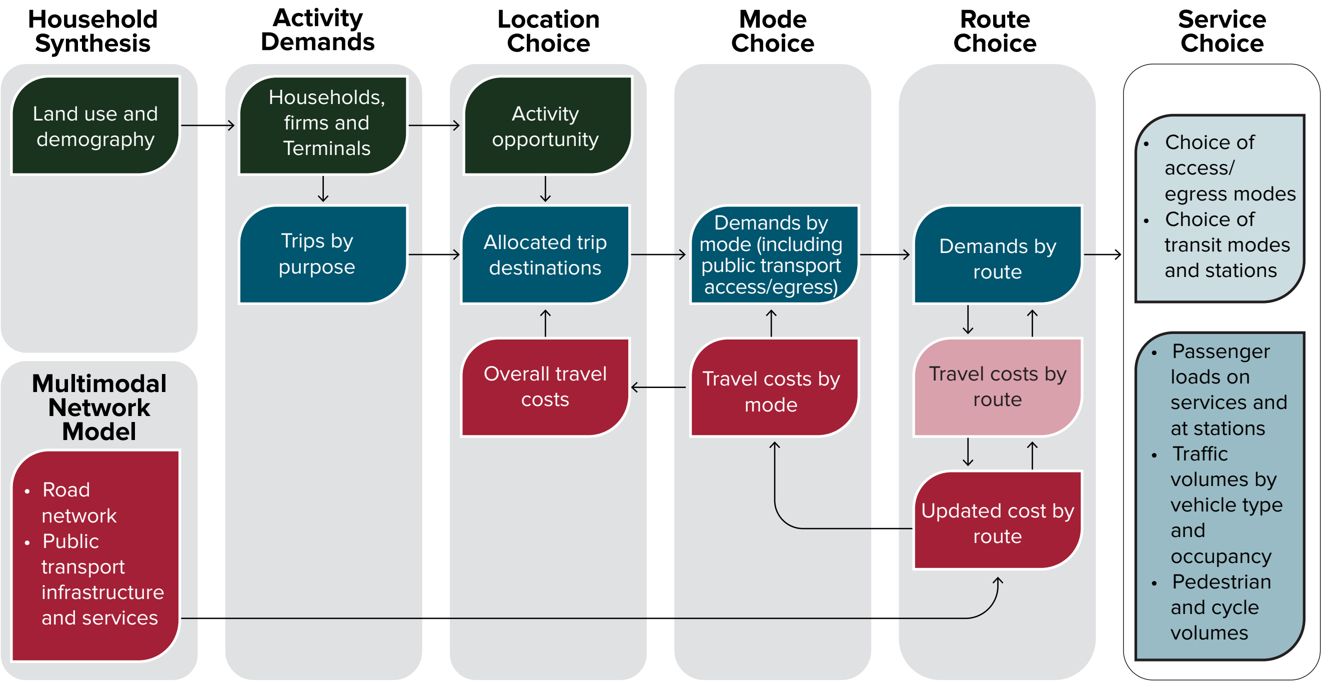
The type and scale of transport models vary from relatively simple intersection models used to predict the local traffic impacts of individual developments, to city-wide strategic models that aim to provide information on likely future conditions across metropolitan regions.

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]

# Sydney, the Hunter and Illawarra

5

## 5.1 Sydney has grown – and so has the time and effort it takes to move around the city

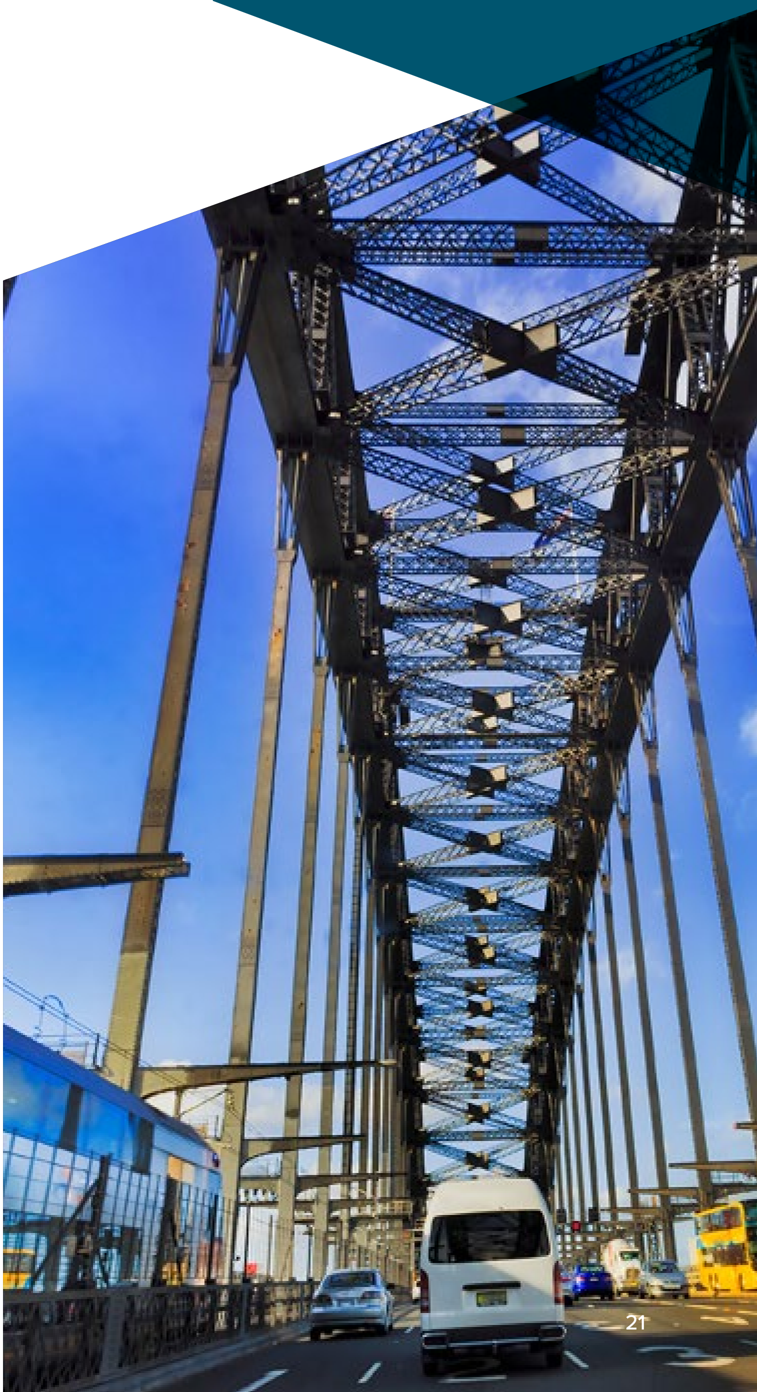
### Sydney's transport network performance over the past decade

Between the 2006 and 2016 Census years Sydney's population grew from just over 4.1 million to just under 4.9 million.[28] This is equivalent to a city the size of Canberra being added to the city every five years, or a Mackay or Launceston almost every year.

More people living and working in Australia's largest city has translated directly into a greater transport task. Over the past decade, the distance travelled by users of Sydney's roads has grown by about 6%.[29] Over the 18 years between 2000 and 2018, the number of public transport journeys made in Greater Sydney each year has increased by 45%, from 526 million to 765 million.[30] In particular, the use of rail services in Sydney has grown considerably in recent years. Rail patronage increased by 27% over the five-year period before 2016–17.[31] Sydney has the largest share of journeys to work by public transport nationally of any city. Public transport commuting mode share increased from 23% to 26% between the 2006 and 2016 Census years.[32]

Notwithstanding current investment in extra capacity, the performance of Sydney's transport network has worsened. Road network performance has deteriorated, affecting the drivers, passengers and cargo of cars, trucks and buses alike.[33] This can be seen by comparing road speeds in Sydney with average levels for all Australian cities.

Available evidence suggests that Sydney's public transport has also become more crowded over this period.[34] For instance, in the 24 months between August 2016 and August 2018, the patronage of Sydney Trains services increased by nearly 10%, with over 3 million additional monthly trips made on the network.



## 5.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit model inputs and assumptions

Since the 2015 Audit, Sydney, the Hunter and the Illawarra's forecast cost of road congestion has increased by 6% (Table 8 and  Figure 5). This is largely due to increases in population forecasts and vehicle kilometers travelled forecasts in the 2019 Audit.

Modelling undertaken in the 2019 Audit differs considerably from work undertaken in 2015 Audit. Changes have been made to the models themselves as well as to the model inputs and assumptions.

The 2015 Audit was based on Veitch Lister Consulting's projection of each city's population based on the most recent ABS forecasts available at the time. The 2019 Audit has slightly higher population and employment projections for Sydney, the Hunter and Illawarra The modelled area is now projected to have 7.5 million people, an increase of 2%. The largest variation in demographic assumptions between the audits is Sydney's inner west, northern and southern suburbs, which is forecast to have larger populations. Areas such as Bringelly, Green Valley, Rouse Hill and McGraphs Hill are forecast to have at least 70% more residents.

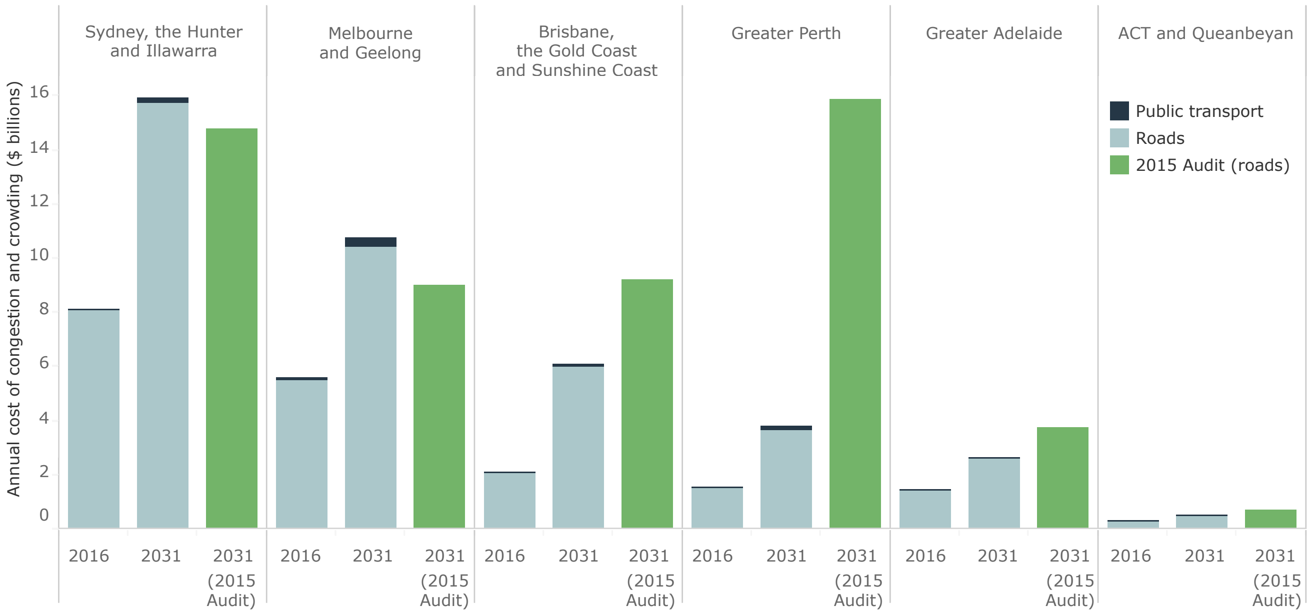
A 5% increase in projected employment has also been projected in the 2019 Audit. The changes of population and employment inputs has led to variations between the Audit's outputs including the annual cost of road congestion and public crowding. Table 9 reflects changes in model inputs and key outputs between the 2015 and 2019 Audit modelling.

**Table 8:** The cost of road congestion and public transport crowding in Sydney, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| 2016 (2019 Audit) | 68 | 8,038 | 8,106 |
| 2031 (2019 Audit) | 223 | 15,693 | 15,916 |
| 2031 (2015 Audit) | N/A | 14,790 | N/A |
| 2031 (change from 2015 Audit) | | +903 (+6%) | |

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[35]

**Figure 5:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[36]

**Table 9:** Changes in key model inputs and outputs between 2015 and 2019 modelling in Sydney, the Hunter and Illawarra

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | ⇧ Population forecasts have increased (+2%) | ⇧ Employment forecasts have increased (+5%), however the proportion of jobs in Sydney Inner City SA3 reduces slightly | ⇧ More investment in the road network (+~21% network lane km) | ⇧ More investment in the PT network (+~12% service kms) | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | |
| Impact on output (AM peak) | Total trips (-24%) | ⇧ Higher total population increases total modelled trips | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| Impact on output (AM peak) | Car trips (-26%) | ⇧ Higher total population increases total modelled car trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| Impact on output (AM peak) | Car vehicle kms travelled (-4%) | — An overall increase in population increases car kilometres, while lower population growth at the urban fringe could reduce this metric. The net effect could be neutral | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| Impact on output (AM peak) | Public transport trips (-18%) | ⇧ Higher total population increases total modelled PT trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | |

Source: Veitch Lister Consulting (2019)[37]

## New network assumptions

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. For Sydney, there are four key differences in network assumptions. Sydney Metro City and Southwest, Parramatta Light Rail, Newcastle Light Rail and Stage 1 F6 extension are all included in the 2019 Audit, but not the 2015 Audit.

## Variation between road network capacities in 2031

On Sydney's worst-performing corridors, road network volume to capacity ratios are similar between the 2019 Audit and the 2015 Audits. Both audits use the same metric to identify congestion. However, the 2019 Audit shows congestion along a longer stretch of the M4, as well as increased congestion on the M31 and M7. There are also increases to congestion on arterial and local roads in Parramatta and the inner city.

Population growth and the construction of Nancy Bird Walton Airport are forecast to result in congestion on the planned A9 motorway and the A44 and in surrounding arterial roads in Luddenham, Badgerys Creek, Kemps Creek, Kingswood, Cambridge Park and Ropes Crossing. Local and arterial roads in Erskine Park also denote large increases in congestion. More congestion is expected on Camden Bypass and Camden Valley Way.

Higher rates of congestion are forecast on arterial roads and local roads off the M2 and M7, including Beaumont Hills, Schofields and Quakers Hill.

More congestion is also evident on the M31 between Campbelltown and Prestons in the 2019 Audit.

Arterial and local roads in the inner west (Marrickville, Enmore, Newtown, Alexandria) will experience less congestion than forecast in the 2015 Audit. This is also the case with arterial roads connecting the M1 in Kingsford, Kensington, Botany, Daceyville, Roseberry. These decreases are likely to be attributed to WestConnex.

Sydney's worst-performing corridors, forecast in the 2019 Audit, are similar to those in the 2015 Audit. However, the 2019 Audit reflects that delays on these corridors is forecast to be worse. In general, vehicle delays are forecast to increase by more than the corresponding change in traffic volumes. This is a function of the underlying dynamics of traffic flow, which means when additional traffic is added to an already congested road the delay is disproportionately higher than in less congested conditions. In the 2019 Audit during AM and PM peak demand, Northern Beaches bus services are forecast to exceed crush capacity for the majority of the services to the Sydney CBD, while much of the Liverpool – Parramatta T-Way and routes running parallel to the T1 Western line from Parramatta either approach or exceed crush capacity. Bus services planned to travel between Parramatta and Liverpool in the southwest, are also expected to exceed crush capacity. Similarly, the 2015 Audit predicts that bus services operating between the Northern Beaches and the Sydney CBD will experience a large increase in demand.

Table 10 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

## Variation between public transport capacities in 2031

Similar levels of public transport demand have been identified between the 2019 Audit and 2015 Audit.

The main areas of weekday train passenger volume to capacity ratios at the 2031 AM peak are concentrated along the T1 Western, T1 North Shore, T2 Inner West, T4 Illawarra and Cronulla, T8 Airport and South lines. In the 2019 Audit, the area with the highest traffic volume and highest crush capacity in the 2031 AM peak is the T8 Airport line between the CBD and Kingsford Smith Airport, and the T8 South line running south from Parramatta to Yennora. The 2031 PM peak shows similar levels of traffic volumes, however no instances of high traffic volume. The 2015 Audit reflects similar patterns of demand.

In the 2019 Audit during AM and PM peak demand, Northern Beaches bus services are forecast to exceed crush capacity for the majority of the services to the Sydney CBD, while much of the Liverpool – Parramatta T-Way and routes running parallel to the T1 Western line from Parramatta either approach or exceed crush capacity. Bus services planned to travel between Parramatta and Liverpool in the southwest, are also expected to exceed crush capacity. Similarly, the 2015 Audit predicts that bus services operating between the Northern Beaches and the Sydney CBD will experience a large increase in demand.

**Table 10:** Most congested roads ranked by total delay hours, 2031 AM Peak, and ranking in 2015 Audit in Sydney, the Hunter and Illawarra

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Central Coast to Sydney corridor (M1) | S/B | 2,300 | 2,500 | 9% | 3,700 | 9,600 | 58% | 6 |
| 2 | Liverpool to Sydney Airport corridor (M5) | E/B | 6,100 | 5,700 | -7% | 5,100 | 9,200 | 81% | 3 |
| 3 | Illawarra to Sydney corridor (A1) | N/B | 2,200 | 2,500 | 15% | 5,300 | 8,400 | 59% | 1 |
| 4 | Mona Vale to Sydney Olympic Park corridor (A3) | S/B | 2,500 | 2,700 | 6% | 5,200 | 7,100 | 37% | 2 |
| 5 | Mittagong to Liverpool corridor (M31) | N/B | 3,400 | 3,400 | -1% | 2,700 | 6,100 | 122% | 9 |
| 6 | Sutherland west to Ryde west corridor (A6) | N/B | 2,200 | 2,300 | 3% | 4,400 | 5,300 | 20% | 4 |
| 7 | Northern Beaches to North Sydney corridor (A8) | S/B | 2,000 | 2,000 | 0% | 4,000 | 4,900 | 22% | 5 |
| 8 | Eastern Creek to Westmead corridor (M4) | E/B | 7,800 | 6,400 | -19% | 3,400 | 4,800 | 41% | 7 |
| 9 | Victoria Road (A40) | E/B | 2,300 | 2,600 | 12% | 2,300 | 4,400 | 90% | 15 |
| 10 | Westmead to Strathfield corridor (M4) | E/B | 5,800 | 6,400 | 10% | 1,800 | 4,100 | 132% | 20 |

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

Source: Veitch Lister Consulting (2019)[38]

## 5.3 Sydney commuters and businesses are exposed to daily road congestion and crowded public transport

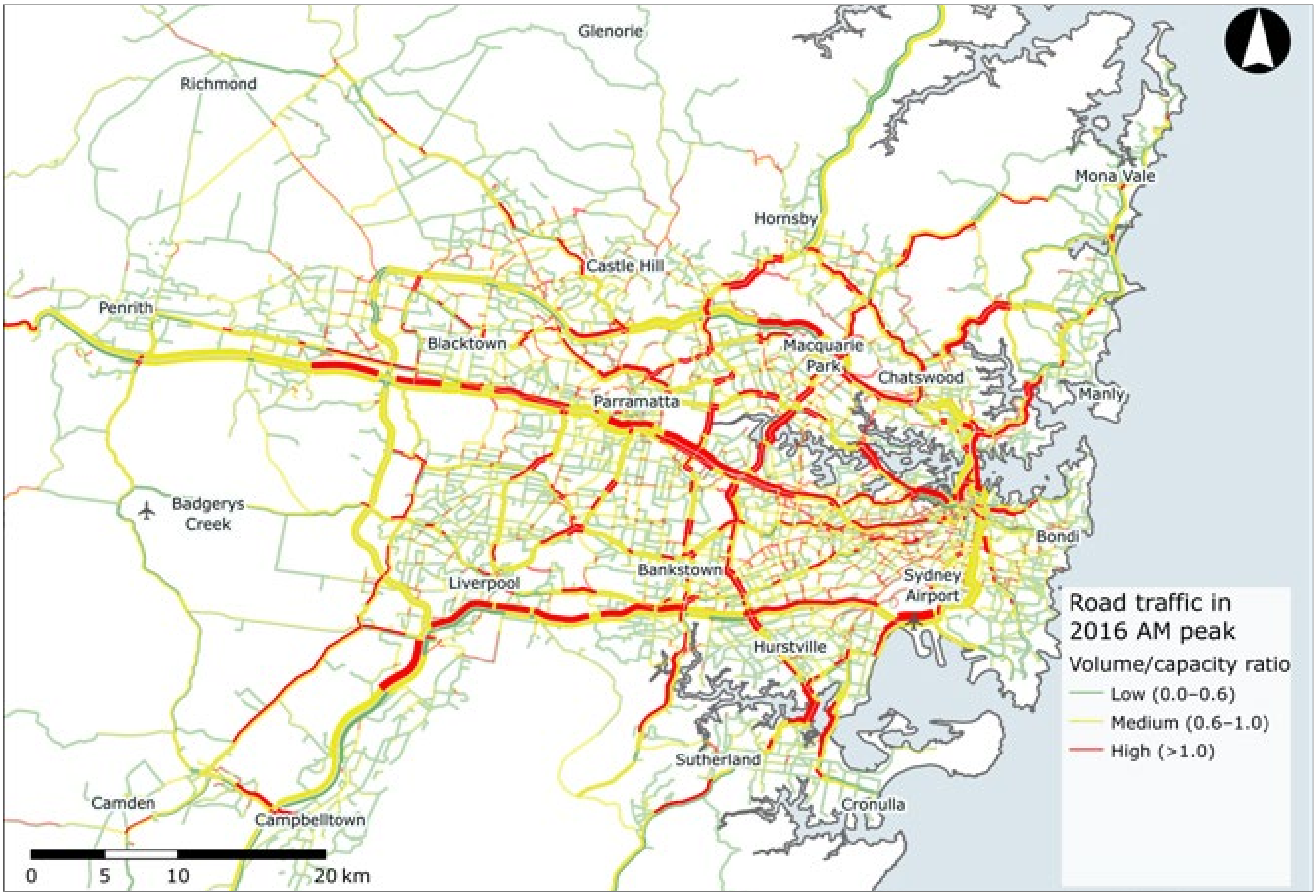
### Snapshot of Sydney's road network in 2016

Sydney's drivers already experience significant congestion. Our modelling indicates the cost of road congestion for Sydney, the Hunter and Illawarra in 2016 was approximately $8.0 billion. Within Sydney, this figure is $6.6 billion. The severity of this congestion is exacerbated during the morning peak period when commutes to work and school overlap (Figure 6). Sydney's major roads also experience similar levels of congestion in the PM peak. Several corridors are affected by substantial two-way congestion in both peak periods, most notably the M4 between Parramatta and the Sydney CBD.

### Sydney's most congested roads in 2016: what the driver experiences

Infrastructure Australia has identified the most congested road corridors in Sydney based on various metrics that relate to a user's experience, including the percentage of total journey time that is spent in congestion. The ten most congested corridors for the AM and PM peaks are shown in Table 11 and Figure 7.

**Figure 6:** Sydney weekday traffic volume / capacity ratio, 2016 AM peak




Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019) [39]

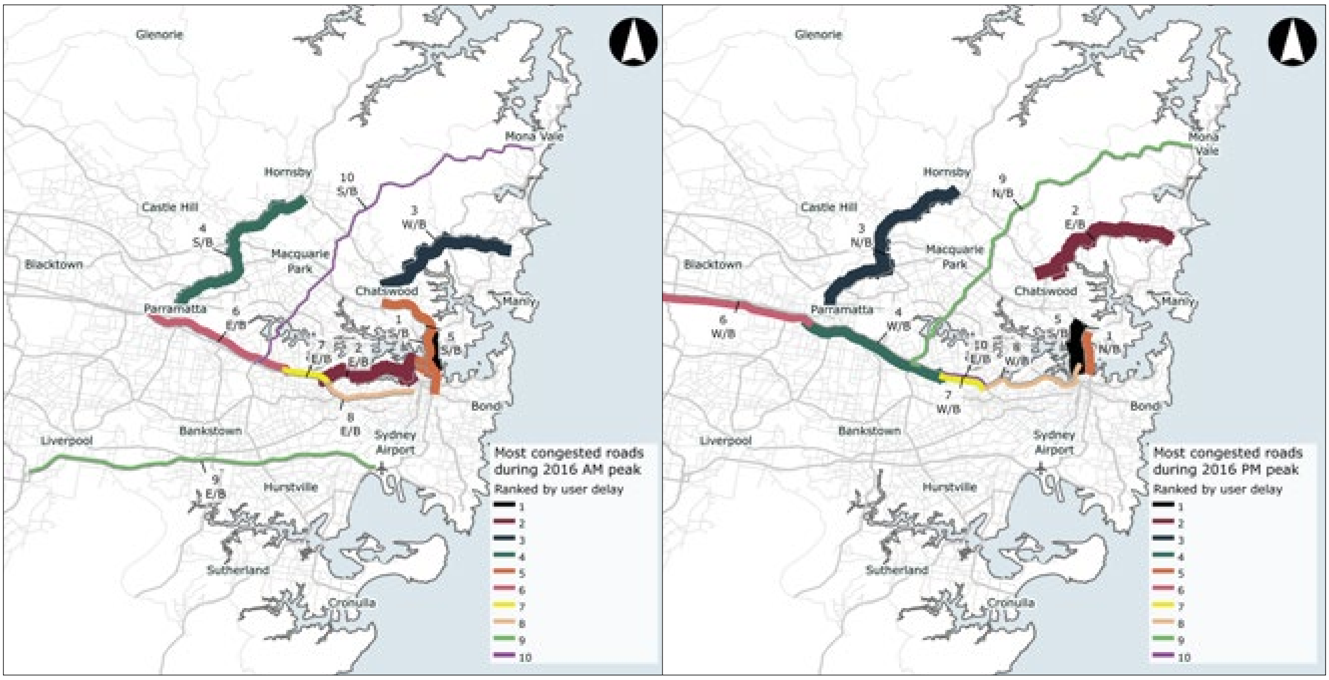
**Table 11:** Sydney's most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | North Sydney to Sydney CBD via Sydney Harbour Tunnel (S/B) | 4 | 81% | 16 | $4.42 | $19.03 |
| 2. | Ashfield to Sydney CBD via City West Link / Anzac Bridge (E/B) | 9 | 69% | 22 | $6.08 | $26.17 |
| 3. | Narraweena to Chatswood via Warringah Road (W/B) | 12 | 68% | 26 | $7.18 | $30.93 |
| 4. | Hornsby to Parramatta via Pennant Hills Road (S/B) | 16 | 67% | 34 | $9.39 | $40.45 |
| 5. | Artarmon to Surry Hills via Pacific Highway / Sydney Harbour Bridge / Cahill Expressway / Eastern Distributor (S/B) | 11 | 67% | 20 | $5.52 | $23.79 |
| 6. | Westmead to Strathfield via M4 (E/B) | 12 | 67% | 17 | $4.69 | $20.22 |
| 7. | Strathfield to Haberfield via Parramatta Road (E/B) | 4 | 67% | 9 | $2.49 | $10.71 |
| 8. | Haberfield to Broadway via Parramatta Road (E/B) | 7 | 66% | 18 | $4.97 | $21.41 |
| 9. | Liverpool to Sydney Airport via M5 (E/B) | 28 | 65% | 34 | $9.39 | $40.45 |
| 10. | Mona Vale to Sydney Olympic Park via A3 (S/B) | 35 | 62% | 54 | $14.91 | $64.24 |
| PM peak | | | | | | |
| 1. | Sydney CBD to North Sydney via Sydney Harbour Tunnel (N/B) | 4 | 74% | 11 | $3.04 | $13.09 |
| 2. | Chatswood to Narraweena via Warringah Road (E/B) | 12 | 68% | 26 | $7.18 | $30.93 |
| 3. | Parramatta to Hornsby via Pennant Hills Road (N/B) | 16 | 66% | 32 | $8.84 | $38.07 |
| 4. | Strathfield to Westmead via M4 (W/B) | 12 | 66% | 16 | $4.42 | $19.03 |
| 5. | North Sydney to Sydney CBD via Sydney Harbour Tunnel (S/B) | 4 | 66% | 7 | $1.93 | $8.33 |
| 6. | Westmead to Eastern Creek via M4 (W/B) | 12 | 63% | 13 | $3.59 | $15.47 |
| 7. | Haberfield to Strathfield via Parramatta Road (W/B) | 4 | 63% | 7 | $1.93 | $8.33 |
| 8. | Sydney CBD to Ashfield via Anzac Bridge / City West Link (W/B) | 9 | 61% | 15 | $4.14 | $17.85 |
| 9. | Sydney Olympic Park to Mona Vale via A3 (N/B) | 35 | 59% | 49 | $13.53 | $58.29 |
| 10. | Strathfield to Haberfield via Parramatta Road (E/B) | 4 | 59% | 6 | $1.66 | $7.14 |

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

Source: Veitch Lister Consulting (2019)[40]

**Figure 7:** Sydney's most congested roads (user experience), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[41]

The city's most congested arterial roads radiate out to the south, west and north from eastern Sydney's 'Global Arc' – between the airport and Macquarie Park – where jobs are concentrated. Widely spaced crossings of Sydney Harbour, Middle Harbour, the Georges River and bushland ridgelines create bottlenecks.

Furthermore, there is significant congestion on roads connecting the west of the city to job centres in the east. The three motorways connecting Greater Western Sydney to the Sydney CBD, Sydney Airport and Port Botany – the M5, M4 and M2 – are congested.

In addition to these Sydney CBD-oriented roads, congestion affects access to Parramatta, and cross-city north-south links such as the A3 corridor (including King Georges Road and Lane Cove Road) that connects the strategic centres of Kogarah, Bankstown, Sydney Olympic Park and Macquarie Park.

In the afternoon peak period (but not in the morning) two road corridors experience 'top 10' congestion in both directions. These are the Warringah Freeway / Gore Hill Freeway corridor north of Sydney Harbour, and the section of Parramatta Road between the current eastern terminus of the M4 and the City West Link.

Unlike Melbourne, Australia's second most congested city, Sydney in 2016 sees congestion beyond the motorway, freeway and arterial network. Local roads, particularly in the suburbs of the inner west, are regularly impacted by significant congestion during peak periods.

## Sydney's most congested roads in 2016: the cost to the community of total vehicle delays

As an indicator of the whole-of-system impacts of congestion (incorporating corridors beyond the metropolitan area of Sydney), Infrastructure Australia has aggregated total delay hours experienced by all vehicles using the most congested road corridors. The ten most congested corridors under this approach for the AM and PM peaks are shown in Table 12 and Figure 8. Delay on these roads accounts for approximately 20% of total delay hours experienced across the Sydney network. The greatest aggregate delays are experienced on long-distance inter-city corridors connecting Sydney with adjacent satellite cities, the Illawarra and Central Coast.

## Sydney's public transport system in 2016

Public transport use in Sydney has also grown substantially in recent years. New railway extensions completed since the 2015 *Australian Infrastructure Audit* include the South West Rail Link and the Inner West Light Rail extension to Dulwich Hill. On the Northern Beaches additional capacity is being provided by the B-Line bus corridor project, which is partially open and will undergo further improvements in coming years.

Increased residential density around many train stations, light rail stops and other interchanges, and the growth of employment within walking distance of stations, make public transport an obvious commuting choice for many Sydneysiders. Network-wide improvements including the roll-out of the Opal integrated ticketing system and the introduction of 'turn up and go' service frequencies on major routes have also supported patronage growth. Increasing road congestion is likely to have made public transport a more attractive option for commuters.

Sydney's increased reliance on public transport results in the users of the busiest train lines experiencing the discomfort of crowded services. More people must stand for longer, and the extra time it takes for people to get on and off contributes to delays.

As shown in Figure 9, the T1 Western and T2 Inner West lines (between Parramatta and the Sydney CBD), the T8 Airport and South line (between East Hills and Sydney Airport) and the T1 North Shore line (between Chatswood and the Sydney CBD) approach – but do not yet exceed – crush capacity in the 2016 base year. For the Audit's transport modelling purposes, crush capacity is defined according to the total number of passengers that a public transport service is designed to carry. For a train service operated using Sydney Trains double-deck rolling stock, crush capacity is exceeded at 1,430 passengers. This is equivalent to 160% of the train's seated load – i.e. for every ten seated passengers six are standing. The crush load of bus and ferry services is similarly based on the seated and designated standing capacity for those modes.

In 2016 Sydney's busiest bus corridors (Figure 10) were at the points of entry to the Sydney CBD for routes with service corridors without a train line. These include the Northern Beaches peninsula, Eastern Valley Way, Victoria Road, the Anzac Parade corridor in south-eastern Sydney, the M2 corridor to the Hills District, and connections to the north-east, north-west and south-west of Parramatta.

Some but not all of Sydney's busiest bus corridors are given priority road space. These include the B-Line / Sydney Harbour Bridge bus lane, the Liverpool–Parramatta T-way and the M2 Busway. Services that operate on corridors with bus priority measures commonly offer faster and more reliable peak period services than driving and local bus routes. Without priority access, these services have to compete with other traffic on congested roads.

Perversely, the popularity of these services can result in crowded buses that take longer to load and unload, reducing their efficiency and attractiveness over time. This can result in bus bunching and delays, even when bus-only lanes are provided. Anecdotal evidence suggests that on some of Sydney's busiest bus corridors the high patronage of bus services is resulting in on-board congestion – or overcrowding – leading to discomfort for passengers and late-running services.

In 2016 passenger volume to capacity ratios were highest for bus services operating on the Northern Beaches (to the Sydney CBD via both Willoughby and Mosman), Anzac Parade, the Liverpool–Parramatta T-way through Smithfield and Merrylands, and the M2 between Old Windsor Road and Windsor Road (east of where the motorway's bus-only lane begins). Figures for the Northern Beaches predate the commencement of B-Line services.

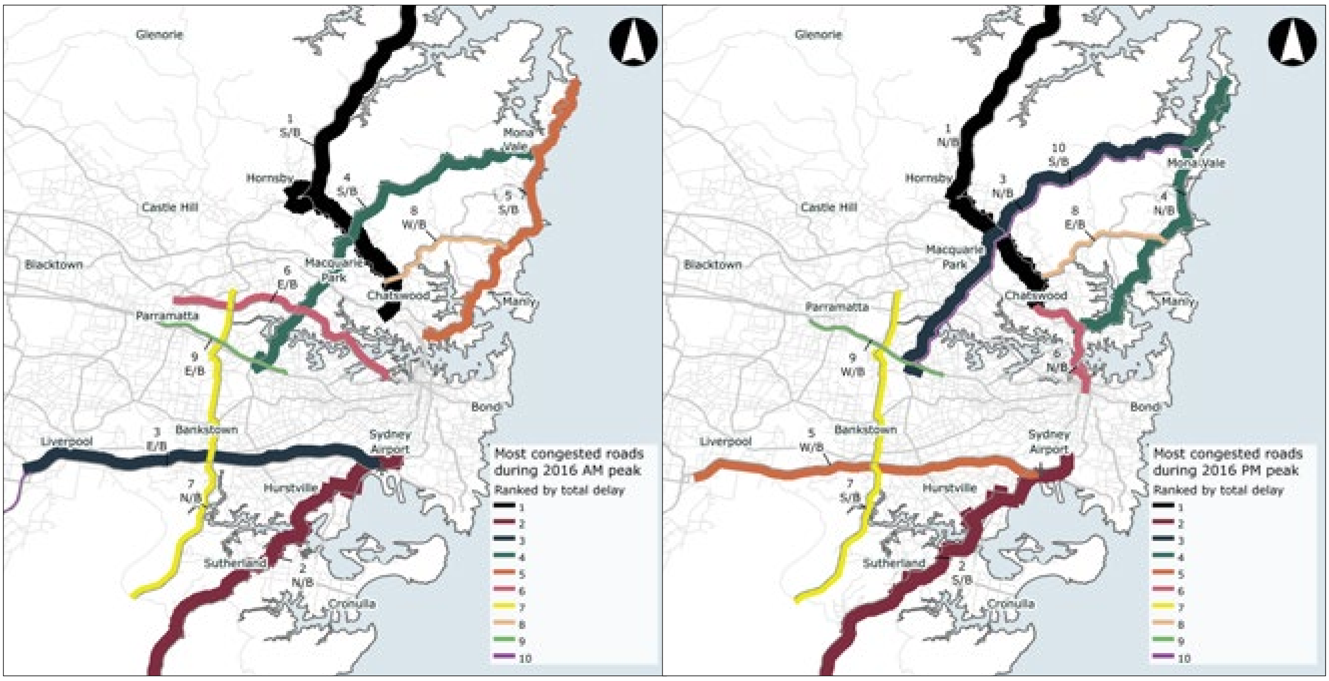
**Table 12:** Sydney's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Central Coast to Sydney corridor (M1) | S/B | 6,200 | $165,000 |
| 2. | Illawarra to Sydney corridor (A1) | N/B | 5,800 | $134,000 |
| 3. | Liverpool to Sydney Airport corridor (M5) | E/B | 4,900 | $109,000 |
| 4. | Mona Vale to Sydney Olympic Park corridor (A3) | S/B | 4,900 | $104,000 |
| 5. | Northern Beaches to North Sydney corridor (A8) | S/B | 3,900 | $78,000 |
| 6. | Victoria Road corridor (A40) | E/B | 3,200 | $67,000 |
| 7. | Sutherland west to Ryde west corridor (A6) | N/B | 3,100 | $67,000 |
| 8. | Narraweena to Chatswood corridor (A38) | W/B | 3,000 | $61,000 |
| 9. | Westmead to Strathfield corridor (M4) | E/B | 2,900 | $62,000 |
| 10. | Mittagong to Liverpool corridor (M31) | N/B | 2,800 | $71,000 |
| PM peak | | | | |
| 1. | Sydney to Central Coast corridor (M1) | N/B | 5,800 | $153,000 |
| 2. | Sydney to Illawarra corridor (A1) | S/B | 4,700 | $108,000 |
| 3. | Homebush Bay to Mona Vale corridor (A3) | N/B | 4,600 | $94,000 |
| 4. | North Sydney to Northern Beaches corridor (A8) | N/B | 3,800 | $75,000 |
| 5. | Sydney Airport to Liverpool corridor (M5) | W/B | 3,500 | $77,000 |
| 6. | Eastern Distributor / Sydney Harbour Bridge / Warringah Freeway / Gore Hill Freeway corridor (M1) | N/B | 2,900 | $65,000 |
| 7. | Ryde west to Sutherland west corridor (A6) | S/B | 2,900 | $62,000 |
| 8. | Chatswood to Narraweena corridor (A38) | E/B | 2,800 | $56,000 |
| 9. | Strathfield to Westmead corridor (M4) | W/B | 2,800 | $60,000 |
| 10. | Mona Vale to Sydney Olympic Park corridor (A3) | S/B | 2,700 | $56,000 |

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

Source: Veitch Lister Consulting (2019)[42]

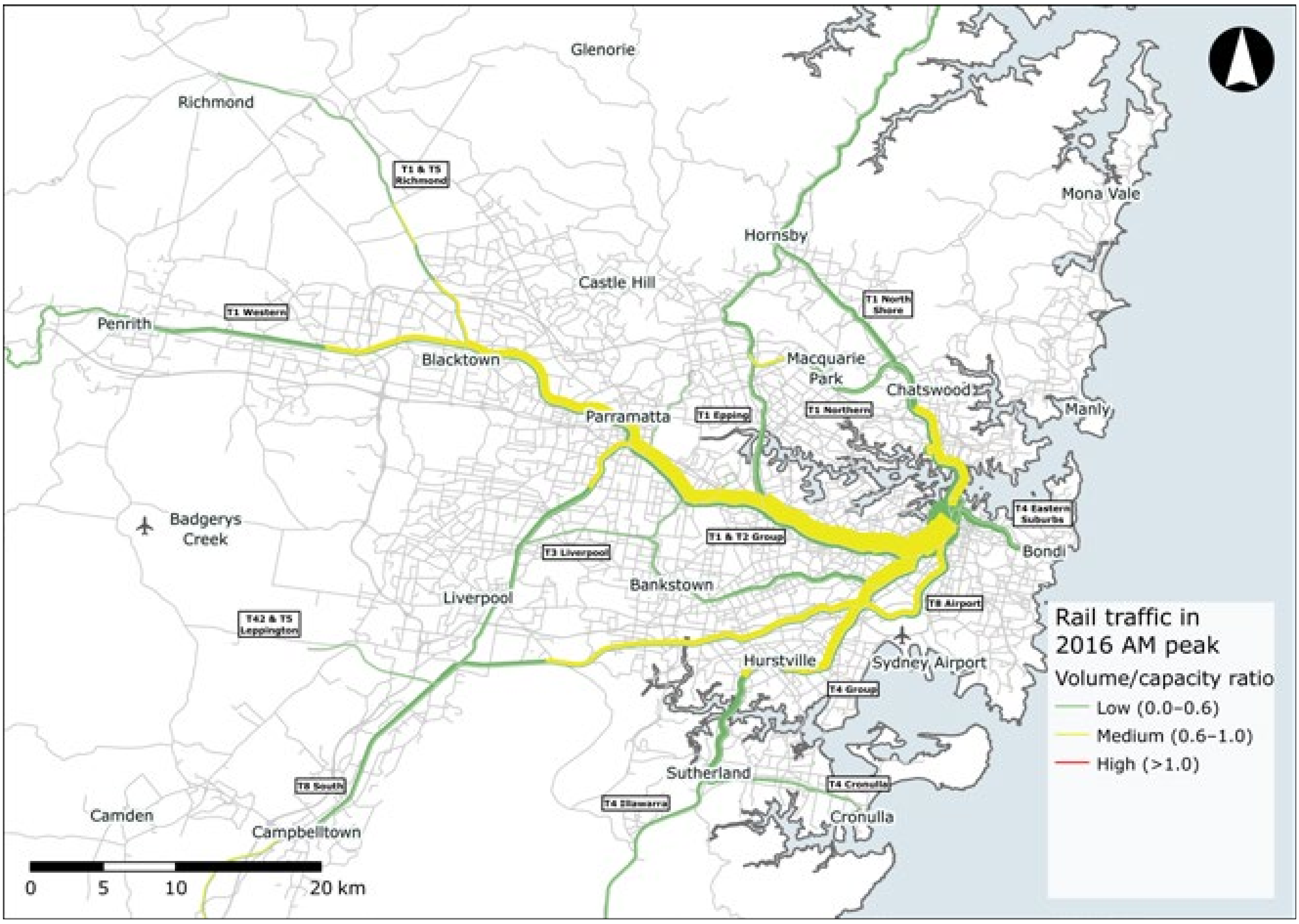
**Figure 8:** Sydney's most congested roads (total vehicle delays), 2016 AM (left) and PM (right) peak periods




Note: The Mittagong to Liverpool corridor (10th most congested corridor in AM peak period) is located beyond the map extent, towards the south west.

Source: Veitch Lister Consulting (2019)[43]

**Figure 9:** Sydney weekday train passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[44]

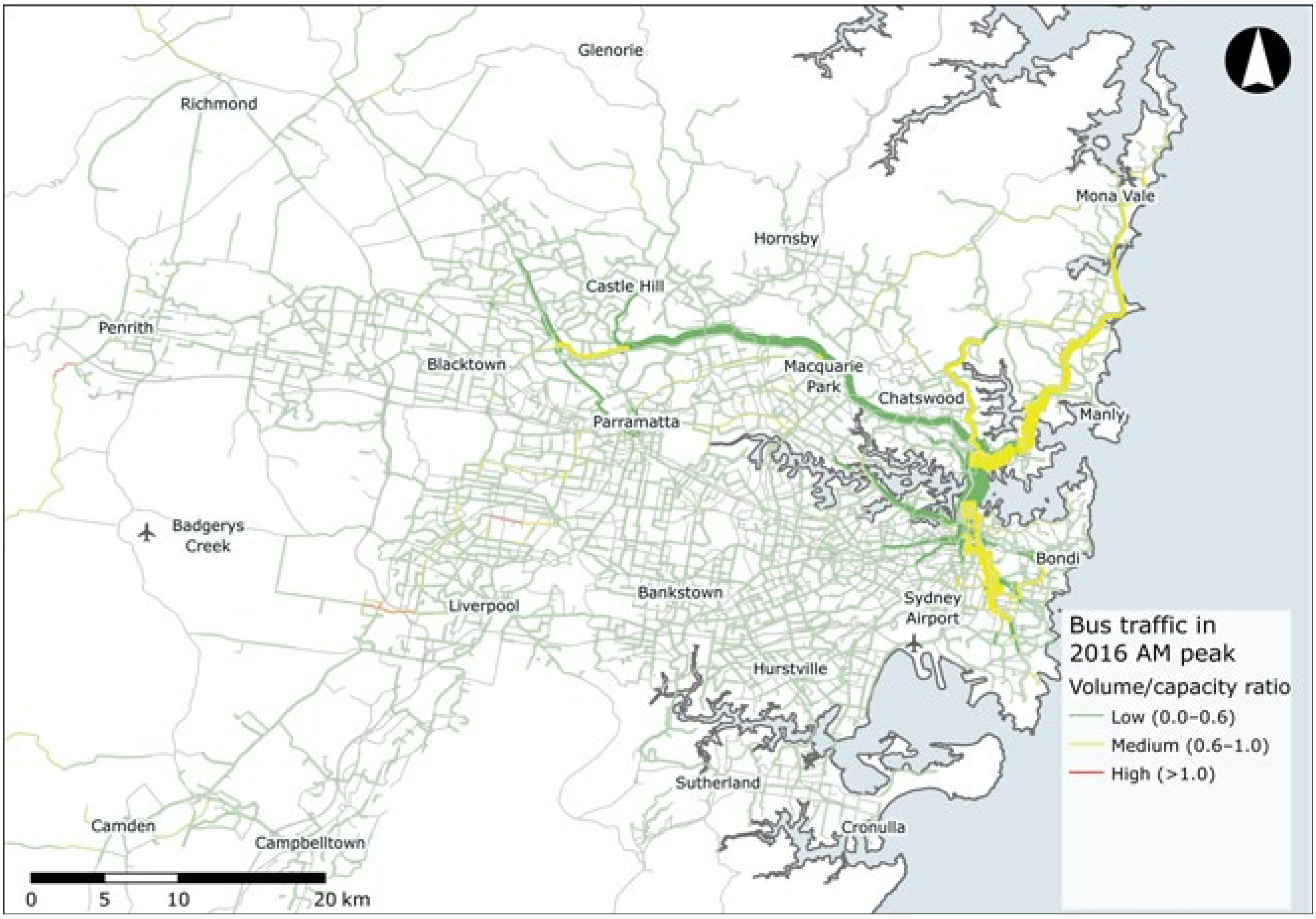
## Sydney's potential transition to a more sustainable transport future

Based on this evidence, the choices for the future development and management of Sydney's transport networks puts the city at a point of transition. As acknowledged by the NSW Government,[45] there is an opportunity to transition Sydney's transport system to a more technologically, environmentally and financially sustainable model.

If this pathway is not taken, there is the risk that further road and public transport congestion will seriously impact the city's liveability. This would damage the city's productivity and global competitiveness.[46] Various external groups which measure and report road congestion currently rate Sydney worse than other Australian cities and various global cities.[47]

A key strategy for mitigating this risk involves spreading Sydney's population and employment growth across a multi-centred metropolis. This theme is at the heart of recently released integrated transport and land use plans for Greater Sydney, with increased focus on liveability. Under these plans a third city - Western Sydney Airport-oriented 'Parkland City' will join the Sydney CBD-focused 'Harbour City', and the Parramatta-centred 'River City'. High-frequency public transport services and improved active transport options will be needed to ensure this urban structure is a success and to achieve the goal of making jobs and services in all the city's centres accessible within 30 minutes of non-car travel time.

**Figure 10:** Sydney weekday bus passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[48]

## Findings

- Extended sections of the M5, M4 and M2 motorways that connect Greater Western Sydney to the Sydney CBD and the city's ports are congested in the peak travel direction every weekday, to a distance of as much as 40km from the CBD.
- Sydney's natural topography, bushland and waterways have the effect of concentrating traffic onto a limited number of corridors at gateways to the Sydney CBD, at crossings of the Parramatta, Cooks and Georges rivers, and across large areas of northern and north-western Sydney. This results in severe congestion on associated roads including the Sydney Harbour Bridge and Tunnel, General Holmes Drive, Warringah Road and the A3.
- The best-serviced bus routes, such as the Northern Beaches and Victoria Road corridors, can become a victim of their own popularity. This can lead to diminishing long-run returns from bus priority investment.

## 5.4 Even with programmed investment, Sydney's transport networks are forecast to become more congested

### Snapshot of Sydney's transport networks in 2031

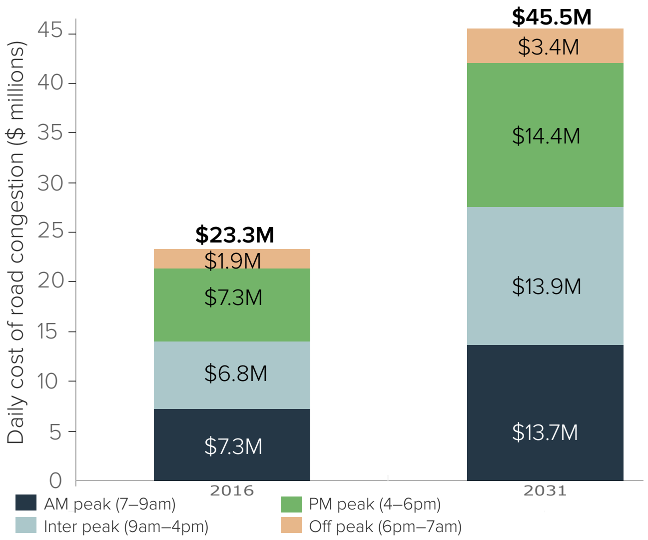
Looking out to 2031, Sydney roads and public transport services will be faced with a substantially larger transport task. The city's population is forecast to grow from 4.9 million to 6.4 million. Nearly 5 million more passenger trips are expected to be made each day. Our modelling indicates the annualised cost of road congestion and public transport crowding for Sydney, the Hunter and Illawarra will be approximately $15.9 billion in 2031.

The extra time spent stuck in traffic and on crowded public transport is expected to contribute to a near-doubled daily cost of congestion – from $23 million to $46 million for the broader region that also includes Newcastle and Wollongong (Figure 11).

The annualised cost of road congestion for Sydney, the Hunter and Illawarra, will increase from $8.0 billion in 2016 to $15.7 billion in 2031. For Sydney, it was $6.6 billion in 2016 and will be $13.1 billion in 2031. The annualised road congestion costs and public transport crowding costs for the broader region will increase from approximately $8.1 billion in 2016 to $15.9 billion in 2031.[49]

Congestion will increase by the greatest rate in the inter-peak period, as the traditional times of heavy traffic delay extends into the middle of the day. Inter-peak congestion costs will overtake AM peak congestion by 2031. Although modelling has only been carried out for weekdays, growth in off-peak traffic is expected to follow a trend that has already seen, over the past decade, an increase in weekend traffic levels also on many major routes in Sydney.[50]

**Figure 11:** Sydney, the Hunter and Illawarra average weekday cost of road congestion, 2016 and 2031




Source: Veitch Lister Consulting (2019)[51]

These forecast outcomes hold despite both the expected rise in public transport mode share and Sydney's historically unprecedented pipeline of transport infrastructure. This comprises projects that were either under construction, under procurement or had funding for construction committed from all relevant governments at the time of Infrastructure Australia's transport modelling for this Audit.[52]

In summary, these major projects were assumed for 2031 forecast purposes:

- Western Sydney Airport road network including M12 motorway
- NorthConnex motorway
- WestConnex motorway
- F6 motorway extension (stage 1)
- Sydney Metro Northwest
- Sydney Metro City & Southwest
- CBD and South East Light Rail (Kingsford / Randwick to city)
- Newcastle Light Rail (Wickham to Newcastle)
- Major bus priority corridors including the Northern Beaches B-Line, Parramatta to city via Ryde, Burwood to city and North Bondi to city.

### Sydney's most congested roads in 2031: what the driver will experience

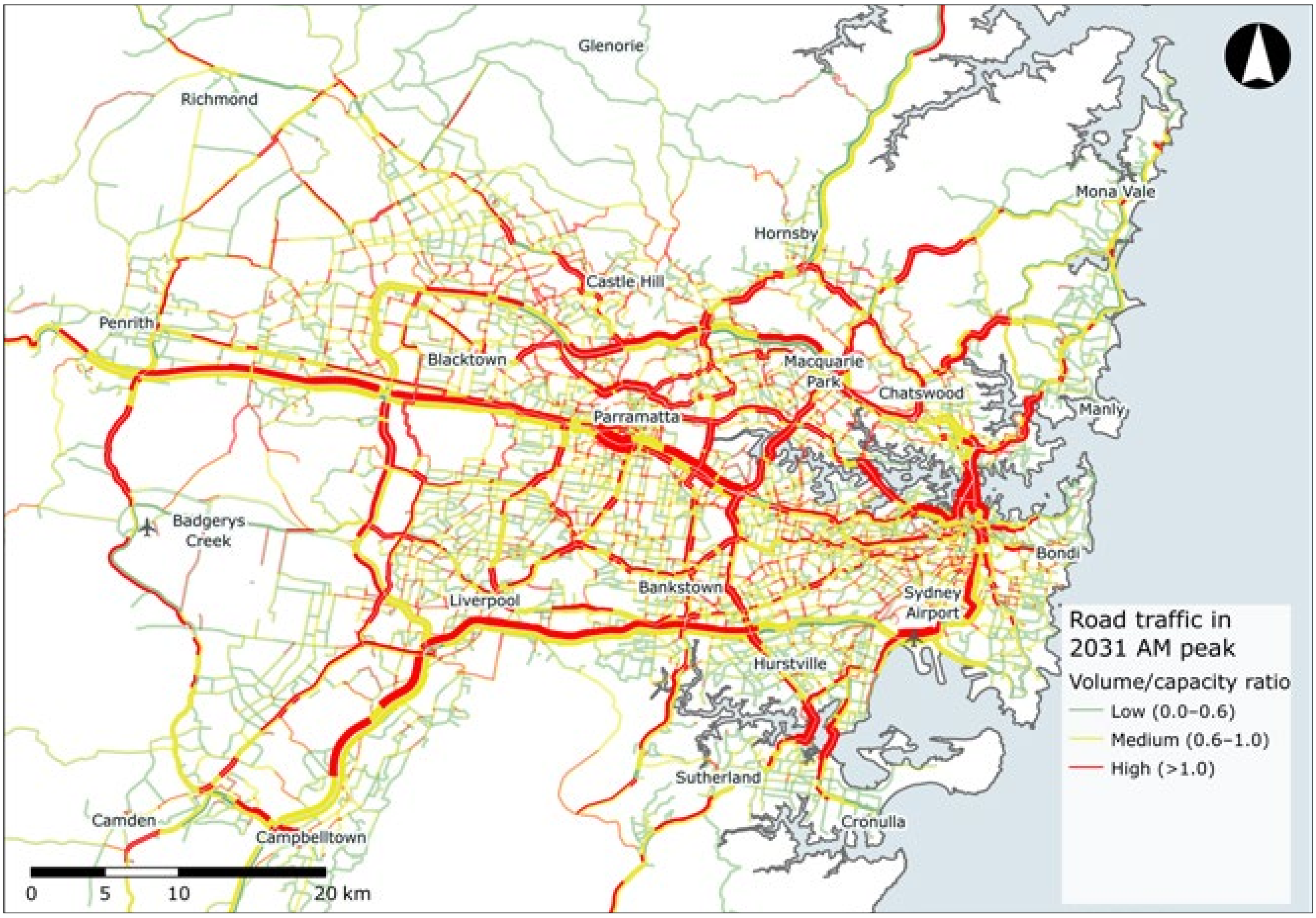
In 2031, Sydney's most congested roads from a user's perspective will broadly be the same as those today (Figure 12, Table 13 and Figure 13).

However, the proportion of the trip that drivers will spend on those roads in congestion is forecast to increase from 60–80% in 2016, to 70–90% in 2031.

By 2031, it will be much more common for peak congestion to be encountered in both directions on Sydney's major routes, as employment grows in north-western and south-western Sydney. The development of Sydney as a multi-centred metropolis will also drive increased congestion on cross-regional north-south routes. These include the M7 and the A3 in addition to the customarily congested routes radial to the Sydney CBD.

As today, the worst bottlenecks in 2031 are expected to include routes that will still be functioning as major bus corridors, the Gore Hill Freeway / Warringah Freeway / Eastern Distributor corridor between the Lower North Shore and the Sydney CBD, and Narraweena (Dee Why) to Chatswood via Warringah Road. M2 corridor bus services will still be crossing Sydney Harbour into the CBD. The Northern Beaches will continue to rely on buses travelling through Frenchs Forest to access Metro and suburban train services at Chatswood.

**Figure 12:** Sydney weekday traffic volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[53]

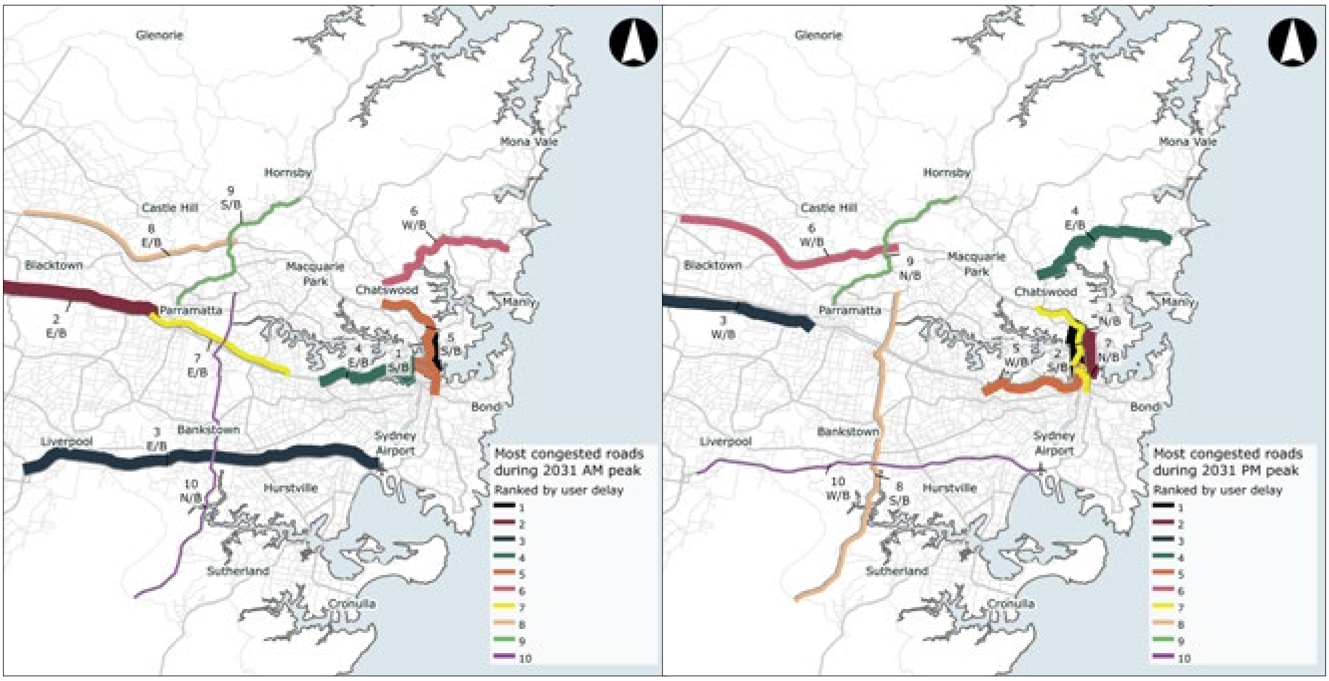
### **Table 13:** Sydney's most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | North Sydney to Sydney CBD via Sydney Harbour Tunnel (S/B) | 4 | 84% | 19 | $5.25 | $22.60 |
| 2. | Mount Druitt to Westmead via M4 (E/B) | 13 | 75% | 25 | $6.90 | $29.74 |
| 3. | Liverpool to Sydney Airport via M5 (E/B) | 28 | 74% | 49 | $13.53 | $58.29 |
| 4. | Ashfield to Sydney CBD via City West Link / Anzac Bridge (E/B) | 9 | 73% | 27 | $7.46 | $32.12 |
| 5. | Artarmon to Surry Hills via Pacific Highway / Sydney Harbour Bridge / Cahill Expressway / Eastern Distributor (S/B) | 11 | 72% | 25 | $6.90 | $29.74 |
| 6. | Narraweena to Chatswood via Warringah Road (W/B) | 12 | 71% | 30 | $8.29 | $35.69 |
| 7. | Westmead to Strathfield via M4 (E/B) | 12 | 71% | 21 | $5.80 | $24.98 |
| 8. | Baulkham Hills to Macquarie Park via M2 (E/B) | 18 | 69% | 26 | $7.18 | $30.93 |
| 9. | Hornsby to Parramatta via Pennant Hills Road (S/B) | 16 | 68% | 36 | $9.94 | $42.83 |
| 10. | Sutherland west (Lucas Heights) to Ryde west (Dundas Valley) via A6 (N/B) | 32 | 68% | 67 | $18.50 | $79.71 |
| PM peak | | | | | | |
| 1. | Sydney CBD to North Sydney via Sydney Harbour Tunnel (N/B) | 4 | 81% | 15 | $4.14 | $17.85 |
| 2. | North Sydney to Sydney CBD via Sydney Harbour Tunnel (S/B) | 4 | 79% | 14 | $3.87 | $16.66 |
| 3. | Westmead to Eastern Creek via M4 (W/B) | 12 | 76% | 25 | $6.90 | $29.74 |
| 4. | Chatswood to Narraweena via Warringah Road (E/B) | 12 | 72% | 32 | $8.84 | $38.07 |
| 5. | Sydney CBD to Ashfield via Anzac Bridge / City West Link (W/B) | 9 | 69% | 22 | $6.08 | $26.17 |
| 6. | Macquarie Park to Baulkham Hills via M2 (W/B) | 18 | 69% | 25 | $6.90 | $29.74 |
| 7. | Surry Hills to Artarmon via Eastern Distributor / Cahill Expressway / Sydney Harbour Bridge / Pacific Highway (N/B) | 12 | 67% | 20 | $5.52 | $23.79 |
| 8. | Ryde west (Dundas Valley) to Sutherland west (Lucas Heights) via A6 (S/B) | 32 | 67% | 63 | $17.40 | $74.95 |
| 9. | Parramatta to Hornsby via Pennant Hills Road (N/B) | 16 | 67% | 34 | $9.39 | $40.45 |
| 10. | Sydney Airport to Liverpool via M5 (W/B) | 27 | 67% | 36 | $9.94 | $42.83 |

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

Source: Veitch Lister Consulting (2019)[54]

### **Figure 13:** Sydney's most congested roads (user experience), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[55]

An increase in congestion is forecast for the M5 between Liverpool and Sydney Airport, notwithstanding capacity expansion at the eastern end of this corridor under the WestConnex program. Congestion is forecast south of Liverpool also, extending towards Campbelltown and the Greater Macarthur Growth Area.

In contrast, improvements to traffic flows following the delivery of other WestConnex projects are expected to result in Parramatta Road between Strathfield and Haberfield dropping off the list of Sydney's ten most congested roads.

It is expected that Pennant Hills Road between Parramatta and Hornsby will continue to remain congested, despite NorthConnex accommodating most traffic on this corridor. (It should be noted that congestion on Pennant Hills Road could be overstated in the modelling, because the NSW Government's commitment to ensure all trucks use NorthConnex could not be modelled.) Other roads around Parramatta, including James Ruse Drive and the M4, will experience bi-directional congestion due in part to the growth of Sydney's second CBD, Parramatta.

While they are not on the list of Sydney's forecast ten most congested roads in 2031, and expected to be carrying low absolute traffic volumes in that year, it is of note in Figure 12 that routes around the designated Western Sydney (Nancy-Bird Walton) Airport-Aerotropolis precinct are predicted to be operating over capacity in 2031. Even with Australian Government-funded investment in road widening through the Western Sydney Infrastructure Program, roads including The Northern Road, Luddenham Road and Badgerys Creek Road are forecast to be subject to delay.

## Sydney's most congested roads in 2031: the forecast cost to the community of total vehicle delays

As for 2016, the most congested road corridors in Greater Sydney have been forecast for 2031 based on aggregating the total delay hours experienced by all vehicles across the network during the modelled period. The ten most congested corridors under this approach are shown by Table 14 and Figure 14.

Relatively long-distance connections between Sydney and satellite cities, the Central Coast and Illawarra, to its north and south will still be among the worst performers in terms of the total costs of congestion experienced by the community. Compared with 2016, however, the corridor seeing the fastest growth in congestion by this measure could be an inland connection – the M31 / M5 corridor that links south-western Sydney's Greater Macarthur growth precincts to eastern Sydney.

## Sydney's public transport system in 2031

Public transport use in Sydney is forecast to grow substantially by 2031, influenced by investment in the public transport network, road congestion, higher-density development along public transport corridors and the assumed increase in parking costs relative to stable public transport fares.

Given these factors and despite major additions – principally in the form of new or upgraded Sydney Metro train lines and light rail lines – Sydney's public transport system is forecast to become more crowded and at consequent risk of delays.

By 2031 it is expected that most Sydney CBD-bound train services will be operating well above seated capacity in the AM peak (Figure 15). The adoption of Metro technology based on fast loading / unloading rolling stock with limited seating means that standing will be common on these new services. From the passenger's perspective these services will deliver more frequent and less crowded services (compared to double-decker trains), with the trade-off of reduced seating.

However, few of Sydney's lines are forecast to be operating above crush capacity in 2031. Lines that will be the most challenged by demand growth are the T8 Airport line from Mascot to the CBD through Green Square (due to growth in the southern Sydney corridor), the same line between Panania and Revesby (due to growth originating from Greater Macarthur, to the south-west), the T2 Inner West line, and the T5 Cumberland line between Merrylands and Parramatta.

Elsewhere on Sydney's train network, the new Sydney Metro services operating by 2031 will provide significant additional capacity. This is expected to reduce the likelihood of crowding through the North Shore and Sydenham–Bankstown corridors and (with new stations operating in the city core and at Barangaroo) within the Sydney CBD itself.

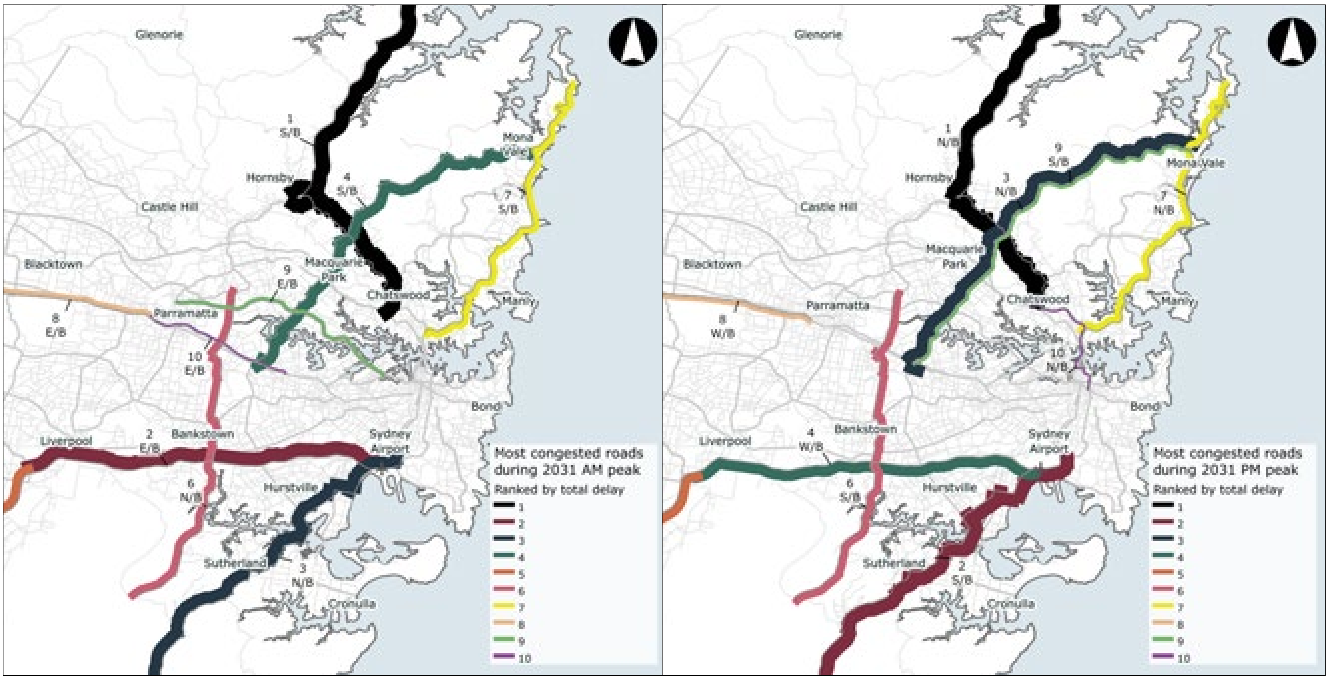
**Table 14:** Sydney's most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Central Coast to Sydney corridor (M1) | S/B | 9,600 | $257,000 |
| 2. | Liverpool to Sydney Airport corridor (M5) | E/B | 9,200 | $198,000 |
| 3. | Illawarra to Sydney corridor (A1) | N/B | 8,400 | $206,000 |
| 4. | Mona Vale to Sydney Olympic Park corridor (A3) | S/B | 7,100 | $148,000 |
| 5. | Mittagong to Liverpool corridor (M31) | N/B | 6,100 | $155,000 |
| 6. | Sutherland west to Ryde west corridor (A6) | N/B | 5,300 | $120,000 |
| 7. | Northern Beaches to North Sydney corridor (A8) | S/B | 4,900 | $100,000 |
| 8. | Eastern Creek to Westmead corridor (M4) | E/B | 4,800 | $103,000 |
| 9. | Victoria Road corridor (A40) | E/B | 4,400 | $93,000 |
| 10. | Westmead to Strathfield corridor (M4) | E/B | 4,100 | $88,000 |
| PM peak | | | | |
| 1. | Sydney to Central Coast corridor (M1) | N/B | 8,700 | $227,000 |
| 2. | Sydney to Illawarra corridor (A1) | S/B | 7,500 | $180,000 |
| 3. | Homebush Bay to Mona Vale corridor (A3) | N/B | 7,100 | $145,000 |
| 4. | Sydney Airport to Liverpool corridor (M5) | W/B | 6,800 | $142,000 |
| 5. | Liverpool to Mittagong corridor (M31) | S/B | 5,400 | $129,000 |
| 6. | Ryde west to Sutherland west corridor (A6) | S/B | 5,400 | $124,000 |
| 7. | North Sydney to Northern Beaches corridor (A8) | N/B | 5,200 | $104,000 |
| 8. | Westmead to Eastern Creek corridor (M4) | W/B | 5,000 | $114,000 |
| 9. | Mona Vale to Sydney Olympic Park corridor (A3) | S/B | 4,800 | $100,000 |
| 10. | Eastern Distributor / Sydney Harbour Bridge / Warringah Freeway / Gore Hill Freeway corridor (M1) | N/B | 4,300 | $98,000 |

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

Source: Veitch Lister Consulting (2019)[56]

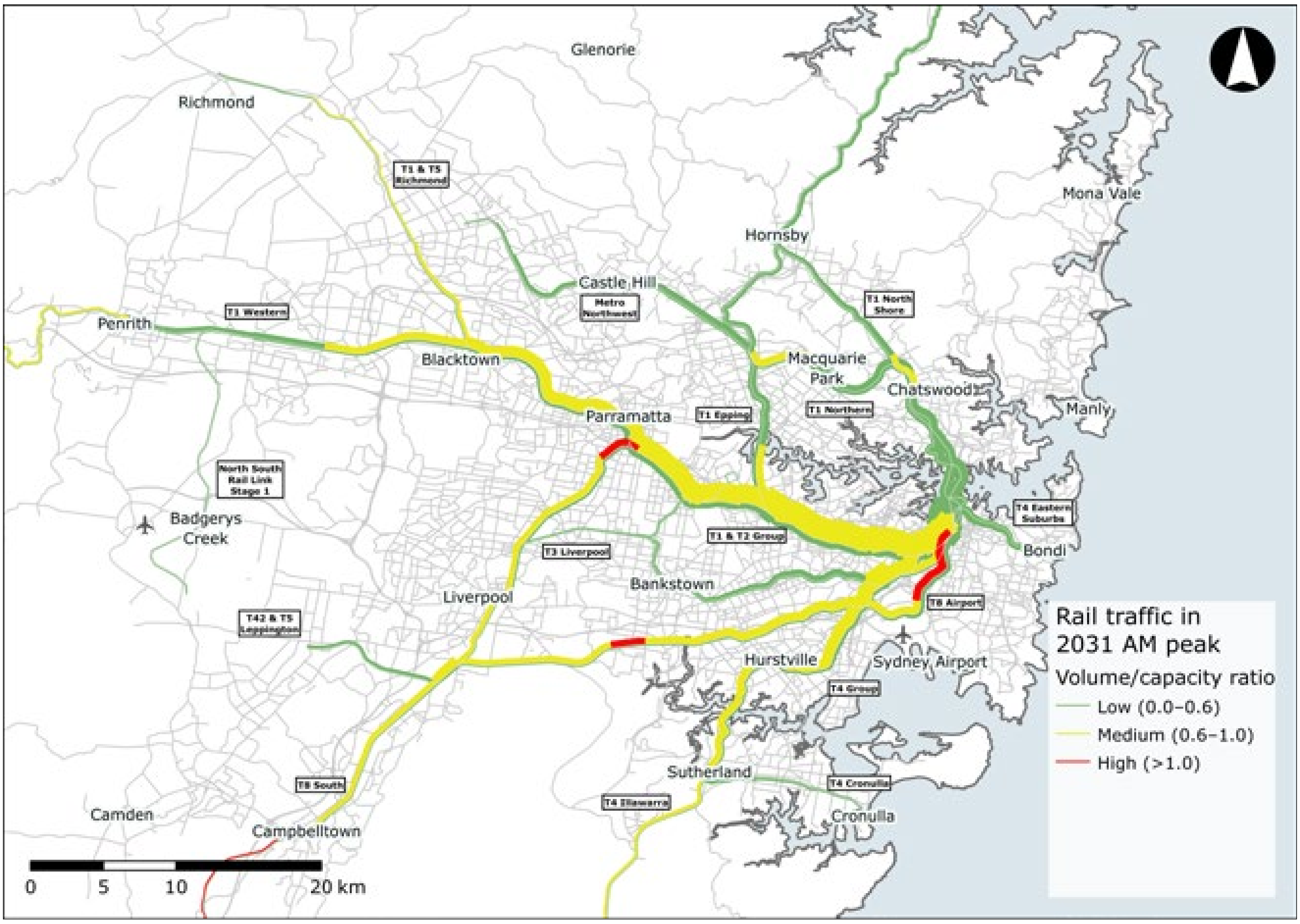
**Figure 14:** Sydney's most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak periods




Note: The Mittagong to Liverpool corridor (5th most congested corridor in both AM and PM peak periods) is located beyond the map extent, towards the south west.

Source: Veitch Lister Consulting (2019)[57]

**Figure 15:** Sydney weekday train passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[58]

Many Sydney bus services are projected to be significantly more crowded in 2031 (Figure 16). Customers travelling on the Northern Beaches corridor are expected to experience congestion and crowding. While urban growth along this corridor is forecast to be low relative to other parts of Sydney to 2031, public transport passengers will continue to have to travel by bus to Chatswood or North Sydney to access train services.

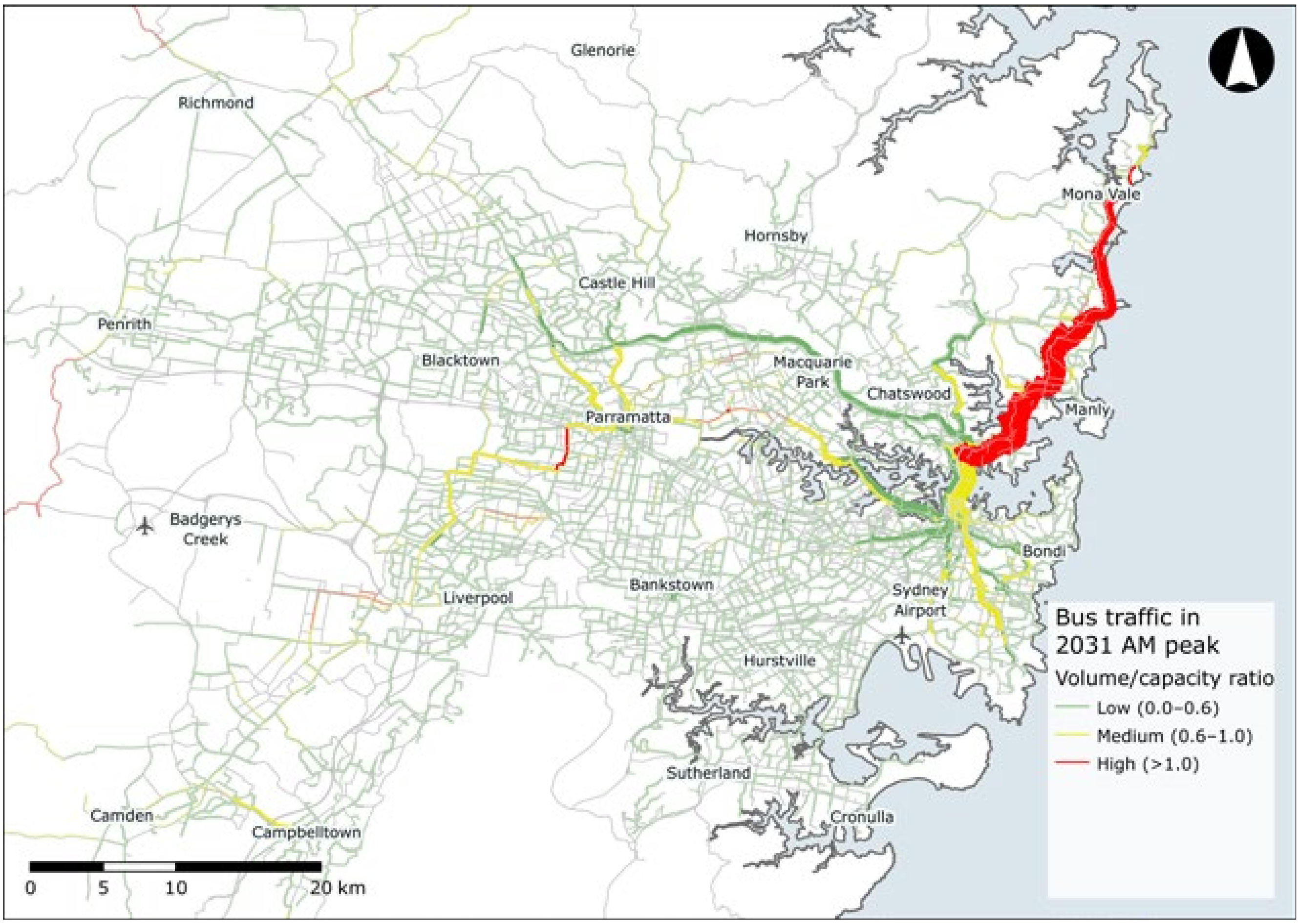
These factors will continue to desire dependence on road-based transport along the full length of the Military, Spit and Pittwater Roads corridor. The provision of bus priority lanes on this corridor is forecast to shift demand to bus services from the use of congested general traffic lanes. In 2031 this demand will, as today, converge with less intensively used M2 Busway services at the northern entry to the Sydney CBD. As a result, services using the Northern Beaches bus corridor are forecast to be operating well in excess of crush capacity all the way from Dee Why to North Sydney in 2031.

In addition, the Liverpool-Parramatta T-Way, and services running along the Victoria Road corridor (where bus priority is assumed to be upgraded) parallel to the T1 Western line, will attract demand in excess of seated capacity. Bus priority measures on these routes mean that they are forecast to offer proportionately faster travel, relative to worsening conditions for driving, in 2031 than they do today. This is forecast to increase demand for travel on these routes, potentially leading to overcrowding and flow-on operating inefficiencies.

By 2031, most bus routes currently operating along the Anzac Parade corridor will have changed to services feeding a higher-capacity light rail system. This is also expected to be the operating model for many bus services connecting to Parramatta Light Rail stops. One exception will be due to ongoing high population growth in the Hills District, which is forecast to increase the use of Old Windsor Road (T-way) and Windsor Road bus services accessing Parramatta.

In contrast to roads around Western Sydney (Nancy-Bird Walton) Airport-Aerotropolis, the first stage of a Western Sydney Airport rail line, between St Mary's and the new airport, is forecast to be operating well under capacity by 2031. This will be a function of the decision to invest in this connection ahead of, and to shape, Aerotropolis land use and transport demand. The importance of this type of integrated land use and transport planning in shaping future travel patterns is explored further in Sydney's Growth Centres.

**Figure 16:** Sydney weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[59]

## Findings:

- The 2019 Audit forecasts that the annualised cost of road congestion for Sydney, the Hunter and Illawarra will grow from approximately $8.0 billion in 2016 to $15.7 billion in 2031. This is 6% higher than the 2031 forecast cost of road congestion in the 2015 Audit.
- Congestion is expected to grow by the greatest amount for the weekday inter peak, business hours period (9am to 4pm).
- Despite major projects expanding the capacity of Sydney's road network, modelling shows widespread peak congestion in 2031.
- Except in the vicinity of NorthConnex (near Pennant Hills, Beecroft, Thornleigh and Wahroonga) and WestConnex links (near Annandale, Leichardt, Enmore, Newtown, Erskineville and Haberfield), nearly the continuous length of the M5, M4 and M2 motorways are forecast to have insufficient capacity in peak periods, as far west as Campbelltown, Penrith and Seven Hills. Non-motorway arterial roads in areas of northern Sydney will also be congested.
- Key north-south corridors, including the M7, A3 and all Sydney Harbour crossings, are forecast to have very significant congestion in 2031.
- Inter-city routes, particularly links connecting Sydney to the Central Coast and Illawarra regions, will be heavily congested by 2031.
- Train services are expected to get more crowded on western and south-western lines radiating from the Sydney CBD as far as St Marys, Campbelltown and Waterfall. In northern Sydney crowding will be somewhat mitigated by the addition of Sydney Metro Northwest services.
- The only groups of Sydney's train passengers forecast to experience travel in crush conditions are those using services south of Granville (affecting travel between Campbelltown, Liverpool and Parramatta) and on two sections of the T8 Airport Line (which will connect the Greater Macarthur growth corridor and Sydney Airport to central Sydney).
- High levels of bus crowding are forecast for passengers using services on the Northern Beaches peninsula, peaking on the Lower North Shore just north of the Sydney Harbour Bridge and Tunnel gateways to the CBD. Crowding is also expected to increase for passengers using services on Victoria Road and on routes connecting Greater Parramatta to its south-west (the Liverpool-Parramatta T-way) and to Macquarie Park.

## Sydney's growth centres: how integrated land use and transport actions are critical to shaping future travel patterns

Sydney's north-west and south-west growth centres are instructive case studies on how integrated transport and land-use planning is critical in shaping travel demand, particularly in new release areas. While demographically and geographically similar, these two areas have been differently served in transport terms during the first five to 10 years of their respective urban development lifecycles.

Greenfields development areas in the North West Sector were serviced from the time of their release by buses which provided relatively reliable and direct same-seat access to the Sydney CBD and Global Arc via the M2 Busway. The Global Arc is an economic corridor stretching from Macquarie Park to Port Botany through Chatswood, St Leonards, North Sydney, the Sydney CBD and Sydney Airport. The northern precincts in the North West Sector (including Rouse Hill) developed with additional access to the North West T-way, which provided similarly competitive travel times to Parramatta and Blacktown.

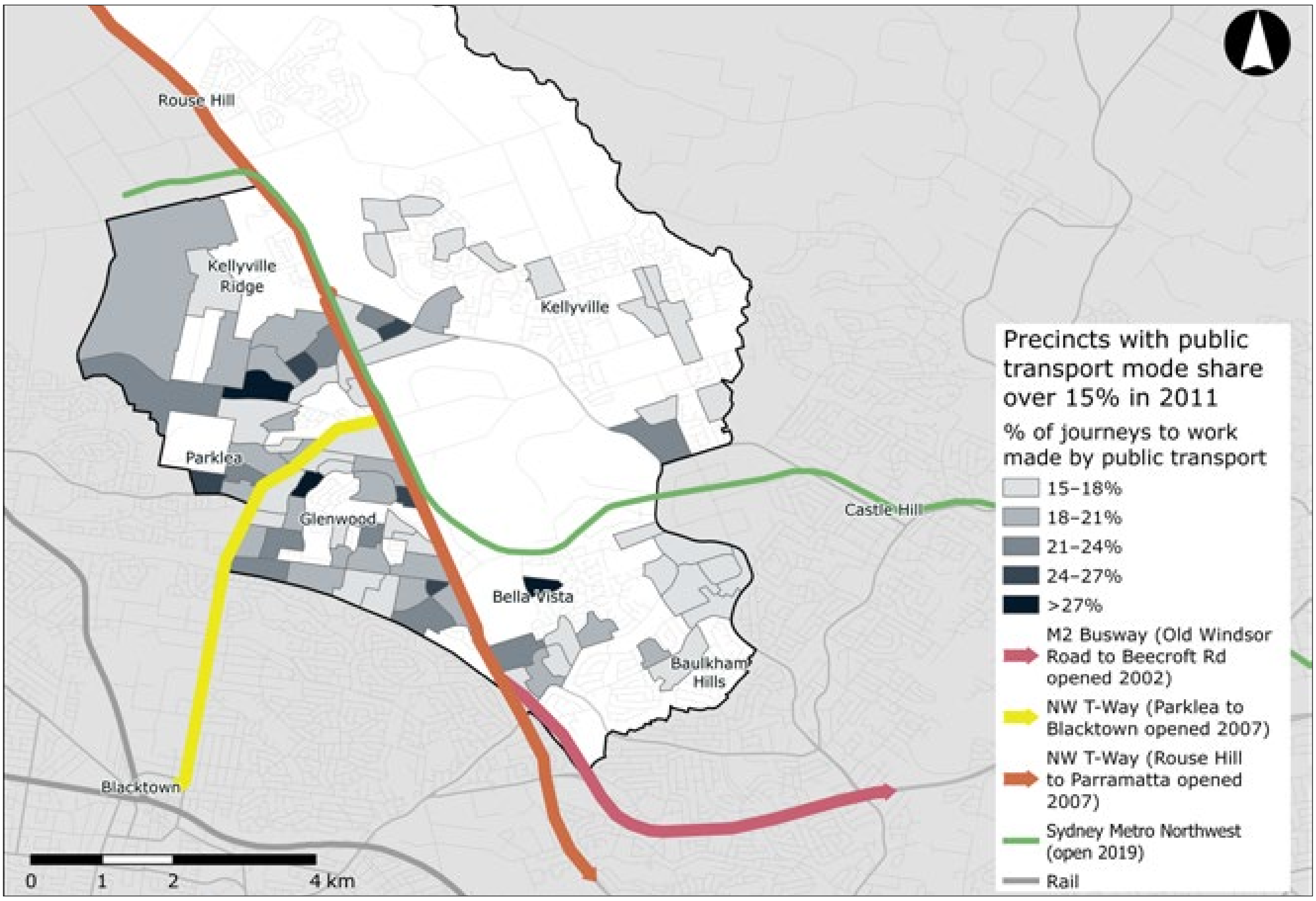
Figure 17 shows public transport journey-to-work mode share for the North West Sector eight years ago, in 2011. Even without direct rail access, the area's rapid bus links had by that year already facilitated its relatively dense development and healthy public transport mode share.

Given forecast ongoing growth in North West Sector population and Global Arc job numbers, it has become necessary to supplement the function of the M2 Busway as the area's primary transit link to the Sydney CBD. The Sydney Metro Northwest opened in May 2019, providing this function for suburbs west of Cherrybrook.

Outcomes in the South West Growth Area, at a somewhat similar stage in its greenfields development lifecycle in 2016 to the north-west five years earlier, contrast markedly with the North West Sector (Figure 17 and Figure 18). This growth area, unlike the North West Sector, was in that year relying on local buses operating in mixed traffic for access to major centres and train services at Campbelltown-Macarthur and Leppington. Only scattered pockets of urban development were generating a 15% public transport mode share.

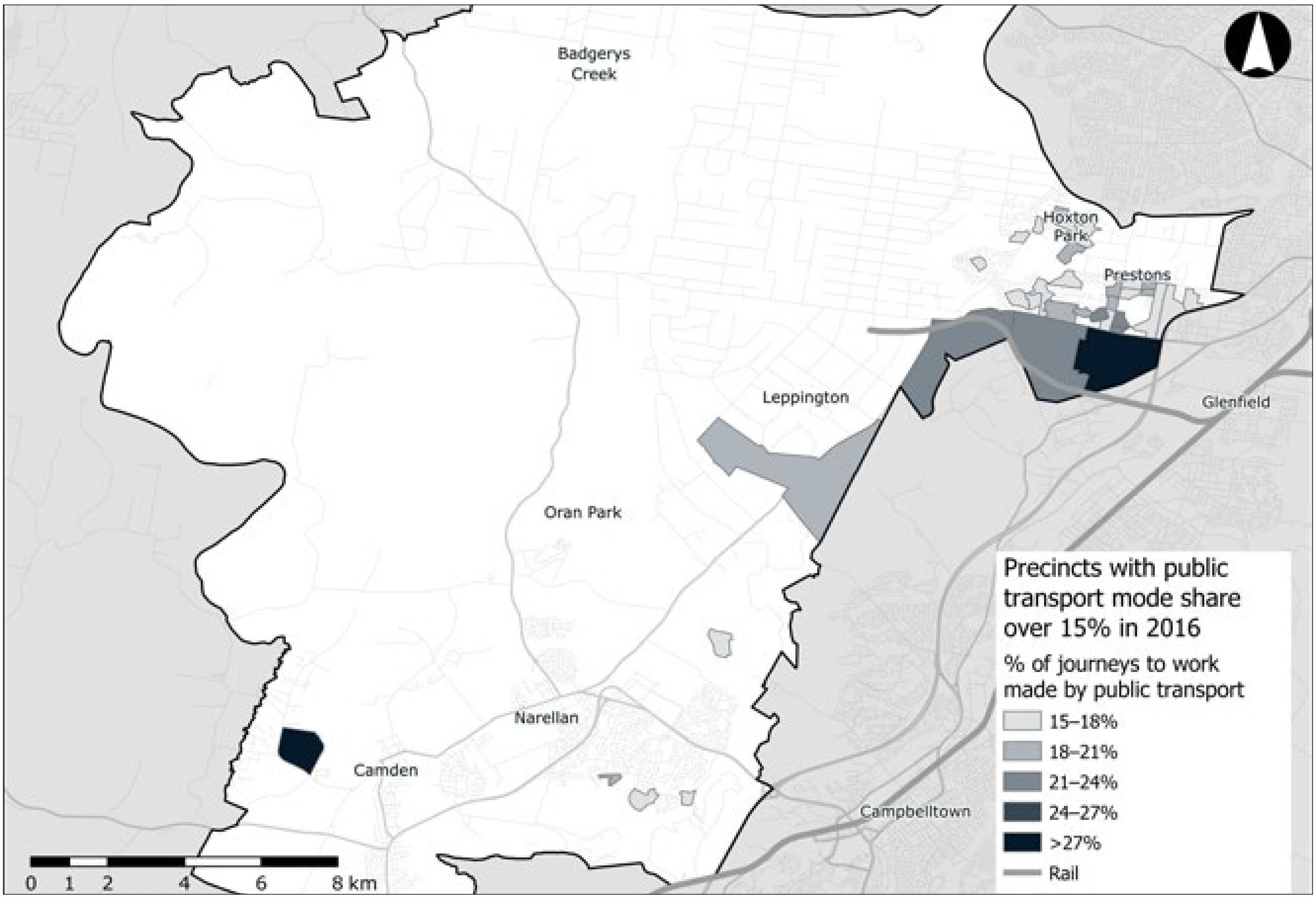
The evidence points towards a significantly greater dependence on driving for commuting and other trip purposes in the south west than the north west areas analysed.

**Figure 17:** Even without direct rail access, public transport mode share is high in the North West Sector




Source: Australian Bureau of Statistics (2011)[60]

**Figure 18:** Unlike the North West Sector, the South West Growth Area has very low public transport mode share




Source: Australian Bureau of Statistics (2016)[61]

## 5.5 Population growth is forecast to result in increased Hunter Region congestion

### Transport network outcomes for Newcastle and its region, today and in 15 years

The population of Newcastle city is forecast to increase by 33,000, or 20%, between 2016 and 2031. There will also be significant growth in surrounding Hunter Region areas, including Maitland (27%) and Port Stephens (24%).

Extra people living, working and visiting the Hunter Region will translate into demand pressures on the region's transport network. Notwithstanding the expected gradual emergence of a stronger public transport culture in Newcastle, increased congestion costs will be experienced across the Hunter Region as a whole. Between 2016 and 2031 the average weekday cost to the region of road congestion is forecast to grow from $3.5 million to $6.6 million, with a minor increase in costs associated with public transport crowding.

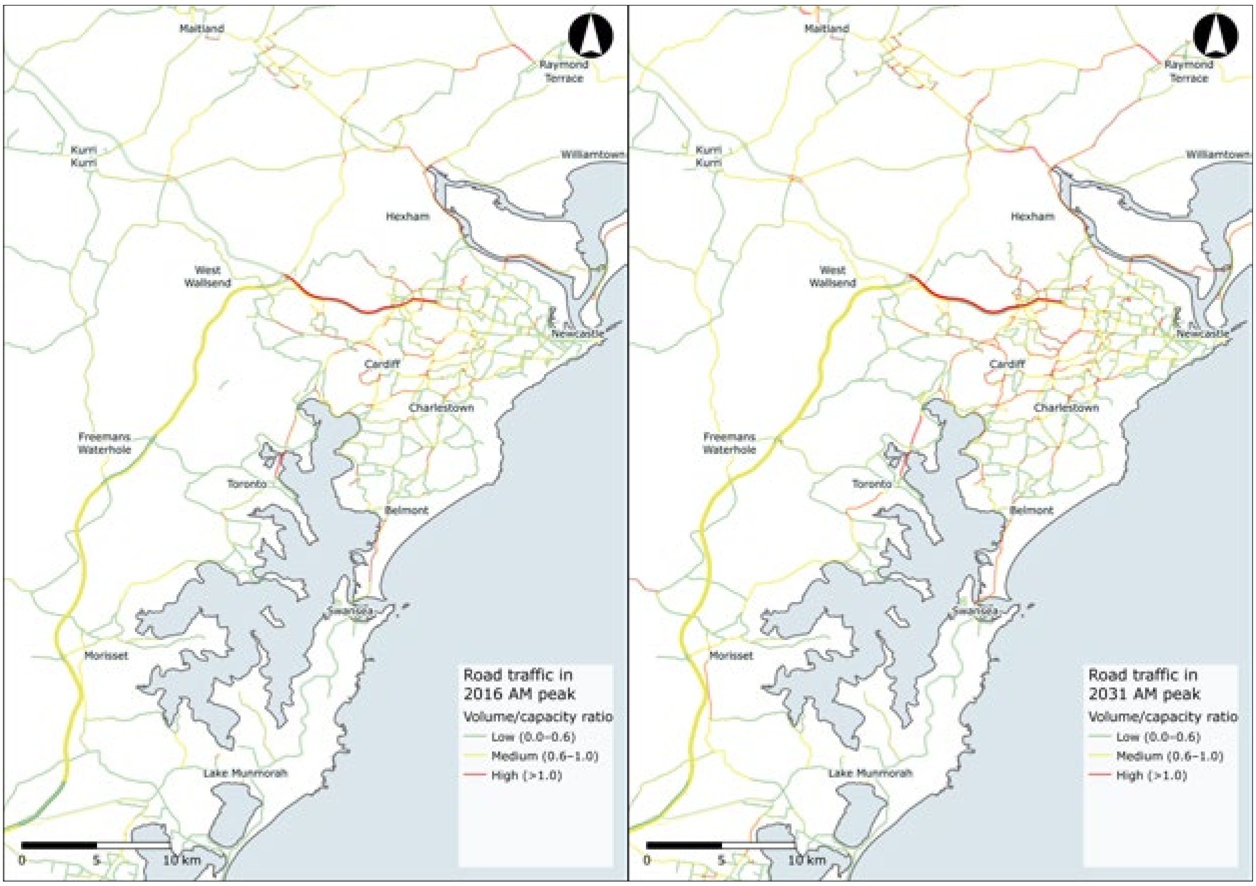
Road congestion is expected to especially affect major connections between central Newcastle and its surrounding region, including the New England Highway (A43 from Maitland), the Pacific Highway (from Swansea) and the Newcastle Link Road (Figure 19).

This congestion will affect access to Newcastle Airport at Williamtown. Closer to Newcastle CBD, delays are forecast on routes to the university and to the Charlestown strategic centre, and further south between Swansea and Belmont along the narrow coastal corridor, acting as a bottleneck for traffic between Lake Macquarie and Newcastle.

While car trips are expected to increase by 20%, public transport travel is forecast to grow (from its current low base) by 43%, on the back of projects including Newcastle Light Rail, and customer-oriented improvements to bus and ferry services under the Transport for Newcastle operating model. Population growth is forecast to result in bus service crowding on routes accessing Raymond Terrace from the east, along the Williamtown–Stockton–University of Newcastle corridor, and at the Charlestown southern gateway into Newcastle CBD (Figure 20).

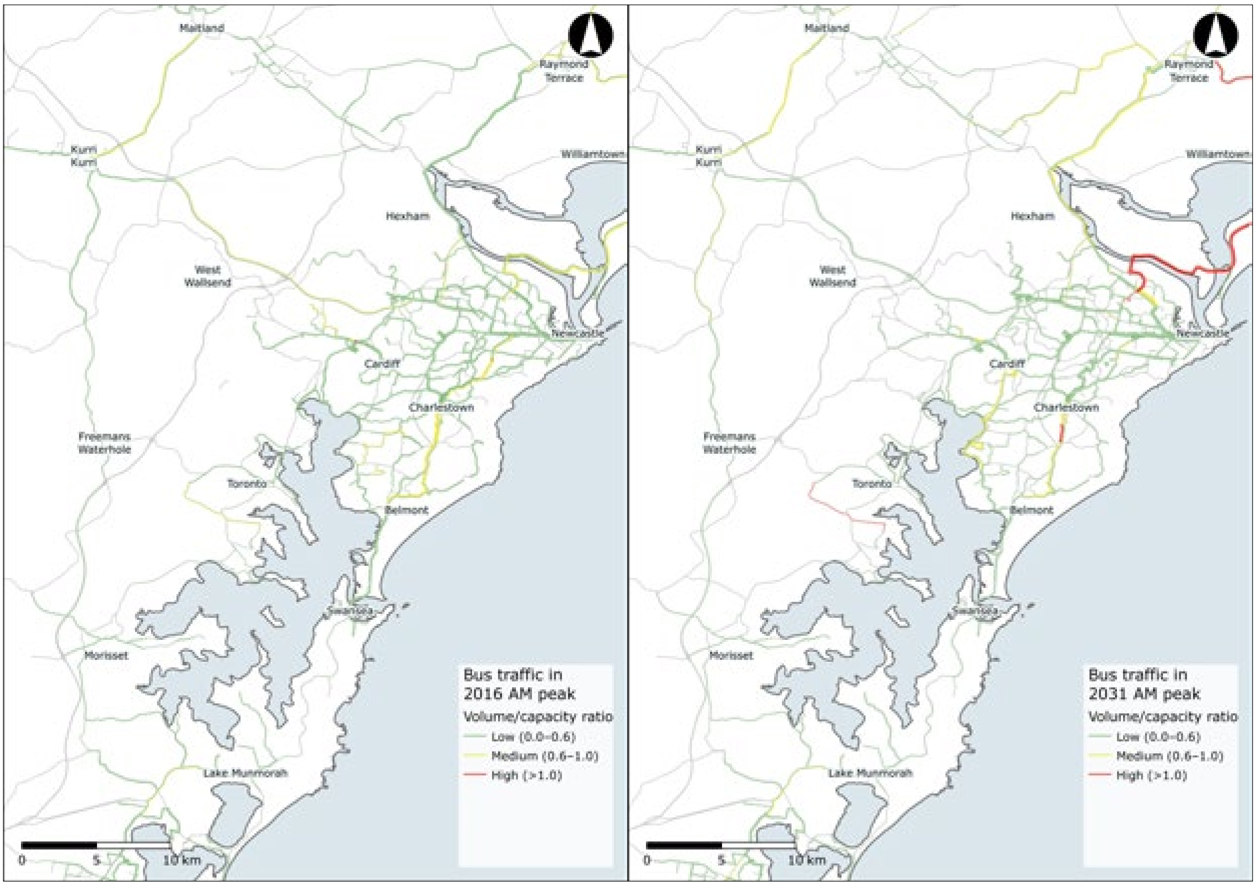
In contrast, modest growth in the patronage of Hunter Region train services is modelled as leading to minor crowding only on the Hunter Line west of Newcastle to Singleton (Figure 21).

**Figure 19:** Hunter Region weekday traffic volume / capacity ratio, 2016 and 2031 AM peak



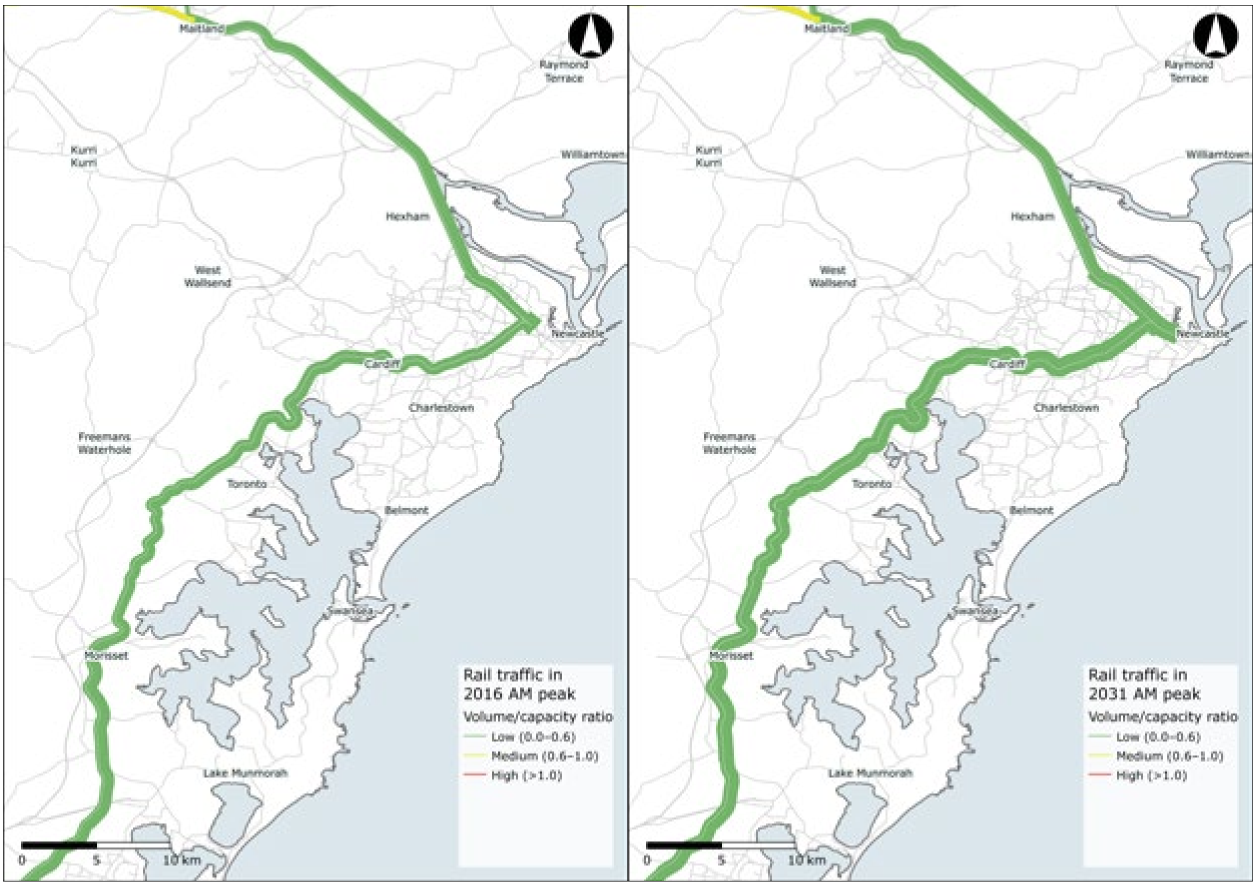

Source: Veitch Lister Consulting (2019)[62]

**Figure 20:** Hunter Region bus passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[63]

**Figure 21:** Hunter Region train passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[64]

## Findings

- There will be increased traffic congestion into Newcastle from the north (Raymond Terrace), north-west (Maitland), west (Wallsend) and south (Lake Macquarie) potentially undermining the competitive lifestyle and affordability advantage enjoyed by the city and the Hunter Region in comparison to Sydney.
- Congestion on the New England Highway corridor will impact the productivity of the Newcastle Port and associated industrial and commercial precincts.
- There will be some crowding of bus services that are concentrated onto a single crossing of the Hunter River connecting the University of Newcastle to the north-east.

## 5.6 The Illawarra Region's geography will constrain its connectivity to Sydney and exacerbate local congestion

### Transport network outcomes for Wollongong and its region, today and in 15 years

Given the limits placed on the expansion of a city located between escarpment and ocean, Wollongong is forecast to see relatively low population growth of about 11,000 people (8%) by 2031. Growth is expected to be somewhat higher in adjacent areas including Dapto-Port Kembla (19%) and Kiama-Shellharbour (21%). Over the Greater Sydney border, significant growth is forecast in the Greater Macarthur land release precincts in Wollondilly (30%).

There is expected to be increased demand for the region's transport network. Car trips are forecast to increase by 19%, and public transport by 30%. Between 2016 and 2031 the average weekday cost to the Illawarra Region of road congestion is forecast to grow from $500,000 to $1.1 million, with a minor further increase in costs associated with public transport crowding.

Key access routes into Wollongong from inner northern suburbs such as Fairy Meadow and Corrimal, as well as southern areas like Dapto and Albion Park, will be affected by congestion (Figure 22). As previously shown in Table 14, road delays will increasingly be experienced by users of the Princes Highway, which connects the Illawarra north to Sydney via the Sutherland Shire and south to Dapto and Kiama. Windang Road south of Port Kembla will also suffer increased congestion.

To the north-west of the Illawarra Region, Greater Macarthur corridor growth will increase traffic using the critical Appin and Picton road links that connect the Illawarra to south-western Sydney – and to the growing economic opportunities presented by the Western Sydney (Nancy-Bird Walton) Airport-Aerotropolis. The congestion of this M31 corridor, already demonstrated at an aggregate level in Table 14, will lead to longer travel times for people commuting between the Illawarra and Sydney centres including Campbelltown-Macarthur and Liverpool. The Illawarra Region would therefore find itself relatively isolated from the benefits of business investment and employment growth around Sydney's second airport.

Greater Macarthur growth will also generate its own demand for public transport travel to the north. Modelling shows this being focused on the Southern Highlands Line, resulting in the crush loading of the relatively low-frequency diesel train services that currently connect to Sydney Trains services at Macarthur. As shown in Figure 23, and previously in Figure 15, the more frequent rail connection between the Illawarra and Sydney – via Waterfall – will also be crowded in 2031.

For bus passengers, longer-distance services to south-western Sydney via Appin and Picton roads will become more crowded (Figure 24) as a result of the congestion affecting the only two connections across the escarpment between Wollongong and Greater Macarthur.

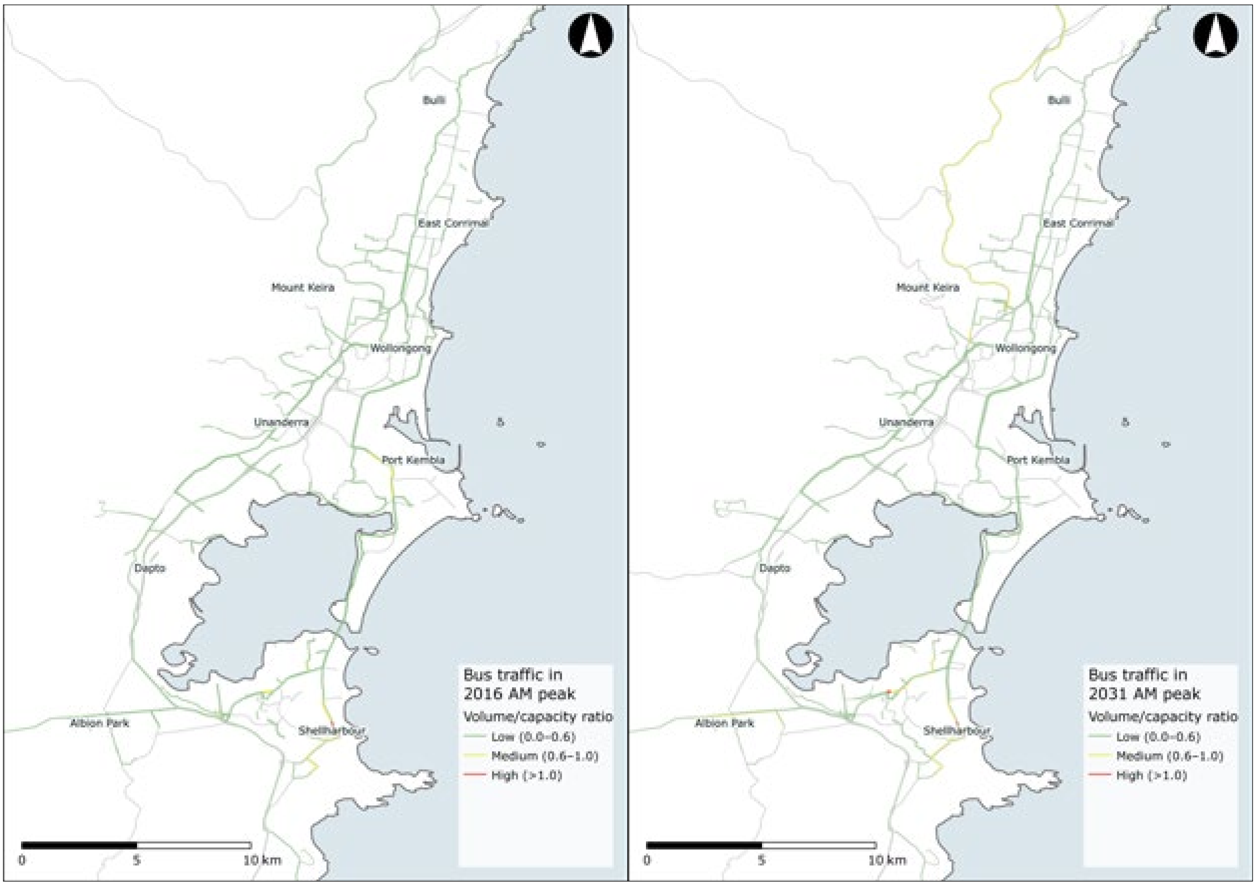
**Figure 22:** Illawarra Region weekday traffic volume / capacity ratio, 2016 and 2031 AM peak


Source: Veitch Lister Consulting (2019)[65]

**Figure 23:** Illawarra Region train passenger volume / capacity ratio, 2016 and 2031 AM peak


Source: Veitch Lister Consulting (2019)[66]

**Figure 24:** Illawarra Region bus passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[67]

## Findings

- The Ilawarra's unique geography constrains access to south-western Sydney via only two links across the escarpment (Appin Road and Picton Road) and along the coastal strip to southern Sydney via the Princes Highway.
- Greater Macarthur growth-related congestion of the Appin and Picton road bottlenecks will delay general traffic and longer-distance bus services between Wollongong, Campbelltown-Macarthur and the WSA-Aerotropolis.
- Freight access will compete with passenger movements for access to road and rail links between Port Kembla and Sydney.

## 5.7 Transport decisions impact access to jobs and services

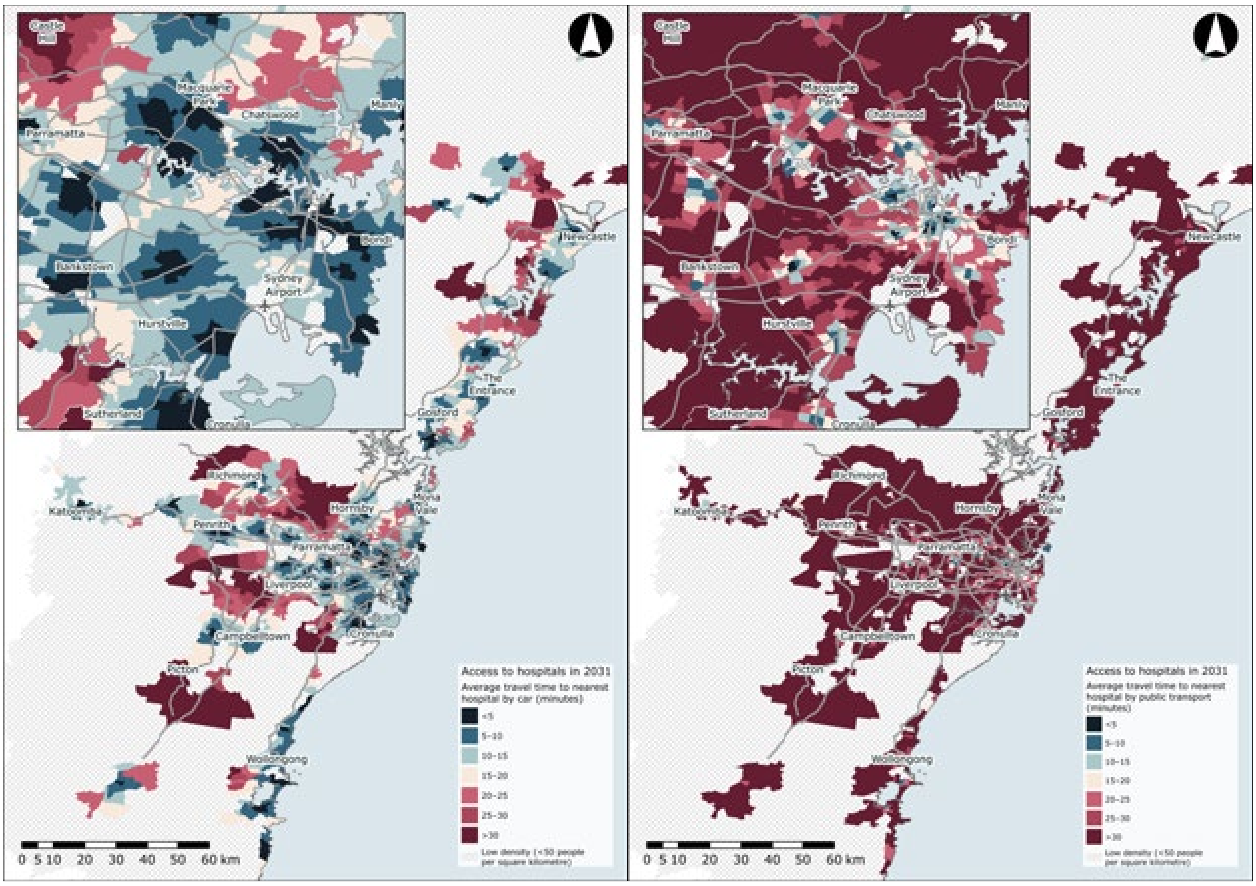
### Hospital access in Sydney, the Hunter, the Central Coast and Wollongong – by car and public transport, in 2031

Greater Sydney and Hunter Region residents' access to critical healthcare is measured as the travel time to their nearest public hospital, or hospital with an emergency department, by car versus public transport (Figure 25).

As can be seen, car accessibility to hospitals is universally superior to that available by public transport. For the modelled areas, the shortest average travel time to the nearest hospital via public transport is just over 20 minutes, for residents in Sydney Inner City, with most other residents needing to travel for more than 30 minutes.

The higher access time to one's nearest hospital by public transport may not be of significant concern to passengers able to drive to an outpatient appointment or to visit a sick family member. However, this can be problematic given the status of hospitals as major regional employers, attracting substantial daily commute flows that may warrant public transport services.

**Figure 25:** Greater Sydney average time to nearest hospital by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[68]

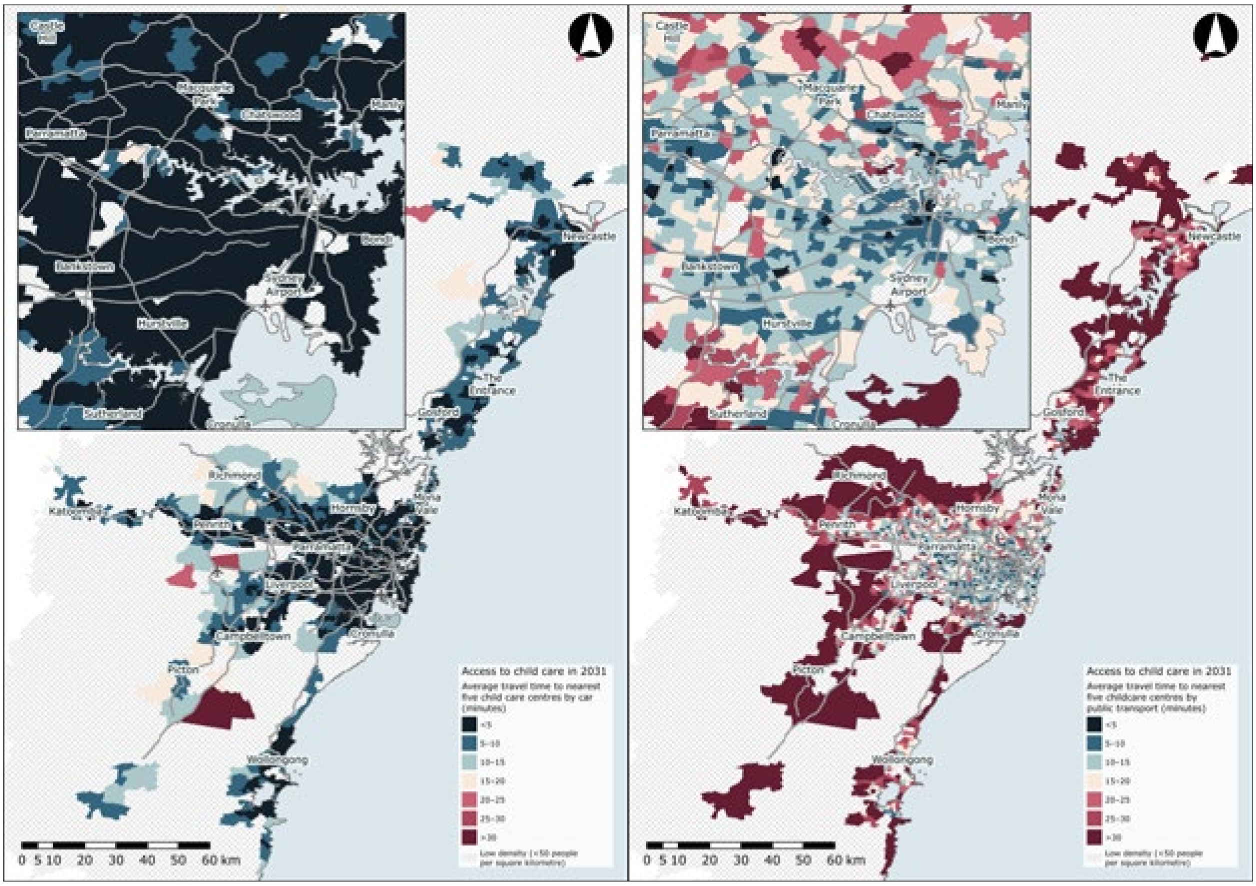
## Access to childcare and schools in Sydney, the Hunter, Central Coast and Wollongong – by car and public transport, in 2031

The modelling indicates that for the Greater Sydney or Hunter Region resident with access to a car, childcare choices and public primary and secondary schools are, on average, accessible within six minutes in 2016, and that this will increase to just seven minutes in 2031 (Figure 26, Figure 27 and Figure 28).

For people using public or active transport by choice or necessity, travel times are much longer, generally approaching 30 minutes for all these social infrastructure destinations in 2016 – and in 2031, even accounting for a modest improvement in average public transport travel times. In the case of childcare centres, best practice integrated land use and transport planning co-locates these with transport interchanges, to facilitate carer drop-off and pick-up being combined with the commuting trip.

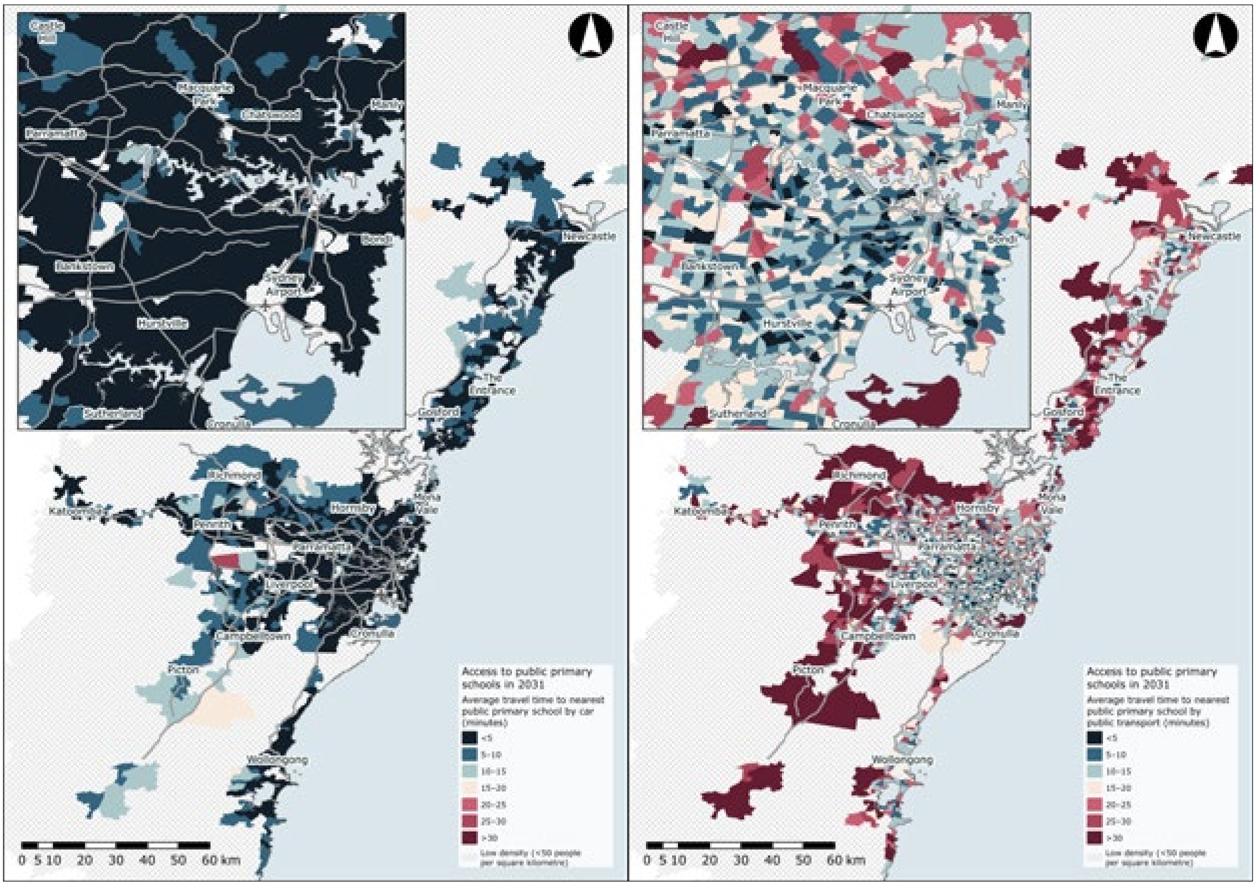
While noting the lower accuracy of this modelling for low-density areas, there is a risk that people who are the most disadvantaged in terms of their access to these three types of social infrastructure live (or will live) in rural residential and future new release areas on the edge of Greater Sydney. These include areas in LGAs such as Hawkesbury, Liverpool / Fairfield (west), the Blue Mountains (south), Wollondilly and Gosford. The supply of both transport and social infrastructure will need to keep pace with significant population growth in designated growth areas to mitigate this risk.

**Figure 26:** Greater Sydney average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



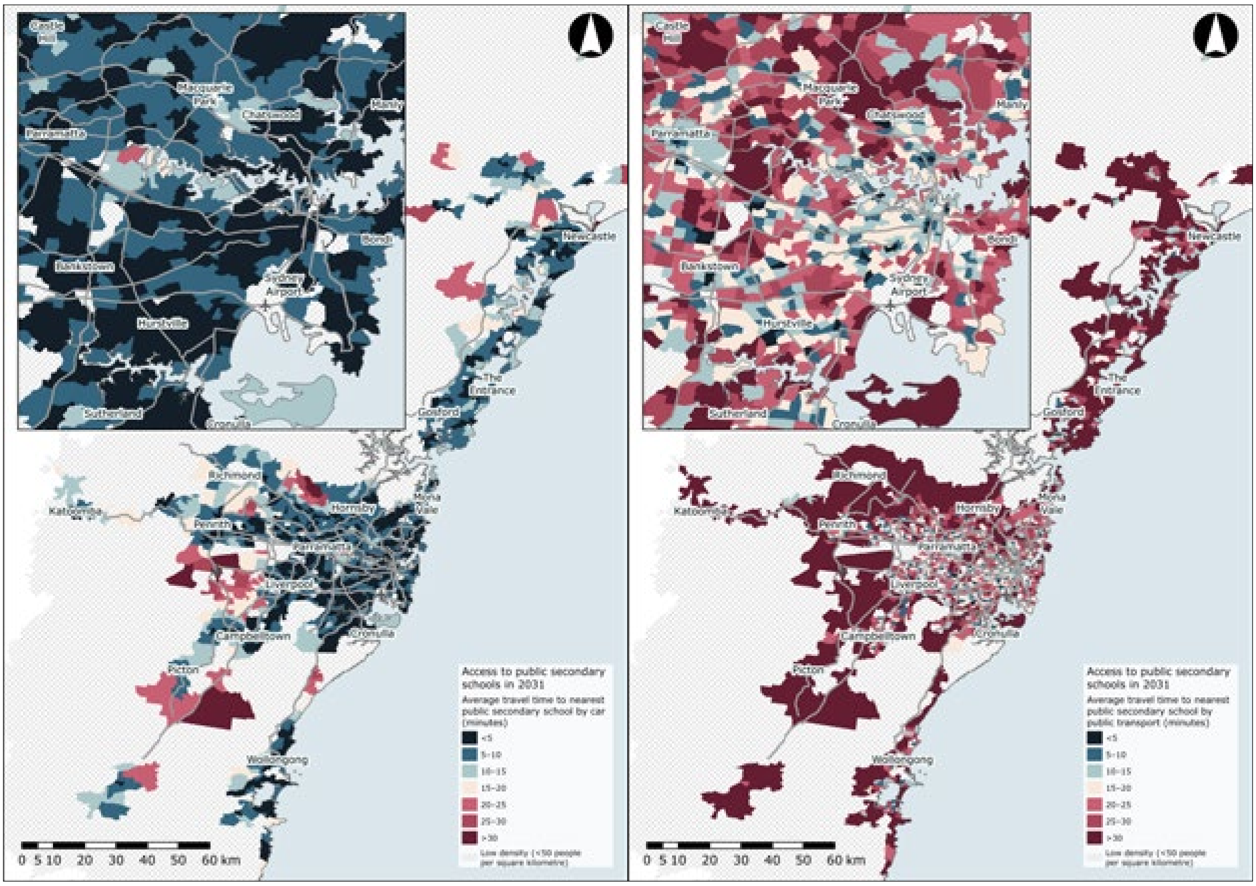

Source: Veitch Lister Consulting (2019)[69]

**Figure 27:** Greater Sydney average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[70]

**Figure 28:** Greater Sydney average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[71]

## Access to jobs in Sydney, the Central Coast and Wollongong – by car and public transport, in 2016 and 2031

Employment accessibility has been measured as the percentage of jobs in each of three self-contained areas (Greater Sydney including the Central Coast, the Illawarra, and the Hunter Region) that can be reached within 30 minutes, from homes in every travel zone, by car (Figure 29) and by public transport (Figure 30) in the two modelled years.

Travel time to work is generally accepted to be longer than for childcare, education and hospital access. The high current and future concentration of jobs within the eastern Greater Sydney Global Arc, especially in the Sydney and North Sydney CBDs, mean that people living in these areas will continue to have good access to employment because of existing transport infrastructure and services in this region.

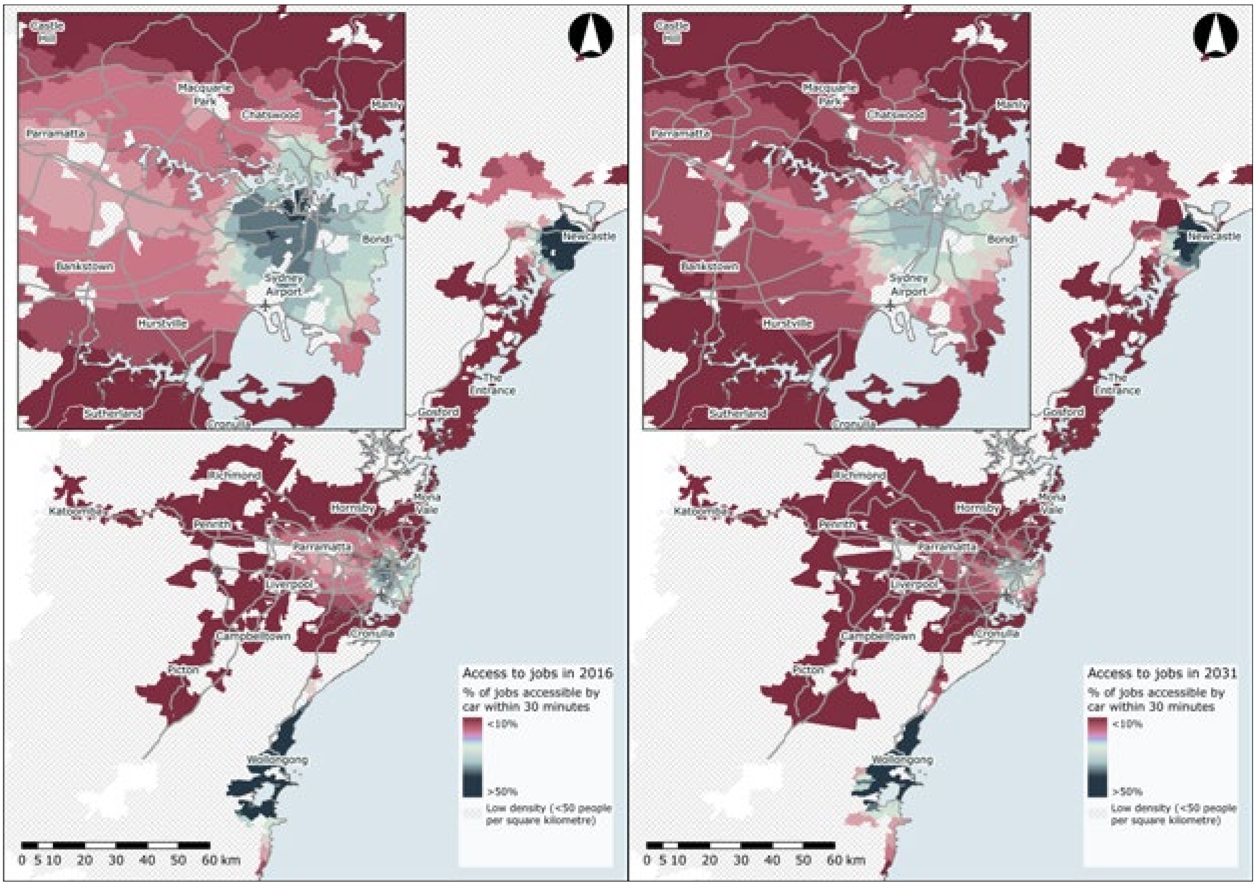
Job accessibility is greater in the smaller regions (the Illawarra and the Hunter) than for Sydney. This does not mean that people in the smaller regions have access to a greater number of jobs, it simply means they have access to a higher percentage of the total jobs in their region.

Job accessibility by car is forecast to generally reduce in the future as a result of road network congestion and dispersed residential development.

Job accessibility by public transport is modelled as relatively stable between 2016 and 2031, with most Greater Sydney residents still not having the choice available to them of reaching their work within a 30-minute train, bus or other transit trip. In both years, the areas with the best public transport job accessibility are Sydney Inner City and North Sydney-Mosman.

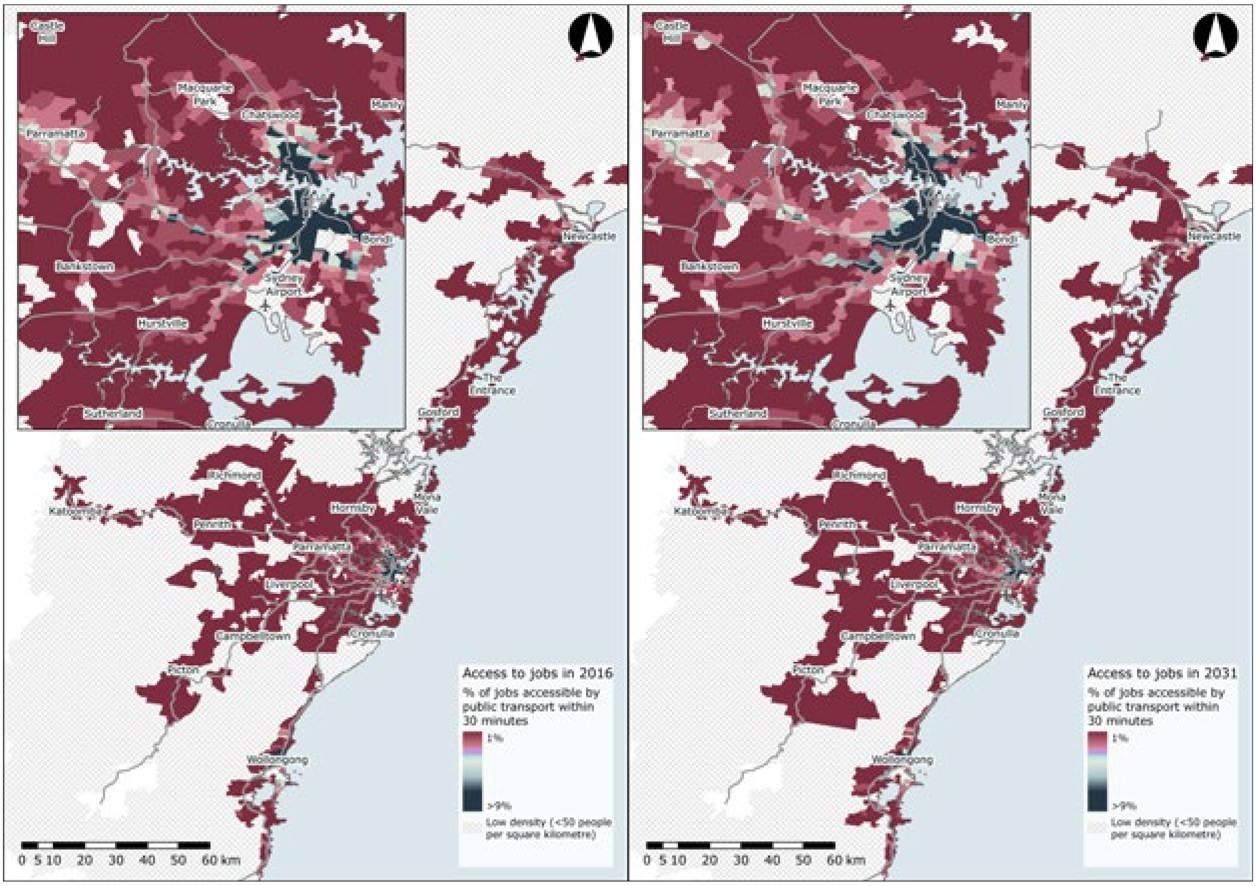
Job accessibility is forecast to be poor for people living in Bringelly-Green Valley, Liverpool, Fairfield and Blacktown due to a mismatch between growth in housing and local employment. Public transport infrastructure assumed for 2031 network performance modelling will not be enough to offer attractive connections to job opportunities across a broader region. Transport disadvantage will therefore persist in these areas.

**Figure 29:** Greater Sydney access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[72]

**Figure 30:** Greater Sydney access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[73]

## Findings

- There is a greater reliance on car use to reach daily needs in newer areas, compared to older areas which have developed with access to rail and other high-frequency public transport services.
- There will be a persistent jobs imbalance in Greater Sydney's outer and newer suburbs, with the largest growth in areas at risk of isolation from employment opportunities being forecast for south-western Sydney.

6

# Melbourne and Geelong

## 6.1 Melbourne has grown, and so has the time and effort it takes to get to the city and to move around

### Melbourne's transport network performance over the past decade

Melbourne is Australia's second largest population centre. Between 2006 and 2016 Melbourne's population increased from approximately 3.6 million to just under 4.5 million. Melbourne's population is skewed towards its south-east, with the city's south-eastern suburbs extending much further than the western and northern suburbs.[74]

The number of people living in Melbourne, and the location of their homes and workplaces, are the key drivers of the pattern and size of the transport task in the city. Over the past decade the distance travelled by people on Melbourne's roads has increased by 9%. Furthermore, the percentage of people using public transport to travel to work in Melbourne has increased from 16% in 2011 to 18% in 2016.[75]

## 6.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit inputs and assumptions

Since the 2015 Audit, Melbourne and Geelong's forecast cost of road congestion has increased by 15% (Table 15 and Figure 31). This is largely the result of increased vehicle kilometres travelled due to better roads and lower fuel prices.

The 2031 population forecast used the 2019 Audit expects 4% more people to live in Melbourne and Geelong than the forecast used in the 2015 Audit. Population is also distributed slightly differently. Forecast population is higher in most areas. The 2019 Audit predicts that Geelong will have 12,000 more residents by 2031. Compared to the last audit, the number of people living in inner areas is assumed to be higher such as Port Phillip, Melbourne City, Maribyrnong, Yarra and Port Phillip.

**Table 15:** The cost of road congestion and public transport crowding in Melbourne and Geelong, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| 2016 (2019 Audit) | 75 | 5,485 | 5,560 |
| 2031 (2019 Audit) | 352 | 10,379 | 10,731 |
| 2031 (2015 Audit) | N/A | 9,006 | N/A |
| 2031 (change from 2015 Audit) | | 1,373 (+15%) | |

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[76]

Outer areas, such as Casey are also expected to have higher populations. Tullamarine, Broadmeadows, Melton and Bacchus Marsh are too, although this is partially offset by a substantial decrease in Sunbury. A limited number of areas are forecast to have slightly smaller populations than in the 2015 Audit.

Table 16 reflects changes in model inputs and key outputs between the 2015 and 2019 Audit modelling.

### A note on Melbourne's demographic projections

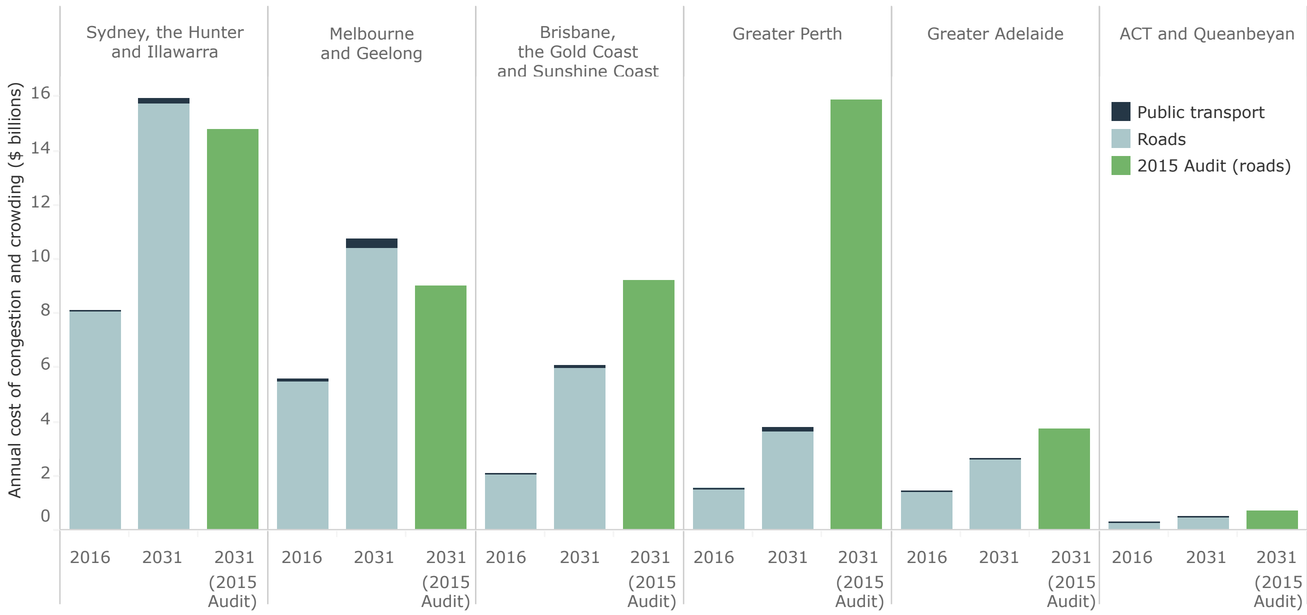
The Audit's transport modelling for Melbourne has largely relied on population and employment projections from the Victorian Government's *Victoria in Future 2016* report.[77]

Some projections for areas outside the Melbourne metropolitan area, which fed into regional rail forecasts, are similar, but not exactly the same as projections from *Victoria in the Future 2016*.

In addition, the 2016 ABS Census revealed that in that year, Victoria's population was 120,000 people higher than the estimate in *Victoria in the Future 2016*.

As a consequence it should be noted that the transport modelling that has informed this section could underestimate the number of trips on Melbourne's road and public transport networks in both the 2016 base and the 2031 forecast years.

**Figure 31:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[78]

**Table 16:** Changes in key model inputs and outputs between 2015 and 2019 modelling in Melbourne and Geelong

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | ⇧ Population forecasts have increased slightly (+4%) | ⇧ Employment forecasts have increased slightly (+4%), however the proportion of jobs in Melbourne City SA3 remains stable | ⇧ More investment in the road network (+9% network lane km) | ⇧ More investment in the PT network* *While service kilometres are 14% lower compared to the 2015 Audit, this is purely due to more conservative bus service assumptions. Rail service kms increase by +15% and Tram by +17% | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | — Tolls grown at CPI. New toll roads with similar costs |
| Impact on output (AM peak) | Total trips (no change) | — Slight increase in total population does not substantially change total modelled trips | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| | Car trips (+4%) | — Slight increase in total population does not substantially change the number of card trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | — Negligible impact |
| | Car vehicle kms travelled (+20%) | — Slight increase in total population does not substantially affect car vehicle kms | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | — Negligible impact |
| | Public transport trips (+1%) | — Slight increase in total population does not substantially change number of PT trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | — Negligible impact |

Source: Veitch Lister Consulting (2019)[79]

## New network assumptions

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. For Melbourne, there are seven key differences in network assumptions. North East Link, Melbourne Metro, Melbourne Airport Rail Link, West Gate Tunnel/Monash Freeway upgrade, Mernda Rail extension, Citylink widening and Fishermans Bend Tram Extension are all included in the 2019 Audit, but not the 2015 Audit.

## Variation between road network capacities in 2031

Traffic volumes on Melbourne's major roads are not consistent between the 2015 and 2019 Audits. However, higher traffic volumes are forecast in the 2019 Audit as a result of population growth and an increase in vehicle kilometres travelled.

The largest increases in traffic are driven by upgrades on the Monash and Princes Freeways and Eastern Freeway Corridor to Ringwood. The widening of the Monash Freeway increases traffic volumes on this corridor and the delivery of the North East Link increases traffic on the Eastern Freeway during those works.

There are congestion decreases to sections of the M2 near the airport, but increases on the M2 nearer to the Melbourne CBD as a result of the widening of Citylink. Alongside this there are also congestion increases to sections of the M80 and the Nepean Highway.

Increased congestion is largely limited to arterial and local roads, which often corresponds to higher population growth. Arterial roads and local roads to the east of the CBD, including Hawthorn, Hawthorn East, Richmond, Toorak and Mount Waverley are forecast to have more congestion.

Higher vehicle delays are forecast on the key corridors in the 2019 Audit relative to those in the 2015 Audit. In percentage terms the increase in delay hours is larger than the corresponding change in traffic volumes. This is a function of the nature of traffic flow, where delays grow more rapidly with each additional vehicle added to an otherwise congested network. Table 17 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

## Variation between public transport capacities in 2031

The proportion of public transport trips forecast in this Audit are similar those forecast in the 2015 Audit. This is despite substantial additional investment in public transport infrastructure. New projects make both car and public transport travel more attractive. As a result, there is not a significant shift in the balance between car and public transport trips. Relative to the 2015 Audit, car vehicle kilometres travelled increases. This is mostly a function of the reduction in fuel cost.

In the 2019 Audit at AM peak, almost all train services reach a moderate volume of suburban rail passengers as they approach the CBD. Despite this, none of the lines reach crush capacity. The highest volume to capacity is on South East lines approaching the city, and eastern lines approaching the city. This is similar to levels of demand within the 2015 Audit.

**Table 17: Most congested roads ranked by total delay hours, 2031 AM Peak and ranking in 2015 Audit in Melbourne and Geelong**

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Princes Freeway / West Gate Freeway corridor | E/B | 5,600 | 6,100 | 8% | 11,500 | 16,800 | 47% | 1 |
| 2 | Princes Freeway / Monash Freeway corridor | W/B | 5,400 | 7,500 | 39% | 9,500 | 15,900 | 67% | 2 |
| 3 | Metropolitan Ring Road (western section) | S/B | 6,600 | 6,800 | 3% | 5,700 | 8,500 | 49% | 6 |
| 4 | Calder Freeway corridor | E/B | 4,000 | 4,700 | 18% | 6,400 | 8,200 | 28% | 4 |
| 5 | Princes Highway / Monash Freeway corridor | W/B | 2,500 | 2,800 | 13% | 5,100 | 7,500 | 46% | 7 |
| 6 | Metropolitan Ring Road (western section) | N/B | 6,500 | 6,400 | -2% | 4,400 | 7,000 | 58% | 8 |
| 7 | Western Freeway corridor | E/B | 3,500 | 3,200 | -10% | 6,600 | 5,700 | -13% | 3 |
| 8 | Hume Freeway corridor | S/B | 4,400 | 4,800 | 9% | 6,000 | 5,700 | -5% | 5 |
| 9 | Outer metropolitan ring corridor (Werribee–Sunbury–Wallan–Mernda) | S/B | - | 900 | - | - | 4,300 | - | - |
| 10 | Sydney Road corridor | W/B | 2,500 | 2,400 | -7% | 4,300 | 4,500 | 4% | 9 |

Note: N/B, S/B, W/B and E/B represent northbound, southbound, westbound and eastbound, respectively. The outer metropolitan ring corridor was not defined in the 2015 Audit.

Source: Veitch Lister Consulting (2019)[80]

## 6.3 Commuters in Melbourne experience high levels of road congestion and public transport crowding every day

### Snapshot of Melbourne's road network in 2016

As at 2016, Melbourne's drivers already experience high levels of congestion. Our modelling indicates the annualised cost of road congestion and public transport crowding in Melbourne and Geelong was approximately $5.5 billion in 2016, of which $5.4 billion was in Melbourne. This congestion is at its worst in the AM peak period, as demonstrated in Figure 32. However, Melbourne's major roads also experience similar levels of congestion in the PM peak period.

Melbourne's most congested roads are those that provide access to the inner city from the western and eastern suburbs, notably the Princes and Monash Freeways. Some key north-south routes also experience significant congestion during peak periods.

### Melbourne's most congested roads in 2016: what the driver experiences

Infrastructure Australia has highlighted the most congested roads in Melbourne based on a variety of metrics that relate directly to the users' experience, including estimating the percentage of journey time that is spent in congestion. Table 18 and Figure 33 feature the ten most congested corridors in the AM and PM peak periods.

The city's most congested roads radiate from Melbourne's CBD to the north, east and west. These roads provide vital access for residents in outer suburbs to reach central employment clusters.

Melbourne's major motorways from the south-east, the Princes and Monash Freeways, experience significant traffic in both peak periods. The Princes Freeway westbound is particularly congested in the morning peak period, experiencing similar eastbound congestion in the evening peak period. Similarly, congestion levels are high westbound on the Monash Freeway in the morning peak period, with the opposite direction highly congested in the evening. The high demand for use of these roads illustrates their role as both important access routes for eastern and western outer suburbs residents and facilitators of cross-city travel.

Congestion on key sections of Melbourne's road network during peak periods causes problems for the movement of traffic within and around the city centre and surrounding suburbs. Sections of CityLink are highly affected by congestion. In particular, the Tullamarine Freeway corridor to Melbourne Airport experiences high levels of congestion in both peak periods. Drivers on this corridor can expect delays of up to 24 minutes in the AM peak period and 16 minutes in the PM peak period. In addition, the western section of the Eastern Freeway is significantly congested, as a consequence of demand for city access and cross-city travel.

However, unlike Sydney, Melbourne's congestion is largely limited to motorway, freeways and arterials. Local streets remain accessible and amenity is high.

**Figure 32:** Melbourne weekday traffic volume / capacity ratio, 2016 AM peak


Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019)[81]

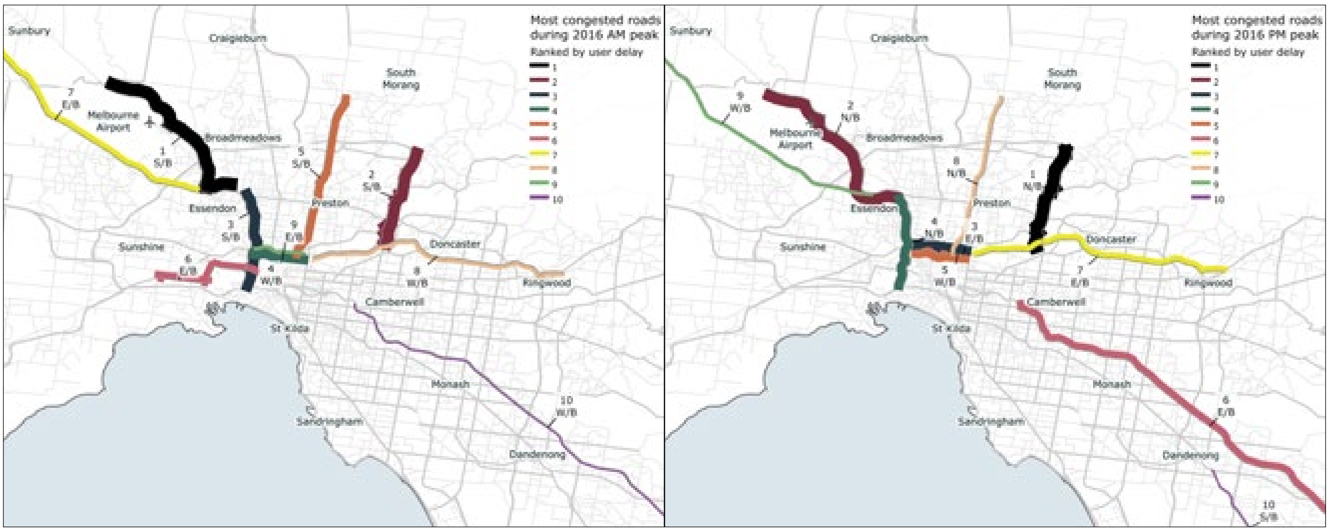
**Table 18:** Melbourne's most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Airport to city via Tullamarine Freeway (S/B) | 17 | 67% | 24 | $6.63 | $28.55 |
| 2. | Metropolitan Ring Road to Eastern Freeway via Greenborough Road / Rosanna Road (S/B) | 11 | 63% | 21 | $5.80 | $24.98 |
| 3. | Tullamarine Freeway to West Gate Freeway via CityLink Western Link (S/B) | 10 | 61% | 10 | $2.76 | $11.90 |
| 4. | Eastern Freeway to CityLink via State routes 29 and 38 (W/B) | 5 | 60% | 10 | $2.76 | $11.90 |
| 5. | Epping to city via High Street / St Georges Road (S/B) | 17 | 59% | 31 | $8.56 | $36.88 |
| 6. | Brooklyn to South Melbourne via Docklands Highway (E/B) | 10 | 59% | 18 | $4.97 | $21.41 |
| 7. | Gisborne South to Tullamarine Freeway via Calder Freeway (E/B) | 31 | 59% | 29 | $8.01 | $34.50 |
| 8. | City to Ringwood via Eastern Freeway (W/B) | 23 | 59% | 22 | $6.08 | $26.17 |
| 9. | CityLink to Eastern Freeway via State routes 38 and 29 (E/B) | 5 | 58% | 9 | $2.49 | $10.71 |
| 10. | Pakenham to city via Princes Freeway / Monash Freeway (W/B) | 57 | 57% | 49 | $13.53 | $58.29 |
| PM peak | | | | | | |
| 1. | Eastern Freeway to Metropolitan Ring Road via Rosanna Road / Greenborough Road (N/B) | 11 | 57% | 17 | $4.69 | $20.22 |
| 2. | City to Airport via Tullamarine Freeway (N/B) | 18 | 56% | 16 | $4.42 | $19.03 |
| 3. | CityLink to Eastern Freeway via State routes 38 and 29 (E/B) | 5 | 52% | 7 | $1.93 | $8.33 |
| 4. | West Gate Freeway to Tullamarine Freeway via CityLink Western Link (N/B) | 10 | 52% | 7 | $1.93 | $8.33 |
| 5. | Eastern Freeway to CityLink via State routes 29 and 38 (W/B) | 5 | 51% | 7 | $1.93 | $8.33 |
| 6. | City to Pakenham via Monash Freeway / Princes Freeway (E/B) | 58 | 50% | 36 | $9.94 | $42.83 |
| 7. | Ringwood to city via Eastern Freeway (E/B) | 23 | 50% | 15 | $4.14 | $17.85 |
| 8. | City to Epping via St Georges Road / High Street (N/B) | 17 | 49% | 21 | $5.80 | $24.98 |
| 9. | Tullamarine Freeway to Gisborne South via Calder Freeway (W/B) | 32 | 46% | 19 | $5.25 | $22.60 |
| 10. | Monash Freeway to Tooradin via South Gippsland Highway (S/B) | 32 | 45% | 22 | $6.08 | $26.17 |

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

Source: Veitch Lister Consulting (2019)[82]

**Figure 33:** Melbourne's most congested roads (user experience), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[83]

## Melbourne's most congested roads in 2016: the cost to the community of total vehicle delays

As a measure of the whole-of-system impacts of congestion, Infrastructure Australia has also identified the most congested road corridors in Greater Melbourne based on aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors under this approach as shown in Table 19 and Figure 34, for the AM and PM peak respectively.

In 2016, Melbourne's most delayed corridors by this aggregate metric were the Westgate Freeway / Princes Freeway and Monash Freeway / Princes Freeway corridors, as displayed in Table 19. These roads provide access to the inner city from the east and west. The aggregate delay incurred on these corridors was significantly larger than on the other high-ranking corridors. Delays on key Melbourne roads not only delay private vehicles but disrupt public transport services as Melbourne's trams and buses largely mix with general traffic.

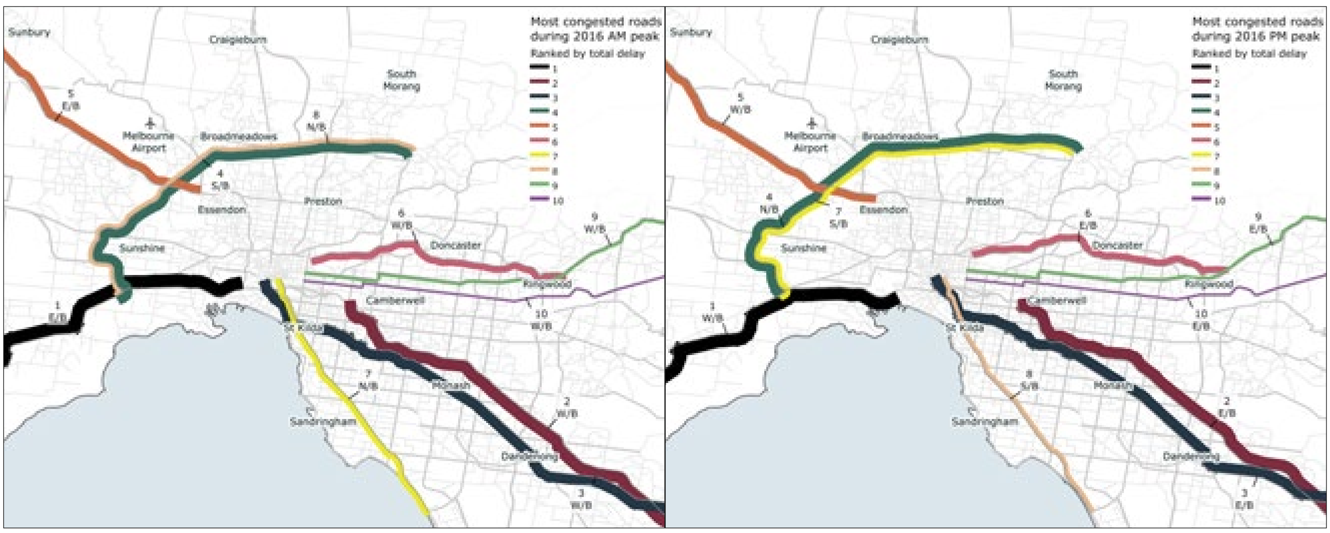
**Table 19:** Melbourne's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Princes Freeway / West Gate Freeway corridor | E/B | 10,800 | $218,000 |
| 2. | Princes Freeway / Monash Freeway corridor | W/B | 8,500 | $172,000 |
| 3. | Princes Highway / Monash Freeway corridor | W/B | 5,300 | $105,000 |
| 4. | Metropolitan Ring Road (western section) | S/B | 4,400 | $85,000 |
| 5. | Calder Freeway corridor | E/B | 3,600 | $74,000 |
| 6. | Eastern Freeway corridor from Ringwood | W/B | 3,300 | $64,000 |
| 7. | Inner beachside suburbs corridor (Nepean Highway) | N/B | 2,900 | $55,000 |
| 8. | Metropolitan Ring Road (western section) | N/B | 2,700 | $51,000 |
| 9. | East-west arterial corridor (Maroondah Highway) | W/B | 2,600 | $55,000 |
| 10. | East-west arterial corridor (Canterbury Road) | W/B | 2,400 | $45,000 |
| PM peak | | | | |
| 1. | West Gate Freeway / Princes Freeway corridor | W/B | 7,100 | $145,000 |
| 2. | Monash Freeway / Princes Freeway corridor | E/B | 6,200 | $125,000 |
| 3. | Monash Freeway / Princes Highway corridor | E/B | 3,800 | $74,000 |
| 4. | Metropolitan Ring Road (western section) | N/B | 3,100 | $64,000 |
| 5. | Calder Freeway corridor | W/B | 2,400 | $47,000 |
| 6. | Eastern Freeway corridor to Ringwood | E/B | 2,400 | $46,000 |
| 7. | Metropolitan Ring Road | S/B | 2,200 | $47,000 |
| 8. | Inner beachside suburbs corridor (Nepean Highway) | S/B | 1,900 | $36,000 |
| 9. | West-east arterial corridor (Maroondah Highway) | E/B | 1,700 | $33,000 |
| 10. | West-east arterial corridor (Canterbury Road) | E/B | 1,600 | $31,000 |

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

Source: Veitch Lister Consulting (2019)[84]

**Figure 34:** Melbourne's most congested roads (total vehicle delays), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[85]

## Melbourne's public transport system in 2016

Melbourne's public transport system is comprised of rail, buses and trams. Melbourne's suburban rail provides access to the CBD from the outer, middle and inner suburbs, while buses and trams primarily service the inner city. Melbourne's SmartBus routes service major roads, providing express services to the CBD, while buses at the local level provide a coverage role. Victoria's regional rail networks (V/Line) service Melbourne's outer growth and regional areas.

The demand for public transport in Melbourne has grown substantially in recent years. This is partially due to congestion on the road network, but also because of increased residential densities around transport interchanges and progressive improvements to service levels and frequencies.

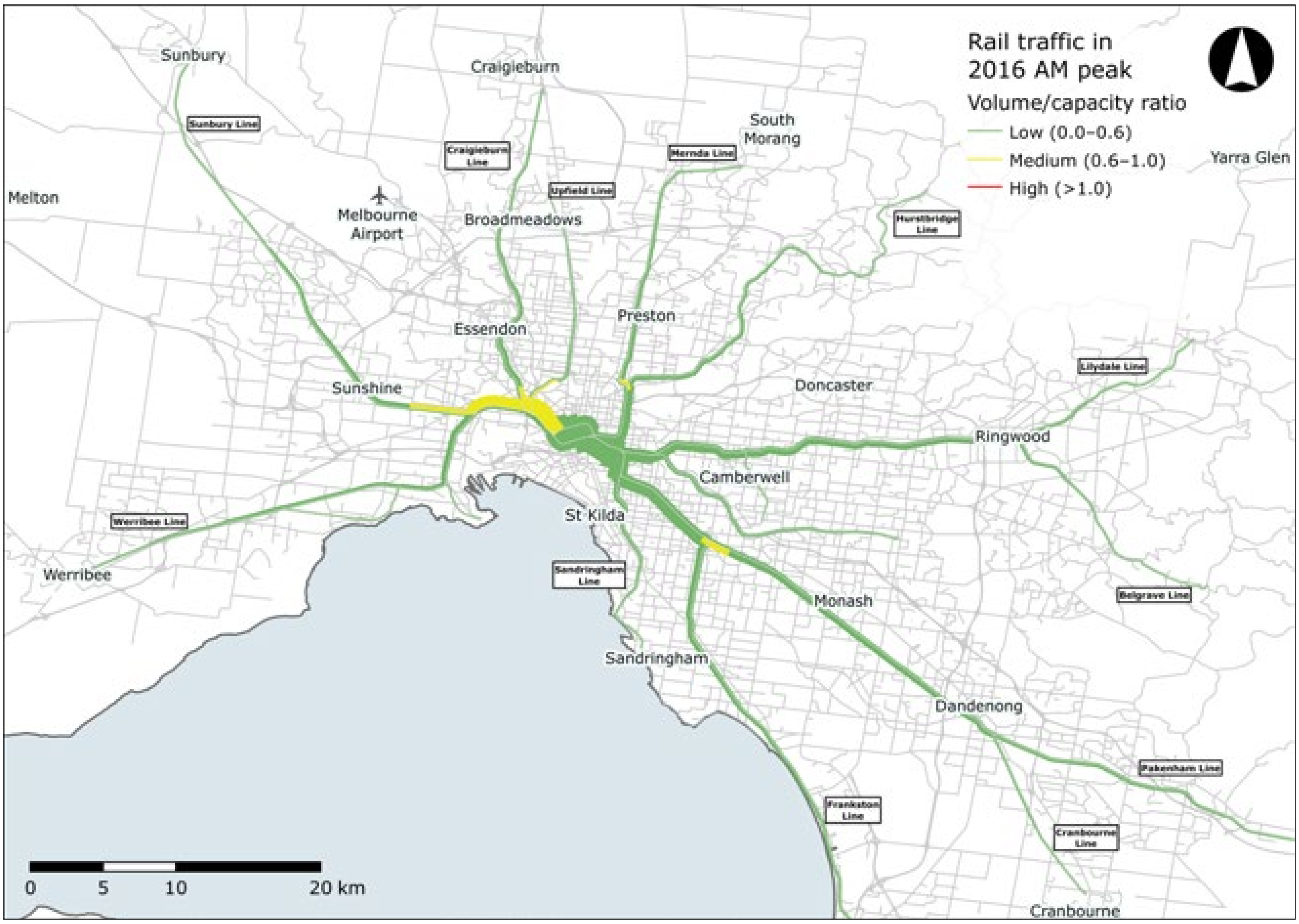
The demand on Melbourne's suburban rail network is highly peak directional. Melbourne's most crowded train services in the AM and PM peaks are on western lines (Figure 35). Rail crowding is highest in the AM peak period on the south-west and north-west lines to the CBD from Werribee and Sunbury respectively. As they reach the city, trains on these lines exceed or have reached their seated capacity while on average are still operating under their maximum (i.e. crush-laden) capacity. This means that train users must stand for longer and services are often delayed by extended boarding and alighting times. The rail network sees comparatively less crowding in the PM peak as travellers tend to depart the city at more diverse times.

Demand on Victoria's regional rail network is also peak directional. Like the suburban rail network, the most crowded sections are on the western lines (Figure 36). Unlike the suburban rail network, medium levels of crowding also occur in the north of the city on the North East Line.

In 2016 Melbourne's bus networks generally witnessed low levels of crowding (Figure 37). SkyBus, serving Melbourne Airport, is identified as Melbourne's most crowded bus corridor in peak periods. Crowding on the SkyBus service is representative of the lack of diversity in public transport available to access the airport. This crowding also occurs in suburbs to the east of Melbourne CBD such as Taylors Lake and Sunshine.

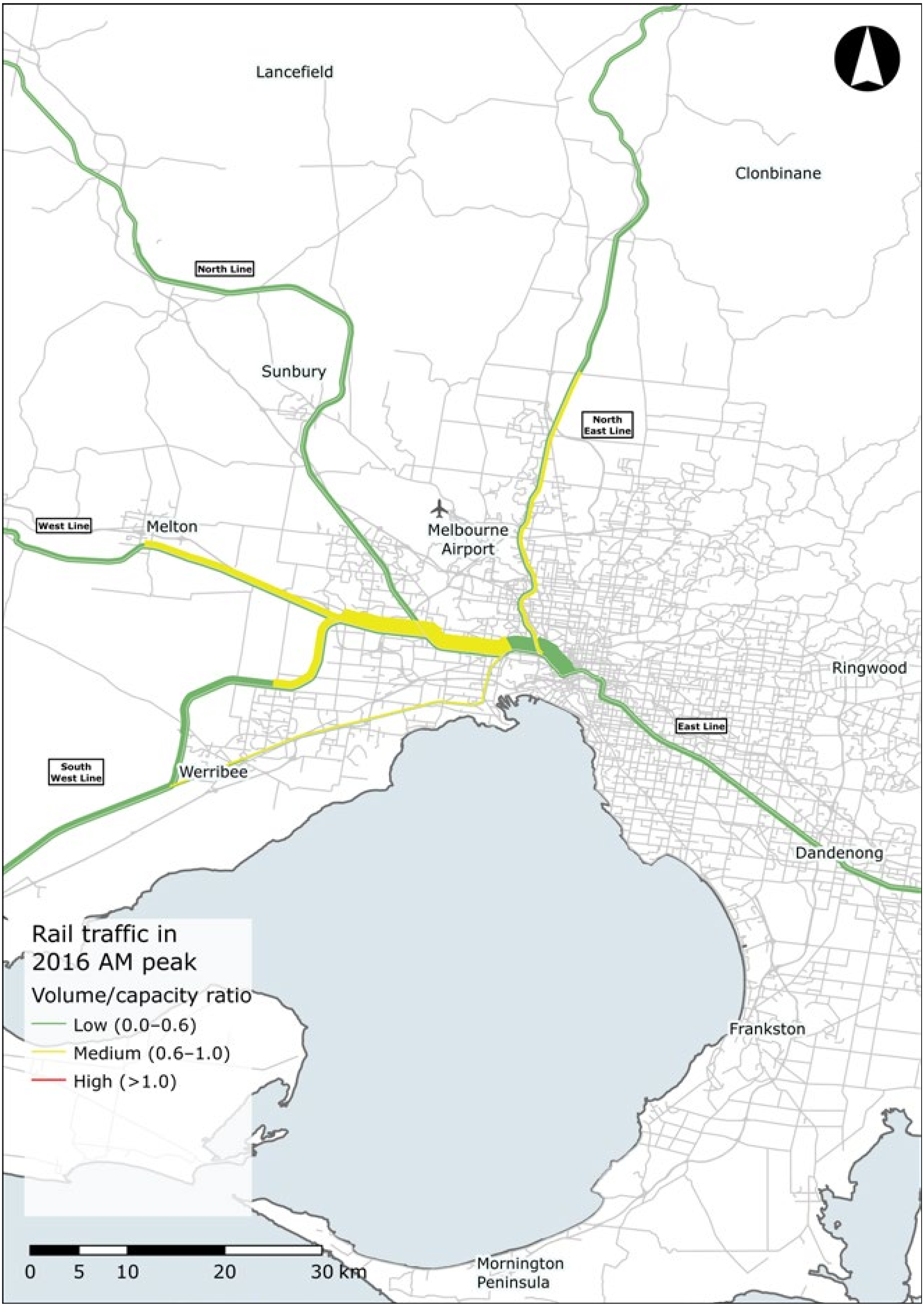
Additionally, buses serving the key activity centres of Monash and Dandenong in the south-eastern suburbs had moderate levels of crowding in peak periods.

**Figure 35:** Melbourne weekday train passenger volume / capacity ratio, 2016 AM peak



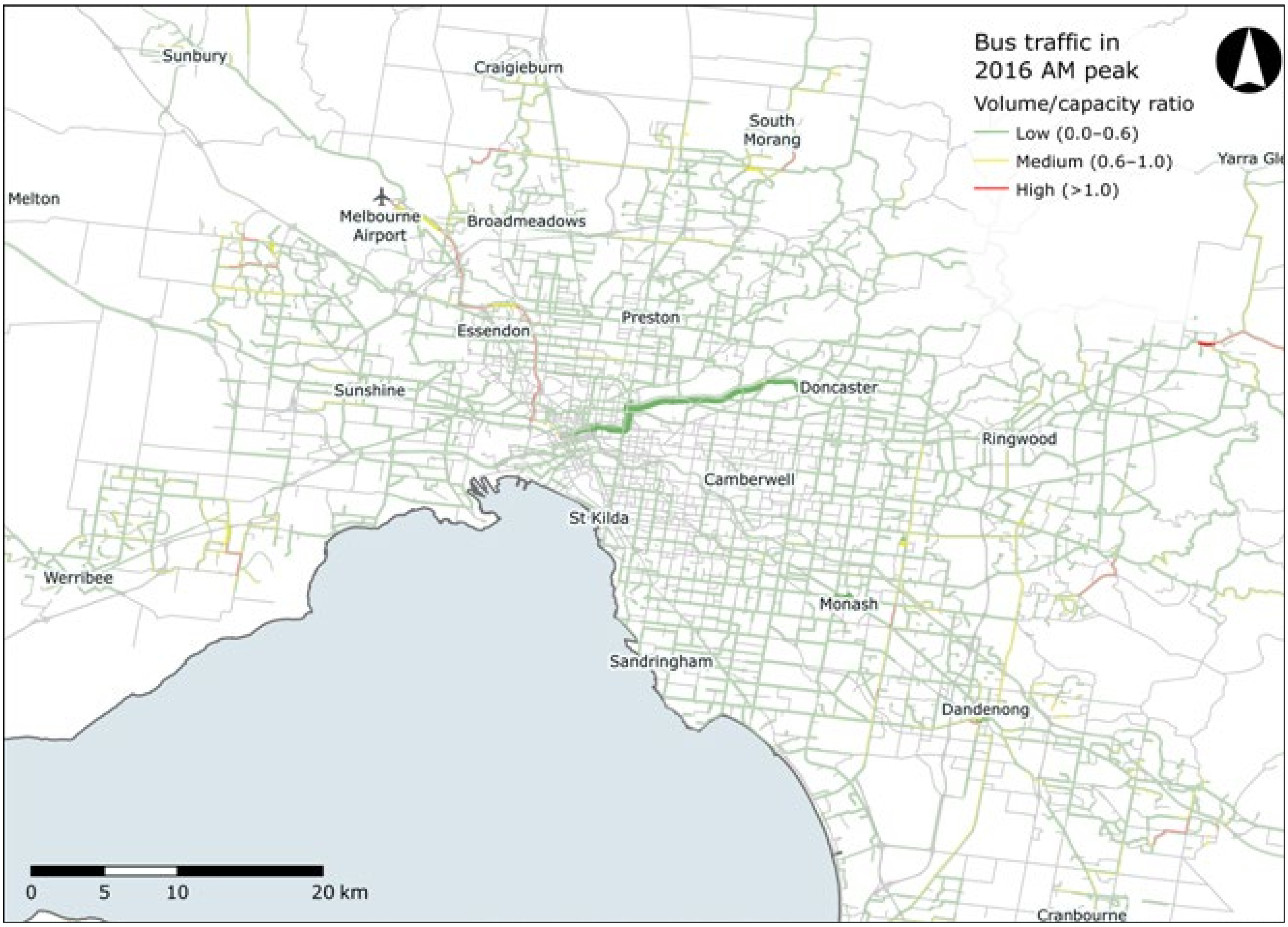

Source: Veitch Lister Consulting (2019)[86]

**Figure 36:** Melbourne weekday regional train passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)87[87]

**Figure 37:** Melbourne weekday bus passenger volume / capacity ratio, 2016 AM peak

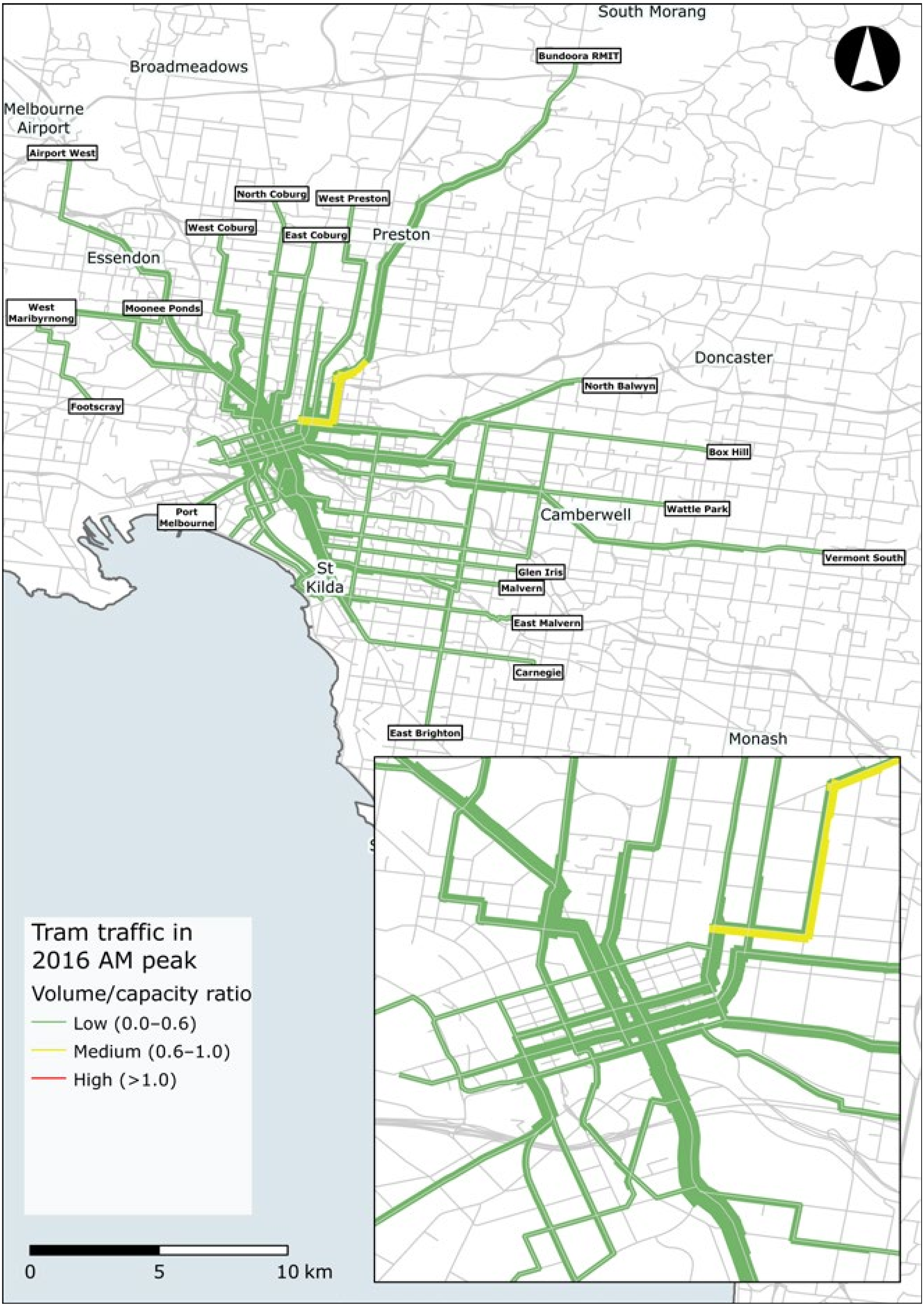



Source: Veitch Lister Consulting (2019)[88]

Melbourne's tram network primarily runs along the major roads of the inner city's established suburbs. Trams facilitate citybound travel, as well as travel within and between these local neighbourhood corridors. Crowding on Melbourne's tram network is relatively low (Figure 38). However, due to the low number of seats on trams, a volume / capacity ratio (VCR) in the 'low' range may still mean that passengers are required to stand. In 2016, the highest level of crowding is observed on the Bundoora line, which is one of the longest routes and serves RMIT and La Trobe universities. In peak periods, passenger loads on this route approach crush capacity.

The improvement of public transport flows on existing corridors has become a focus for the Victorian Government. The Level Crossing Removal Project aims to eliminate 75 level crossings across Metropolitan Melbourne by 2025, in order to reduce the conflict between rail and road users.[89]

**Figure 38:** Melbourne weekday tram passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[90]

## Findings

- Key roads providing access to the inner city from surrounding suburbs are subject to the most significant congestion, affecting drivers travelling in peak periods.
- The route between Melbourne Airport and the city is among the worst performing in both peak periods by this measure. As well as being one of its most congested roads, this is Melbourne's busiest bus route.
- The worst three performing corridors from the perspective of total delays to all vehicles, in both AM and PM peak periods, are the major links in the Greater Melbourne motorway network: the West Gate, Princes and Monash Freeways. The Calder and Eastern Freeways are also on this 'top 10' list.
- Melbourne's arterial roads are most congested in the city's growth areas and at river crossings.
- Increased congestion on Melbourne's roads significantly impacts the city's wider transport network, as buses and trams mix with general traffic. This is especially the case in the inner north of the city, for instance at the western end of the Eastern Freeway where congestion is the result of demand for city access and cross-town travel.
- Population growth in Melbourne's outer suburbs has driven higher passenger volumes on the outer section of many rail lines, including the Sunbury, Werribee, Craigieburn, Mernda, Pakenham and Cranbourne lines. The first two of these experience the highest degree of crowding.

## 6.4 Even with programmed investment, Melbourne's road networks are forecast to become more congested

### Snapshot of Melbourne's transport networks in 2031

By 2031, Melbourne's population is projected to have grown to just over 6 million people (a net increase from 2016 of 90,000 people each year on average) both through densification in established areas and through greenfield development. The highest increase in residential density is forecast for Melbourne's inner-city suburbs, with slower population growth forecast for middle ring suburbs, particularly in the east. Population in Melbourne's outer western and northern areas is forecast to grow strongly. For example, in the west Melton-Bacchus Marsh and Wyndham will house approximately 260,000 extra residents, accommodating almost 20% of Melbourne's total growth.

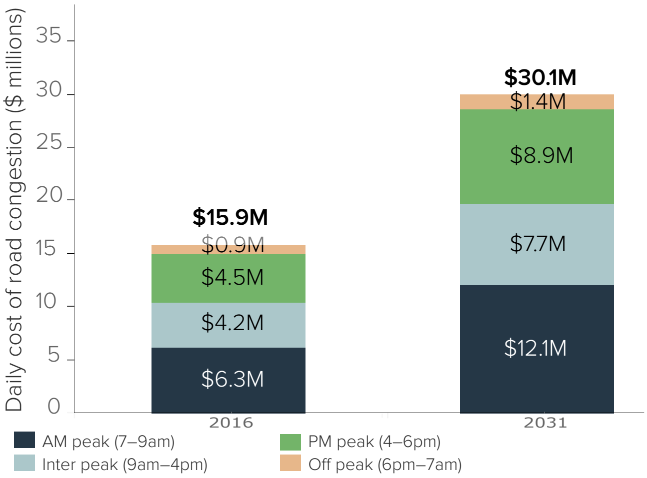
In light of the nature and location of the forecast growth, by 2031 more people will live on Melbourne's periphery. This will increase the pressure on transport infrastructure in these growth areas, as well as on the corridors which link them to major activity centres. Trips on Melbourne's transport network are expected to increase by approximately 25%, totaling almost 18 million daily trips. Despite efforts to improve public transport and roads to meet demand, commuters in 2031 can expect increasingly crowded public transport as well as more congested roads.

Trips on public transport are forecast to grow significantly faster than by car, continuing recent shift towards public transport. The move to public transport is an expected result of the increased time and monetary costs of driving due to congestion and parking cost rises, as well as public transport improvements. Trips on public transport will increase by 52% while car use will increase by 24%.

Despite ongoing mode shift from cars to public transport, congestion on Melbourne's roads will continue to grow substantially. Our modelling indicates the annualised cost of road congestion in Melbourne and Geelong will be approximately $10.4 billion in 2031, of which $10.1 billion is in Melbourne

The proportion of travel time attributable to congestion is forecast generally to increase from 55–65% in 2016 to 65–75% in 2031. This means that drivers on certain corridors during peak periods in 2031 could spend up to three-quarters of their journey duration in congestion. The average weekday cost of road congestion in Melbourne and Geelong is expected to almost double, from about $16 million in 2016 to $30 million in 2031 (Figure 39).

**Figure 39:** Melbourne and Geelong average weekday cost of road congestion, 2016 and 2031




Source: Veitch Lister Consulting (2019)[91]

While the forecast total cost of public transport crowding is significantly less than for road congestion, this is expected to increase at a greater rate between 2016 and 2031. The annualised cost of Melbourne and Geelong's public transport crowding is shown to increase by over four times, from $75 million in 2016 to $352 million in 2031.

These forecast outcomes account for projects that were either under construction, under procurement or had funding for construction committed from all relevant governments at the time of modelling for the Audit.[92]

Major projects included in Melbourne's 2031 forecast are:

- North East Link
- Melbourne Metro
- West Gate Tunnel
- Monash Freeway Upgrade
- Mernda Rail Extension
- Fishermans Bend Tram Link
- Melbourne Airport Rail Link
- CityLink Tulla Widening
- Mordialloc Bypass.

## Melbourne's most congested roads in 2031: what the driver will experience

In 2031, car travel is forecast to remain the most popular form of travel, accounting for approximately 77% of average weekday kilometres. Melbourne's most congested roads will remain broadly the same as today (Table 20, Figure 40 and Figure 41), with some additions.

Strong population growth forecast for Melbourne's outer suburbs particularly in the north by 2031 mean corridors serving growth areas will become the most congested. Increased pressure on the city's radial freeways is forecast. The Hume Freeway, which is only lightly congested in 2016, tops the list in 2031, demonstrating the effect of increased demand to access the city from outer suburbs. The Western Freeway will become congested due to growth of the corridor to Bacchus Marsh. The CityLink-Eastern Freeway connection across Melbourne's inner north is predicted to remain one of the city's worst performers in 2031. The Monash, Princes and Eastern Freeways, as well as the north and southbound CityLink (Western Link) sections, are all expected to witness increased traffic volumes. In some cases this congestion will affect what has previously been regarded as the counter peak direction of travel.

Monash and Princes Freeway impacts are forecast in spite of capacity expansion through the Monash Freeway Upgrade (which will widen and upgrade both freeways). Similarly, congestion on the Eastern Freeway and CityLink (Western Link) is forecast to worsen. This is despite the addition of lanes between Springvale Road and Chandler Highway on the Eastern Freeway through the M80 upgrade, as well as the CityLink Tulla Widening which will provide additional capacity between the city and Melbourne Airport.

The collective effect of the forecast growth in congestion is that by 2031 drivers on these roads are expected to spend 70% of their trip duration in congestion, as opposed to 60% in 2016.

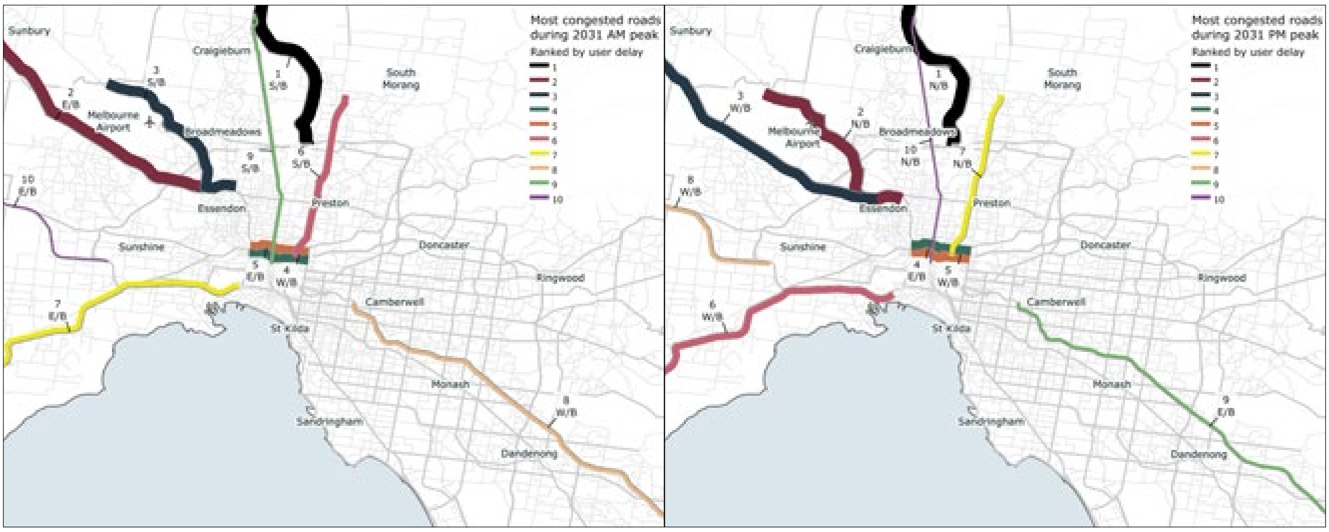
**Table 20:** Melbourne's most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Donnybrook to Metropolitan Ring Road via Hume Freeway (S/B) | 18 | 77% | 39 | $10.77 | $46.40 |
| 2. | Gisborne South to Tullamarine Freeway via Calder Freeway (E/B) | 31 | 72% | 51 | $14.08 | $60.67 |
| 3. | Airport to city via Tullamarine Freeway (S/B) | 17 | 71% | 32 | $8.84 | $38.07 |
| 4. | Eastern Freeway to CityLink via State routes 29 and 38 (W/B) | 5 | 70% | 16 | $4.42 | $19.03 |
| 5. | CityLink to Eastern Freeway via State routes 38 and 29 (E/B) | 5 | 68% | 14 | $3.87 | $16.66 |
| 6. | Epping to city via High Street / St Georges Road (S/B) | 17 | 66% | 42 | $11.60 | $49.97 |
| 7. | Geelong to city via Princes Freeway / Westgate Freeway (E/B) | 57 | 65% | 69 | $19.06 | $82.09 |
| 8. | Pakenham to city via Princes Freeway / Monash Freeway (W/B) | 57 | 64% | 67 | $18.50 | $79.71 |
| 9. | Craigieburn to city via Sydney Road (S/B) | 27 | 64% | 63 | $17.40 | $74.95 |
| 10. | Bacchus Marsh to Metropolitan Ring Road via Western Freeway (E/B) | 41 | 64% | 46 | $12.70 | $54.72 |
| PM peak | | | | | | |
| 1. | Metropolitan Ring Road to Donnybrook via Hume Freeway (N/B) | 18 | 73% | 31 | $8.56 | $36.88 |
| 2. | City to Airport via Tullamarine Freeway (N/B) | 18 | 66% | 26 | $7.18 | $30.93 |
| 3. | Tullamarine Freeway to Gisborne South via Calder Freeway (W/B) | 32 | 63% | 37 | $10.22 | $44.02 |
| 4. | CityLink to Eastern Freeway via State routes 38 and 29 (E/B) | 5 | 62% | 11 | $3.04 | $13.09 |
| 5. | Eastern Freeway to CityLink via State routes 29 and 38 (W/B) | 5 | 61% | 11 | $3.04 | $13.09 |
| 6. | City to Geelong via West Gate Freeway / Princes Freeway (W/B) | 56 | 59% | 51 | $14.08 | $60.67 |
| 7. | City to Epping via St Georges Road / High Street (N/B) | 17 | 57% | 28 | $7.73 | $33.31 |
| 8. | Metropolitan Ring Road to Bacchus Marsh via Western Freeway (W/B) | 41 | 57% | 34 | $9.39 | $40.45 |
| 9. | City to Pakenham via Monash Freeway / Princes Freeway (E/B) | 58 | 56% | 47 | $12.98 | $55.91 |
| 10. | City to Craigieburn via Sydney Road (N/B) | 26 | 55% | 43 | $11.88 | $51.16 |

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

Source: Veitch Lister Consulting (2019)[93]

**Figure 40:** Melbourne's most congested roads (user experience), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[94]

**Figure 41:** Melbourne weekday traffic volume / capacity ratio, 2031 AM peak


Source: Veitch Lister Consulting (2019)[95]

Strong population growth drives most of the modelled increases in congestion, given the limitations on modelling assumptions for the addition of capacity to Melbourne's strategic road network.[96] The modelling conservatively assumes a 'do minimum' scenario, meaning that the additional road projects added to the model for 2031 forecasting purposes are restricted to those with explicit funding commitments by government. It is expected that Melbourne's future road network will be further developed than assumed for the purposes of the Audit. However, until specific commitments are made, the 2031 forecast serves a critical purpose in highlighting where demand pressures for infrastructure investment and other solutions will be felt the most.

## Melbourne's most congested roads in 2031: the forecast cost to the community of total vehicle delays

Infrastructure Australia has forecast the most congested road corridors in Greater Melbourne for 2031, as for 2016, based on aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors in the AM and PM peak periods under this approach are shown in Table 21 and Figure 42.

Strong population growth in Melbourne's outer northern and western suburbs reflecting key radial roads leading from the north and west are ranked higher on the 2031 list. The aggregate delay incurred on the western section of the Metropolitan Ring Road is expected to be almost double southbound, and more than double northbound, compared to 2016. The addition of both the Hume Freeway and Sydney Road corridors to the 2031 forecast reflects the impact of increased traffic expected from Melbourne's northern growth corridor. Both roads are predicted to experience over 4,000 hours of aggregate delay in the AM peak period.

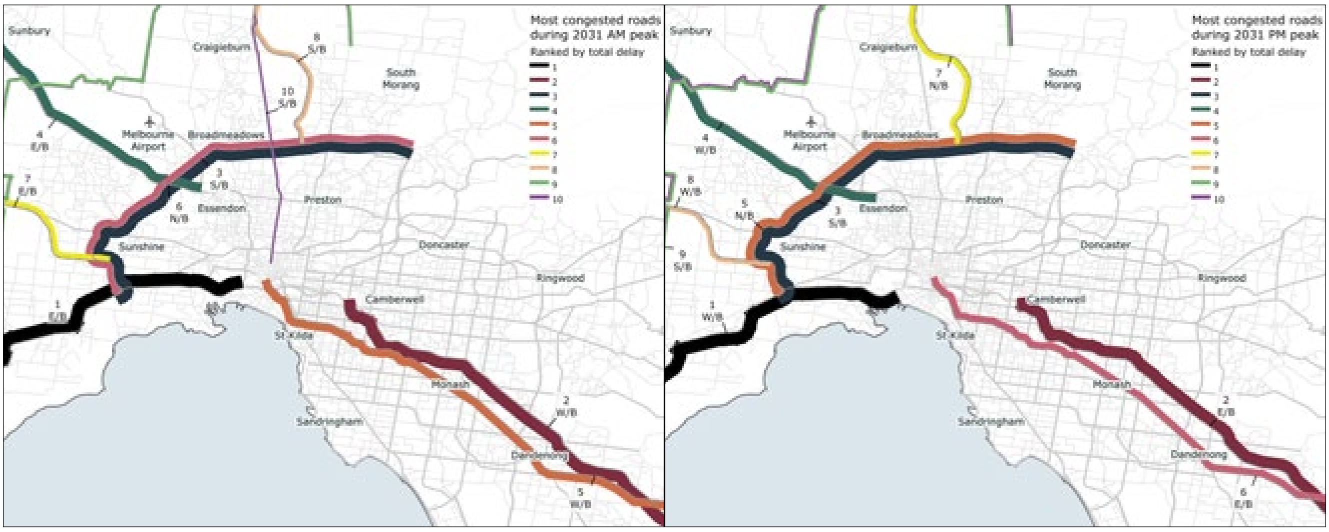
**Table 21:** Melbourne's most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Princes Freeway / West Gate Freeway corridor | E/B | 16,800 | $334,000 |
| 2. | Princes Freeway / Monash Freeway corridor | W/B | 15,900 | $311,000 |
| 3. | Metropolitan Ring Road (western section) | S/B | 8,500 | $173,000 |
| 4. | Calder Freeway corridor | E/B | 8,200 | $160,000 |
| 5. | Princes Highway / Monash Freeway corridor | W/B | 7,500 | $144,000 |
| 6. | Metropolitan Ring Road (western section) | N/B | 7,000 | $144,000 |
| 7. | Western Freeway corridor | E/B | 5,700 | $112,000 |
| 8. | Hume Freeway corridor | S/B | 5,700 | $108,000 |
| 9. | Outer metropolitan ring corridor (Werribee–Sunbury–Wallan–Mernda) | N/B | 5,100 | $97,000 |
| 10. | Sydney Road corridor | S/B | 4,500 | $91,000 |
| PM peak | | | | |
| 1. | West Gate Freeway / Princes Freeway corridor | W/B | 12,300 | $250,000 |
| 2. | Monash Freeway / Princes Freeway corridor | E/B | 11,200 | $224,000 |
| 3. | Metropolitan Ring Road (western section) | S/B | 6,200 | $128,000 |
| 4. | Calder Freeway corridor | W/B | 6,200 | $124,000 |
| 5. | Metropolitan Ring Road (western section) | N/B | 6,100 | $124,000 |
| 6. | Monash Freeway / Princes Highway corridor | E/B | 5,200 | $100,000 |
| 7. | Hume Freeway corridor | N/B | 4,600 | $88,000 |
| 8. | Western Freeway corridor | W/B | 4,300 | $87,000 |
| 9. | Outer metropolitan ring corridor (Mernda–Wallan–Sunbury–Werribee) | S/B | 4,100 | $78,000 |
| 10. | Outer metropolitan ring corridor (Werribee–Sunbury–Wallan–Mernda) | N/B | 3,300 | $62,000 |

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

Source: Veitch Lister Consulting (2019)[97]

**Figure 42:** Melbourne's most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[98]

## Melbourne's public transport system in 2031

By 2031, the demand placed on Melbourne's public transport network is expected to have increased substantially. The forecast shift to public transport use in Melbourne is modelled as being primarily driven by service expansions, infrastructure improvements such as the Melbourne Metro and the Melbourne Airport Rail Link, as well as by increased road network congestion.

Melbourne's suburban rail patronage is expected to increase dramatically by 2031. Suburban rail passenger kilometres are expected to rise by 88% from 2016, while passenger kilometres for regional rail travel are forecast to triple (Figure 43). Most city-bound lines will be operating well above seated capacity in the AM peak. The high number of boarding on the outer sections of the Pakenham and Cranbourne lines will mean that passenger loadings are forecast to approach crush capacity along the majority of this these corridors by 2031. Similar outcomes are expected on the Mernda and Craigieburn lines, both of which serve growth areas. Outer ring passenger growth is modelled as resulting in passengers in middle ring suburbs facing longer standing times and potentially delayed services.

The construction of new rail tunnels through Melbourne's CBD as part of the Melbourne Metro project will allow more services and passengers to travel through the inner city. It is expected that 80,000 extra passengers in each direction will travel on lines serving the western suburbs, while 55,000 additional passengers will travel on lines serving Melbourne's south-eastern suburbs in each direction.[99]

Rapid population growth in the outer suburbs of Melbourne will place additional pressure on the regional rail (V/Line) network (Figure 44). The North, West and North East Lines will be particularly impacted and will reach crush capacity, with passengers being unable to board some services. The East line will also be impacted, particularly in areas east of Dandenong.

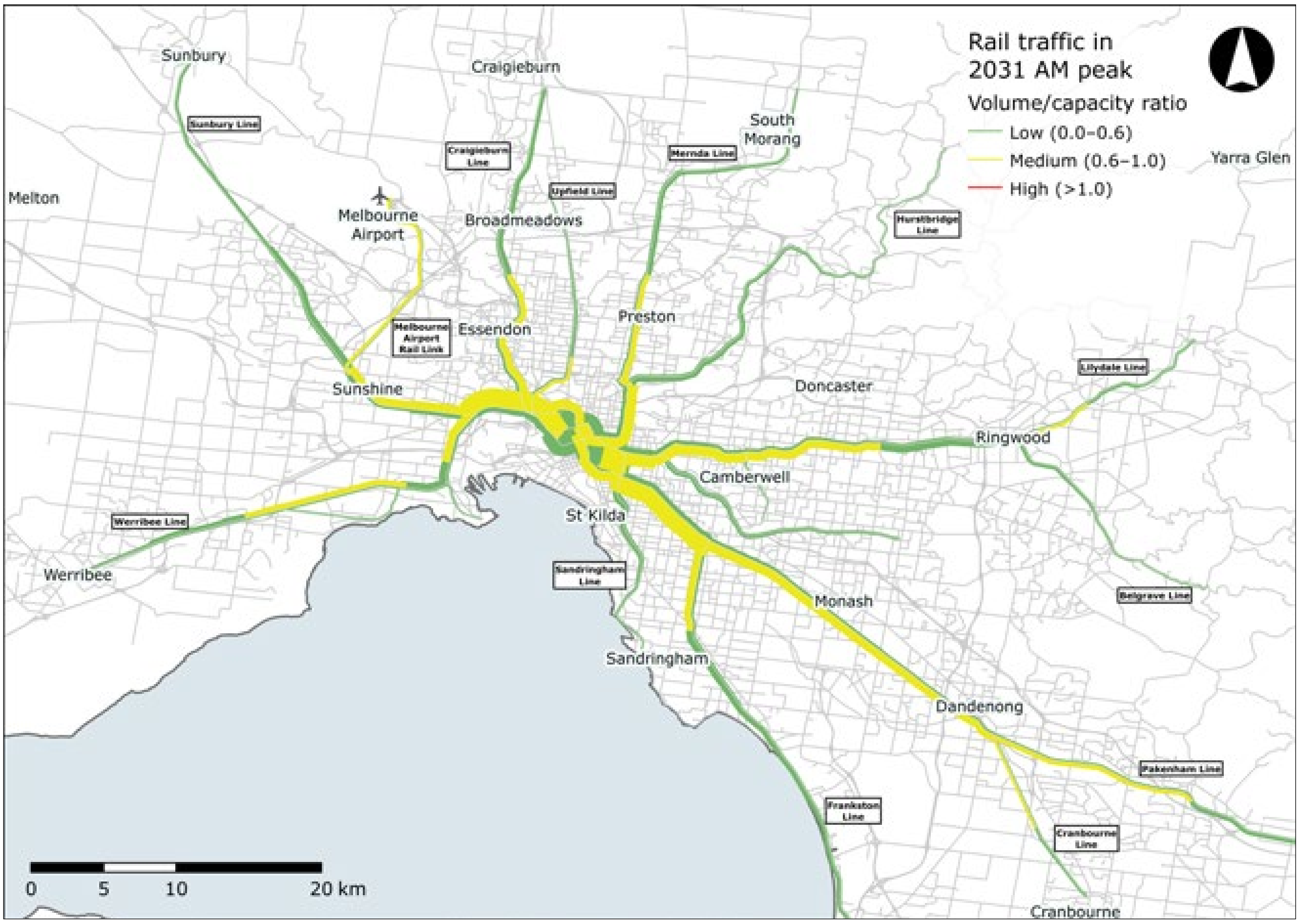
The impacts of crowding on the regional rail network may be overstated in the results, due to the capacity of rail services being understated in the model inputs. The selection and configuration of rolling stock, as well as timetabled service frequencies, can significantly impact the capacity of rail lines. Consequently, modelled crowding on the regional rail network may lead to a greater level of mode switching to parallel modes. As a result, crowding on those services and congestion on certain road corridors could be marginally overestimated.

Melbourne's bus routes are projected to become significantly more crowded by 2031 (Figure 45), especially in growth areas. Patronage in established suburbs is expected to stay relatively moderate, due to slower population growth and alternative modes of public transport. However, bus routes in growth areas are forecast to experience the most significant crowding by 2031, particularly feeder services to the rail network at Melbourne's northern and western fringes. Passenger loadings on the Eastern Freeway busway from Doncaster are also expected to increase, causing moderate levels of crowding. This focus of bus crowding is due to employment opportunities being centralised in the CBD, while population is widely dispersed.

The construction of Melbourne Airport Rail Link accounts for the largest reduction in bus passengers between 2016 and 2031. The Rail Link replaces the SkyBus to the airport and the Mernda Rail replaces the local bus feeder in this corridor.

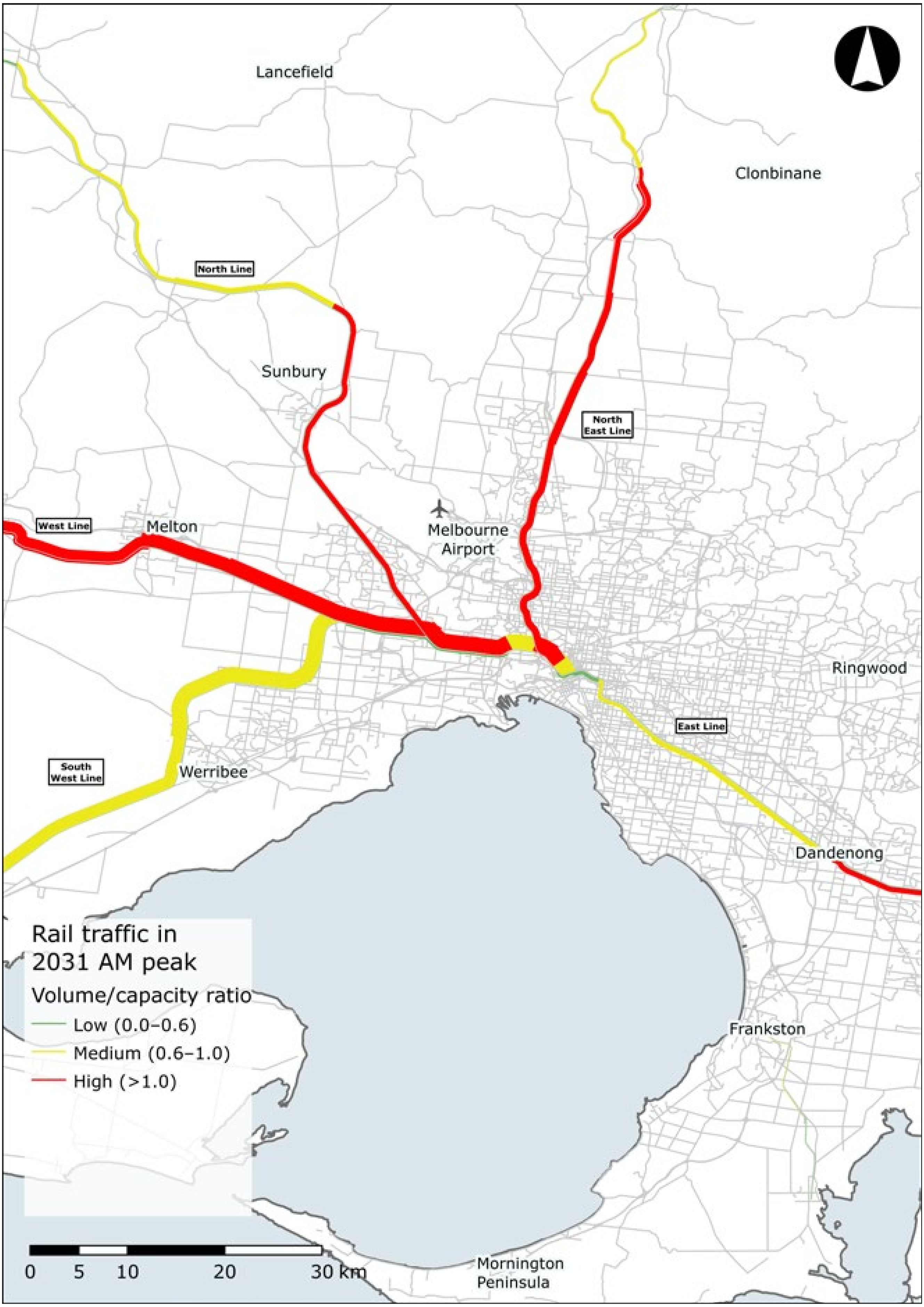
While crowding on the Melbourne's tram network is low to moderate in 2016, by 2031 crowding on the network is expected to have increased and spread (Figure 46). The crowding observed on the Bundoora route serving RMIT and La Trobe universities is expected to worsen. By 2031 passengers can expect high levels of crowding from Preston inbound in the AM peak period and to Northcote outbound in the PM peak period. In addition, crowding is expected to increase on routes serving the inner west. Increased crowding on Melbourne's tram network is predicted to be driven by strong population growth, particularly in Darebin North and Maribyrnong, as well as by more passengers using trams to access the rail system. It is expected that some sections of the 82 tram line (Footscray to Moonee Ponds) will exceed crush capacity, suggesting that assumed 2031 service levels will be insufficient to cater for growth.

**Figure 43:** Melbourne weekday train passenger volume / capacity ratio, 2031 AM peak



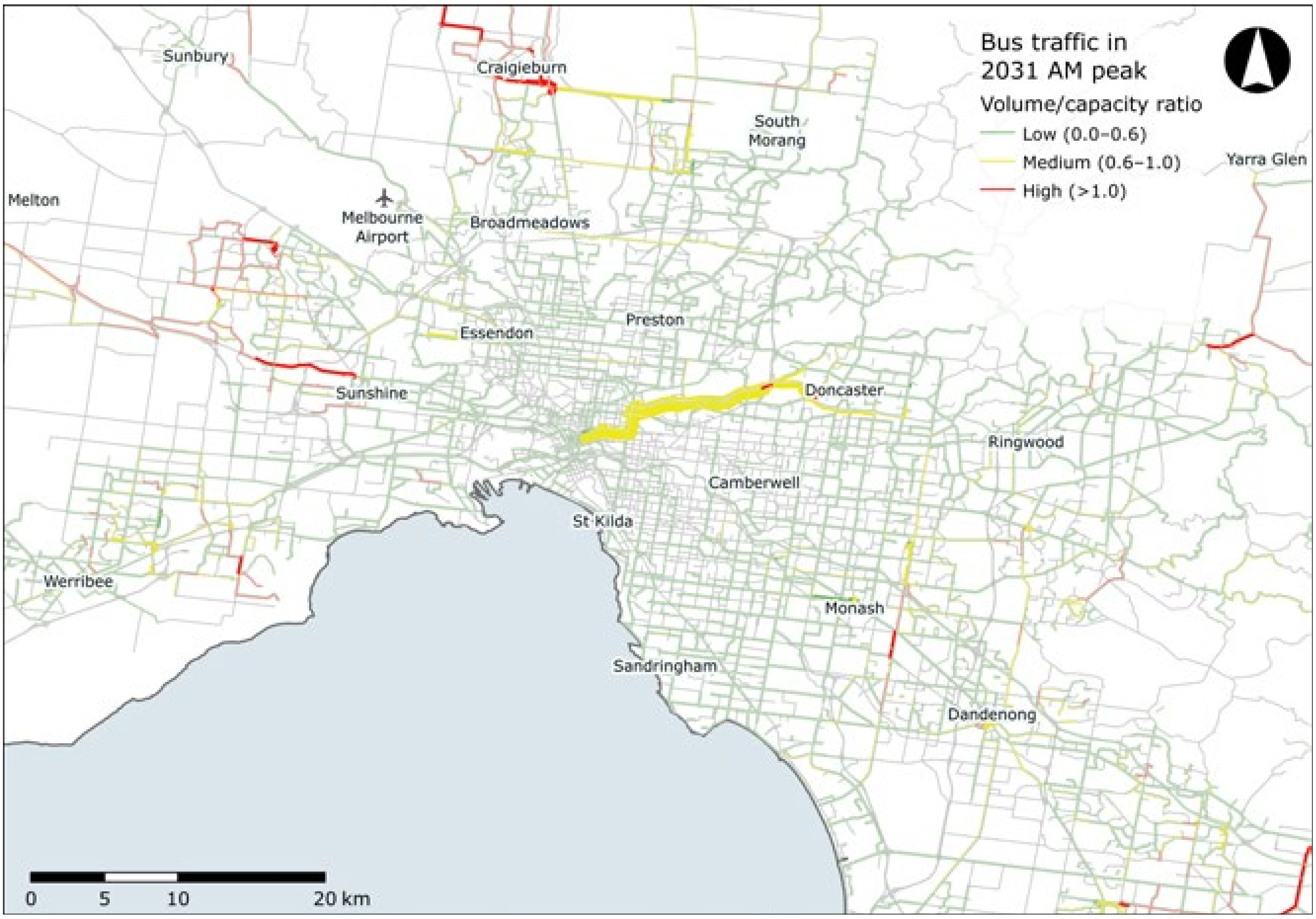

Source: Veitch Lister Consulting (2019)[100]

**Figure 44:** Melbourne weekday regional train passenger volume / capacity ratio, 2031 AM peak



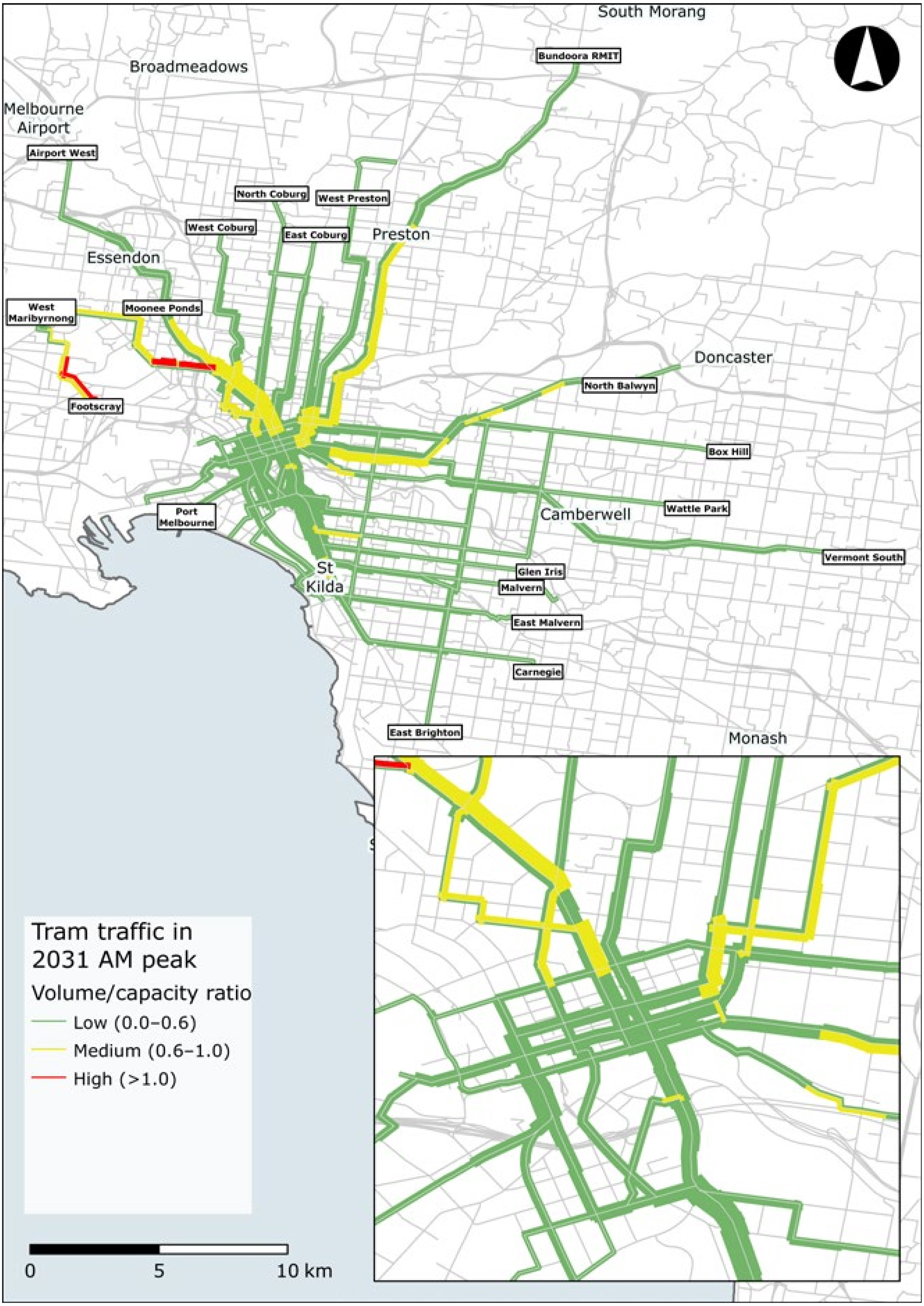

Veitch Lister Consulting (2019)[101]

**Figure 45:** Melbourne weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[102]

**Figure 46:** Melbourne weekday tram passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[103]

## Findings

- The 2019 Audit forecasts that the annualised cost of road congestion for Melbourne and Geelong will grow from approximately $5.5 billion in 2016 to $10.4 billion in 2031. This is 15% higher than the 2031 forecast cost of road congestion in the 2015 Audit.
- Despite major projects expanding Melbourne's road capacity, modelling shows widespread congestion in peak periods as travellers access employment opportunities concentrated in the inner city.
- Key radial freeways, which connect outer suburbs into the city centre, are expected to become significantly more congested by 2031. Worsened congestion on the Princes and Monash freeways will affect today's counter-peak direction. Bi-directional peak congestion will also delay traffic on the M80 Metropolitan Ring Road. Strong population growth is forecast to drive similar outcomes for the Hume, Calder and Western Freeways.
- In addition to freeways, arterial roads which serve Melbourne's fastest-growing areas will be affected by congestion. These include outer western corridors around Derrimut, Taylors Lakes and Bulla, northern arterial corridors parallel to the Hume Freeway, and outer south-eastern arterials, south of Doveton.
- Population growth in outer suburbs will mean that by 2031 trains will approach crush capacity as they reach Melbourne CBD, and take up the additional CBD capacity provided by Melbourne Metro. The Craigieburn Line serving Melbourne's northern growth corridor will see a particularly significant rate of growth, joining the Sunbury, Werribee, Mernda, Pakenham and Cranbourne lines in experiencing crowded conditions close to the city centre.
- Bus services acting as rail feeder services in the outer northern and western fringe growth areas are expected to experience the highest levels of bus crowding.
- High levels of tram crowding are forecast particularly for the Bundoora route serving RMIT and La Trobe University, as well as routes servicing the inner west.

## 6.5 Population growth in the Geelong regions is forecast to result in increased congestion

### Transport in Geelong and its surrounding areas, today and in 15 years

Geelong city is forecast to increase its population by 48,000 residents, or 25%, by 2031, reaching a population of 240,000. There will also be significant growth in surrounding regions, such as Whittlesea-Wallan in the north, expected to accommodate 161,000 more people by 2031, and Melton-Bacchus Marsh and Wyndham in the west, expected to grow by 260,000 residents. Melton-Bacchus Marsh and Wyndham are expected to account for almost 20% of Greater Melbourne's total growth.

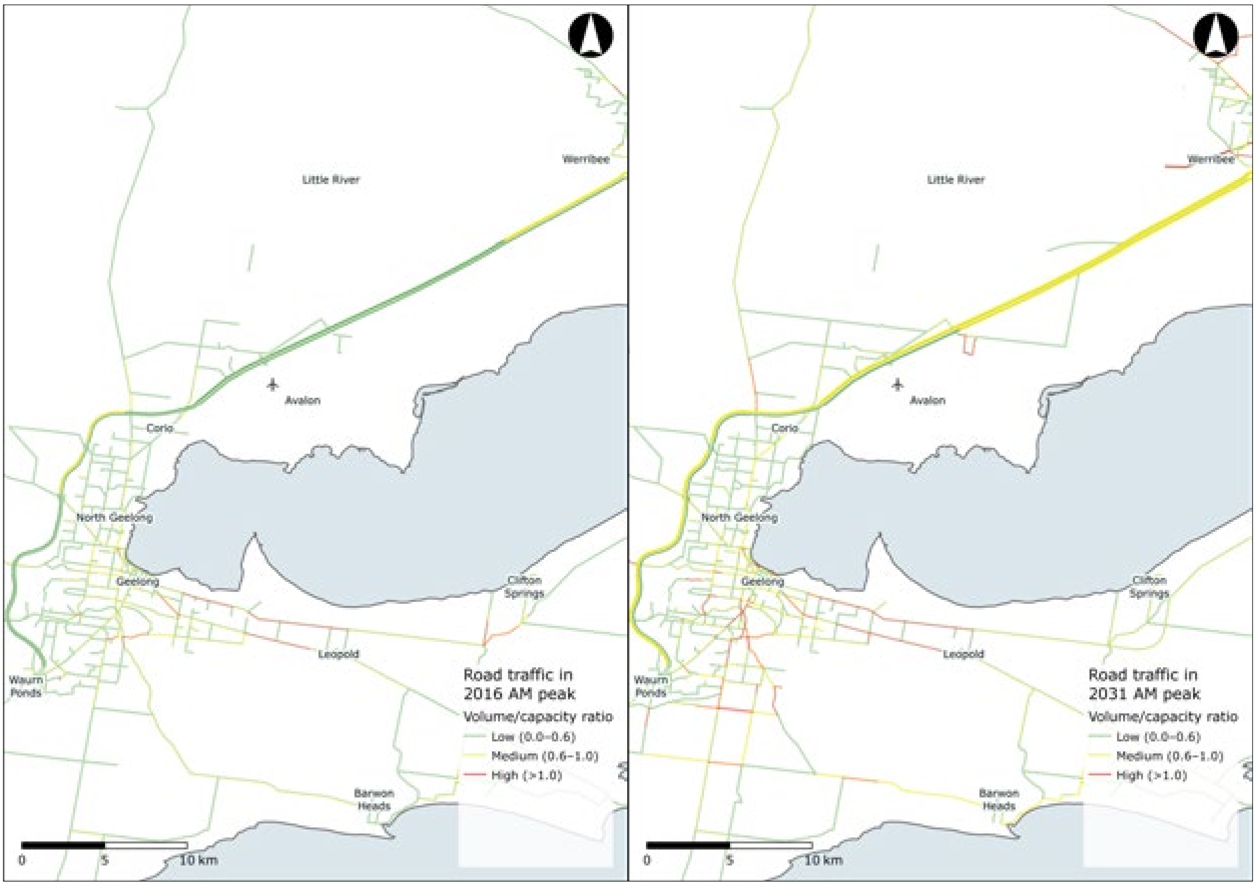
These growth rates will result in increased demand pressures on the region's transport network. In a similar manner to Melbourne, predicted growth in public transport will exceed car use growth. Trips by car are expected to increase by 32%, while trips on public transport will grow by 76%.

The result of Geelong's population growth will be, notwithstanding higher public transport use, increased road congestion (Figure 47). Between 2016 and 2031 the cost of congestion in this region is forecast to double. The annual cost of congestion is expected to grow from $127 million in 2016 to $297 million in 2031. Road congestion will particularly affect key access routes to Geelong from the surrounding region.

Passenger uplift for bus patronage is expected to be lower than for rail, although still greater than population growth. By 2031, there is forecast to be a 35% daily increase in bus passenger boardings in Geelong over 2016,[104] with modest expansion assumed for the bus network. This means that while bus passengers in Geelong primarily experience low to moderate levels of crowding in 2016, by 2031 key routes are forecast to exceed capacity (Figure 48).

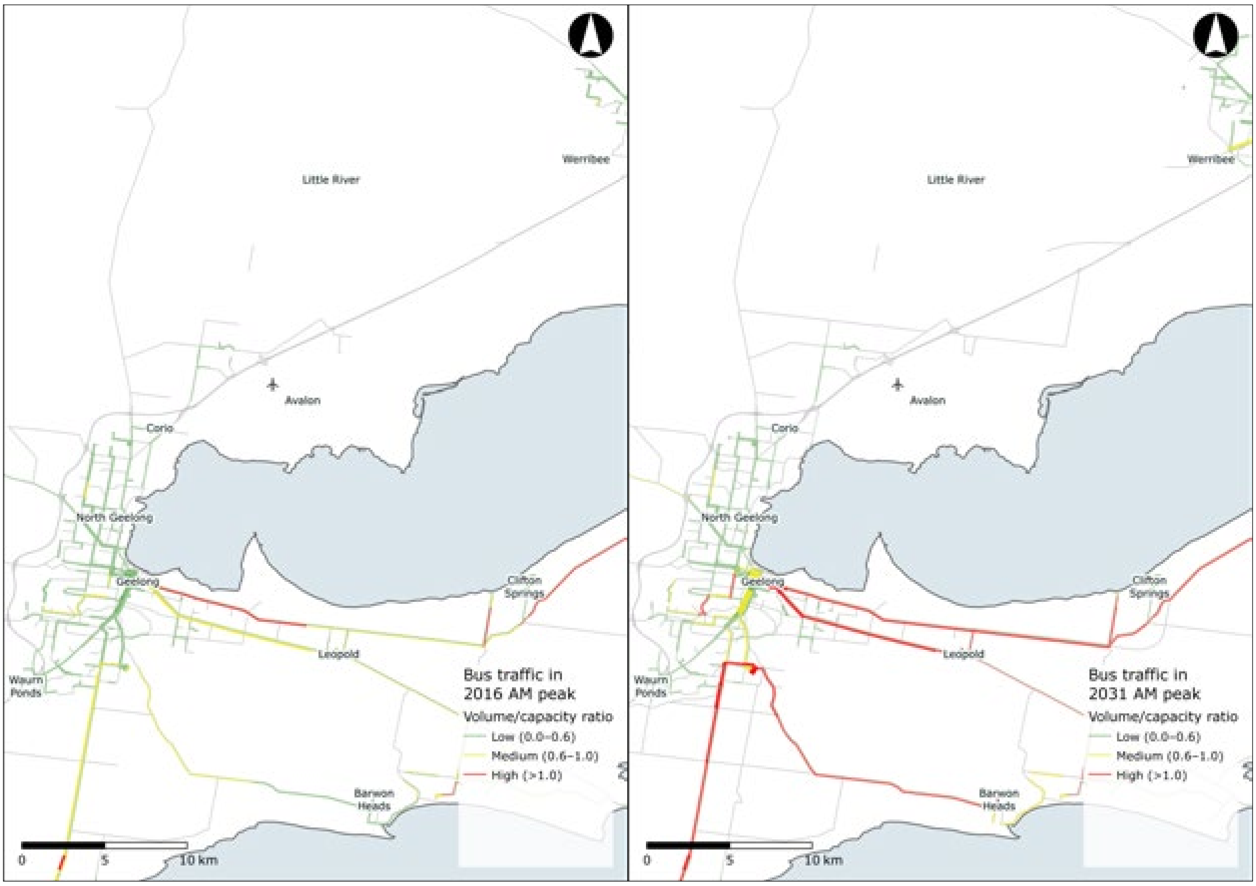
Due to population growth in Geelong and strong employment growth in Melbourne, patronage on regional rail is expected to significantly increase. By 2031, daily regional rail passenger boardings in Geelong are forecast to increase by 28,000, a percentage change of 145% from 2016 (Figure 49). This will result in a substantial increase in crowding on trains travelling between Geelong and Melbourne's city centre in peak periods.

**Figure 47:** Geelong region weekday traffic volume / capacity ratio, 2016 and 2031 AM peak



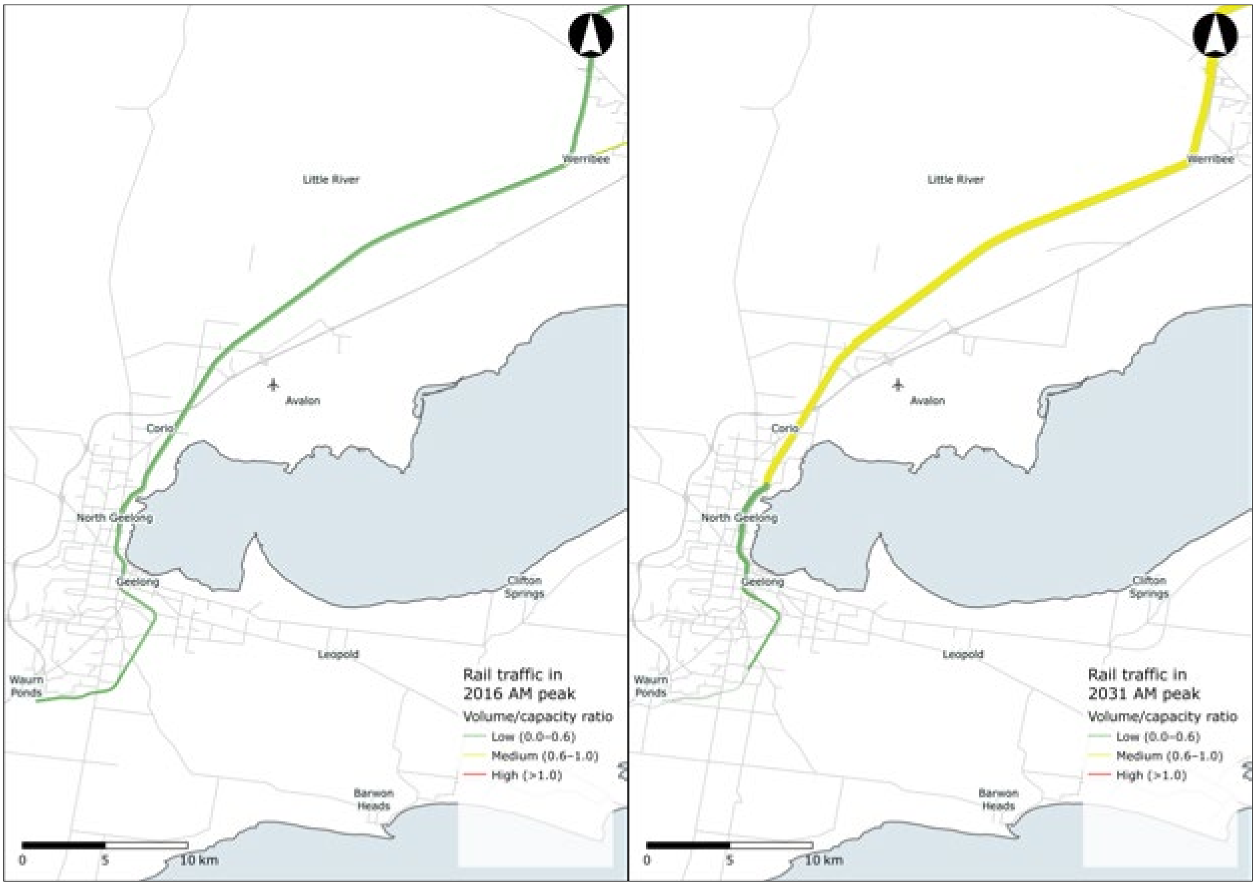

Source: Veitch Lister Consulting (2019)[105]

**Figure 48:** Geelong region bus passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[106]

**Figure 49:** Geelong region train passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[107]

## Findings

- Strong population growth in Geelong is expected to cause higher levels of road congestion and public transport crowding.
- The cost of road and public transport congestion is expected to almost double between 2016 and 2031.
- The concentration of employment opportunities in Melbourne's city centre will increase congestion at the southern end of the Princes Freeway, an important access route to jobs to Geelong's north.
- Regional rail patronage is expected to increase by 145% between 2016 and 2031, resulting in higher levels of crowding on rail services between Geelong and central Melbourne.

## 6.6 Transport decisions impact access to jobs and services

### Hospital access in Melbourne and Geelong – by car and public transport, in 2031

Greater Melbourne residents' access to critical healthcare is measured as the travel time to the nearest public hospital, or hospital with an emergency department, by car versus public transport (Figure 50).

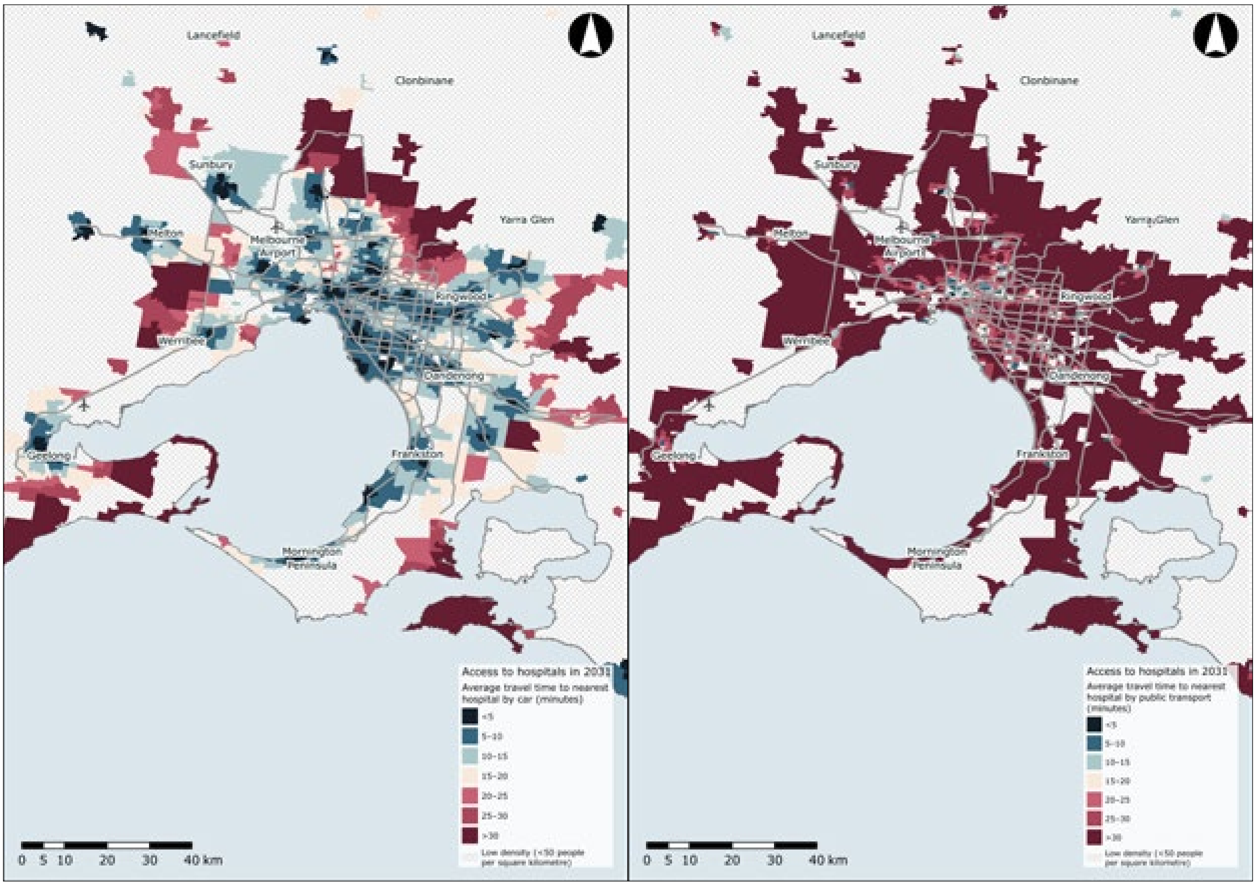
Residents with access to a car have much greater access to hospitals than residents who rely on public transport. By 2031 it is expected that average travel time to a public hospital in Greater Melbourne will be 13 minutes. However, by public transport, most residents of Greater Melbourne will need to spend upwards of 30 minutes to reach their nearest public hospital.

### Access to childcare and schools in Melbourne and Geelong – by car and public transport, in 2031

The average resident of the Greater Melbourne region with access to a car can reach childcare services (Figure 51) and public primary schools (Figure 52) within a four-minute trip in 2016. This is expected to extend to a five-minute trip by 2031. Access to public secondary schools (Figure 53) is slightly longer, taking approximately six minutes in 2016, and extending to seven minutes in 2031.

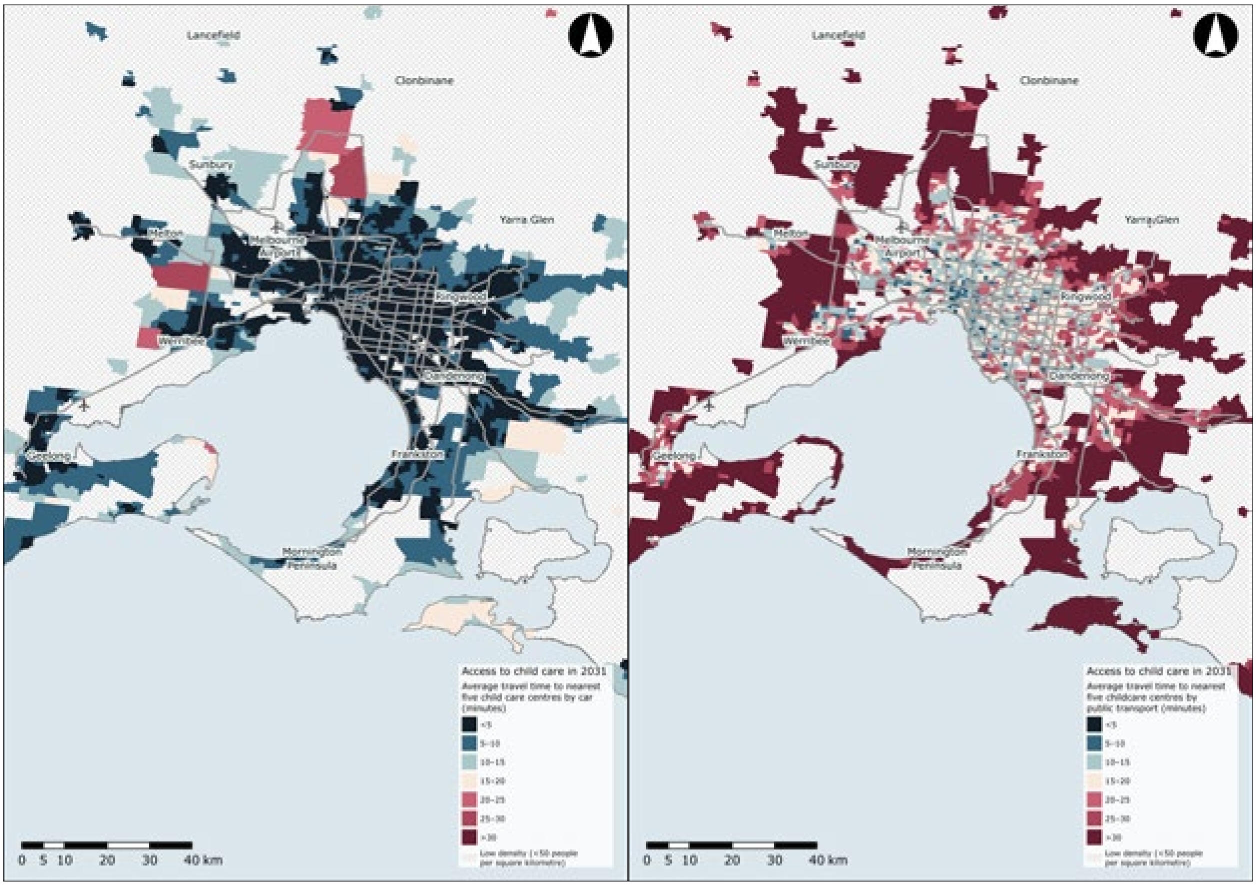
For residents without access to a car, public or active transport times are significantly longer to access these social infrastructure destinations. In 2016 these travel times are in excess of 30 minutes, and by 2031 are forecast to increase further. Areas with longer average travel times are those further away from the CBD where public transport does not offer a realistic alternative to car use. This highlights that public transport infrastructure in Melbourne is more effective at serving commuting to the CBD and immediate surrounding areas, while being less effective at catering to local travel needs.

**Figure 50:** Greater Melbourne average time to nearest hospital by car (left) and public transport (right), 2031 AM peak



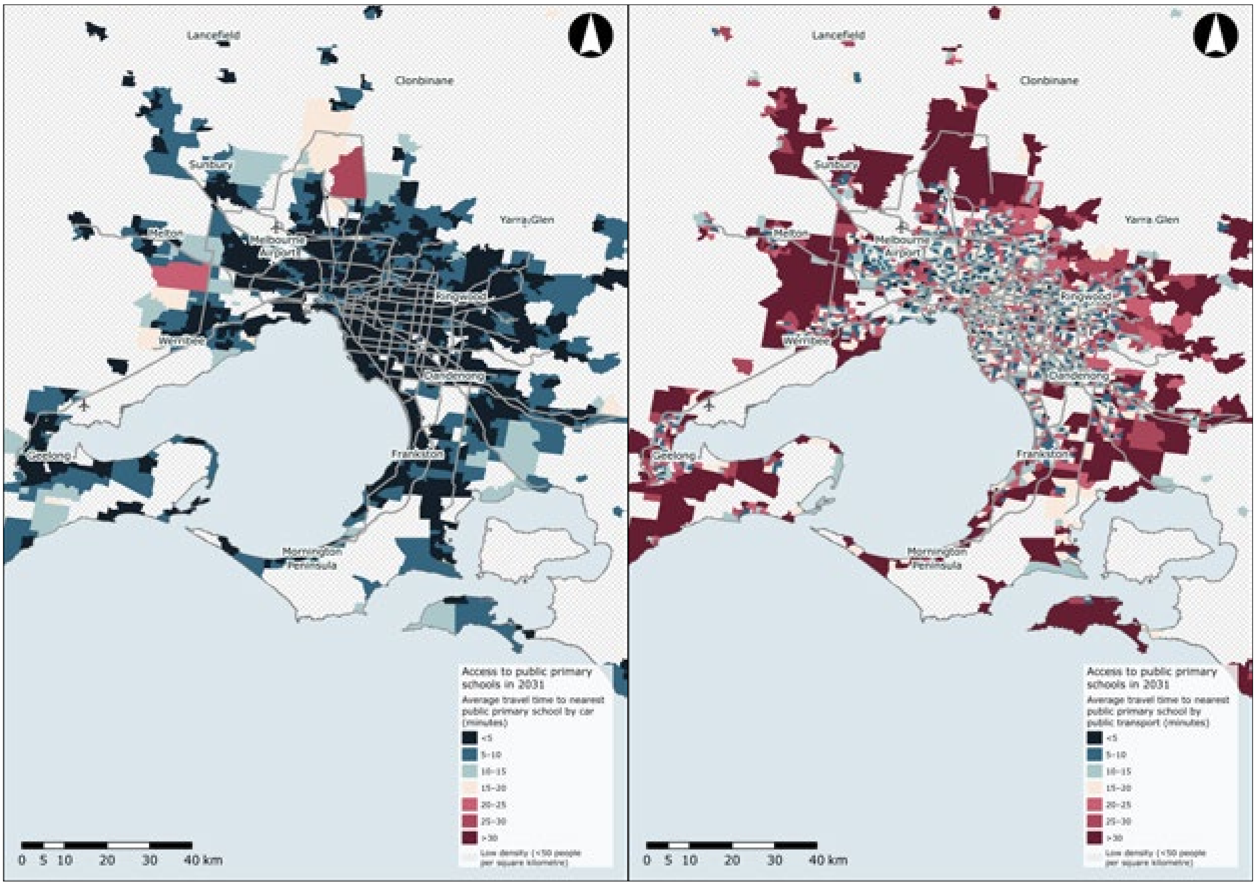

Source: Veitch Lister Consulting (2019)[108]

**Figure 51:** Greater Melbourne average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



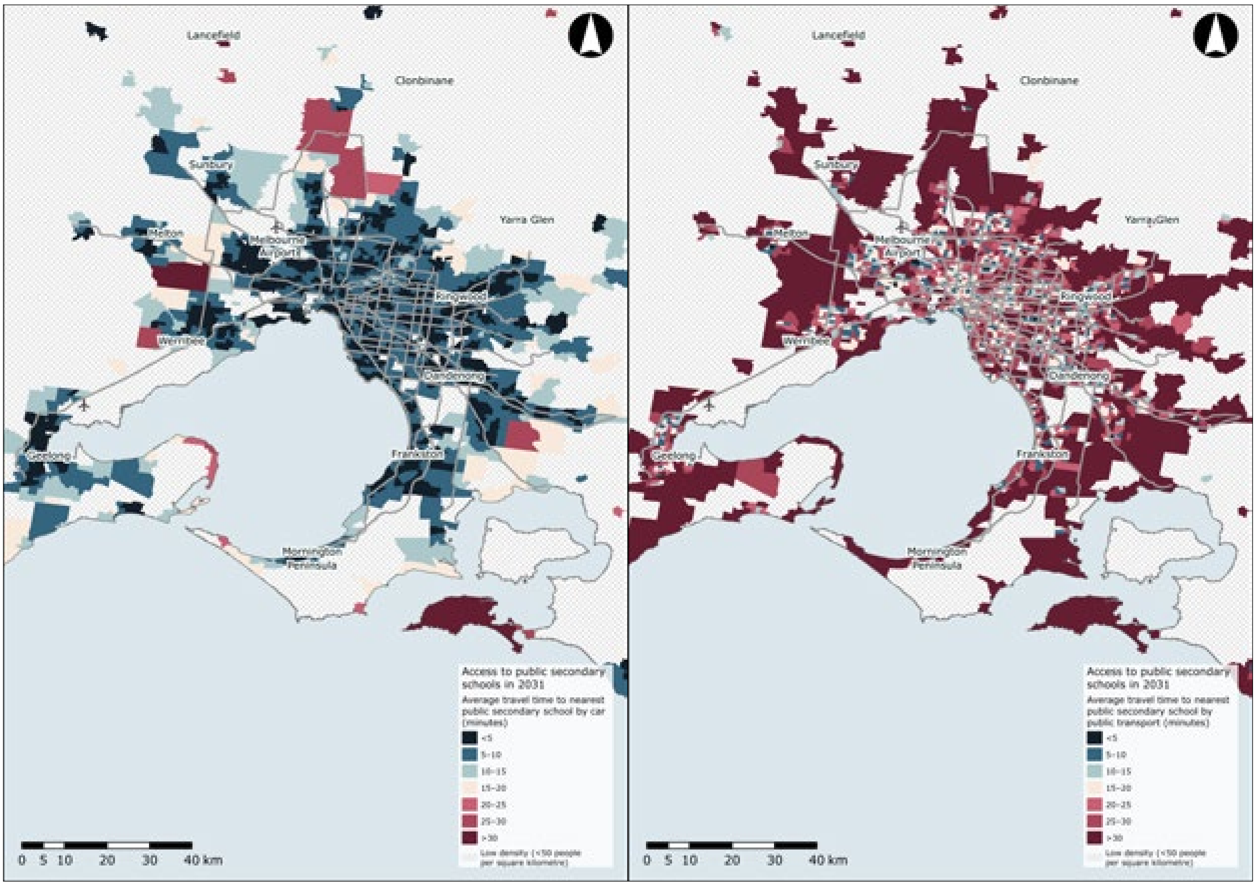

Source: Veitch Lister Consulting (2019)[109]

**Figure 52:** Greater Melbourne average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[110]

**Figure 53:** Greater Melbourne average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[111]

## Access to jobs in Melbourne and Geelong – by car and public transport, in 2016 and 2031

Access to employment opportunities varies considerably across Melbourne depending on residential location and mode of travel.

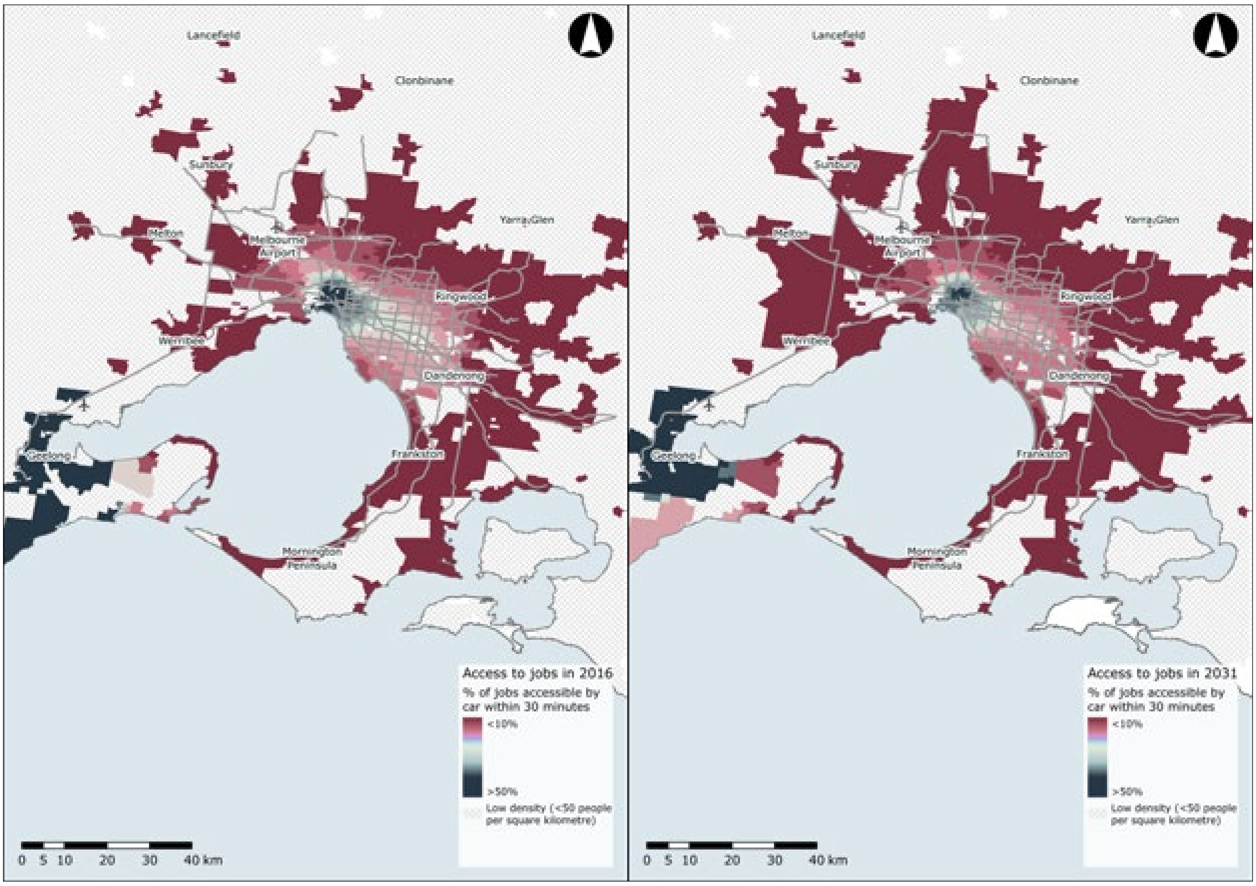
Employment accessibility has been measured as the percentage of jobs in two self-contained areas (Greater Melbourne and Geelong) that can be reached within 30 minutes, from homes in every travel zone, by car (Figure 54) and by public transport (Figure 55) in the two modelled years.

A large proportion of Greater Melbourne's employment opportunities are in the CBD and adjacent suburbs, meaning that ease of access to those areas is the primary driver of job accessibility. In 2016, residents of Melbourne city had access to 44.6% of the city's job market by car, reducing to 40.2% by 2031.

Job accessibility by public transport is forecast to be relatively stable between 2016 and 2031. Most Melbourne residents are unable to reach many jobs within a 30-minute commute. In both modelled years, Melbourne city has the best access to jobs via public transport due to the high concentration of jobs in that area, and its role as the centre of the region's public transport network. Outside of inner suburbs, most residents can access an extremely small proportion of the city's jobs within 30 minutes – typically less than half a percent or one out of 200 regional jobs.

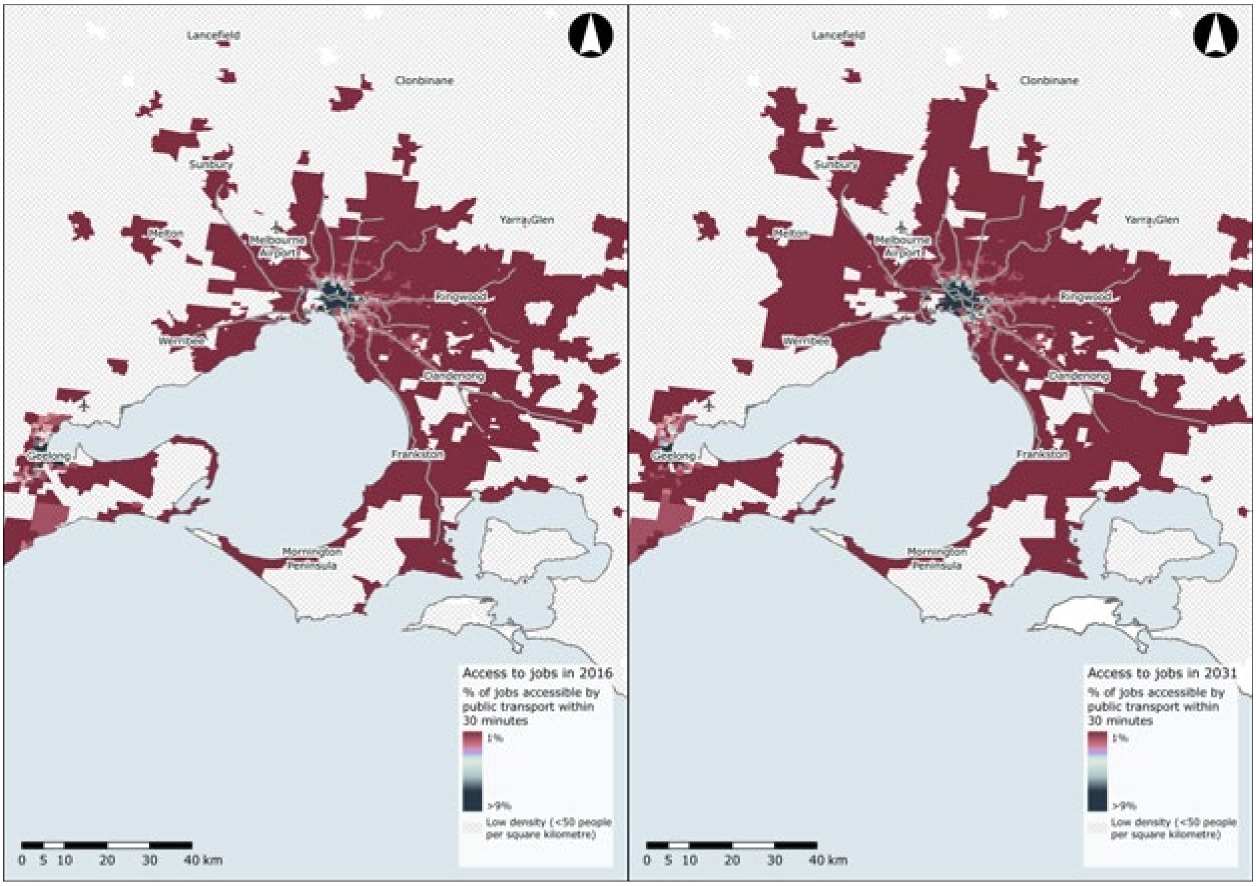
The percentage of jobs accessible is greater in Geelong than Melbourne. This does not mean that people in Geelong have access to a greater number of jobs, it simply means they have access to a higher percentage of the total jobs in the Geelong region. This is largely a function of the size of the area relatively to Melbourne.

**Figure 54:** Greater Melbourne access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[112]

**Figure 55:** Greater Melbourne access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[113]

## Findings

- Greater Melbourne's employment opportunities are concentrated in its central areas. Outside the Melbourne City area most residents are unable to reach many jobs within a 30-minute commute.
- Even for commuters who drive, there are significant spatial variations in access to employment. To Melbourne's east, job clusters in middle-ring suburbs (e.g., Monash and Dandenong) are accessible by the city's freeway network. By contrast, areas a similar distance to the west of Melbourne have more limited local employment options.
- For residents with access to a car, accessibility to hospitals is generally good, with an average travel time of 13 minutes in 2031. By public transport, however, most residents of Greater Melbourne will need to travel for more than 30 minutes to reach their nearest public hospital in 2031.
- For the residents of Geelong, access to local jobs within the region are relatively high by either car or public transport.

# 7 Brisbane, the Gold Coast and Sunshine Coast

## 7.1 Brisbane's population is growing, and so is its transport task

### Brisbane's transport network performance over the past decade

Between the 2006 and 2016 Census years Brisbane's population grew from almost 1.8 million[114] to over 2.2 million. Brisbane's population has consistently expanded into the city fringes, particularly to the north and south west. There have also been strong surges of growth in central areas within 10km of the CBD. Brisbane's population growth has placed greater pressure on the city's transport infrastructure, both in terms of access to the CBD from outer areas and movement through the city.

In the decade preceding 2016, passenger kilometres on Brisbane's roads increased by about 14%. Despite investment in extra capacity, growth in demand has progressively caused the deterioration of the performance of Brisbane's road network, affecting bus passengers, car users and truck drivers.

## 7.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit inputs and assumptions

Since the 2015 Audit, Brisbane, the Gold Coast and Sunshine Coast's forecast cost of road congestion has decreased by 35% (Table 22 and Figure 56). This is largely the result of model recalibration based on actual journey to work data.

In the 2015 Audit, 2031 population projections for South East Queensland were derived from ABS Series B projections. In the 2019 Audit, projections have been provided by the Queensland Government. There are marginal differences between these projections. The Brisbane, greater capital city statistical areas, and Gold Coast and Sunshine Coast population is forecast to be two percent higher in the 2019 Audit.

**Table 22:** The cost of road congestion and public transport crowding in Brisbane, the Gold Coast and Sunshine Coast, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| 2016 (2019 Audit) | 14 | 2,084 | 2,098 |
| 2031 (2019 Audit) | 90 | 5,969 | 6,059 |
| 2031 (2015 Audit) | N/A | 9,206 | N/A |
| 2031 (change from 2015 Audit) | | -3,237 (-35%) | |

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[115]

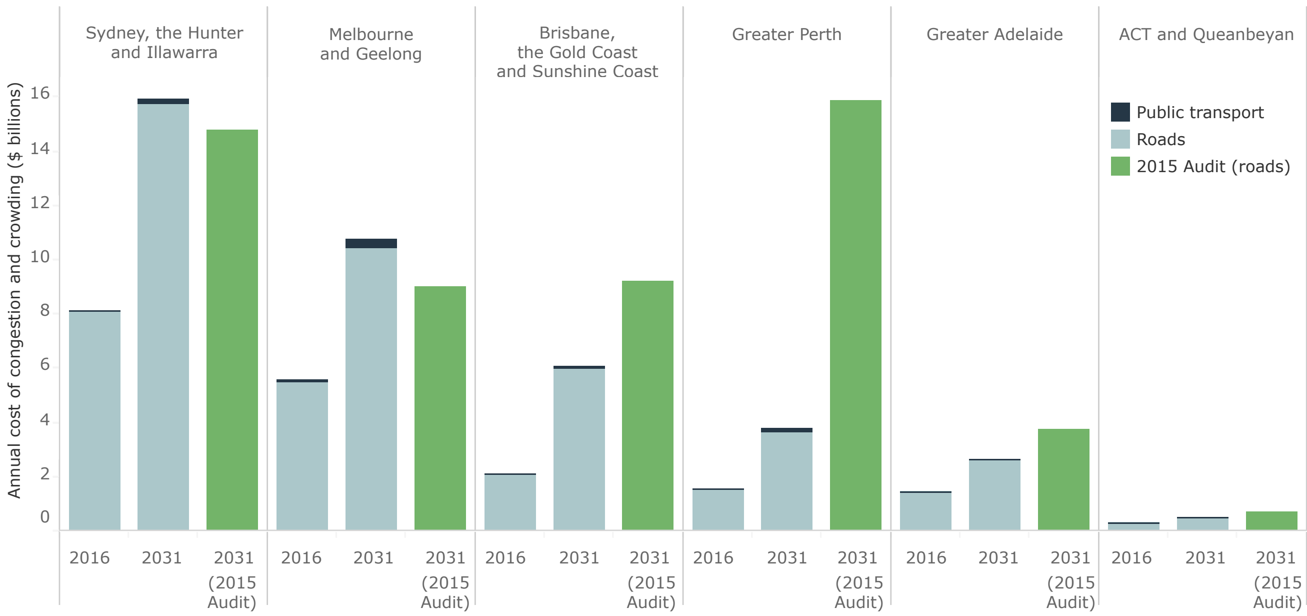
In addition to the slightly higher population and employment, the mapping suggests the following key differences in demographic assumptions between 2015 and 2019 Audits:

- Statistical Area Level 3s in inner Brisbane are forecast to have slightly larger populations than was previously expected
- The largest difference in forecast population in Brisbane Greater Capital City Stastical Area is in Springfield Redback (44,000 fewer residents)
- Sunshine Coast and Caboolture regions also have significantly lower population in the 2019 Audit.

Employment assumptions remain largely unchanged. Table 24 reflects changes in model inputs and key outputs between the 2015 and 2019 Audit modelling.

The largest single contributor to the decreased forecast cost of road congestion in Brisbane, the Gold Coast and Sunshine Coast 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.

**Figure 56:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[116]

## The challenge of matching transport needs to population projections: differences between the Infrastructure Australia and Queensland Government (ShapingSEQ) datasets

Forecasting future congestion is highly dependent on projections of future population distribution. This report uses baseline projections from the Queensland Government Statistician's Office (Rebased 2015ed) that reflect current planning schemes as approved by local councils.

These projections are consistent with our methodology of modelling a 'business as usual' future scenario. The Queensland Government has developed a separate set of demographic forecasts for their South East Queensland Regional Plan 2017, ShapingSEQ, which provides a policy framework for managing the region's population growth.

The ShapingSEQ demographic data is a policy aspiration of the Queensland Government, in contrast to the Queensland Government Statistician's Office baseline projection, which is based on historical trends.

As a result, there is variation between model outputs in this report and Queensland Government policy as represented by the ShapingSEQ plan and the Queensland Government State Infrastructure Plan (Part B).

The differences in demographic projections are shown in Table 23. The primary difference is that ShapingSEQ anticipates growth will be 58,453 people lower in 2031 as well as increased development in southern Brisbane, and less growth along the Ipswich corridor and on the Gold Coast, thereby reducing pressure on transport links in these areas..

**Table 23:** Resident population projections, Statistical Area Level 4 (SA4), 2031 and 2041

| SA4 | Rebased 2015ed | Shaping SEQ | Difference | Rebased 2015ed | Shaping SEQ | Difference |
|---|---|---|---|---|---|---|
| | 2031 | | | 2041 | | |
| Brisbane – East | 264,956 | 262,383 | -2,573 | 272,596 | 271,035 | -1,561 |
| Brisbane – North | 242,814 | 243,883 | 1,069 | 259,254 | 264,839 | 5,584 |
| Brisbane – South | 404,314 | 426,782 | 22,468 | 439,225 | 489,409 | 50,184 |
| Brisbane – West | 198,206 | 196,644 | -1,561 | 201,349 | 200,742 | -608 |
| Brisbane Inner City | 345,549 | 354,137 | 8,588 | 395,476 | 413,127 | 17,651 |
| Gold Coast | 815,634 | 785,638 | -29,996 | 988,358 | 944,524 | -43,834 |
| Ipswich | 578,779 | 537,913 | -40,866 | 794,886 | 719,479 | -75,407 |
| Logan – Beaudesert | 472,609 | 469,905 | -2,704 | 598,440 | 615,109 | 16,669 |
| Moreton Bay – North | 337,397 | 335,122 | -2,275 | 406,704 | 409,856 | 3,152 |
| Moreton Bay – South | 249,936 | 243,837 | -6,099 | 265,517 | 255,056 | -10,460 |
| Sunshine Coast | 480,714 | 476,209 | -4,505 | 566,195 | 558,354 | -7,841 |
| **Total region** | **4,390,908** | **4,332,455** | **-58,453** | **5,188,000** | **5,141,530** | **-46,471** |

Source: Supplied by Queensland Government

**Table 24:** Changes in key model inputs and outputs between 2015 and 2019 modelling in Brisbane, the Gold Coast and Sunshine Coast

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | ⇩ Population forecasts are similar (-2%) | ⇩ Employment forecasts are similar and proportion of jobs in Brisbane Inner SA3 remains stable | ⇧ More investment in the road network (+5% network lane km) | ⇧ More investment in the PT network (+~22% service kms) | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | |
| Impact on output (AM peak) | Total trips (no change) | ⇩ Slightly lower total population reduces total modelled trips | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| | Car trips (-24%) | ⇩ Slightly lower total population reduces total modelled car trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| | Car vehicle kms travelled (-4%) | ⇩ An overall reduction in population reduces car kilometres. Lower population growth in urban fringe and peri-urban areas also causes a reduction in this metric | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| | Public transport trips (-24%) | ⇩ Slightly lower total population reduces total modelled PT trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | |

Source: Veitch Lister Consulting (2019)[117]

## New network assumptions

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. For Brisbane, the Gold Coast and Sunshine Coast, there are three key differences in network assumptions. Cross River Rail, Brisbane Metro and the Gold Cost Light Rail Stage 2 are included in the 2019 Audit but not the 2015 Audit.

## Variation between road network capacities in 2031

There are only minor differences between the South East Queensland forecast traffic volumes in the 2019 Audit in the 2031 AM and PM peaks. This is mainly a result of the small variation in population forecasts. The worst-performing corridors (Pacific Motorway, Bruce Highway, Ipswich Motorway and Mt Lindesay Highway) are largely consistent between the audits.

The 2015 and 2019 Audits identify roads that have different levels of congestion at the AM and PM peaks. For instance, The Gateway Motorway and arterial roads around Brisbane Airport are forecast to have less congestion in the 2019 Audit. Likewise, there is forecast to be less congestion in the 2019 Audit on local and arterial roads in Wynnum West, Manly West and Tingalpa. A similar trend is mirrored in Forestlake, Richlands and Inala.

Vehicle delays are forecast to decrease by more than the corresponding change in traffic volumes. This is a function of the underlying dynamics of traffic flow, which is when additional traffic is added to an already congested road, as a result, delay is disproportionately higher than in less congested conditions.

Table 25 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

**Table 25:** Most congested roads ranked by total delay hours, 2031 AM Peak and ranking in 2015 Audit in Brisbane, the Gold Coast and Sunshine Coast

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Beenleigh to city corridor (Pacific Motorway) | N/B | 6,500 | 7,300 | 13% | 7,500 | 11,700 | 55% | 1 |
| 2 | Helensvale to Beenleigh corridor (Pacific Motorway) | N/B | 7,600 | 8,200 | 8% | 4,800 | 9,300 | 94% | 5 |
| 3 | Sippy Downs to Mango Hills corridor (Bruce Highway) | S/B | 3,900 | 3,900 | 1% | 5,200 | 6,700 | 28% | 3 |
| 4 | Goodna to Mount Gravatt corridor (Ipswich Motorway / Kessels Road) | E/B | 4,000 | 4,600 | 16% | 3,400 | 5,700 | 67% | 8 |
| 5 | Ipswich to Goodna corridor (Brisbane Road / Ipswich Motorway) | E/B | 4,000 | 4,300 | 7% | 3,900 | 5,600 | 43% | 7 |
| 6 | Beaudesert to North Logan corridor (Mount Lindesay Highway) | N/B | 2,000 | 1,900 | -4% | 5,000 | 5,200 | 4% | 4 |
| 7 | Loganholme to Mount Gravatt corridor (Pacific Motorway) | N/B | 6,400 | 7,300 | 15% | 4,300 | 4,900 | 14% | 6 |
| 8 | Bald Hills to Tingalpa corridor (Gateway Motorway) | S/B | 4,900 | 5,300 | 10% | 2,200 | 4,200 | 89% | 10 |
| 9 | Beenleigh to Helensvale corridor (Pacific Motorway) | S/B | 7,400 | 7,100 | -5% | 5,800 | 4,100 | -30% | 2 |
| 10 | Ipswich Motorway to Indooroopilly corridor (Centenary Highway) | N/B | 3,900 | 3,900 | 0% | 2,700 | 3,400 | 26% | 9 |

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

Source: Veitch Lister Consulting (2019)[118]

### Variation between public transport capacities in 2031

In both the 2015 and 2019 Audit, Brisbane's rail and bus routes are projected to carry significantly more commuters by 2031 due to population growth. Both audits have similar patterns of public transport demand.

The 2015 Audit suggests that the Rosewood and Ipswich Line, and the Springfield line are likely to experience high instances of crush capacity at AM peak. By comparison, the 2019 Audit suggests that rail crowding in 2031 will be low, with exceptions of medium crowding on small sections of the Rosewood and Ipswich line. This crowding is likely to be a result of projected population growth in Ipswich and surrounding areas.

Bus travel demand in the metropolitan area is similar in both the 2015 and 2019 Audits. Both audits highlight that bus services from Springwood, Brown Plains and surrounding areas will have high demand.

## 7.3 Brisbane residents, visitors and businesses are exposed to daily road congestion and crowded public transport

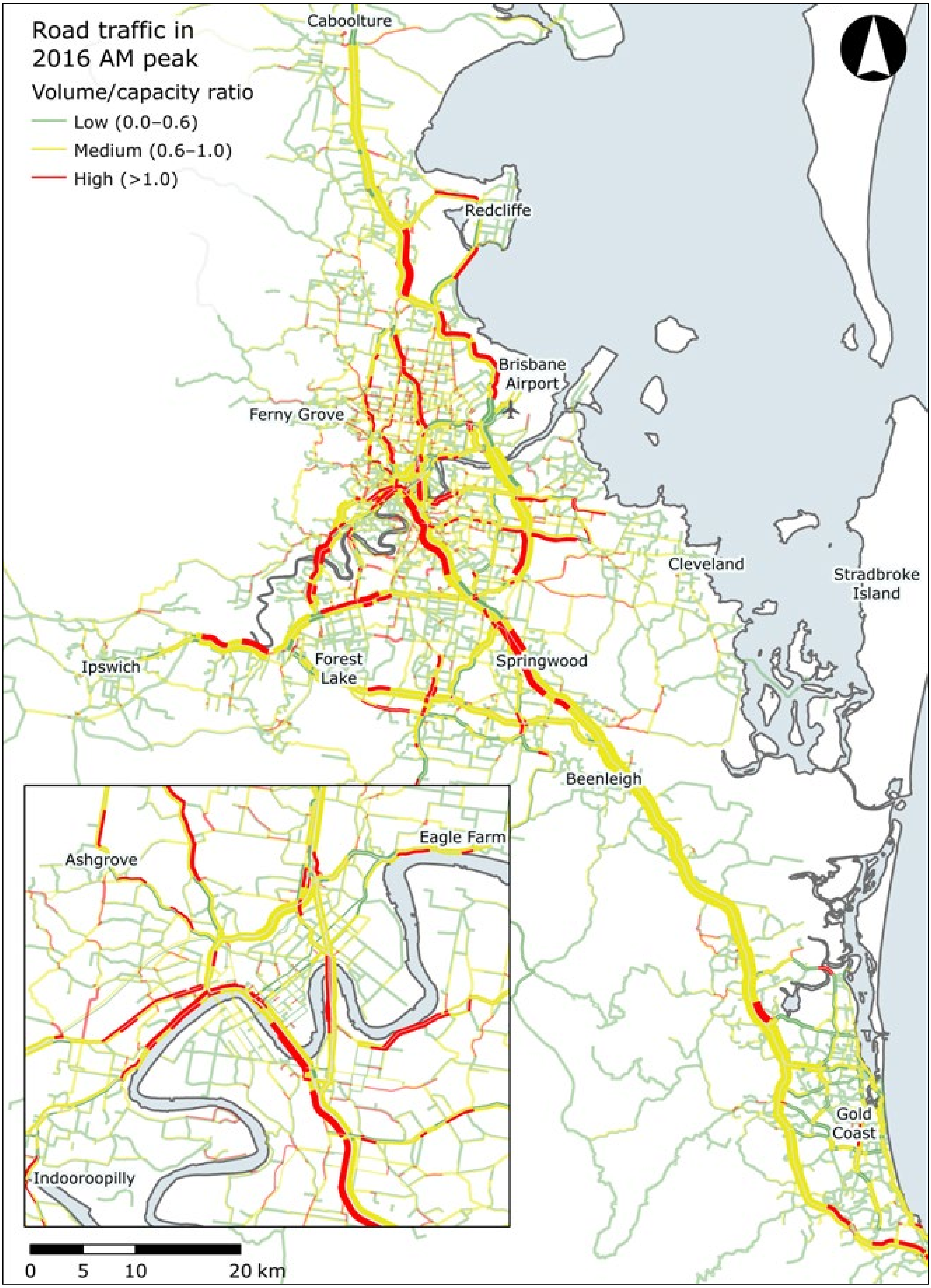
### Snapshot of Brisbane's road network in 2016

Brisbane's drivers already experience congestion on a day-to-day basis (Figure 57), although this is lower than the congestion experienced in other Australian capital cities. Our modelling indicates the annualised cost of road congestion and public transport crowding in the Brisbane GCCSA, Gold Coast and the Sunshine Coast was approximately $2.1 billion in 2016. For Brisbane only, this was $1.7 billion.

Brisbane's most significant congestion occurs along a north-south spine – in particular, on the Pacific Motorway and Gateway Motorway / Bruce Highway corridors, which link Brisbane with the Gold Coast and Sunshine Coast respectively.

The Ipswich Motorway and Centenary Highway also experience significant levels of congestion. These are important connections between Brisbane CBD and the Ipswich growth corridor.

**Figure 57:** Brisbane weekday traffic volume / capacity ratio, 2016 AM peak




Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019)[119]

## Brisbane's most congested roads in 2016: what the driver experiences

Infrastructure Australia has measured the most congested corridors in Brisbane based on a variety of metrics that relate to user experience, including the percentage of total journey time that is spent in congestion. The ten most congested corridors for the AM and PM peaks are shown in Table 26 and Figure 58.

The city's most congested corridors are those that provide access to the CBD from outer suburbs. Travel in the peak direction is most constrained southbound for roads north of the Brisbane River and northbound for roads south of the Brisbane River. However, some routes experience high levels of congestion in both directions of travel, such as the Centenary Highway and the Pacific Motorway.

Brisbane's major activity centres in the south are affected by congestion on the Bruce Highway, Sandgate Road and the Gateway Motorway, as residents in Brisbane's northern suburbs travel south for work, particularly during peak periods.

In addition, corridors servicing east-west movements such as the Ipswich Motorway and the Logan Motorway are subject to moderate to high levels of congestion. These corridors service demand for travel from growth areas in the western part of the city to the CBD.

## Brisbane's most congested roads in 2016: the cost to the community of total vehicle delays

As a measure of the whole-of-network impacts of congestion, Infrastructure Australia has aggregated total delay hours experienced by all vehicles using the most congested roads during the modelled period. The ten most congested corridors under this approach for the AM and PM peak are shown in Table 27 and Figure 59.

## Brisbane's public transport system in 2016

The use of public transport in Brisbane has increased significantly in recent years. Between 2004–05 and 2014–15 the public transport task increased by about 27%.

Brisbane's rail system connects Brisbane's outer suburbs to the CBD, and enables travel between the city centre, the Gold Coast and Sunshine Coast. Brisbane has a relatively uncongested railway network, with low VCRs on all lines, as observable in Figure 60.

Brisbane's bus network includes high-capacity corridors, such as the South Eastern and Northern busways, feeder services to rail stations and local services. With the exception of some busway services, Brisbane's bus network primarily caters to the city's internal demand, serving a radial function rather than cross-regional travel demand.

In 2016, varied levels of crowding were apparent on Brisbane's major bus corridors during peak periods (Figure 61). The most crowded sections of the bus network are those just before bus routes join major busways, and areas outside the catchment of the rail network. This means that passengers experience modest crowding on major busways close to the CBD, while in the outer suburbs crowding can be quite significant. Brisbane's busiest routes in both peak periods include La Trobe Terrace, Given Terrace and Caxton Street just north of the CBD, Kelvin Grove Road north of the CBD and Ipswich Road south of the Pacific Motorway.

The model does not take into account congestion of buses on the dedicated busway corridor, only crowding of passengers within bus capacity.

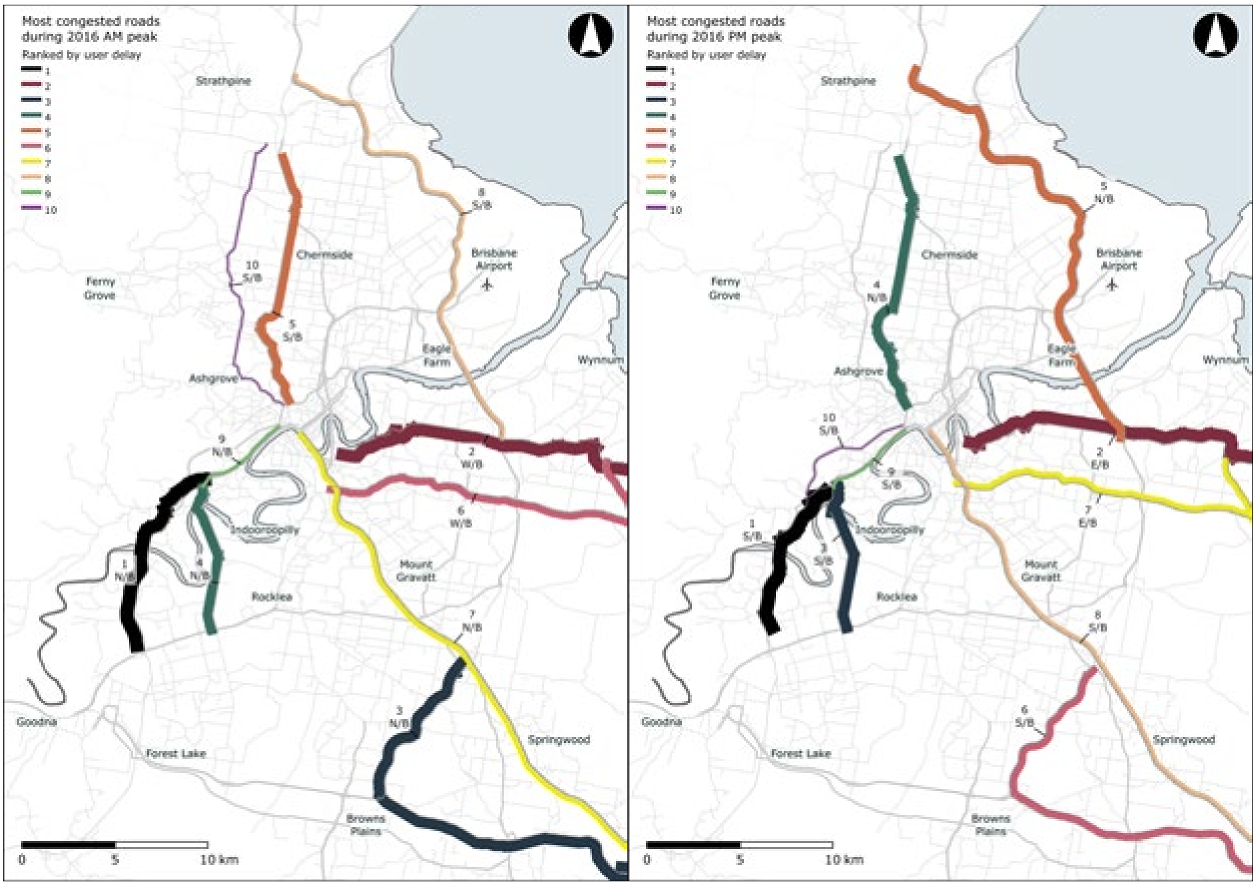
**Table 26:** Brisbane's most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Ipswich Motorway to Indooroopilly via Centenary Highway (N/B) | 10 | 68% | 18 | $4.97 | $21.41 |
| 2. | Thorneside to Woolloongabba via Wynnum Road (W/B) | 17 | 59% | 25 | $6.90 | $29.74 |
| 3. | Loganholme to Mount Gravatt via Pacific Motorway (N/B) | 17 | 58% | 14 | $3.87 | $16.66 |
| 4. | Ipswich Motorway to Indooroopilly via Oxley Road (N/B) | 8 | 57% | 13 | $3.59 | $15.47 |
| 5. | M1 to Inner City Bypass via Kelvin Grove (S/B) | 14 | 57% | 22 | $6.08 | $26.17 |
| 6. | Thorneside to Woolloongabba via Old Cleveland Road (W/B) | 21 | 56% | 25 | $6.90 | $29.74 |
| 7. | Beenleigh to city via Pacific Motorway (N/B) | 35 | 55% | 27 | $7.46 | $32.12 |
| 8. | Bald Hills to Tingalpa via Gateway Motorway (S/B) | 26 | 55% | 20 | $5.52 | $23.79 |
| 9. | Moggill Road to Inner City Bypass via Coronation Drive (N/B) | 5 | 52% | 7 | $1.93 | $8.33 |
| 10. | M1 to Inner City Bypass via Bridgeman Road (S/B) | 16 | 50% | 20 | $5.52 | $23.79 |
| PM peak | | | | | | |
| 1. | Indooroopilly to Ipswich via Centenary Highway (S/B) | 9 | 66% | 14 | $3.87 | $16.66 |
| 2. | Woolloongabba to Thorneside via Wynnum Road (E/B) | 17 | 54% | 20 | $5.52 | $23.79 |
| 3. | Indooroopilly to Ipswich via Oxley Road (S/B) | 8 | 52% | 10 | $2.76 | $11.90 |
| 4. | Inner City Bypass to M1 via Kelvin Grove (N/B) | 14 | 50% | 17 | $4.69 | $20.22 |
| 5. | Tingalpa to Bald Hills via Gateway Motorway (N/B) | 26 | 50% | 16 | $4.42 | $19.03 |
| 6. | Mount Gravatt to Loganholme via Pacific Motorway (S/B) | 16 | 48% | 9 | $2.49 | $10.71 |
| 7. | Woolloongabba to Thorneside via Old Cleveland Road (E/B) | 21 | 48% | 18 | $4.97 | $21.41 |
| 8. | City to Beenleigh via Pacific Motorway (S/B) | 34 | 48% | 20 | $5.52 | $23.79 |
| 9. | Inner City Bypass to Moggill Road via Coronation Drive (S/B) | 5 | 47% | 6 | $1.66 | $7.14 |
| 10. | Inner City Bypass to Moggill Road via Milton Road (S/B) | 7 | 46% | 5 | $1.38 | $5.95 |

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

Source: Veitch Lister Consulting (2019)[120]

**Figure 58:** Brisbane's most congested roads (user experience), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[121]

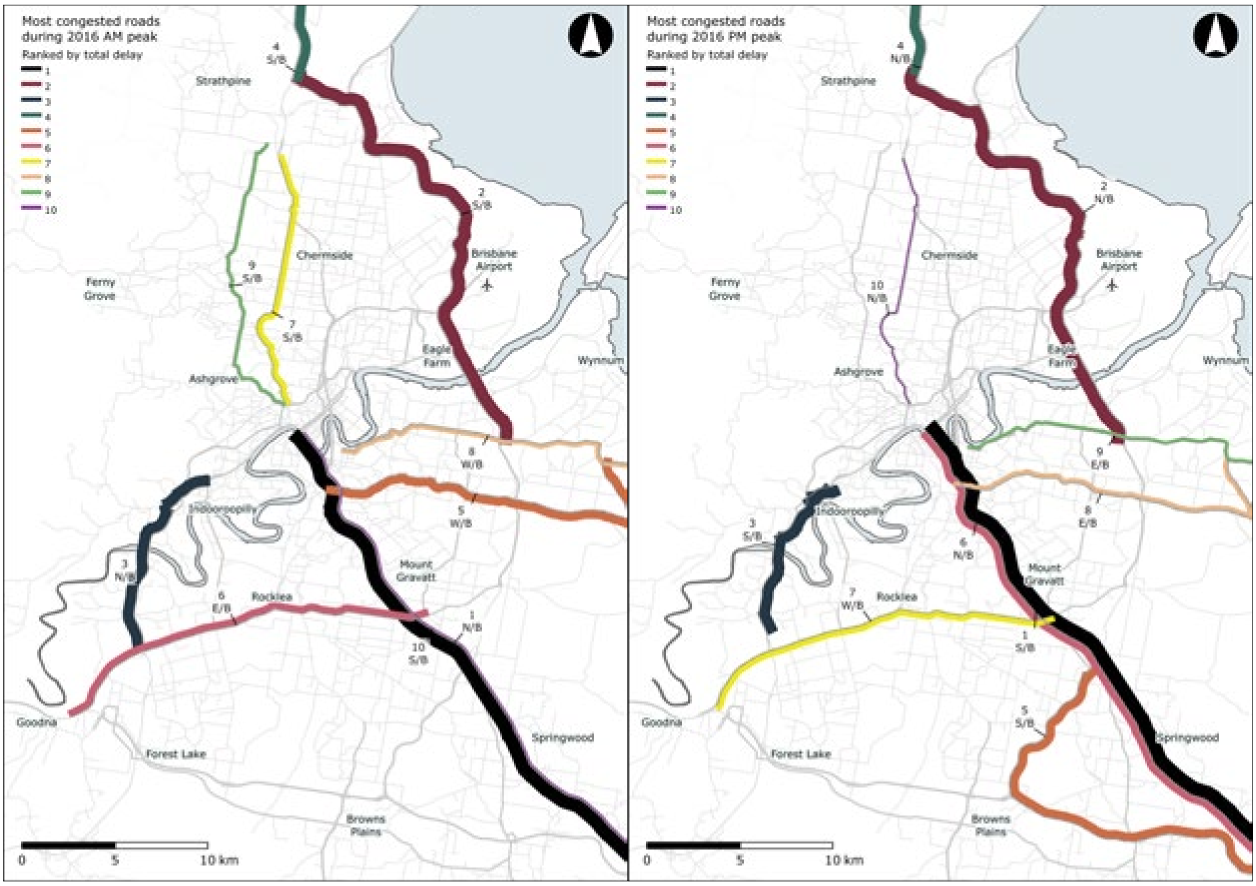
**Table 27:** Brisbane's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Beenleigh to city corridor (Pacific Motorway) | N/B | 4,800 | $95,000 |
| 2. | Bald Hills to Tingalpa (Gateway Motorway) | S/B | 2,400 | $50,000 |
| 3. | Ipswich Motorway to Indooroopilly corridor (Centenary Highway) | N/B | 2,100 | $42,000 |
| 4. | Sippy Downs to Mango Hills corridor (Bruce Highway) | S/B | 2,000 | $41,000 |
| 5. | Woolloongabba to Thorneside (Old Cleveland Road) | W/B | 1,700 | $33,000 |
| 6. | Goodna to Mount Gravatt corridor (Ipswich Motorway / Kessels Road) | E/B | 1,700 | $34,000 |
| 7. | M1 to Inner City Bypass corridor (via Kelvin Grove) | S/B | 1,500 | $29,000 |
| 8. | Thorneside to Woolloongabba corridor (Wynnum Road) | W/B | 1,400 | $27,000 |
| 9. | M1 to Inner City Bypass corridor (Bridgeman Road) | S/B | 1,200 | $23,000 |
| 10. | City to Beenleigh corridor (Pacific Motorway) | S/B | 1,200 | $25,000 |
| PM peak | | | | |
| 1. | City to Beenleigh corridor (Pacific Motorway) | S/B | 3,700 | $71,000 |
| 2. | Tingalpa to Bald Hills corridor (Gateway Motorway) | N/B | 2,100 | $43,000 |
| 3. | Ipswich Motorway to Indooroopilly corridor (Centenary Highway) | S/B | 1,800 | $35,000 |
| 4. | Mango Hills to Sippy Downs corridor (Bruce Highway) | N/B | 1,700 | $35,000 |
| 5. | Mount Gravatt to Loganholme corridor (Pacific Motorway) | S/B | 1,600 | $32,000 |
| 6. | City to Beenleigh corridor (Pacific Motorway) | N/B | 1,500 | $30,000 |
| 7. | Mount Gravatt to Goodna corridor (Kessels Road / Ipswich Motorway) | W/B | 1,300 | $26,000 |
| 8. | Woolloongabba to Thorneside corridor (Old Cleveland Road) | E/B | 1,200 | $23,000 |
| 9. | Woolloongabba to Thorneside corridor (Wynnum Road) | E/B | 1,200 | $23,000 |
| 10. | Inner City Bypass to M1 (via Kelvin Grove) | N/B | 1,200 | $22,000 |

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

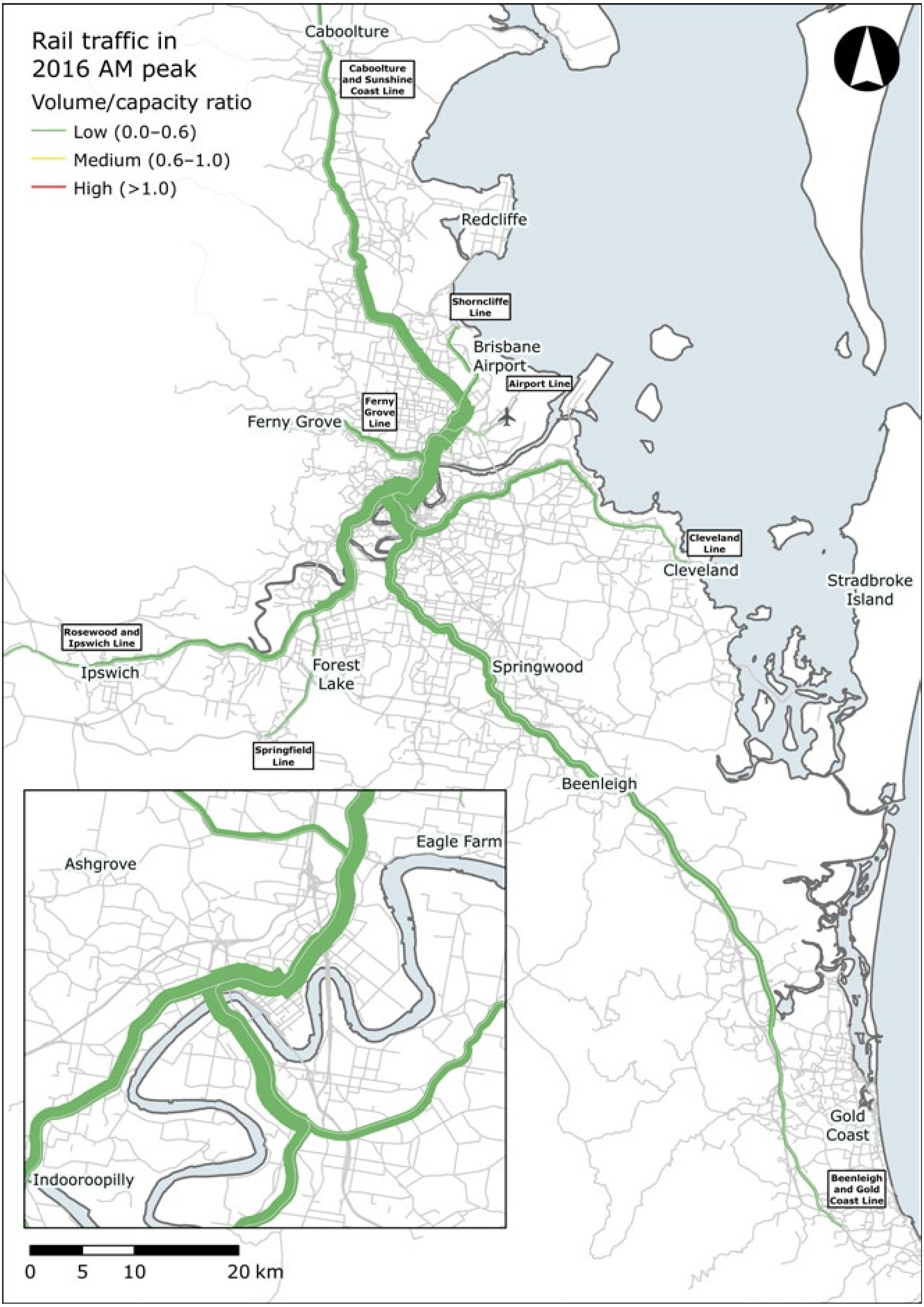
Source: Veitch Lister Consulting (2019)[122]

**Figure 59:** Brisbane's most congested roads (total vehicle delays), 2016 AM (left) and PM (right) peak periods



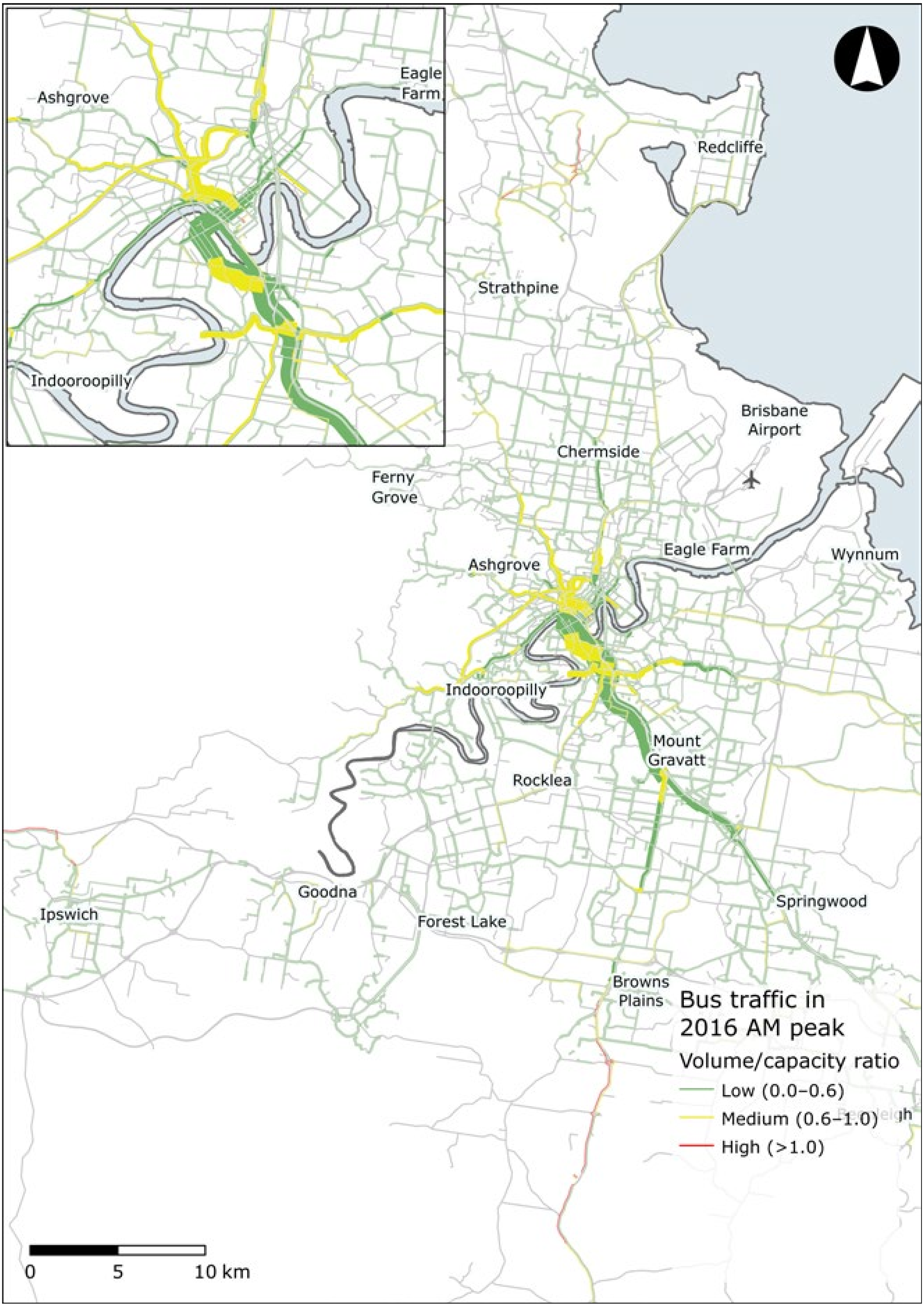

Source: Veitch Lister Consulting (2019)[123]

**Figure 60:** Brisbane weekday train passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[124]

**Figure 61:** Brisbane weekday bus passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[125]

## Findings

- Brisbane's most congested transport corridors are key routes providing access to the CBD from outer suburbs. Congestion is most severe at access points immediately surrounding the CBD.
- The Brisbane River concentrates traffic and commuters onto several key corridors that provide river crossings. Travel in the peak direction is most constrained southbound for roads north of the Brisbane River and northbound for roads south of the Brisbane River).
- Some routes experience high levels of congestion in both directions of travel, most notably the Centenary Highway and the Pacific Motorway.
- The demand for travel between Brisbane's northern suburbs and the major activity centres in the south drives congestion on the Bruce Highway, Sandgate Road and Gateway Motorway.
- The most significant corridors servicing east-west movements are the Ipswich Motorway (with high levels of congestion) and the Logan Motorway (with moderate congestion). Congestion on these corridors result from the demand for travel from the western parts of the city (Ipswich, Springfield and Redbank) to the activity centres located further east.
- Brisbane's bus routes outside of major busways are subject to significant crowding in peak periods, while bus corridors closer to the CBD experience more modest crowding in peak periods. This indicates that there is insufficient bus capacity to cater for Brisbane's expanding population outside of established suburbs.
- There are currently low levels of crowding on Brisbane's rail services.

## 7.4 Even with programmed investment, Brisbane's transport networks are forecast to become more congested

### Snapshot of Brisbane's transport networks in 2031

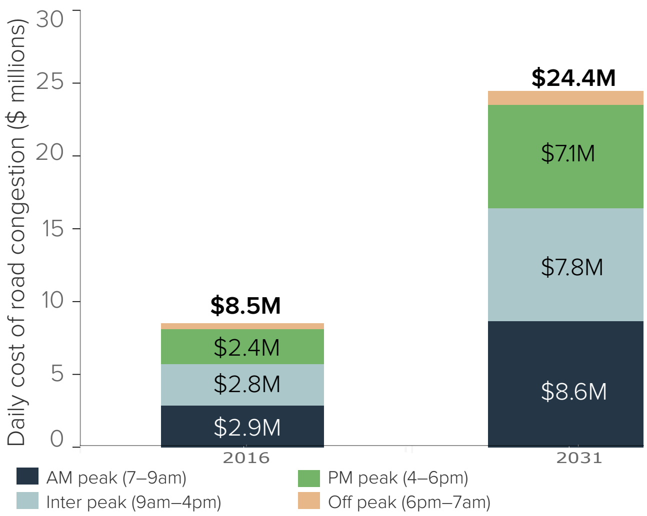
Brisbane's transport network demand is forecast to increase roughly in line with population growth. Greater Brisbane's population is estimated to grow by approximately 30%, to just over 3 million people, by 2031. Population is predicted to grow most quickly in the outer suburbs of Brisbane, such as Jimboomba, Springfield-Redbank and Ipswich. In line with Brisbane's population growth, trips on Brisbane's transport network are expected to increase by 26%, to over 6 million daily trips, by 2031.

Trips by public transport will grow at a faster rate than by car, continuing a shift towards public transport use in the city seen over the last few years. Public transport journeys are expected to increase by 55%, while the use of cars will only increase by 21%.

Despite this shift towards public transport, congestion on Brisbane's roads is forecast to grow substantially. Our modelling indicates the annualised cost of road congestion in 2031 will be approximately $6.0 billion for Brisbane GCCSA, the Gold Coast and Sunshine Coast. For Brisbane, it will be $4.7 billion.

This will result in more time spent in traffic and on crowded public transport. As a result, the daily cost of road congestion on Brisbane, the Gold Coast and Sunshine Coast's roads is expected to almost triple, from about $8.5 million in 2016 to $24.4 million in 2031 (Figure 62). Congestion on the rail network will also increase, but this will be from a relatively low base and is expected to have a small impact. In comparison, road congestion and bus network delays and crowding will be a larger impact. While the cost of public transport crowding is significantly less than for road congestion, it is expected to increase more than six-fold. The annualised cost across Brisbane, the Gold Coast and Sunshine Coast will increase from $14 million in 2016 to $90 million in 2031, with most of this cost being borne by bus passengers.

**Figure 62:** Brisbane, the Gold Coast and Sunshine Coast's average weekday cost of road congestion, 2016 and 2031




Source: Veitch Lister Consulting (2019)[126]

The transport outcomes forecast for Brisbane account for projects that were either under construction, under procurement, or had a public commitment to fund construction from all relevant governments at the time of modelling for the *Australian Infrastructure Audit*.[127]

Major projects included in Brisbane, the Gold Coast and Sunshine Coast's forecast comprise:

- Cross River Rail
- Brisbane Metro
- Gold Coast Light Rail Stage 2
- Gateway Motorway widening
- Pacific Motorway widening
- South East Busway extension
- Inner City Bypass widening
- Logan Enhancement Project
- Pacific Motorway Upgrades.

As noted in Table 23, the population projections informing this Audit do not align with those in ShapingSEQ. The key difference is that ShapingSEQ identifies less growth and reduced pressure on corridors linking the outer suburbs and satellite cities, due to more infill development.

## Brisbane's most congested roads in 2031: what the driver will experience

Between 2016 and 2031 there is expected to be a noticeable shift in the location of congestion in Brisbane. In 2016, Brisbane's inner eastern roads were some of its most congested. However, by 2031 Brisbane's most congested roads will be those linking the city centre with growth areas to the south-west. Aside from this shift, north-south corridors such as the Pacific and Bruce highways, as well as the Ipswich Motorway, will continue to be some of the most congested roads in the city (Table 28, Figure 63 and Figure 64).

By 2031, traffic is forecast to grow substantially on Greater Brisbane's road network. The patterns of congestion identified in the 2016 model are forecast to become more pronounced. Commuters on Brisbane's roads can expect higher levels of traffic and longer delays, and it will become more common for peak congestion to be encountered in both directions.

Population growth, particularly in Brisbane's western and southern suburbs, will increase traffic volumes on key city centre access routes. Brisbane's north-south development pattern will mean that major northern corridors such as the Bruce Highway and Gateway Motorway will become in-demand thoroughfares for commuters and freight vehicles. Longer sections of road that are subject to high and moderate congestion levels are predicted to be common on these corridors by 2031.

Population growth in Brisbane's southern suburbs will drive increasing congestion on the Pacific Motorway. Forecasts indicate that a greater proportion of the motorway will operate in highly congested conditions in peak periods. Congestion is expected to extend well into Brisbane's outer suburbs. The Pacific Motorway corridor south of Eight Mile Plains can expect a 25% increase in traffic volumes by 2031.

Long sections of Greater Brisbane's main east-west corridors can also be expected to experience worsening traffic congestion. Population growth in Ipswich is expected to place an additional 12,000 vehicles per day on the Logan Motorway in both directions. Congestion increases can also be expected on the Ipswich and Centenary Highways as commuters access central Brisbane from Ipswich. By 2031 the Mount Lindesay Highway is expected to carry traffic volumes well above its design capacity as a consequence of population growth in southern areas such as Jimboomba.

## Brisbane's most congested roads in 2031: the forecast cost to the community of total vehicle delays

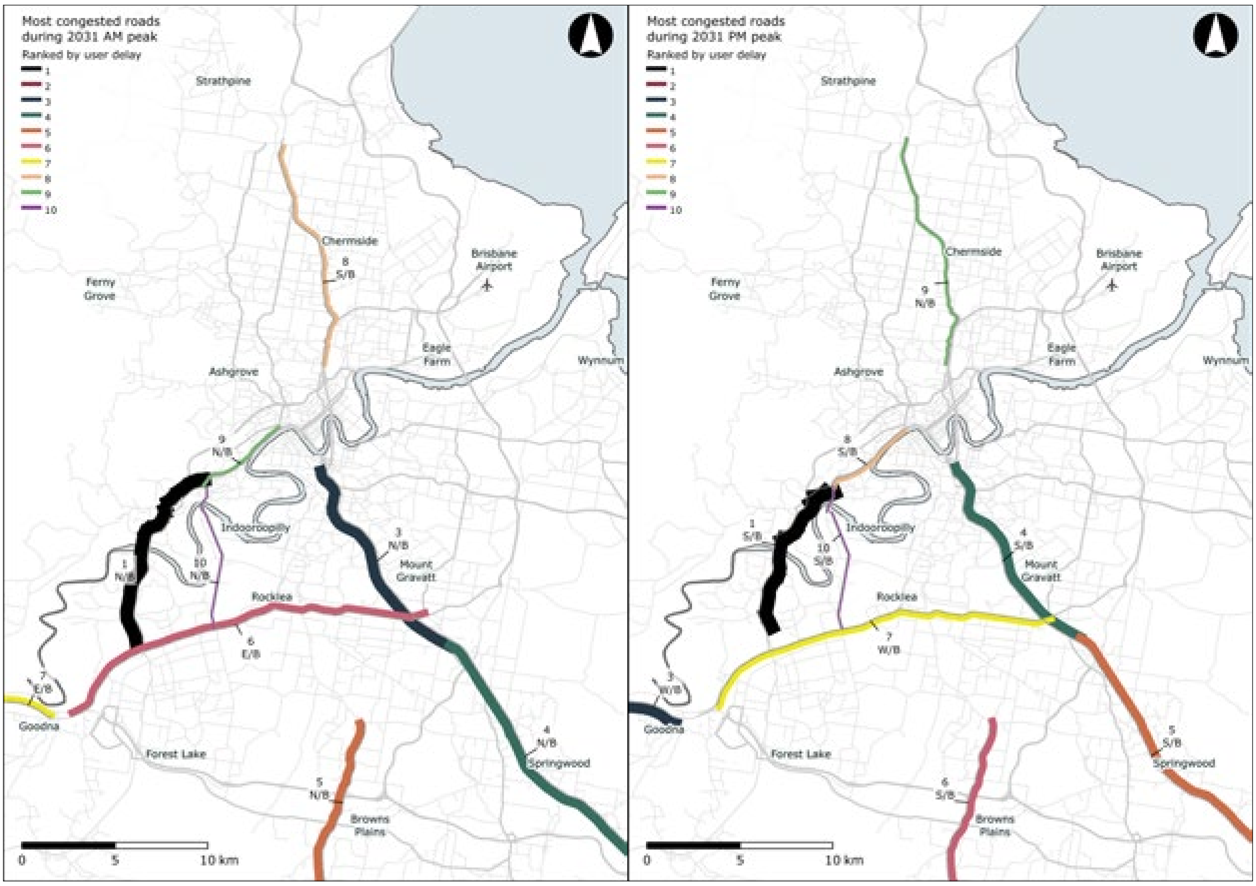
As for 2016, the most congested road corridors in Greater Brisbane have been forecast for 2031 based on aggregating the total delay hours experienced by all vehicles across the network during the modelled period. The ten most congested corridors under this approach are shown in Table 29 and Figure 65.

**Table 28:** Brisbane's most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Ipswich Motorway to Indooroopilly via Centenary Highway (N/B) | 10 | 76% | 26 | $7.18 | $30.93 |
| 2. | Helensvale to Beenleigh via Pacific Motorway (N/B) | 26 | 73% | 37 | $10.22 | $44.02 |
| 3. | Beenleigh to city via Pacific Motorway (N/B) | 35 | 71% | 53 | $14.64 | $63.05 |
| 4. | Loganholme to Mount Gravatt via Pacific Motorway (N/B) | 17 | 70% | 23 | $6.35 | $27.36 |
| 5. | Beaudesert to North Logan via Mount Lindesay Highway (N/B) | 47 | 68% | 73 | $20.16 | $86.85 |
| 6. | Goodna to Mount Gravatt via Ipswich Motorway / Kessels Road (E/B) | 19 | 68% | 34 | $9.39 | $40.45 |
| 7. | Ipswich to Goodna via Brisbane Road / Ipswich Motorway (E/B) | 15 | 68% | 28 | $7.73 | $33.31 |
| 8. | M1 to Inner City Bypass via Gympie Road / Lutwyche Road (S/B) | 13 | 65% | 12 | $6.90 | $29.74 |
| 9. | Moggill Road to Inner City Bypass via Coronation Drive (N/B) | 5 | 65% | 12 | $3.31 | $14.28 |
| 10. | Ipswich Motorway to Indooroopilly via Oxley Road (N/B) | 8 | 65% | 18 | $4.97 | $21.41 |
| PM peak | | | | | | |
| 1. | Indooroopilly to Ipswich via Centenary Highway (S/B) | 9 | 74% | 20 | $5.52 | $23.79 |
| 2. | Beenleigh to Helensvale via Pacific Motorway (S/B) | 27 | 71% | 36 | $9.94 | $42.83 |
| 3. | Goodna to Ipswich via Ipswich Motorway / Brisbane Road (W/B) | 15 | 69% | 27 | $7.46 | $32.12 |
| 4. | City to Beenleigh via Pacific Motorway (S/B) | 34 | 66% | 42 | $11.60 | $49.97 |
| 5. | Mount Gravatt to Loganholme via Pacific Motorway (S/B) | 16 | 63% | 16 | $4.42 | $19.03 |
| 6. | North Logan to Beaudesert via Mount Lindesay Highway (S/B) | 47 | 63% | 56 | $15.47 | $66.62 |
| 7. | Mount Gravatt to Goodna via Kessels Road / Ipswich Motorway (W/B) | 18 | 61% | 23 | $6.35 | $27.36 |
| 8. | Inner City Bypass to Moggill Road via Coronation Drive (S/B) | 5 | 60% | 10 | $2.76 | $11.90 |
| 9. | Inner City Bypass to M1 via Lutwyche Road / Gympie Road (N/B) | 13 | 60% | 20 | $5.52 | $23.79 |
| 10. | Indooroopilly to Ipswich Motorway via Oxley Road (S/B) | 8 | 59% | 14 | $3.87 | $16.66 |

Source: Veitch Lister Consulting (2019)[128]

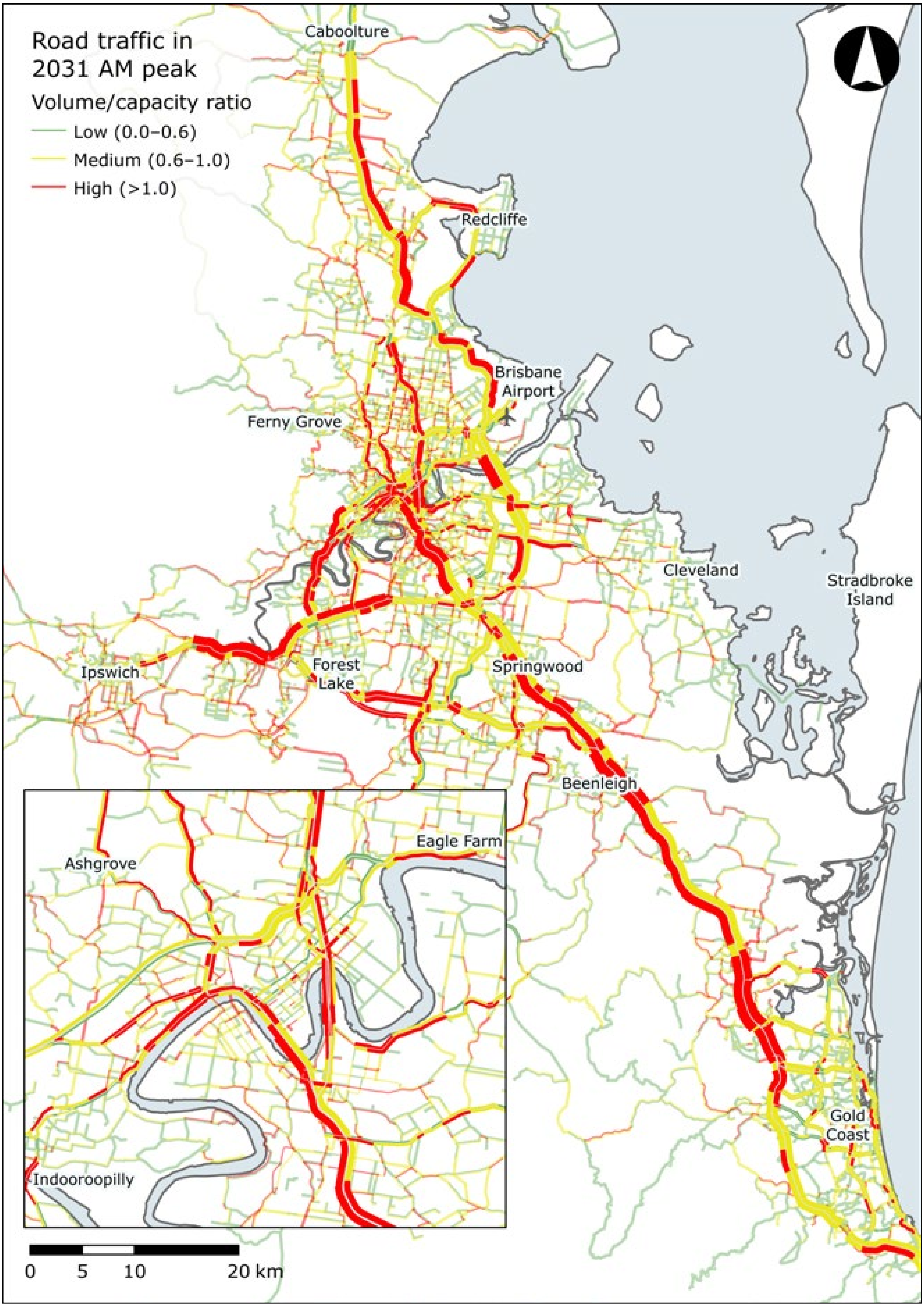
**Figure 63:** Brisbane's most congested roads (user experience), 2031 AM (left) and PM (right) peak periods




Note: The Beenleigh to Helensvale via Pacific Motorway corridor (2nd most congested corridor in both AM and PM peak periods) is located beyond the map extent, towards the Gold Coast in the south east.

Source: Veitch Lister Consulting (2019)[129]

**Figure 64:** Brisbane weekday traffic volume / capacity ratio, 2031 AM peak



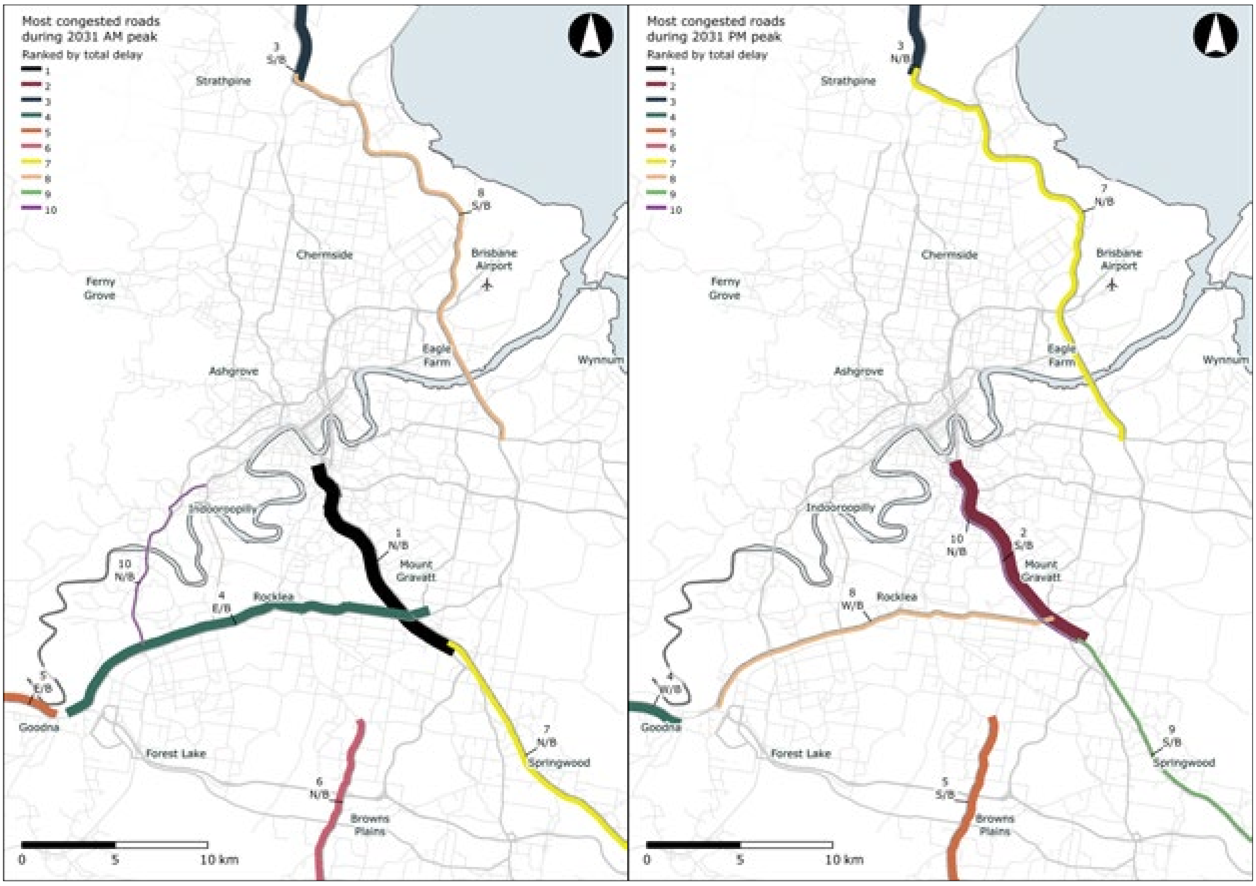

Source: Veitch Lister Consulting (2019)[130]

### **Table 29:** Brisbane's most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Beenleigh to city corridor (Pacific Motorway) | N/B | 11,700 | $235,000 |
| 2. | Helensvale to Beenleigh corridor (Pacific Motorway) | N/B | 9,300 | $189,000 |
| 3. | Sippy Downs to Mango Hills corridor (Bruce Highway) | S/B | 6,700 | $142,000 |
| 4. | Goodna to Mount Gravatt corridor (Ipswich Motorway / Kessels Road) | E/B | 5,700 | $114,000 |
| 5. | Ipswich to Goodna corridor (Brisbane Road / Ipswich Motorway) | E/B | 5,600 | $111,000 |
| 6. | Beaudesert to North Logan corridor (Mount Lindesay Highway) | N/B | 5,200 | $101,000 |
| 7. | Loganholme to Mount Gravatt corridor (Pacific Motorway) | N/B | 4,900 | $100,000 |
| 8. | Bald Hills to Tingalpa corridor (Gateway Motorway) | S/B | 4,200 | $89,000 |
| 9. | Beenleigh to Helensvale corridor (Pacific Motorway) | S/B | 4,100 | $86,000 |
| 10. | Ipswich Motorway to Indooroopilly corridor (Centenary Highway) | N/B | 3,400 | $67,000 |
| PM peak | | | | |
| 1. | Beenleigh to Helensvale corridor (Pacific Motorway) | S/B | 9,500 | $188,000 |
| 2. | City to Beenleigh corridor (Pacific Motorway) | S/B | 9,400 | $183,000 |
| 3. | Mango Hills to Sippy Downs corridor (Bruce Highway) | N/B | 5,500 | $114,000 |
| 4. | Goodna to Ipswich corridor (Ipswich Motorway / Brisbane Road) | W/B | 5,500 | $108,000 |
| 5. | North Logan to Beaudesert corridor (Mount Lindesay Highway) | S/B | 3,900 | $75,000 |
| 6. | Helensvale to Beenleigh corridor (Pacific Motorway) | N/B | 3,800 | $77,000 |
| 7. | Tingalpa to Bald Hills corridor (Gateway Motorway) | N/B | 3,800 | $78,000 |
| 8. | Mount Gravatt to Goodna corridor (Kessels Road / Ipswich Motorway) | W/B | 3,700 | $72,000 |
| 9. | Mount Gravatt to Loganholme corridor (Pacific Motorway) | S/B | 3,500 | $69,000 |
| 10. | Beenleigh to city corridor (Pacific Motorway) | N/B | 3,500 | $71,000 |

Source: Veitch Lister Consulting (2019)[131]

### **Figure 65:** Brisbane's most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak periods




Note: The Beenleigh to Helensvale via Pacific Motorway corridor (2nd and 9th most congested corridor in AM peak period, and 1st and 6th most congested corridor in PM peak period) is located beyond the map extent, towards the Gold Coast in the south east.

Source: Veitch Lister Consulting (2019)[132]

## Brisbane's public transport system in 2031

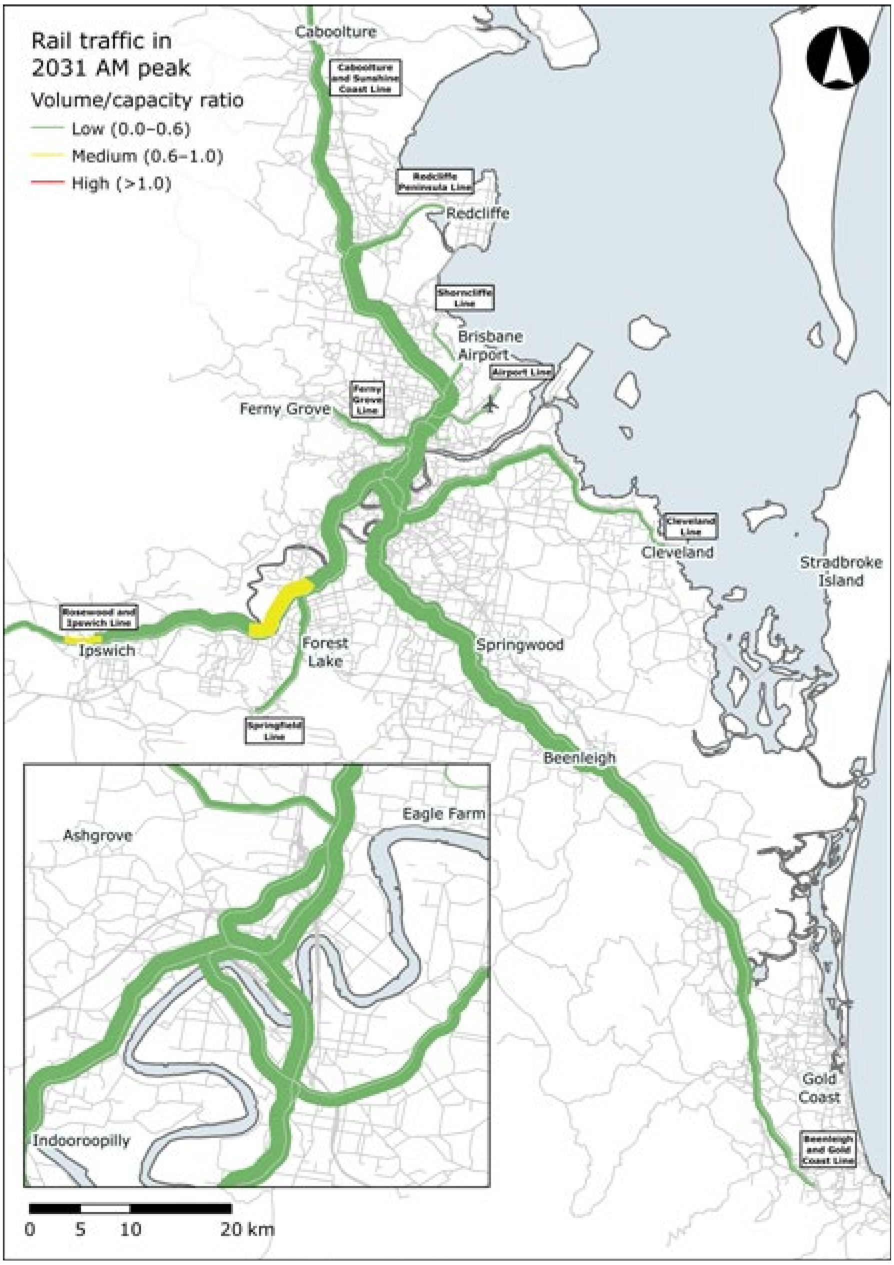
Public transport use in Brisbane is forecast to grow in coming years. By 2031 people in Brisbane are expected to take around 278,000 extra public transport trips (Figure 66). Patronage on rail is forecast to increase more than buses. Infrastructure improvements such as Cross River Rail as well as congestion of the road network are expected to increase the popularity of rail.

Despite increased patronage on Brisbane's trains, in 2031 the network will generally continue to see only modest crowding. This is due to the construction of the Cross River Rail that will quadruple the passenger-carrying capacity of the regional rail network. The only rail sections expected to experience higher levels of crowding by 2031 will be specific sections of the Rosewood and Ipswich lines, due to high levels of population growth projected in Ipswich.

Brisbane's bus routes are also projected to carry significantly more commuters by 2031 due to population growth (Figure 67). The strongest growth is expected on the South Eastern Busway along the Pacific Motorway (where line 1 of the proposed Brisbane Metro will run). Significant passenger increases are also predicted for the Northern Busway.

Due to increased patronage, bus crowding in 2031 is expected to reproduce 2016 patterns, with intensified levels of crowding. More significant crowding can be expected on buses further from the city, particularly on routes that serve areas outside rail catchments. Consequently, the modelling shows that long-distance commuters will experience longer periods of standing, and can expect more significant delays. In contrast, bus passengers using high-frequency corridors such as the South Eastern and Northern busways will experience greater crowding closer to the CBD.

**Figure 66:** Brisbane weekday train passenger volume / capacity ratio, 2031 AM peak



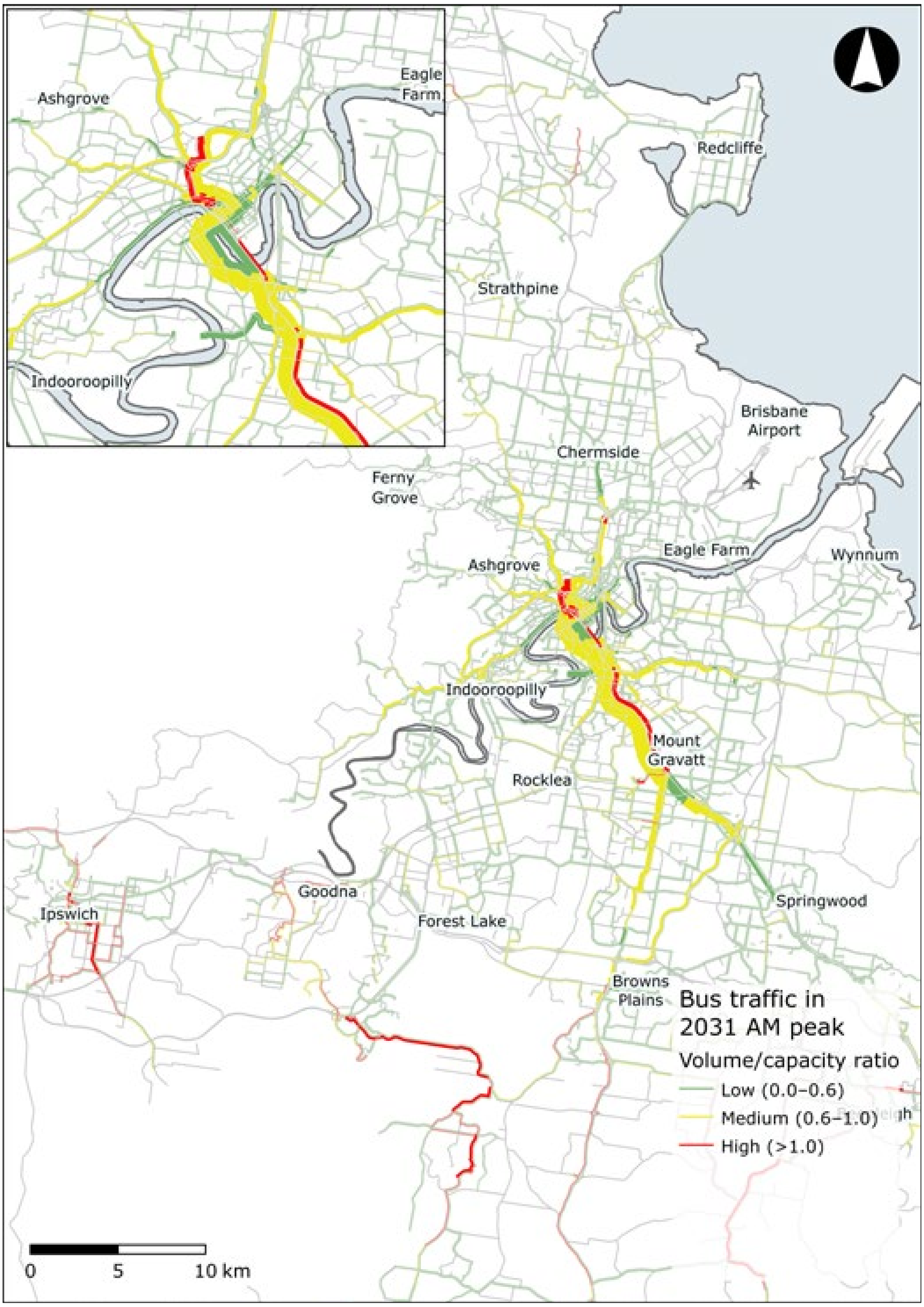

Source: Veitch Lister Consulting (2019)[133]

High levels of crowding outbound on the South Eastern busway are a function of the conservative approach taken to modelling Brisbane Metro. The model simply scales up 2016 frequencies to model the Brisbane Metro in 2031. In reality, counter peak crush capacity is likely to be reduced by additional services. Additionally, a network-wide set of seated capacities for buses has been assumed. In reality, it is like that Brisbane Metro vehicles in 2031 will have higher seating capacities. This means that it is likely that the counter peak capacity used in the 2031 forecast is likely to overstate crowding.

It is important to note bus service frequencies in 2031 are subject to significant uncertainty given the relatively flexible nature of bus service planning. The modelling assumes an annual growth rate of 1.5% in bus service kilometres across all cities. This assumption was based on growth in service kilometres recorded, and averaged, across Sydney, Melbourne and Adelaide. No data was available for Brisbane.

The model does not take into account congestion of buses on the dedicated busway corridor, only crowding of passengers within bus capacity.

**Figure 67:** Brisbane weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[134]

## Findings

- The 2019 Audit forecasts that the annualised cost of road congestion for Brisbane, the Gold Coast and Sunshine Coast will grow from approximately $2.1 billion in 2016 to $6.0 billion in 2031. This is 35% lower than the 2031 forecast cost of road congestion in the 2015 Audit.
- This is due to population growth and a 50% increase in bus patronage on public transport.
- Brisbane's most congested roads will be those linking the city centre with growth areas.
- Brisbane's south-western rail lines will experience high levels of crowding due to projected population growth in Ipswich and surrounding areas.
- Without adequate infrastructure and services to support population growth, bus crowding in outer suburbs will be intensified further by 2031.

## 7.5 Population growth is forecast to increase congestion on the Gold Coast's key access routes

### Transport on the Gold Coast and its surrounding region, today and in 15 years

The Gold Coast region is forecast to experience significant population growth by 2031. Gold Coast City will grow by about 25%, while surrounding regions will grow more rapidly. Nerang and Surfers Paradise will each grow by about 30%, Southport with grow by 40%, while Ormeau-Oxenford will grow by over 70%. These growth rates will result in increased demand for use of the region's public transport network. In a similar manner to Brisbane, growth in public transport will outstrip cars. Trips by car are expected to increase by 37%, while trips on public transport will grow by 67%. The growth in demand will result in increased road congestion costs on the Gold Coast. This will quadruple,from $243 million in 2016 to $973 million in 2031.

Despite planned upgrades to the Pacific Motorway and widening of the Southport-Burleigh Road corridor, increased congestion is still forecast for the Gold Coast's roads (Figure 68). The Pacific Motorway, a key arterial route connecting the Gold Coast to Brisbane, is forecast to experience more traffic and longer delays by 2031. Additionally, roads linking the central Gold Coast with surrounding regions, such as Hope Island Road, Gooding Drive, Robina Parkway and Bermuda Street, are expected to become increasingly congested. While in 2016 the Gold Coast's population was primarily clustered along the seaboard, by 2031 it is expected to become more dispersed, growing strongly in areas such as Ormeau-Oxenford and Southport.

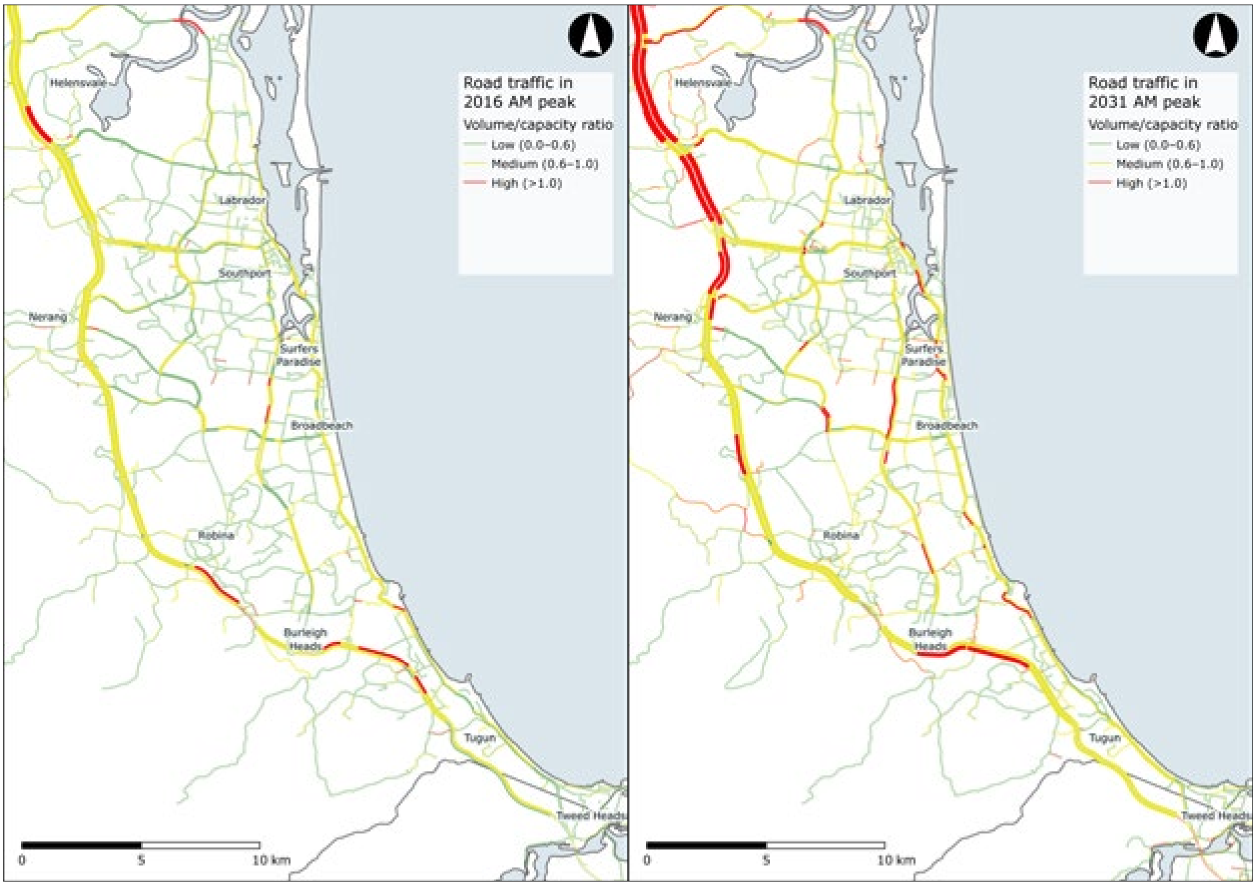
In 2016 the Gold Coast region experienced low levels of public transport crowding, with the exception of some bus routes. Crowded routes were those connecting to the rail system, facilitating the high demand for travel between the Gold Coast light rail system and the rail link to Brisbane.

Bus services have since been replaced by stage 2 of the Gold Coast Light Rail (G:Link) providing additional capacity in the corridor.

By 2031, growth rates in the Gold Coast region are expected to significantly increase patronage across the public transport network, in particular on routes travelling north where people are commuting mainly to work from Helensvale and on the light rail in both directions through Southport.

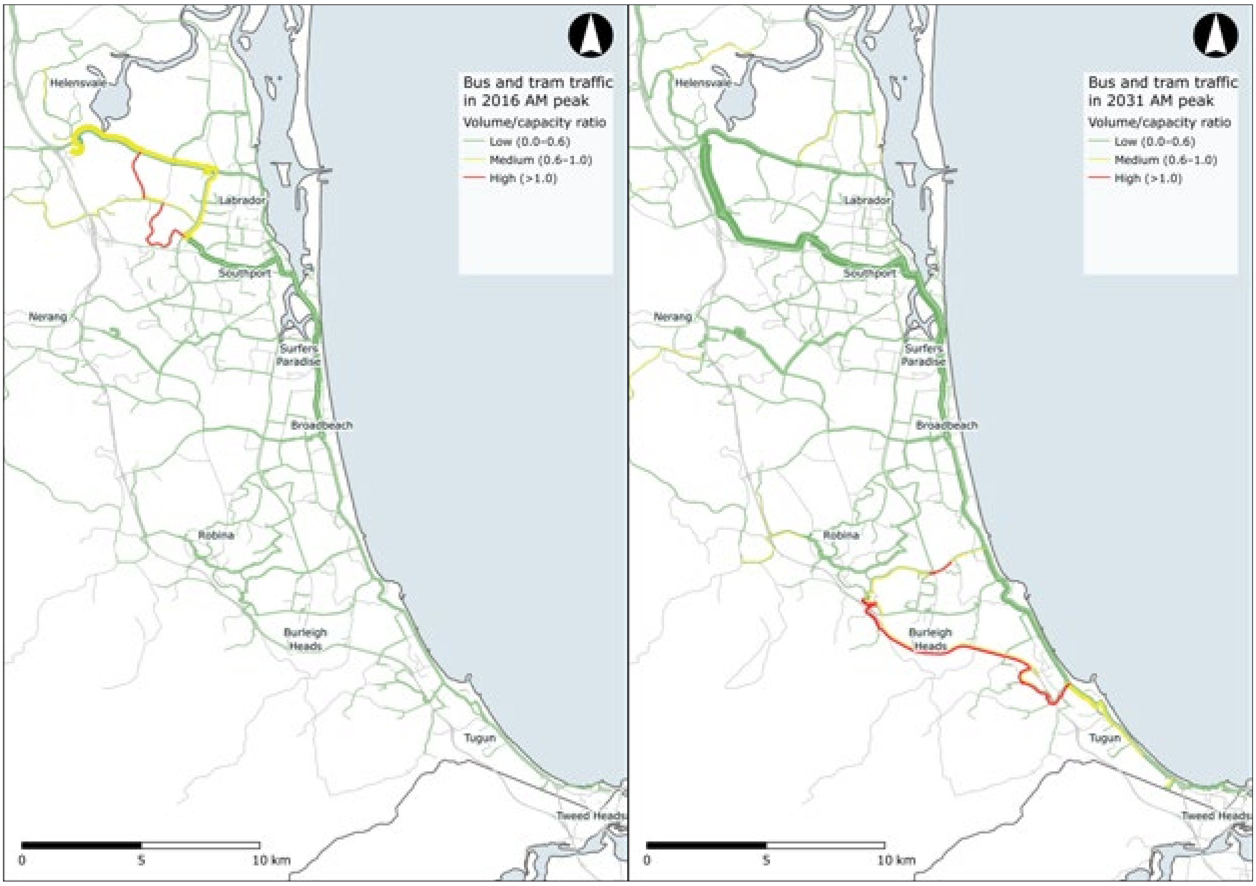
In 2031, the Gold Coast's most significant crowding is forecast on routes connecting the Brisbane rail line to Burleigh Heads and Coolangatta, as displayed in Figure 69.

**Figure 68:** Gold Coast weekday traffic volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[135]

**Figure 69:** Gold Coast bus and light rail passenger volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[136]

## Findings

- The population of the Gold Coast is forecast to grow by 200,000 people by 2031. While this represents growth of 37%, total hours driven are forecast to increase much more rapidly, by approximately 100% in both peak periods by that year.
- Key routes linking the Gold Coast with Brisbane and other surrounding areas are forecast to become increasingly congested, causing delays particularly for commuters travelling in peak periods.
- Despite road improvements, Gold Coast roads are expected to experience increased congestion. This will be seen in the counter-peak as well as the peak direction, especially on the Pacific Motorway, with an additional 31,000 peak period vehicles forecast to be travelling in each direction by 2031.
- In 2031 the extension of the Gold Coast Light Rail to Helensvale will have additional patronage of 3,000 passengers in each direction at peak. Away from the light rail, passengers will experience high levels of crowding on buses connecting the rail network to Burleigh Heads and Coolangatta.
- Many of these light rail and bus users will be among the 10,000 extra passengers forecast as travelling between Helensville and Brisbane city every weekday by 2031.
- Crowding of rail services will however remain low.

## 7.6 The Sunshine Coast is growing, and so are its transport network demands

### Transport on the Sunshine Coast and its region, today and in 15 years

The Sunshine Coast region is forecast to experience significant population growth by 2031, expecting growth of 33%, or 120,000 people. Caloundra can expect growth of 61%, while Maroochydore is predicted to grow by 29%. Consequently, demand for the region's public transport will grow. Public transport demand will increase by 56%, or to about 39,000 trips per day, while car trips will only grow by 33%.

Increased demand is expected to heighten congestion costs. The cost of congestion on the Sunshine Coast's roads will more than double, from $123 million in 2016 to $324 million in 2031.

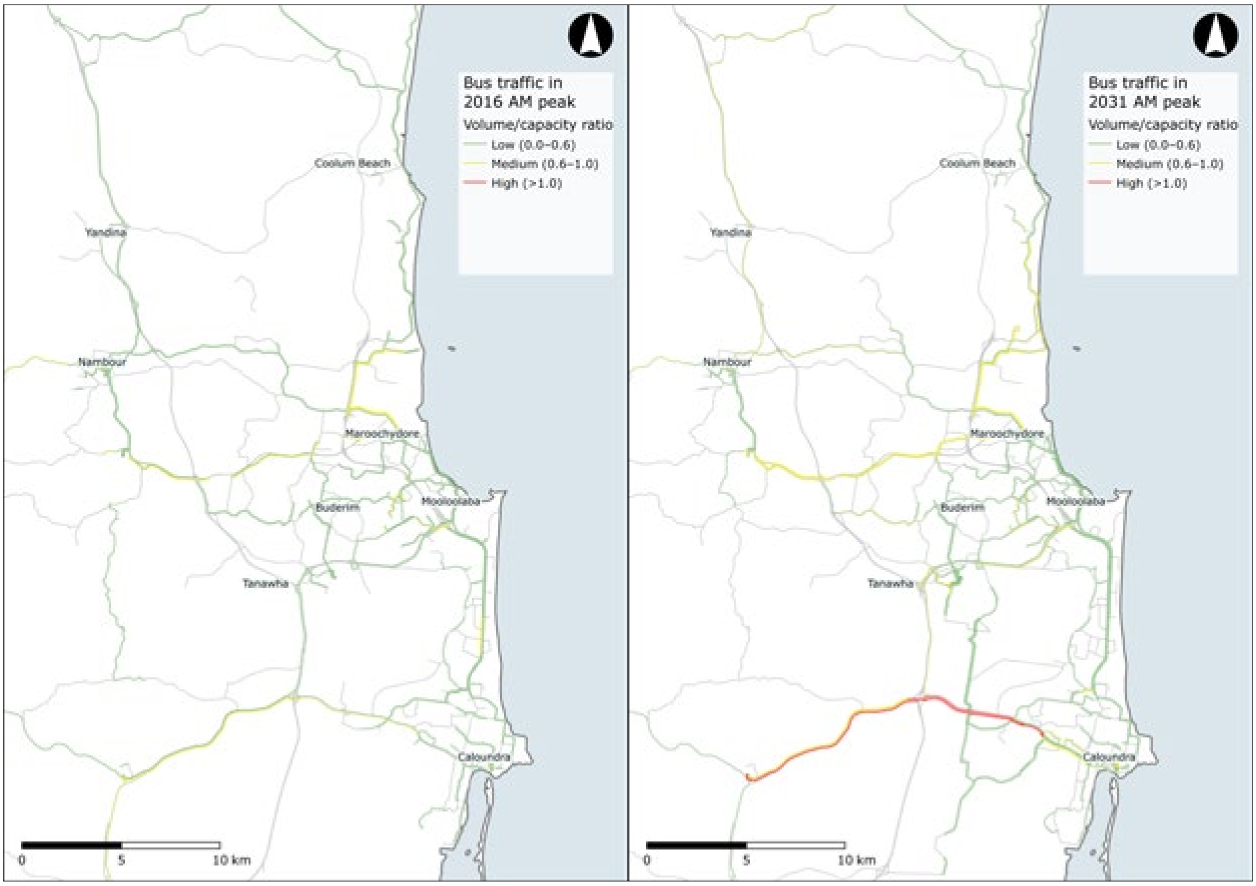
Road congestion experienced on the Bruce Highway, the Sunshine Motorway, Emu Mountain Road, Nicklin Way and Kawana Way in 2016 is forecast to rise and extend by 2031. The highway, a key arterial route between the Sunshine Coast and Brisbane, is expected to accommodate a further 21,000 vehicles in each direction by 2031. Other corridors experiencing congestion in 2016 were key routes linking the Sunshine Coast city centre to the railway line at Woombye, as well as the Sunshine Motorway running between the airport and the city centre. The congestion on these roads is forecast to worsen by 2031 (Figure 70).

In 2016, the Sunshine Coast's bus network experienced low levels of crowding. Moderate levels of crowding occurred on lower-volume routes. By 2031, crowding on particular routes are expected to increase. Routes providing access to Caloundra from the west are predicted to be the most crowded, as illustrated in Figure 71. This movement pattern may be driven by the significant increase in employment opportunities expected in Caloundra.

**Figure 70:** Sunshine Coast weekday traffic volume / capacity ratio, 2016 and 2031 AM peak


Source: Veitch Lister Consulting (2019)[137]

**Figure 71:** Sunshine Coast bus volume / capacity ratio, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[138]

## Findings

- Key routes linking the Sunshine Coast to Brisbane are expected to become significantly more congested by 2031, primarily as a result of population growth. At least 21,000 additional vehicles are forecast to travel in each direction on the Bruce Highway during peak periods, adding to congestion in both directions. There will be further delays on the Gateway Motorway for people travelling between the Sunshine Coast and the centre of Brisbane.
- Strong patronage growth is expected along the Sunshine Coast Line. With the addition of patronage growth on the Caboolture Line, trains passing through Albion are expected to carry approximately 27,000 passengers in each direction by 2031.
- Public transport routes providing access to Caloundra from surrounding areas are forecast to become significantly more congested as Caloundra becomes a larger employment centre.
- Intra-regional roads, including the Sunshine Motorway and Emu Mountain Road, will experience worsening congestion as will arterials servicing the Mooloolaba region.

## 7.7 Transport decisions impact access to jobs and services

### Hospital access in Brisbane, the Gold Coast and Sunshine Coast – by car and public transport, in 2031

Southeast Queensland residents' access to healthcare is measured as the travel time to their nearest public hospital, or hospital with an emergency department, by car versus public transport.

Figure 72 demonstrates that access to hospitals in Brisbane, the Gold Coast and Sunshine Coast is significantly quicker by car than public transport. For residents with access to a car in the modelled areas, the Gold Coast was found to have the shortest average travel time to a hospital at 18 minutes in the AM peak in 2031.

Without reliance on a car, 30-minute access to healthcare will be limited to people living near rail lines and other major public transport corridors including the South East and Inner Northern busways and the Gold Coast Light Rail.

Residents of some other areas away from trunk public transport corridors could have to spend over an hour accessing a hospital by public transport in 2031. This will also be true for some parts of the Gold Coast and the Sunshine Coast, although this travel time will an improvement from 2016 in both cities due to public transport upgrades (by nine minutes in the Gold Coast and 11 minutes in the Sunshine Coast).

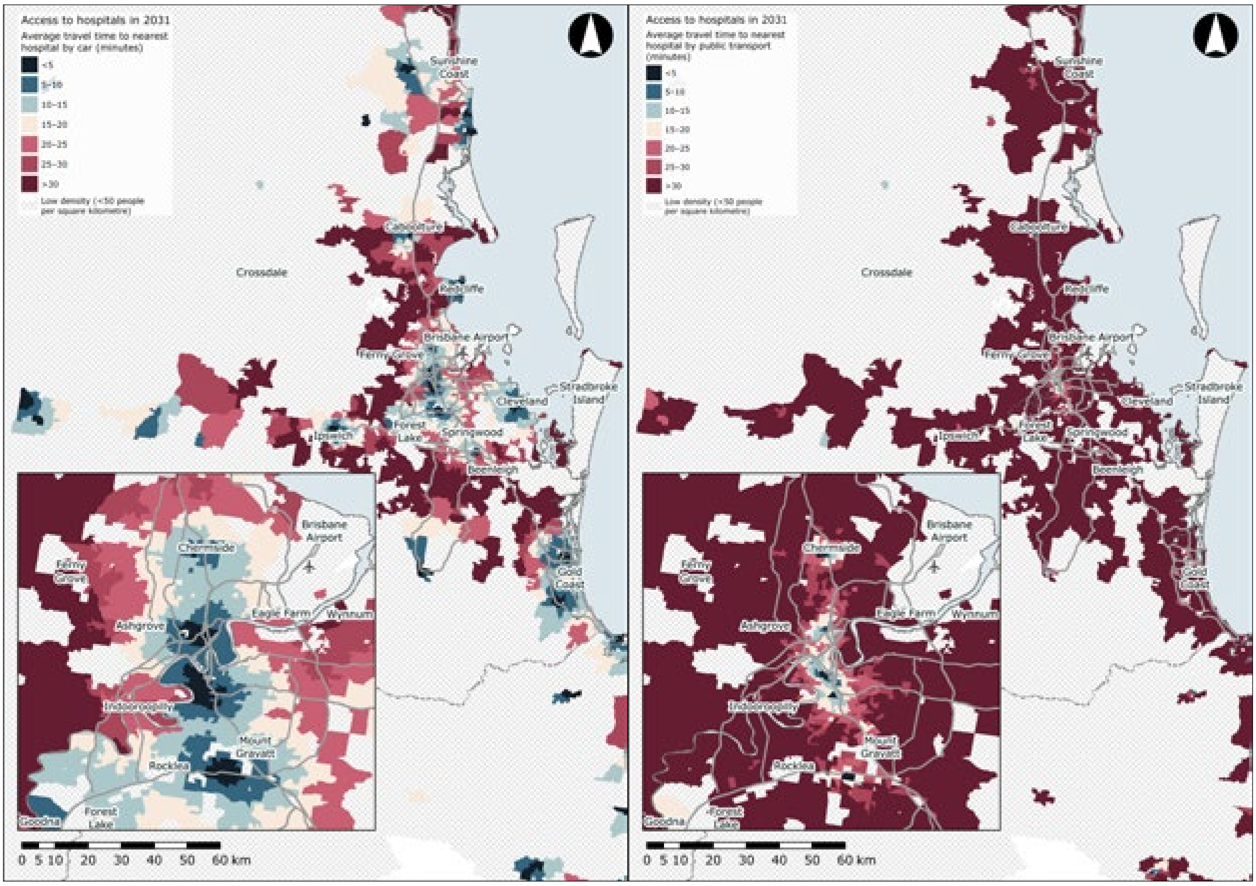
### Access to childcare and schools in Brisbane, the Gold Coast and Sunshine Coast – by car and public transport, in 2031

Modelling indicates that residents with access to a car, childcare centres, public primary schools and public secondary schools will be, on average, accessible within seven minutes in 2031. In 2016, these services were, on average, accessible within 5 to 6 minutes (Figure 73, Figure 74 and Figure 75). The average Gold Coast resident can expect similar travel times to Brisbane, while residents of the Sunshine Coast can expect longer travel times due to its dispersed population.

In comparison, residents without access to a car have significantly slower travel times. On average, residents in 2031 can expect to access these services in approximately 46 minutes by public transport, which is marginally faster than 2016. This marginal improvement reflects most public transport investments in Brisbane having involved upgrades of existing corridors, rather than expansion of the overall transport network.

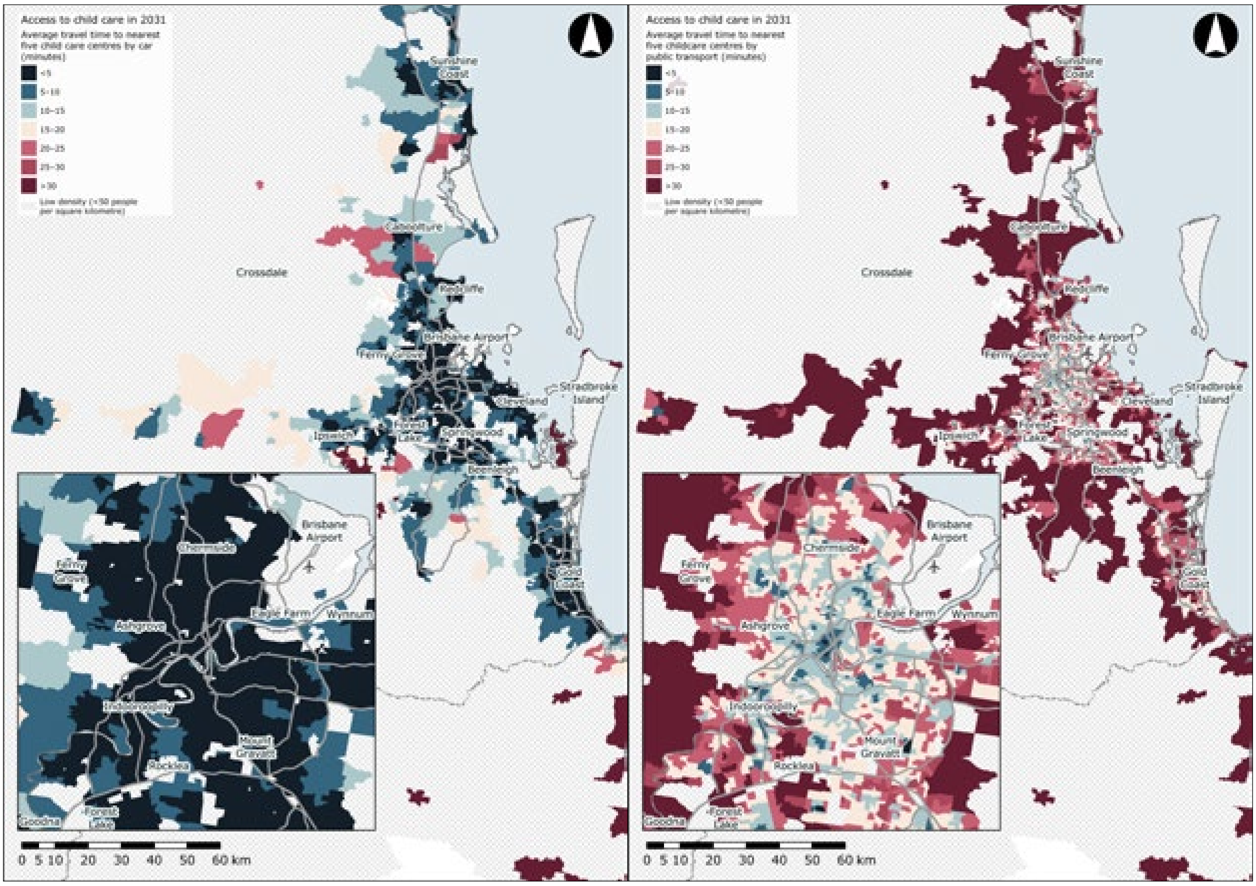
Public transport advancements in the Gold Coast and Sunshine Coast are forecast to improve non-car travel times to social infrastructure destinations compared with 2016. In 2031, most residents of the Gold Coast can expect a public transport travel time of 47 minutes to a hospital, while residents of the Sunshine Coast can expect a time of just under an hour.

**Figure 72:** Greater Brisbane average time to nearest hospital by car (left) and public transport (right), 2031 AM peak



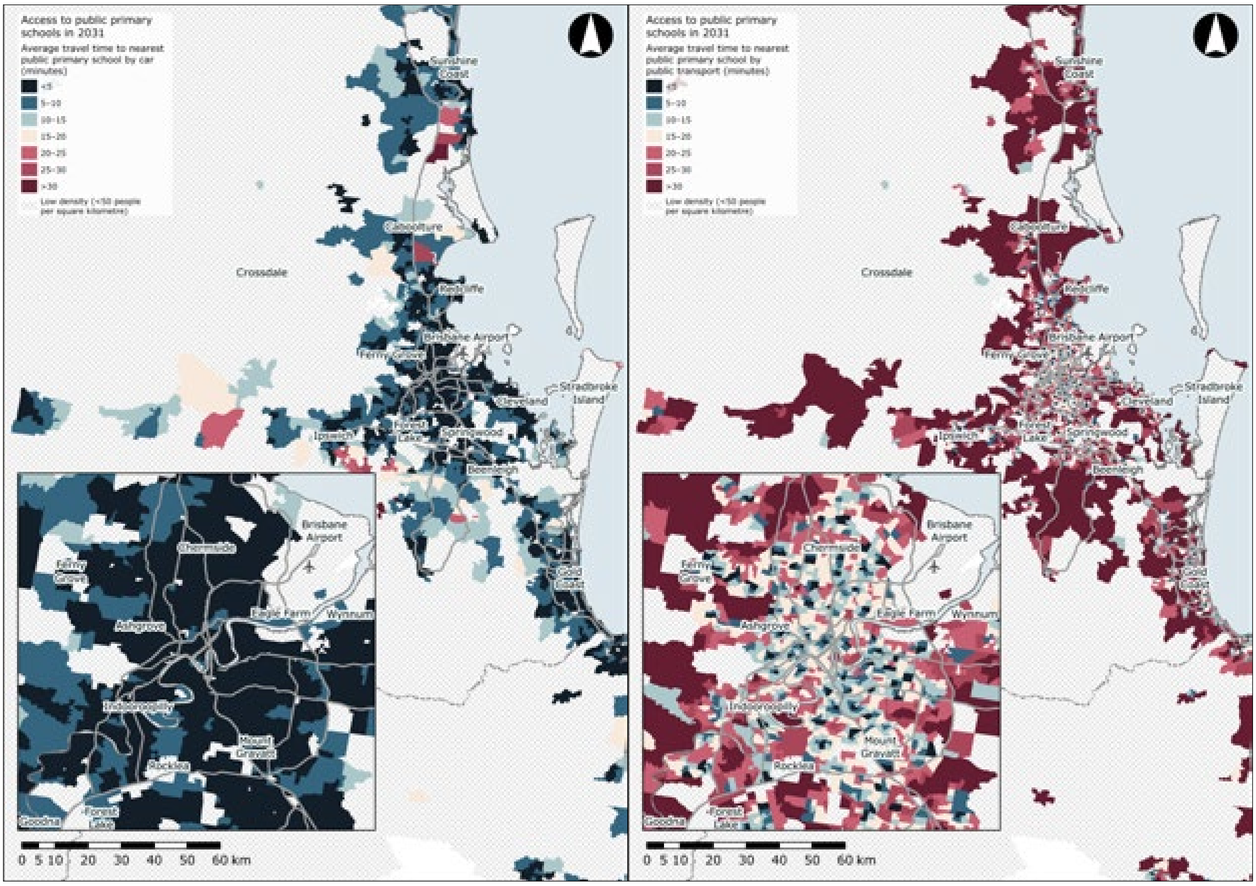

Source: Veitch Lister Consulting (2019)[139]

**Figure 73:** Greater Brisbane average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



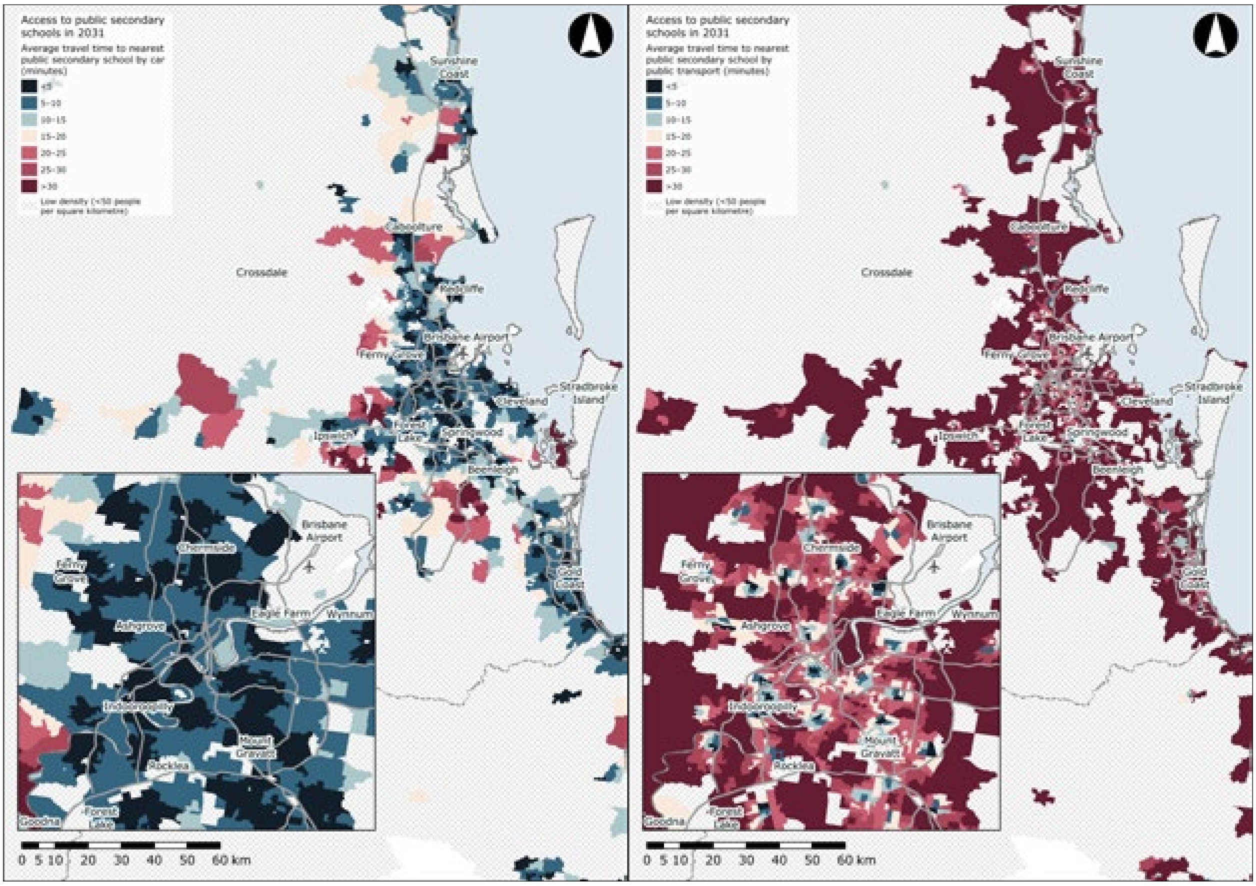

Source: Veitch Lister Consulting (2019)[140]

**Figure 74:** Greater Brisbane average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[141]

**Figure 75:** Greater Brisbane average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[142]

## Access to jobs in Brisbane, the Gold Coast and Sunshine Coast – by car and public transport, in 2016 and 2031

Employment accessibility has been measured as the percentage of jobs that can be reached in each of the three self-contained areas (the Greater Brisbane Capital City Statistical Area, the Gold Coast and the Sunshine Coast) within 30 minutes from home by car (Figure 76) and by public transport (Figure 77) in the two modelled years.

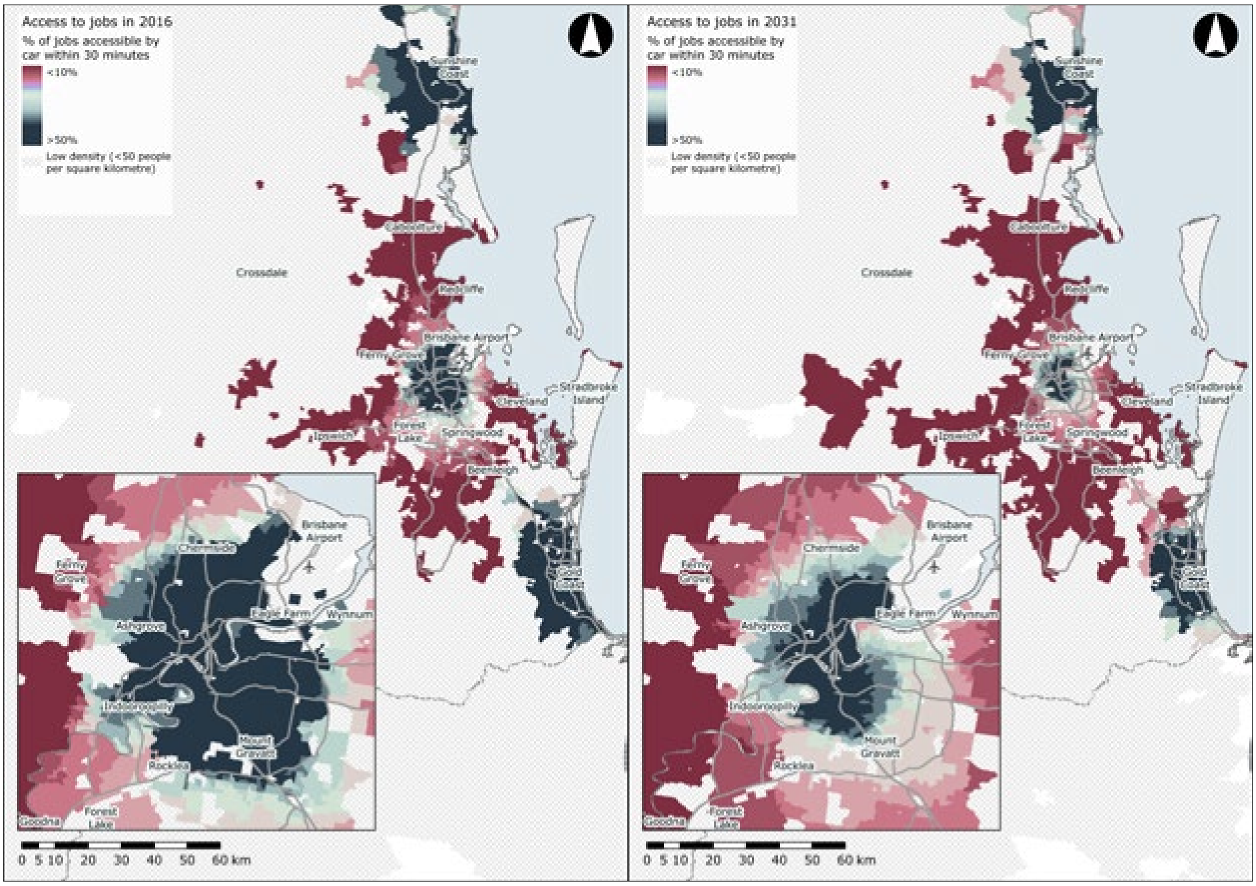
The high current and future concentration of jobs in Brisbane's urban core means that people living in or near these areas will continue to have good access to employment using existing infrastructure and services in this region. Ease of access to Brisbane's CBD determines employment accessibility. Residents living in areas with direct road or public transport access to the CBD have the highest level of access by both car and public transport.

Residents with access to a car generally have greater access to jobs across all parts of Brisbane. However, between 2016 and 2031 AM peak accessibility by car is expected to deteriorate due to increased congestion on Brisbane's roads. Comparatively, access to jobs by public transport is expected to stay relatively constant.

For residents of the Gold Coast and Sunshine Coast, job accessibility within a 30-minute car trip is forecast to stay relatively high, albeit due to traffic congestion this accessibility will decrease slightly between 2016 and 2031, more significantly in the Gold Coast than the Sunshine Coast. Residents travelling to work by public transport in these areas have a much more limited choice of jobs within 30 minutes. However, public transport upgrades will improve accessibility for residents serviced by upgraded corridors.

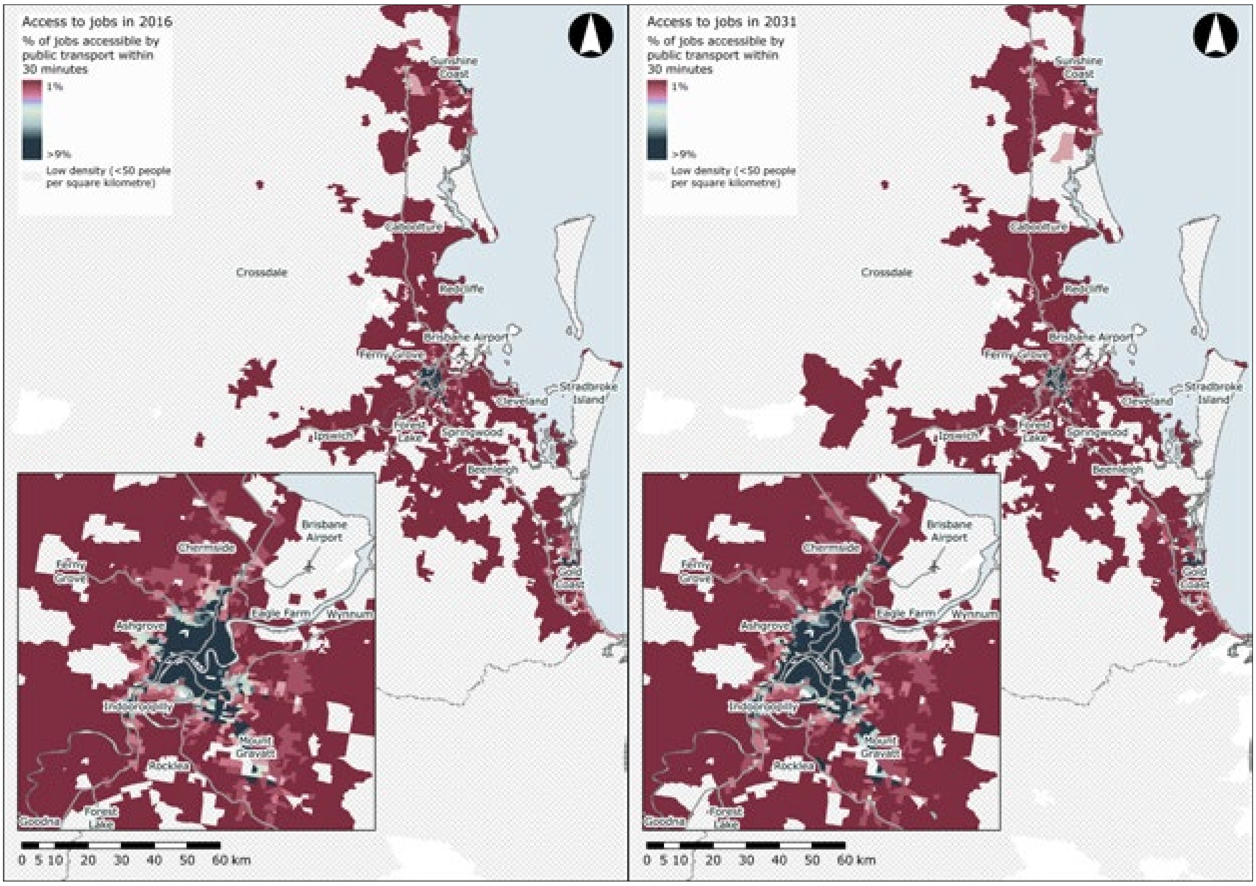
The percentage of jobs accessible is greater in Sunshine Coast and Gold Coast than Brisbane. This does not mean that people in these areas have access to a greater number of jobs, it simply means they have access to a higher percentage of the total jobs in their region. This is largely a function of the size Sunshine Coast and Gold Coast relative to Brisbane.

**Figure 76:** Greater Brisbane access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[143]

**Figure 77:** Greater Brisbane access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[144]

## Findings

- Despite improvements to public transport, cars consistently provide faster access to social infrastructure in Greater Brisbane. This is not forecast to change by 2031, except for residents living near major public transport corridors.
- In Brisbane and on the Sunshine and Gold Coasts access to jobs by public transport is expected to stay largely consistent to 2031.
- In Brisbane, Sunshine Coast and the Gold Coast access to jobs by car is expected to decline. Access in the Western Suburbs of Sunshine Coast as well as the north, south and west of Brisbane and the Gold Coast will decline.

8

# Greater Perth

## 8.1 Perth has grown, and so has its transport task

### Perth's transport network performance over the past decade

Between 2006 and 2016, Perth's population grew from just under 1.5 million to over 2 million people.[145] The mining boom years between 2007 and 2013 drove a significant amount of population growth, particularly around Perth and surrounding suburbs.[146] Since 2014 this rate of growth has slowed due to the end of the mining boom reducing the demand for residential settlement. While there has been a consequent loss of population in some inner suburbs,[147] in 2016 Perth's highest housing densities were still to be found in Perth City and South Perth.

Perth's population boom between 2007 and 2013 translated directly into a greater transport task. Between 2004–05 and 2014–15 passenger kilometres on Perth's road network increased by about 10%.

The impact of heightened demand on Perth's road network can be considered by comparing road speeds and travel reliability in Perth with average levels for all Australian cities since 2013.

## 8.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit inputs and assumptions

Since the 2015 Audit, Perth's forecast cost of road congestion has decreased by 77% (Table 30 and Figure 78). This is largely due to higher population projections used in the 2015 Audit.

In the 2015 Audit, 2031 population projections for Perth were derived from ABS Series B projections. In the latest work, projections have been provided by the Western Australian Government. The 2015 Audit used population and employment projections developed at the height of Western Australia's mining boom. This means that 2015 Audit's population projections for 2031 were 22% higher than those used for the 2019 Audit. As a result, forecast congestion in the 2015 Audit was significantly higher than the 2019 forecast.

**Table 30:** The cost of road congestion and public transport crowding in Greater Perth, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| 2016 (2019 Audit) | 17 | 1,525 | 1,542 |
| 2031 (2019 Audit) | 159 | 3,620 | 3,779 |
| 2031 (2015 Audit) | N/A | 15,865 | N/A |
| 2031 (change from 2015 Audit) | | -12,245 (-77%) | |

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[148]

The mapping also suggests the following key differences in demographic assumptions between 2015 and 2019 Audits:

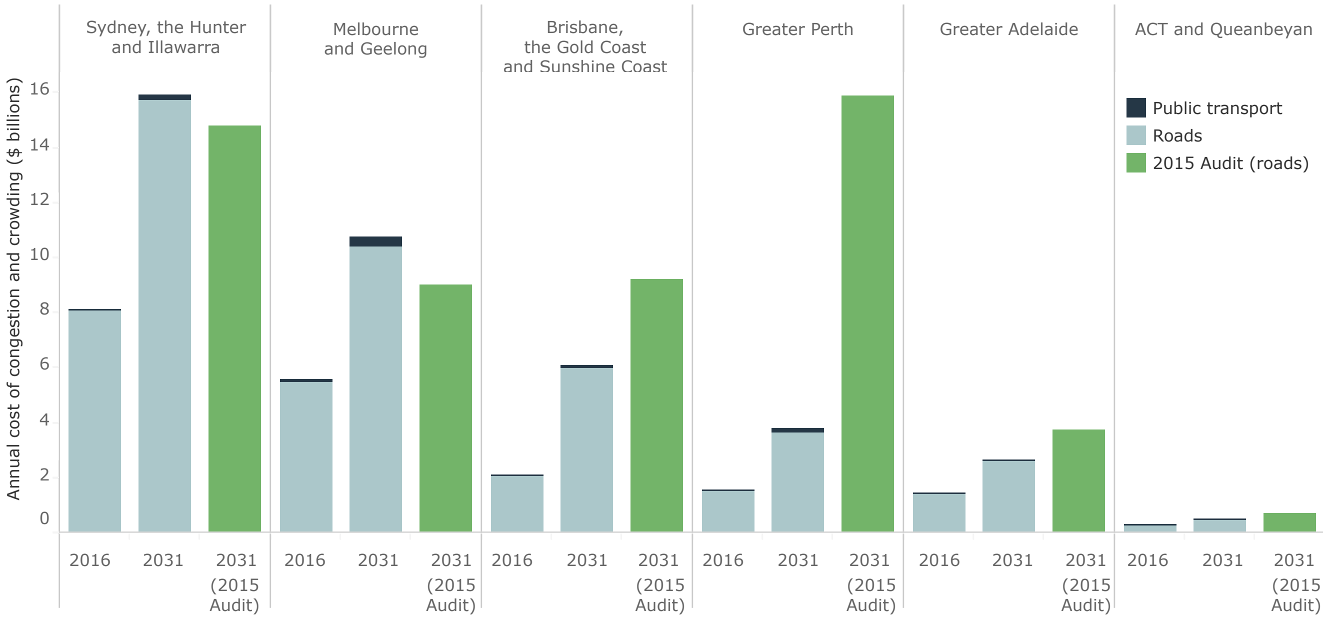
- The largest differences between audits are apparent in the outer statistical area levels 3s
- In the south, Rockingham has 107,000 fewer residents and Mandurah has 87,800 fewer residents
- In the north, Wanneroo has 101,500 fewer residents, Swan has 75,900 fewer residents, and Joondalup has 50,200 fewer residents
- Perth City shows the next largest reduction with 43,000 fewer residents.

Figure 79 provides a population forecast comparison between the 2015 Audit and the 2019 Audit.

Reduced population forecasts also decreased projected employment by 22% in the 2019 Audit.

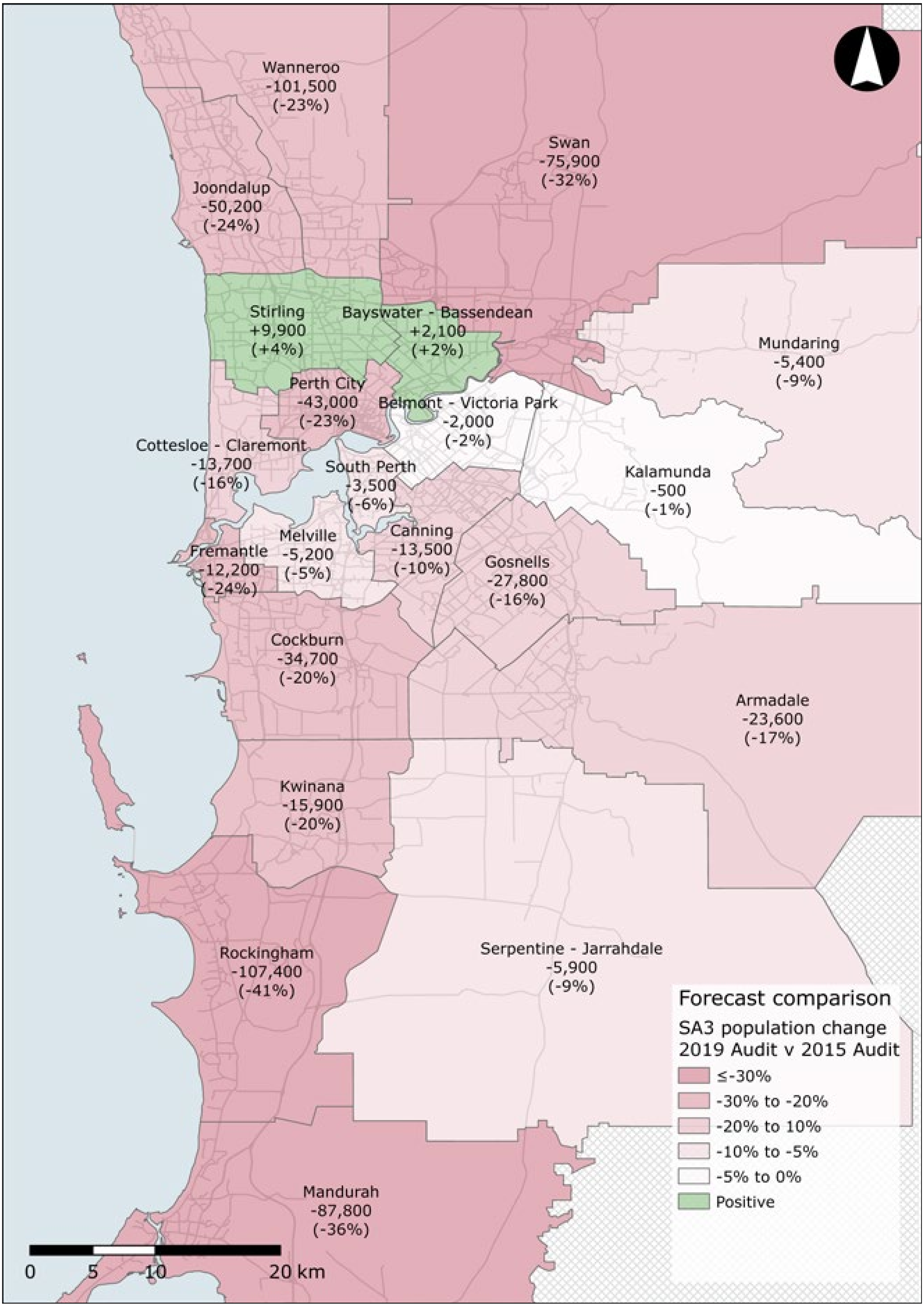
Table 31 reflects changes in model inputs and key outputs between the 2015 and 2019 Audit modelling.

**Figure 78:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[149]

**Figure 79:** 2031 population forecast for Greater Perth: 2019 Audit compared to the 2015 Audit




Source: Veitch Lister Consulting (2019)[150]

**Table 31:** Changes in key model inputs and outputs between 2015 and 2019 modelling in Greater Perth

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | ⇩ Population forecasts have reduced (-19%) | ⇩ Employment forecasts have reduced (-22%), however the proportion of jobs in Perth City SA3 remains stable | ⇧ More investment in the road network (+5% network lane km) | ⇧ More investment in the PT network (+~30% service kms) | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | |
| Impact on output (AM peak) | Total trips (-40%) | ⇩ Lower total population reduces total modelled trips | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| Impact on output (AM peak) | Car trips (-37%) | ⇩ Lower total population reduces total modelled car trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| Impact on output (AM peak) | Car vehicle kms travelled (-20%) | ⇩ An overall reduction in population reduces car kilometres. Lower population growth at the urban fringe also causes a reduction in this metric | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| Impact on output (AM peak) | Public transport trips (-18%) | ⇩ Lower total population reduces total modelled PT trips | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | |

Source: Veitch Lister Consulting (2019)[151]

## New network assumptions

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. For Perth, there are three key differences in network assumptions. The Roe Highway extension was included in the 2015 Audit but not the 2019 Audit. While being committed and partially funded at the time of modelling, and therefore not meeting the fully-funded requirement for inclusion, the Karnup and Midland Station projects within the METRONET program were included in the 2019 Audit but not the 2015 Audit. Additionally, the 2019 Audit includes Tonkin Highway Grade Separations as part of the NorthLink, but did not include the grade separations on Tonkin Highway south of Roe Highway, which have now been committed.

## Variation between road network capacities in 2031

In the 2019 Audit, due to large reduction in population forecasts, traffic volumes and delays have decreased. However, the worst-performing corridors are largely consistent between the audits. Results for the AM and PM peak showed a similar outcome.

Traffic volumes on Kwinana Freeway, Graham Farmer Freeway, Mitchell Freeway, Marmion Avenue/West Coast Hwy Corridor and Roe Highway have decreased between the 2015 and 2019 Audits, however still remain high. Other arterial roads and highways such as Canning Road, Gnangara Road, Armadale Road, the West Coast Highway and the Stirling Highway have less traffic volume in the 2019 Audit, however still have sections that are high in the 2031 AM peak.

The 2019 Audit forecasts decreases to traffic volumes on arterial and local roads throughout Perth. However, high congestion is still forecast to occur on local and arterial roads in the Perth CBD. West Leederville, Subiaco, Leederville, North Perth and Lawley are also predicted to maintain high congestion forecasts on their local roads.

Vehicle delays are forecast to decrease by more than the corresponding change in traffic volumes in the 2019 Audit. This is a function of the underlying dynamics of traffic flow, when additional traffic is added to an already congested road, the resultant delay is disproportionately higher than in less congested conditions.

Table 32 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

### Variation between public transport capacities in 2031

The revised population forecasts have lowered the projected public transport passenger volumes in the 2019 Audit.

However by 2031, all trains still reach a high to moderate volume of suburban rails passengers as they approach the Perth CBD in the 2019 Audit. In the 2019 Audit, the Mandurah line experiences high congestion from Kwinana Town Centre to Cockburn Central and from Brentwood to the CBD. Similarly, the Joondalup/ Butler line experience high congestion from Joondalup to the CBD.

Both audits indicate that bus crowding is predicted to worsen on major routes from 2031. However, the 2019 Audit shows that radial routes converging on the CBD will experience the greatest levels of crowding, as will routes running parallel to rail lines. The 2015 Audit forecasts wider network demand, including high instances of seating capacity and crush capacity on arterial roads, freeways and highways connected to the CBD.

## 8.3 Commuters in Perth experience substantial levels of road congestion and public transport crowding today

### Snapshot of Perth's road network in 2016

Perth's drivers already experience congestion on their roads. Our modelling indicates the annualised cost of road congestion was approximately $1.5 billion in 2016.

This congestion is most significant in the AM peak period when commutes to schools and work overlap (Figure 80). The same roads experience congestion in the PM peak period, albeit to a lesser extent and over shorter sections. Perth's most congested corridors are major north-south freeways, and the arterial roads feeding those freeways, as well as key river crossings which act as pinch points in the network.

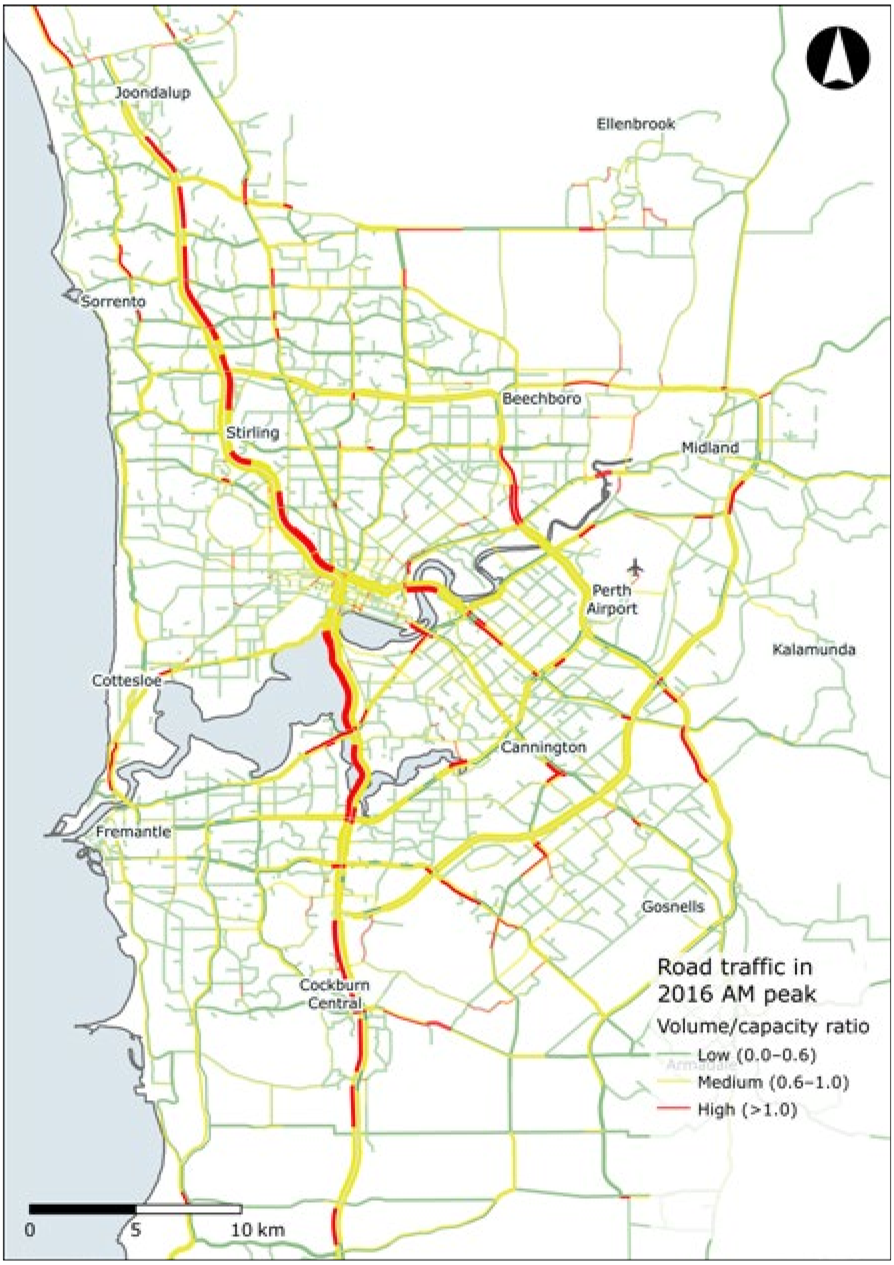
**Table 32:** Most congested roads ranked by total delay hours, 2031 AM Peak and ranking in 2015 Audit in Greater Perth

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes: | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Kwinana Freeway corridor | N/B | 3,700 | 3,500 | -6% | 12,800 | 8,600 | -32% | 1 |
| 2 | Mitchell Freeway corridor | S/B | 6,200 | 5,700 | -9% | 8,400 | 5,200 | -38% | 3 |
| 3 | Marmion Avenue / West Coast Highway corridor | S/B | 2,100 | 1,800 | -13% | 9,900 | 4,100 | -59% | 2 |
| 4 | Old Coast Road / Mandurah Road / Stock Road / Stirling Highway corridor | N/B | 2,600 | 1,800 | -29% | 8,200 | 3,200 | -60% | 4 |
| 5 | Tonkin Highway corridor | N/B | 3,700 | 3,200 | -14% | 6,200 | 3,100 | -49% | 6 |
| 6 | Wanneroo Road corridor | S/B | 2,100 | 1,700 | -20% | 7,800 | 2,500 | -68% | 5 |
| 7 | Kwinana Freeway corridor | S/B | 2,600 | 2,500 | -3% | 1,100 | 2,300 | 111% | 25 |
| 8 | Tonkin Highway corridor | S/B | 2,500 | 2,500 | 3% | 2,800 | 2,200 | -23% | 11 |
| 9 | Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor | W/B | 3,100 | 2,600 | -16% | 4,100 | 2,100 | -49% | 8 |
| 10 | Albany Highway corridor | N/B | 2,200 | 1,700 | -21% | 4,400 | 1,900 | -56% | 7 |

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

Source: Veitch Lister Consulting (2019)[152]

**Figure 80:** Perth weekday traffic volume / capacity ratio, 2016 AM peak




Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019)[153]

## Perth's most congested roads in 2016: what the driver experiences

Infrastructure Australia has highlighted the most congested roads in Perth based on a variety of metrics that relate directly to the user's experience, including estimating the percentage of journey time that is accounted for by congestion. Table 33 and Figure 81 show the ten most congested corridors in the AM and PM peak periods, respectively.

Perth's most congested roads radiate from the city centre. These routes facilitate access to the city's major cluster of employment opportunities. In 2016 Perth's major motorways, the Mitchell and Kwinana Freeways, were highly congested, especially during peak periods. Sections of the Mitchell Freeway, a major access route from the north, were Perth's most congested corridor in both the AM and PM peak periods. Traffic volumes reached close to design capacity on this road from Woodvale through to the CBD. Similarly, the Kwinana Freeway, facilitating traffic movement from the south, was heavily congested in both peak periods. Arterial roads serving parallel routes throughout the city also experience moderate to high levels of congestion during peak periods, highlighting the demand for north-south movement in Perth.

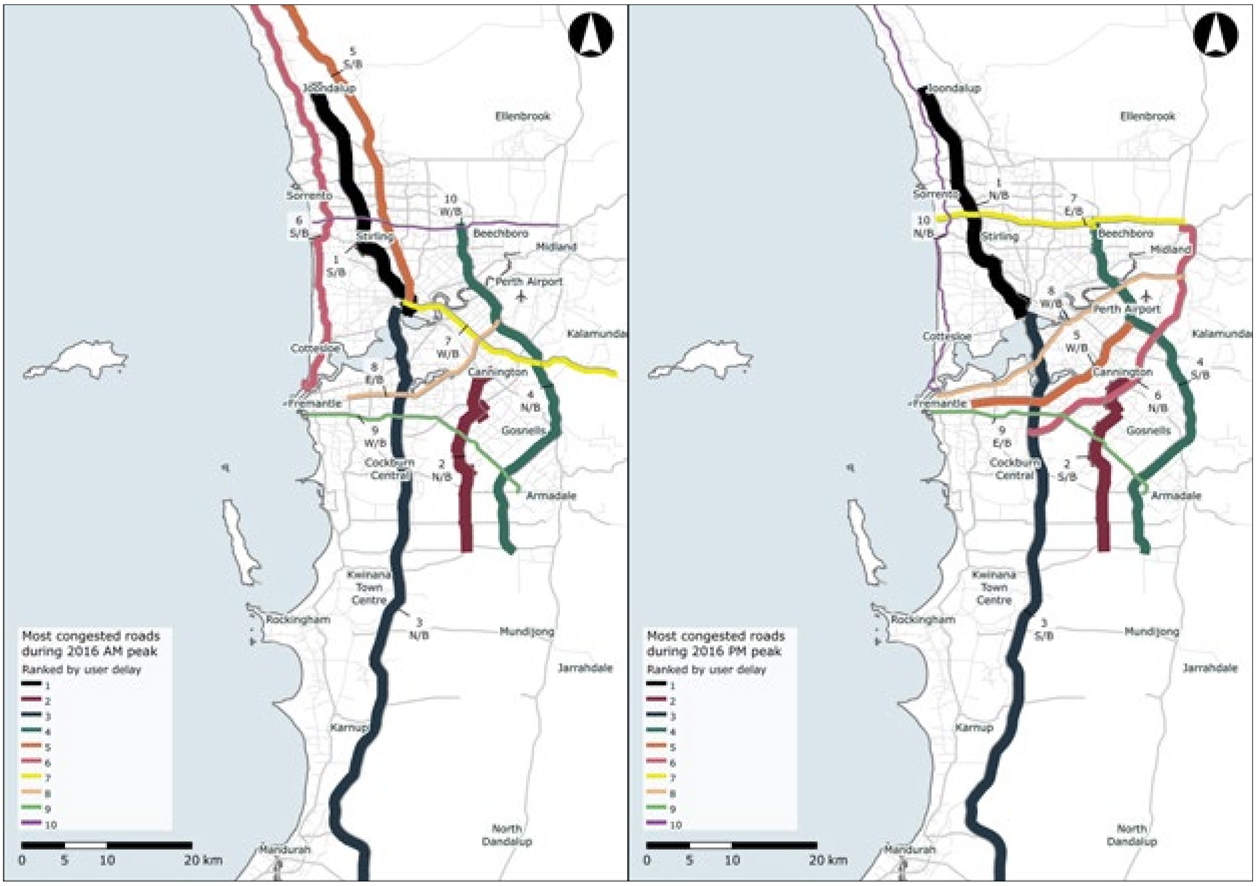
**Table 33:** Perth's most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Mitchell Freeway corridor (S/B) | 29 | 51% | 20 | $5.52 | $23.79 |
| 2. | Nicholson Road corridor (N/B) | 22 | 40% | 12 | $3.31 | $14.28 |
| 3. | Kwinana Freeway corridor (N/B) | 80 | 40% | 32 | $8.84 | $38.07 |
| 4. | Tonkin Highway corridor (N/B) | 44 | 36% | 17 | $4.69 | $20.22 |
| 5. | Wanneroo Road corridor (S/B) | 47 | 35% | 22 | $6.08 | $26.17 |
| 6. | Marmion Avenue / West Coast Highway corridor (S/B) | 61 | 34% | 28 | $7.73 | $33.31 |
| 7. | Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor (W/B) | 24 | 34% | 12 | $3.31 | $14.28 |
| 8. | Leach Highway corridor (E/B) | 19 | 33% | 9 | $2.49 | $10.71 |
| 9. | Randford Road / South Street corridor (W/B) | 26 | 33% | 13 | $3.59 | $15.47 |
| 10. | Reid Highway corridor (W/B) | 25 | 33% | 10 | $2.76 | $11.90 |
| PM peak | | | | | | |
| 1. | Mitchell Freeway corridor (N/B) | 29 | 41% | 13 | $3.59 | $15.47 |
| 2. | Nicholson Road corridor (S/B) | 22 | 34% | 9 | $2.49 | $10.71 |
| 3. | Kwinana Freeway corridor (S/B) | 80 | 34% | 25 | $6.90 | $29.74 |
| 4. | Tonkin Highway corridor (S/B) | 44 | 31% | 14 | $3.87 | $16.66 |
| 5. | Leach Highway corridor (W/B) | 19 | 31% | 8 | $2.21 | $9.52 |
| 6. | Roe Highway corridor (N/B) | 34 | 31% | 10 | $2.76 | $11.90 |
| 7. | Reid Highway corridor (E/B) | 25 | 30% | 9 | $2.49 | $10.71 |
| 8. | Great Eastern Highway (west) / Canning Highway corridor (W/B) | 30 | 29% | 13 | $3.59 | $15.47 |
| 9. | South Street / Ranford Road corridor (E/B) | 26 | 29% | 11 | $3.04 | $13.09 |
| 10. | West Coast Highway / Marmion Road corridor (N/B) | 61 | 29% | 22 | $6.08 | $26.17 |

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

Source: Veitch Lister Consulting (2019)[154]

**Figure 81:** Perth's most congested roads (user experience), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[155]

## Perth's most congested roads in 2016: the cost to the community of total vehicle delays

As a measure of the whole-of-system impacts of congestion by Infrastructure Australia has also identified the most congested road corridors in Greater Perth and Peel aggregating the total delay experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors under this approach are shown in Table 34 and Figure 82, for the AM and PM peak respectively.

In 2016, Perth's most delayed road corridors were served by the Kwinana Freeway and the Mitchell Freeway. Significant delays on these roads contributed to traffic overspill to and increased delays on generally parallel arterial roads. The Marmion Avenue / West Coast Highway provides an alternative route for commuters travelling from the north, while the Old Coast Road / Mandurah Road / Stock Road / Stirling Highway route provides an alternative for commuters entering the city centre from the south. Both corridors incurred significant delays during peak periods. Other corridors facilitating orbital and radial movements through the city, including the Tonkin Highway, also significantly contributed to delays on Perth's road network.

## Perth's public transport system in 2016

Demand for public transport in Perth has grown substantially over the past 10 years. A significant reason for this was the completion of the Mandurah rail line in 2007 (see Perth's railways: a network that has tripled in size over 30 years) and complementary redesign of the bus network. The new railway drew passengers into the network and resulted in a significant increase in patronage.

In the last few years, patronage has declined, likely due to the winding up of the mining boom.[156] Nevertheless, patronage is still significantly higher than a decade ago. The Mandurah and Joondalup lines carry the most passengers on Perth's rail network and are also the most crowded.

In the AM peak, both lines get busier as services approach the CBD (Figure 83), and passengers joining the train are generally required to stand. However, neither railway is currently at their maximum, or what would be considered crush capacity. Lines that carry fewer passengers, such as the Fremantle, Midland and Armadale lines, are not subject to such significant crowding.

Perth's busiest bus corridors are to the inner north, inner south and east of the city (Figure 84). They generally become more crowded as they approach the CBD.

There is also congestion in areas which are not directly served by a railway line, such as near Perth Airport and in the Beechboro / Bennett Springs district. We note the construction of the Forrestfield-Airport Link scheduled for a delayed completion in the second half of 2021.

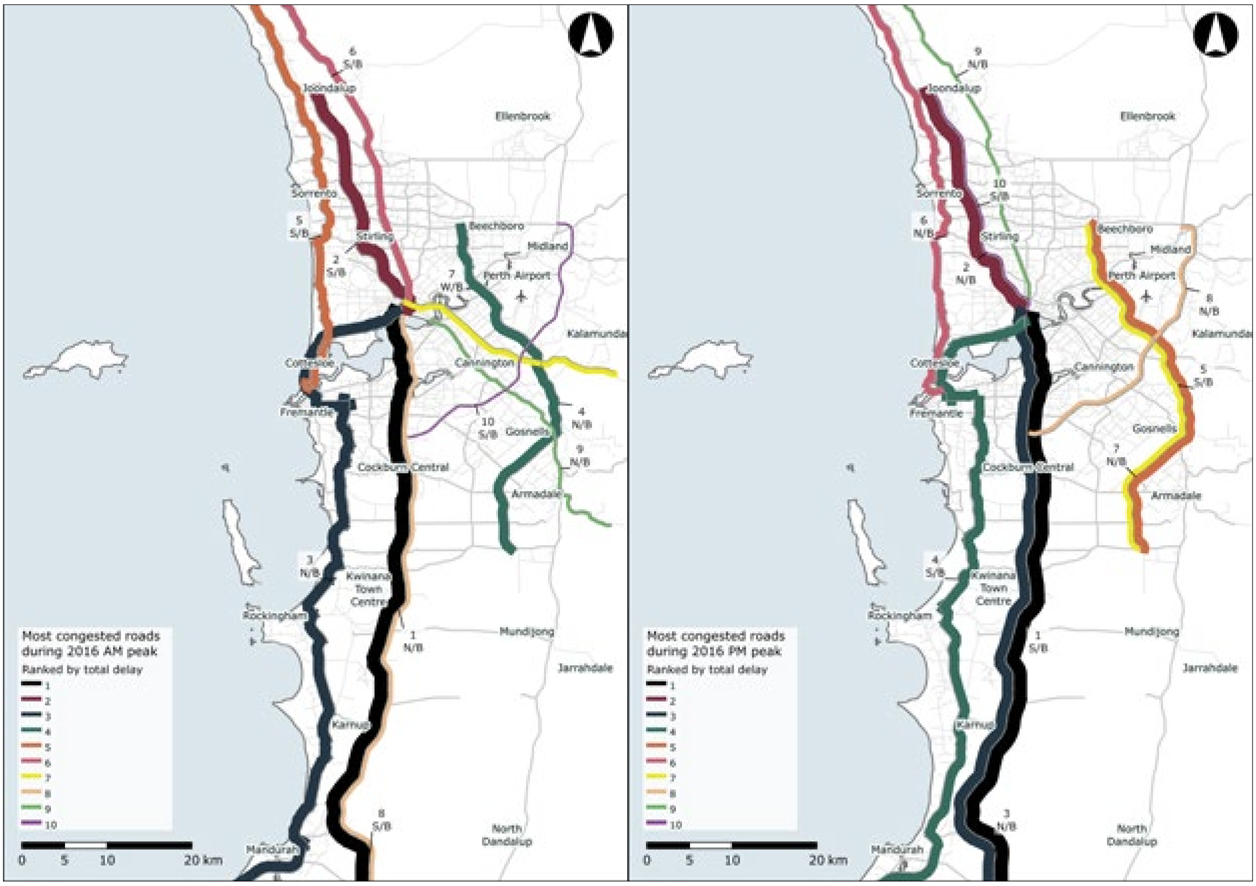
**Table 34:** Perth's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Kwinana Freeway corridor | N/B | 4,600 | $91,000 |
| 2. | Mitchell Freeway corridor | S/B | 3,000 | $58,000 |
| 3. | Old Coast Road / Mandurah Road / Stock Road / Stirling Highway corridor | N/B | 1,500 | $31,000 |
| 4. | Tonkin Highway corridor | N/B | 1,400 | $29,000 |
| 5. | Marmion Avenue / West Coast Highway corridor | S/B | 1,300 | $25,000 |
| 6. | Wanneroo Road corridor | S/B | 1,100 | $22,000 |
| 7. | Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor | W/B | 1,100 | $22,000 |
| 8. | Kwinana Freeway corridor | S/B | 1,000 | $22,000 |
| 9. | Albany Highway corridor | N/B | 900 | $17,000 |
| 10. | Roe Highway corridor | S/B | 900 | $19,000 |
| PM peak | | | | |
| 1. | Kwinana Freeway corridor | S/B | 4,000 | $78,000 |
| 2. | Mitchell Freeway corridor | N/B | 2,400 | $44,000 |
| 3. | Kwinana Freeway corridor | N/B | 1,700 | $35,000 |
| 4. | Stirling Highway / Stock Road / Mandurah Road / Old Coast Road corridor | S/B | 1,300 | $26,000 |
| 5. | Tonkin Highway corridor | S/B | 1,200 | $24,000 |
| 6. | West Coast Highway / Marmion Avenue corridor | N/B | 1,000 | $19,000 |
| 7. | Tonkin Highway corridor | N/B | 900 | $18,000 |
| 8. | Roe Highway corridor | N/B | 900 | $18,000 |
| 9. | Wanneroo Road corridor | N/B | 800 | $15,000 |
| 10. | Mitchell Freeway corridor | S/B | 800 | $15,000 |

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

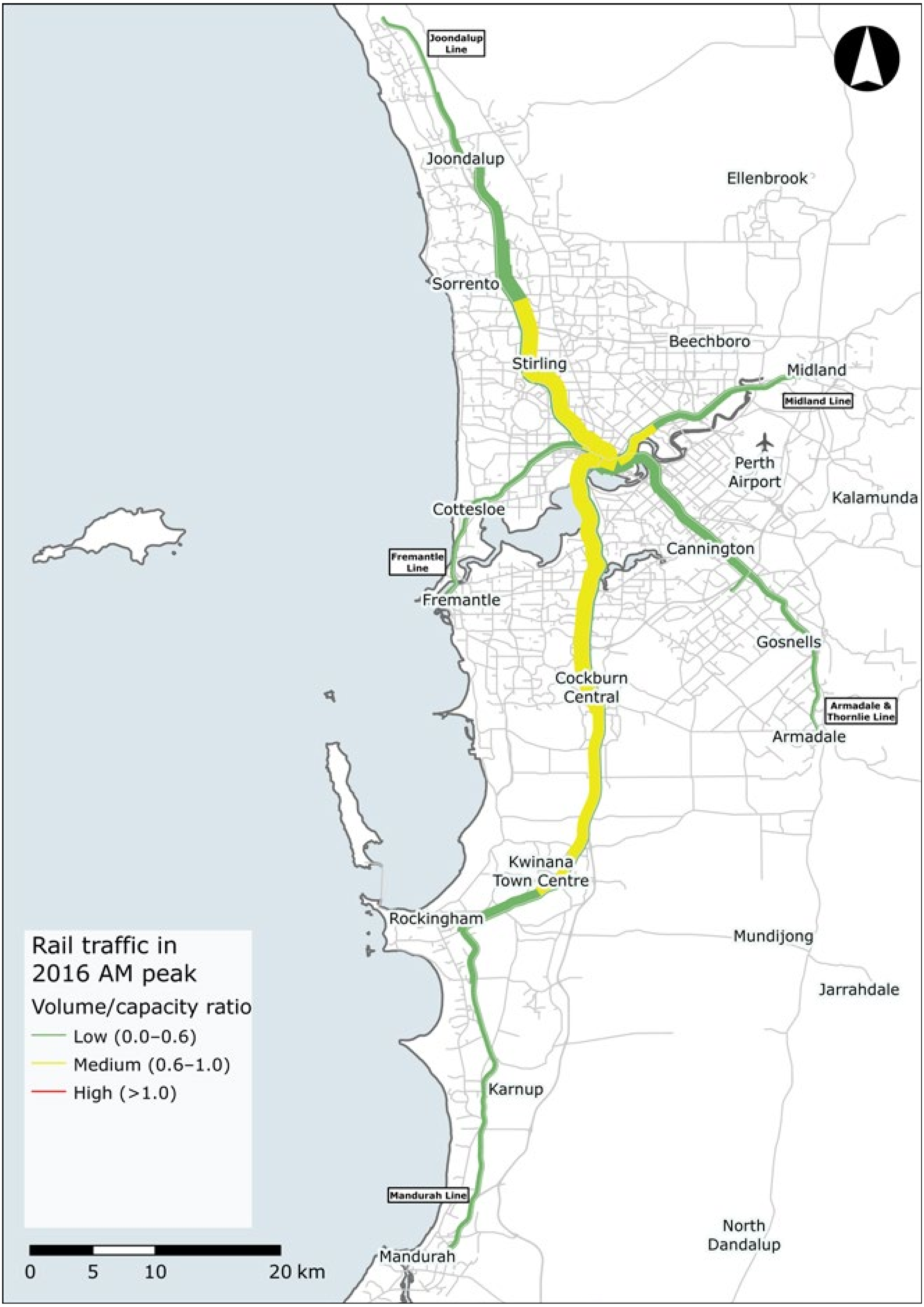
Source: Veitch Lister Consulting (2019)[157]

**Figure 82:** Perth's most congested roads (total vehicle delay), 2016 AM (left) and PM (right) peak periods



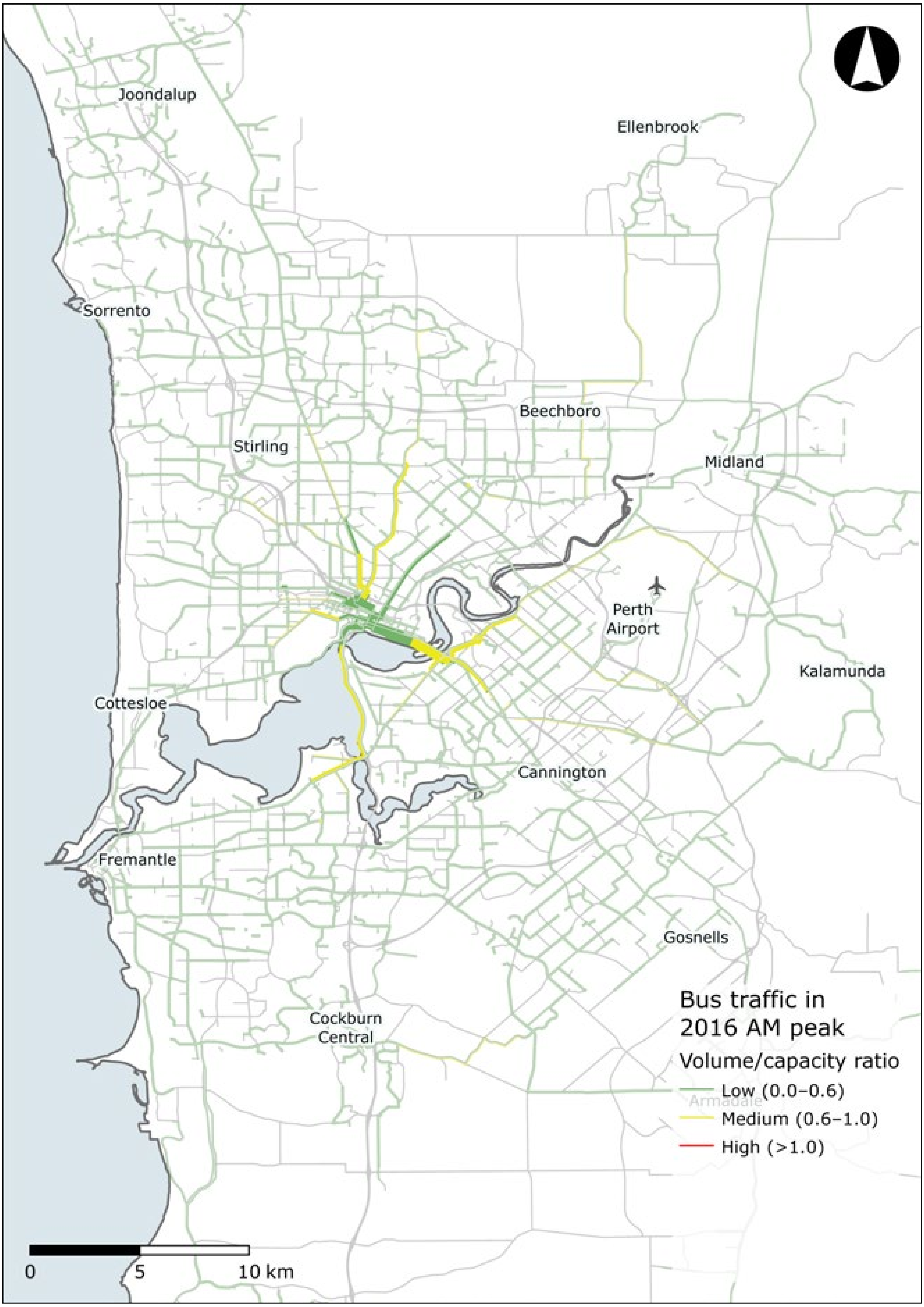

Source: Veitch Lister Consulting (2019)[158]

**Figure 83:** Perth weekday train passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[159]

**Figure 84:** Perth weekday bus passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[160]

## Perth's railways: a network that has tripled in size over 30 years

Between 1985 and 2008 the Western Australian Government added over 100 km of railway to Perth's network. By 2012, the city's rail patronage had grown by a factor of 10 compared to 1981, from 6.5 million to 63 million annual passengers. One of the strongest performers was the Mandurah Line, running parallel to the coast 71 km south of Perth CBD. By one year after this line was completed in 2007 it was carrying 55,000 passengers per day compared to the 14,000 bus passengers that had previously travelled along the corridor.

Part of the success of Perth's newer train lines in converting passengers from car to public transport use is attributed to the decision to locate many track sections in the median of freeways radial to the CBD. Nearly half of the rail kilometres built since 1985 follow similar alignment. As well as having construction speed and cost advantages, trains running along freeways during peak periods are visibly attractive to car commuters sitting in congested traffic.

Given the low residential density typical of surrounding Perth's newer stations, a low proportion of train customers walk to rail relative to rail systems in Australia's south-eastern capitals. For first and last mile mass transit access, high-frequency feeder buses that are scheduled to integrate with the train timetable are comparatively important. These services meet the train line at interchanges that are designed to make the transfer experience as seamless as possible.

Additionally, extensive commuter car parking has been provided around most suburban train stations. This services commuters who find this travel choice faster than a feeder bus or need their car on the way to and from the station.

The resulting approach to station precinct design has enabled the rapid expansion of rail patronage in a low-density setting where there is a concentrated demand for travel towards the predominant centre of Perth CBD. However, it is in some tension with the aspiration to achieve high-density mixed used development around stations. At some locations this urban form has been delivered or is emerging. These locations include Subiaco, and the growing regional centre at Joondalup at the northern end of Perth's coastal rail corridor.

Some other stations present a more challenging environment for the achievement of a population of over 10,000 residents within a 1km radius – the density threshold that may be required to warrant a major, transit-oriented development redesign of the station precinct.

## Findings

- Peak period road users can expect to spend a significant proportion of their journeys on the cities' worst roads in congested conditions.
- Perth's most congested corridors in 2016 are expected to worsen by 2031, including the Mitchell and Kwinana Freeways. By 2031 peak users of these corridors can expect to spend up to 60% of their travel time stuck in traffic, up from 40% in 2016 for the worst-performing corridors.
- Long delays are also forecast on key arterial corridors. Users travelling the length of the Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor can expect a travel time of nearly 45 minutes in 2031.
- In outer areas, significant population growth to 2031 will drive congestion on arterial roads. In the far north the Marmion Avenue / West Coast Highway and Wanneroo Road corridors will perform poorly. In the south a similar outcome is expected on the Nicholson Road corridor.
- The cost of public transport crowding in Perth will increase almost fivefold by 2031. The Joondalup and Mandurah lines will continue to see the most crowded services. Generally, population growth in emerging and established areas appears not to be adequately serviced by additional rail infrastructure and services by 2031.
- Buses will experience more significant crowding in 2031, due to increased population and travel demand, and as a result of more commuters choosing buses over crowded trains. Key bus routes will reach crush capacity close to the CBD, with Kwinana Freeway services particularly affected.

## 8.4 Perth's transport networks are forecast to become more congested

### Snapshot of Perth's transport networks in 2031

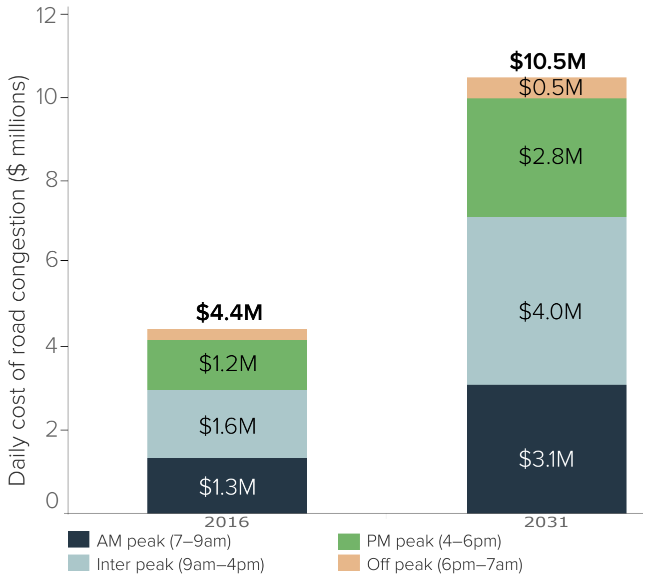
Demand for transport in Perth is predicted to increase roughly in line with population growth. Greater Perth's population is forecast to grow by about 30%, to just over 2.6 million, by 2031. Population is expected to grow most quickly on the urban fringe, with significant growth in Wanneroo (75%) and Mandurah (58%). There will also be some urban infill development, with significant growth in Perth City (33%) and Cockburn (34%).

As a result, trips on Perth's transport network are forecast to increase by 33%, to over 7 million daily trips. Trips by public transport are expected to grow at a faster rate than by car, continuing a shift towards public transport usage seen in the city over the last few years. Trips on public transport will increase by 42% and by car by 32%.

Despite the mode shift from cars to public transport, congestion on Perth's roads is forecast to grow substantially. Our modelling indicates the annualised cost of road congestion will be approximately $3.6 billion in 2031. Congestion will continue to be particularly acute on key north-south arterial roads, as well as on the Mitchell and Kwinana Freeways and the Tonkin Highway. The daily cost of road congestion on Perth's roads is expected to more than double as a result, from about $4.4 million in 2016 to $10.5 million in 2031 (Figure 85).

The cost of public transport crowding is also forecast to increase significantly, while totalling significantly less than the cost of road congestion. The annualised cost of public transport crowding in Perth is expected to increase almost ten fold, from $17 million in 2016 to $159 million in 2031, with the majority of the increase being associated with rail crowding.

**Figure 85:** Perth's average weekday cost of road congestion, 2016 and 2031




Source: Veitch Lister Consulting (2019)[161]

These forecast outcomes account for projects that were either under construction, under procurement or had funding for construction committed from all relevant governments at the time of modelling for the *Infrastructure Australia Audit*.[162]

Major projects included in Perth's 2031 forecast comprise:

- NorthLink WA
- Tonkin Highway Grade Separation
- Forrestfield Airport Link
- Thornlie–Cockburn Link
- Yanchep Rail Extension
- Mitchell Freeway widening
- Kwinana Freeway widening.

## Perth's most congested roads in 2031: what the driver will experience

In 2031, Perth's worst-performing roads will be broadly the same as today, but suffering greater congestion and delays (Figure 86). The north-south Mitchell and Kwinana Freeways, and their connecting routes, are expected to experience the city's worst traffic congestion in 2031.

Based on estimating the percentage of journey time that will be accounted for by congestion on Perth's road network in 2031, Table 35 and Figure 87 show the ten most congested corridors in the AM and PM peak periods, respectively.

**Figure 86:** Perth weekday traffic volume / capacity ratio, 2031 AM peak


Source: Veitch Lister Consulting (2019)[163]

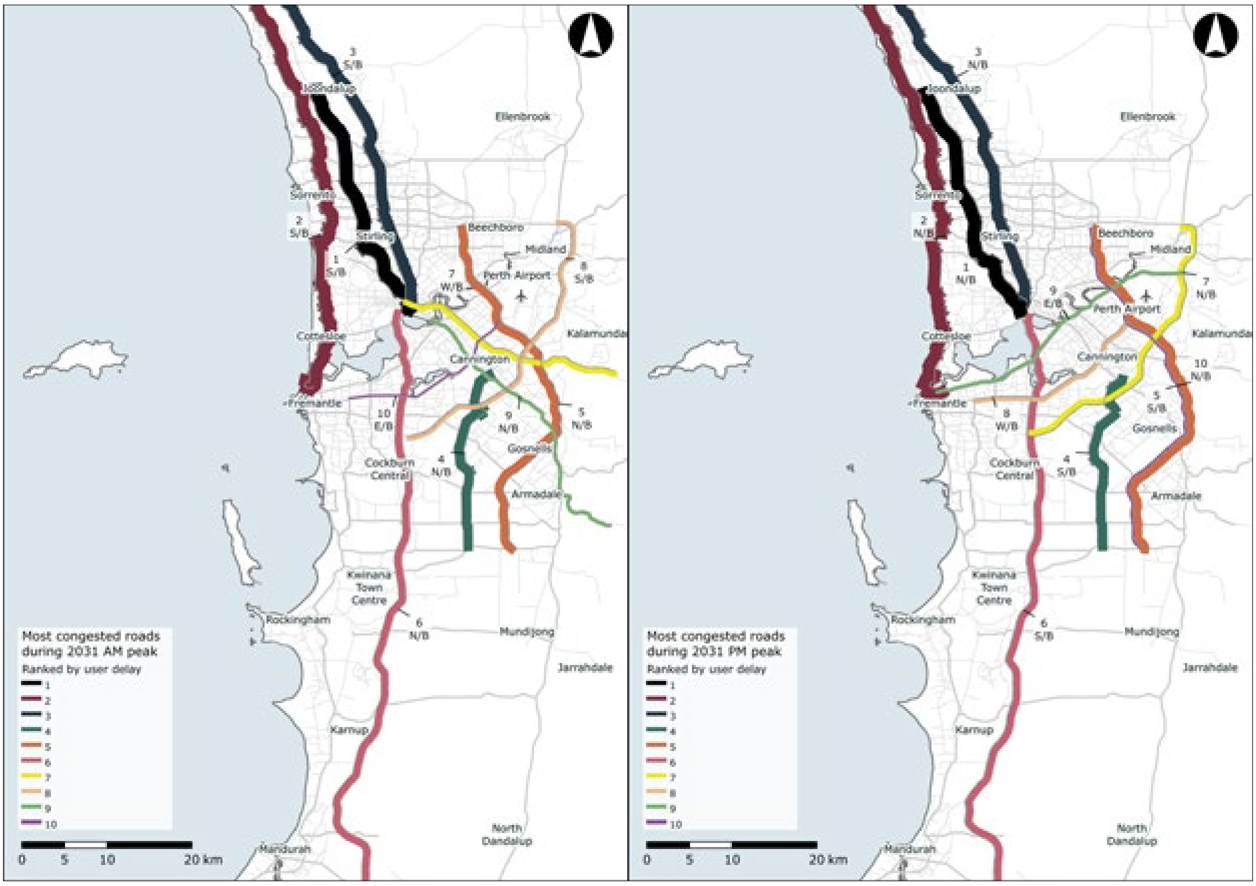
## **Table 35:** Perth's most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Mitchell Freeway corridor (S/B) | 29 | 62% | 31 | $8.56 | $36.88 |
| 2. | Marmion Avenue / West Coast Highway corridor (S/B) | 61 | 54% | 64 | $17.67 | $76.14 |
| 3. | Wanneroo Road corridor (S/B) | 47 | 53% | 48 | $13.26 | $57.10 |
| 4. | Nicholson Road corridor (N/B) | 22 | 52% | 19 | $5.25 | $22.60 |
| 5. | Tonkin Highway corridor (N/B) | 44 | 51% | 30 | $8.29 | $35.69 |
| 6. | Kwinana Freeway corridor (N/B) | 80 | 51% | 50 | $13.81 | $59.48 |
| 7. | Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor (W/B) | 24 | 47% | 20 | $5.52 | $23.79 |
| 8. | Roe Highway corridor (S/B) | 34 | 44% | 18 | $4.97 | $21.41 |
| 9. | Albany Highway corridor (N/B) | 33 | 43% | 24 | $6.63 | $28.55 |
| 10. | Leach Highway corridor (E/B) | 19 | 42% | 13 | $3.59 | $15.47 |
| PM peak | | | | | | |
| 1. | Mitchell Freeway corridor (N/B) | 29 | 56% | 25 | $6.90 | $29.74 |
| 2. | West Coast Highway / Marmion Road corridor (N/B) | 61 | 50% | 53 | $14.64 | $63.05 |
| 3. | Wanneroo Road corridor (N/B) | 47 | 48% | 40 | $11.05 | $47.59 |
| 4. | Nicholson Road corridor (S/B) | 22 | 48% | 17 | $4.69 | $20.22 |
| 5. | Tonkin Highway corridor (S/B) | 44 | 47% | 27 | $7.46 | $32.12 |
| 6. | Kwinana Freeway corridor (S/B) | 80 | 46% | 42 | $11.60 | $49.97 |
| 7. | Roe Highway corridor (N/B) | 34 | 44% | 18 | $4.97 | $21.41 |
| 8. | Leach Highway corridor (W/B) | 19 | 41% | 13 | $3.59 | $15.47 |
| 9. | Canning Highway / Great Eastern Highway (west) corridor (E/B) | 30 | 41% | 21 | $5.80 | $24.98 |
| 10. | Tonkin Highway corridor (N/B) | 44 | 40% | 20 | $5.52 | $23.79 |

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

Source: Veitch Lister Consulting (2019)[164]

## **Figure 87:** Perth's most congested roads (user experience), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[165]

Between 2016 and 2031, vehicle congestion in Perth is expected to have worsened and spread. By 2031, users of the above corridors can expect to spend 40–60% of their time in dense traffic. Inevitably, increased congestion will result in deteriorating road performance, affecting travel times predominantly for commuters travelling to and from central Perth in peak periods. Motorists can expect lengthier periods of congestion stretching greater distances from the city centre in both the morning and evening by 2031.

Perth's forecast population growth will be the principal factor increasing pressure on the city's key access routes by 2031. Despite widening of the Mitchell and Kwinana Freeways, these roads will experience severe congestion in the citybound direction in the AM peak period, with the opposite expected in the PM peak period. Motorists on the Kwinana Freeway are also forecast to experience high levels of congestion in the counter-peak direction. These routes provide access to Perth's city centre for commuters and freight operators travelling from both the north and south. Severe congestion on these corridors will be extremely disruptive to daily travel by cars, buses and trucks. Modelling suggests that by 2031 the Mitchell Freeway will be struggling to accommodate an expected traffic volume well in excess of its design capacity.

Additional demand on Perth's central north-south freeway corridor will also increase traffic volumes on other major roads such as the Roe and Tonkin highways. This is forecast to eventuate despite significant road upgrades, such as interchange grade separation for the Tonkin Highway. While this is expected to improve traffic conditions on some sections of the corridor, the Swan River Crossing will remain a highly congested corridor.

In addition to congestion on major freeways, surface arterial road corridors providing access to these freeways are forecast to experience significant levels of congestion by 2031. Roads providing on-ramp access to freeways, especially in growth areas, will be subject to increased delays due to rising demand for access to jobs and other opportunities in central Perth. Increased traffic and congestion will also be felt at river crossings at Fremantle and to the north-east of the CBD.

## Perth's most congested roads in 2031: the forecast cost to the community of total vehicle delays

Modelling has forecast the most congested road corridors in Greater Perth for 2031, as for 2016, based on aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors in the AM and PM peak periods under this approach are shown in Table 36 and Figure 88. The greatest delays are forecast to be experienced on major freeways and key arterial roads.

## Perth's public transport system in 2031

By 2031, Perth's public transport network will need to cater for a much larger population. Overall public transport boardings are forecast to increase strongly, by 95% for rail and 80% for buses.[166] Trains will be expected to cater for long-distance travel, while buses will be more relied on for shorter trips.

Patronage on Perth's rail system is expected to be supported by investments that expand service catchments. Patronage on the Joondalup Line is forecast to grow most significantly, as a result of the rail extension to Yanchep, catering for Perth's most northerly residents.

As in 2016, in 2031 crowding on Perth's rail will be concentrated on the Mandurah and Joondalup lines that facilitate travel from the outer north and south (Figure 89). For both lines, crowding is forecast to increase beyond their maximum or crush capacity in the AM peak on certain sections. The Mandurah Line will experience its most significant crowding between Parmelia and Jandakot as a result of increasing demand not being matched by increased service frequencies. Similarly, the Joondalup Line is forecast to be most crowded between Woodvale and the city.

Perth's bus network is also forecast to experience significant patronage uplift by 2031, particularly on corridors radial to the CBD. This is predicted to be driven by population growth in both emerging and established areas. Bus crowding is predicted to worsen on major routes by 2031 (Figure 90). Radial routes converging on the CBD will experience the greatest levels of crowding. These include routes along the Kwinana and Mitchell Freeways, close to the CBD. In addition, routes running parallel to rail lines are predicted to be increasingly crowded as commuters opt for buses over busy trains. Routes serving areas beyond rail catchments will also experience moderate crowding in 2031.

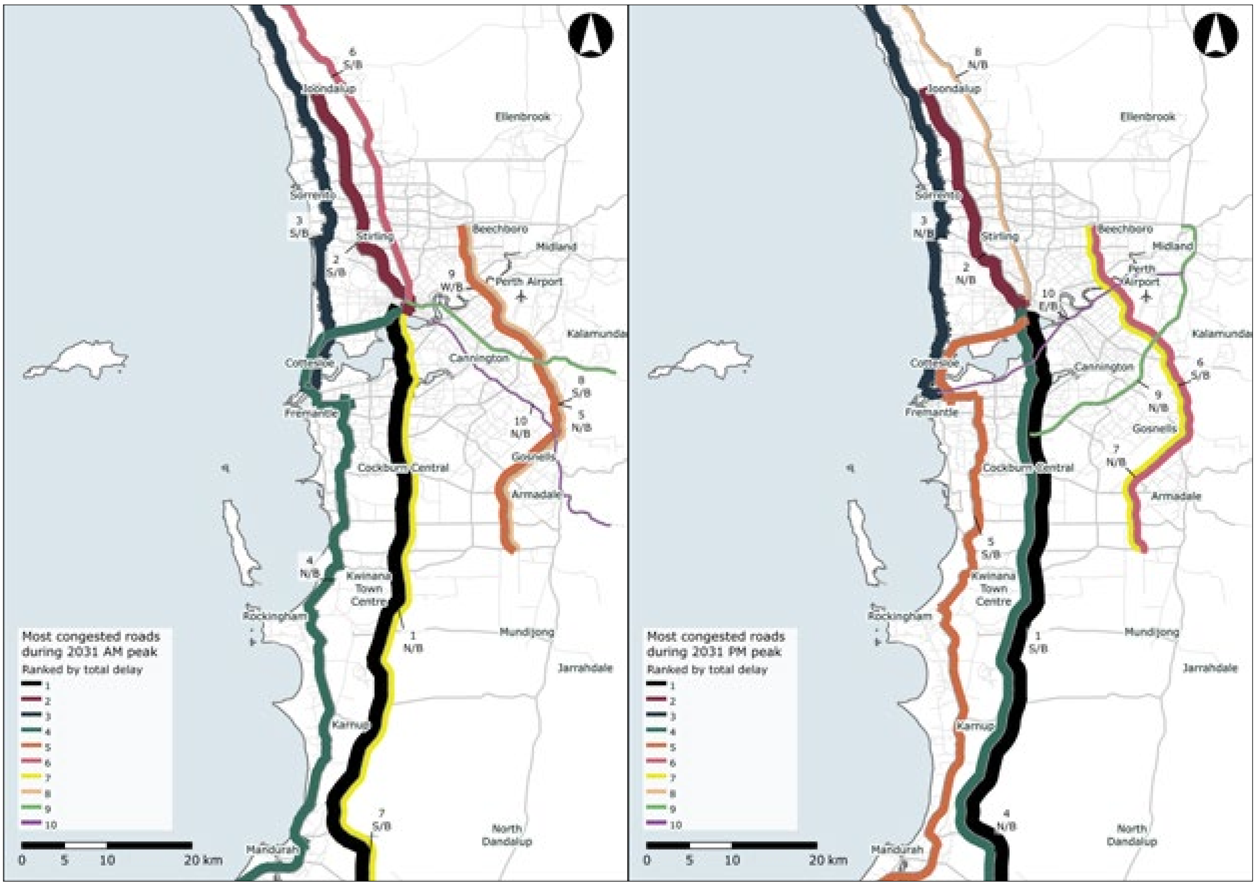
**Table 36:** Perth's most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Kwinana Freeway corridor | N/B | 8,600 | $169,000 |
| 2. | Mitchell Freeway corridor | S/B | 5,200 | $101,000 |
| 3. | Marmion Avenue / West Coast Highway corridor | S/B | 4,100 | $81,000 |
| 4. | Old Coast Road / Mandurah Road / Stock Road / Stirling Highway corridor | N/B | 3,200 | $66,000 |
| 5. | Tonkin Highway corridor | N/B | 3,100 | $65,000 |
| 6. | Wanneroo Road corridor | S/B | 2,500 | $49,000 |
| 7. | Kwinana Freeway corridor | S/B | 2,300 | $49,000 |
| 8. | Tonkin Highway corridor | S/B | 2,200 | $45,000 |
| 9. | Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor | W/B | 2,100 | $42,000 |
| 10. | Albany Highway corridor | N/B | 1,900 | $37,000 |
| PM peak | | | | |
| 1. | Kwinana Freeway corridor | S/B | 7,500 | $148,000 |
| 2. | Mitchell Freeway corridor | N/B | 4,700 | $90,000 |
| 3. | West Coast Highway / Marmion Avenue corridor | N/B | 3,500 | $68,000 |
| 4. | Kwinana Freeway corridor | N/B | 3,300 | $71,000 |
| 5. | Stirling Highway / Stock Road / Mandurah Road / Old Coast Road corridor | S/B | 2,900 | $61,000 |
| 6. | Tonkin Highway corridor | S/B | 2,900 | $61,000 |
| 7. | Tonkin Highway corridor | N/B | 2,400 | $50,000 |
| 8. | Wanneroo Road corridor | N/B | 2,200 | $42,000 |
| 9. | Roe Highway corridor | N/B | 1,800 | $39,000 |
| 10. | Canning Highway / Great Eastern Highway (west) corridor | E/B | 1,600 | $32,000 |

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

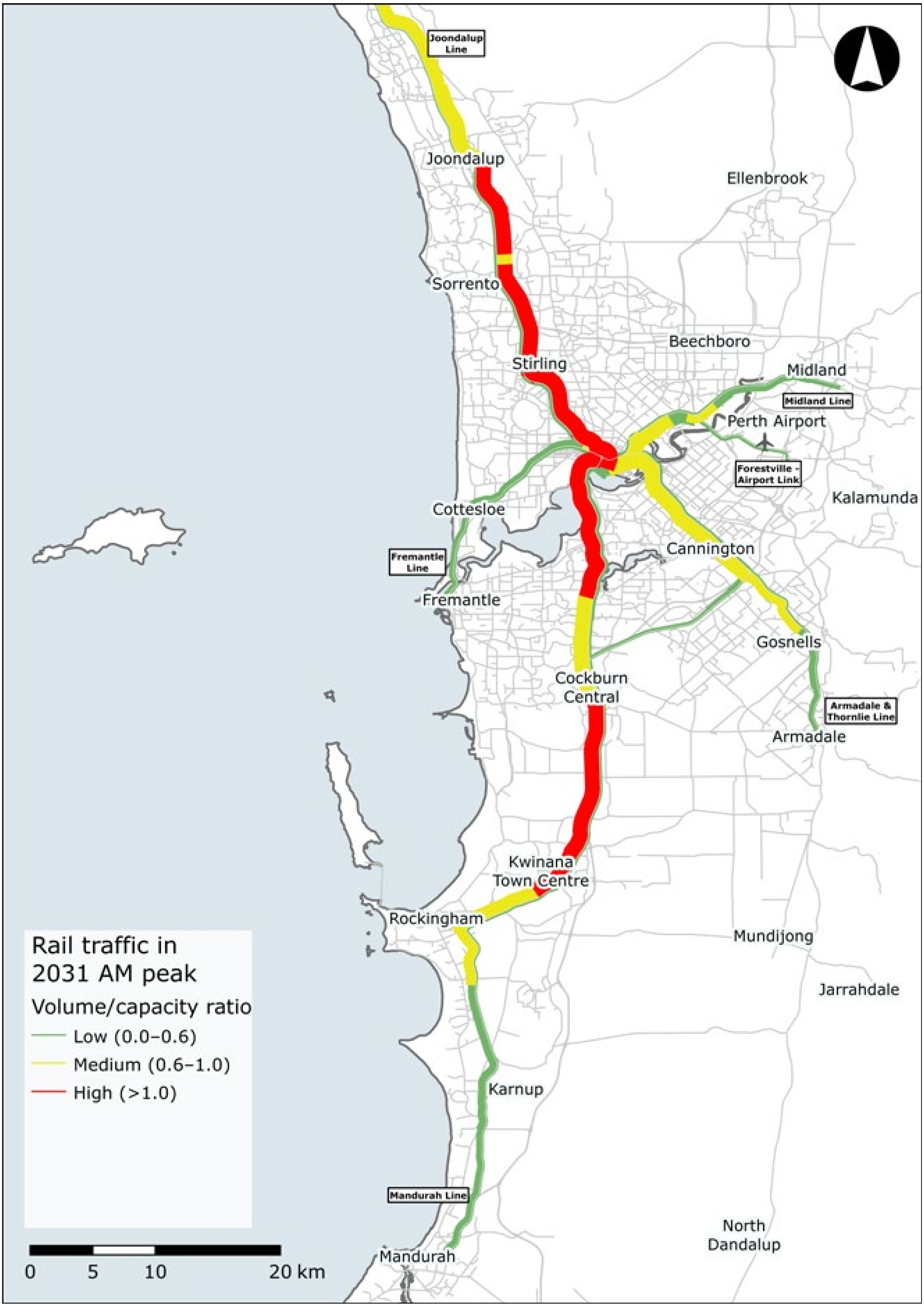
Source: Veitch Lister Consulting (2019)[167]

**Figure 88:** Perth's most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak periods



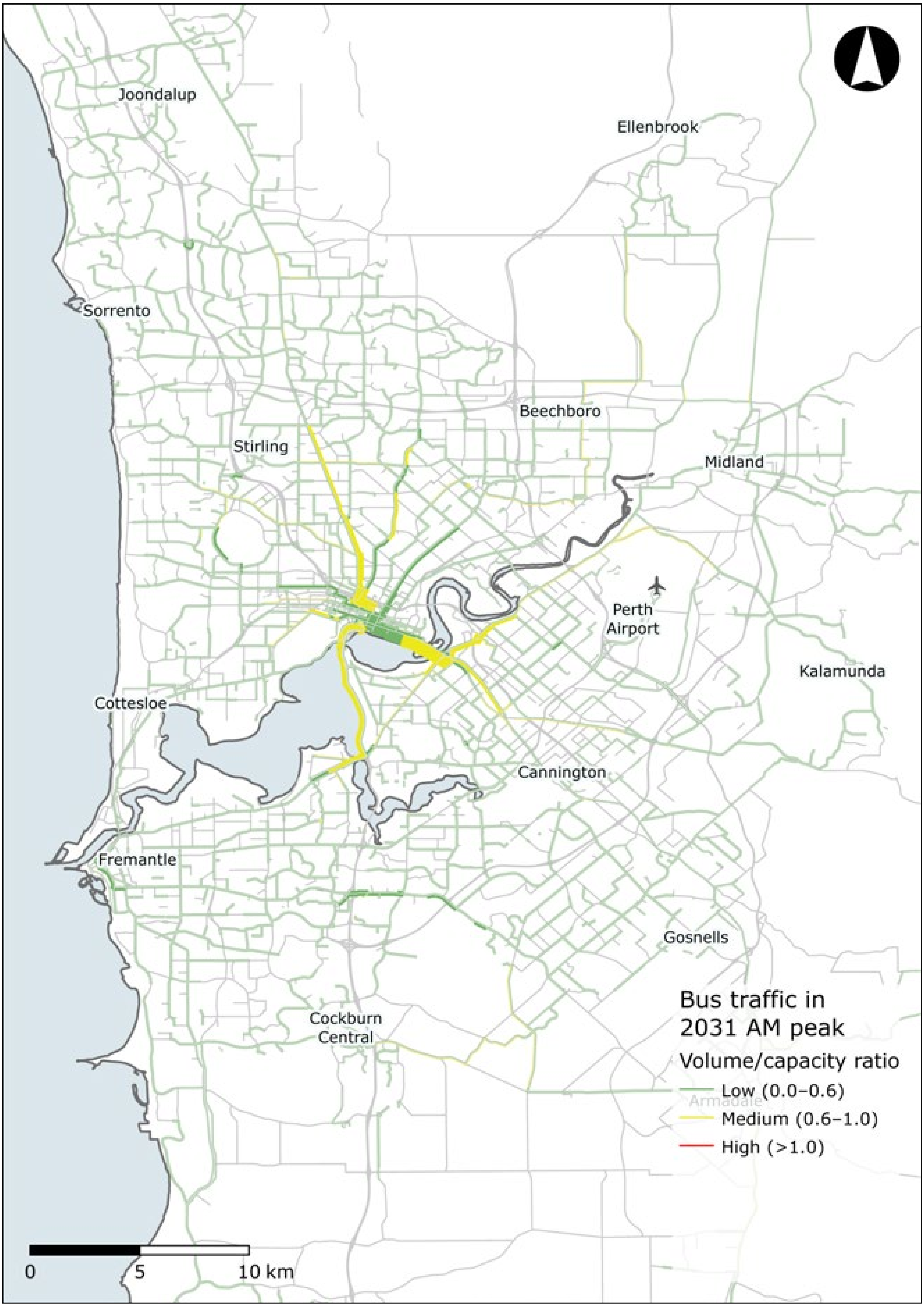

Source: Veitch Lister Consulting (2019)[168]

**Figure 89:** Perth weekday train passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[169]

**Figure 90:** Perth weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[170]

## Findings

- The 2019 Audit forecasts that the annualised cost of road congestion for Greater Perth will grow from approximately $1.5 billion in 2016 to $3.6 billion in 2031. This is 77% lower than the 2031 forecast cost of road congestion in the 2015 Audit.
- Peak period road users can expect to spend a significant proportion of their journeys on the cities' worst roads in congested conditions.
- Perth's most congested corridors in 2016 are expected to worsen by 2031, including the Mitchell and Kwinana freeways. By 2031 peak users of these corridors can expect to spend up to 60% of their travel time stuck in traffic, up from 40% in 2016 for the worst-performing corridors.
- Long delays are also forecast on key arterial corridors. Users travelling the length of the Welshpool Road East / Orrong Road / Graham Farmer Freeway corridor can expect a travel time of nearly 45 minutes in 2031.
- In outer areas, significant population growth to 2031 will drive congestion on arterial roads. In the far north the Marmion Avenue / West Coast Highway and Wanneroo Road corridors will perform poorly. In the south a similar outcome is expected on the Nicholson Road corridor.
- The cost of public transport crowding in Perth will increase almost fivefold by 2031. The Joondalup and Mandurah lines will continue to see the most crowded services. Generally, population growth in emerging and established areas appears not to be adequately serviced by additional rail infrastructure and services by 2031.
- Buses will experience more significant crowding in 2031, due to increased population and travel demand, and as a result of more commuters choosing buses over crowded trains. Key bus routes will reach crush capacity close to the CBD, with Kwinana Freeway services particularly affected.

## 8.5 Transport decisions impact access to jobs and services

### Hospital access in Perth – by car and public transport, in 2031

Greater Perth's access to critical healthcare is measured by the time it takes to travel to the nearest public hospital, or hospital with an emergency department, by car versus public transport (Figure 91).

Despite all but one of Greater Perth's public hospitals having close access to rail services, car accessibility to hospitals is superior to public transport. While in 2031 the average time to the nearest public hospital in Greater Perth is forecast to be 16 minutes by car (a four-minute increase from 2016), residents without access to a car will continue to be subject to longer travel times.

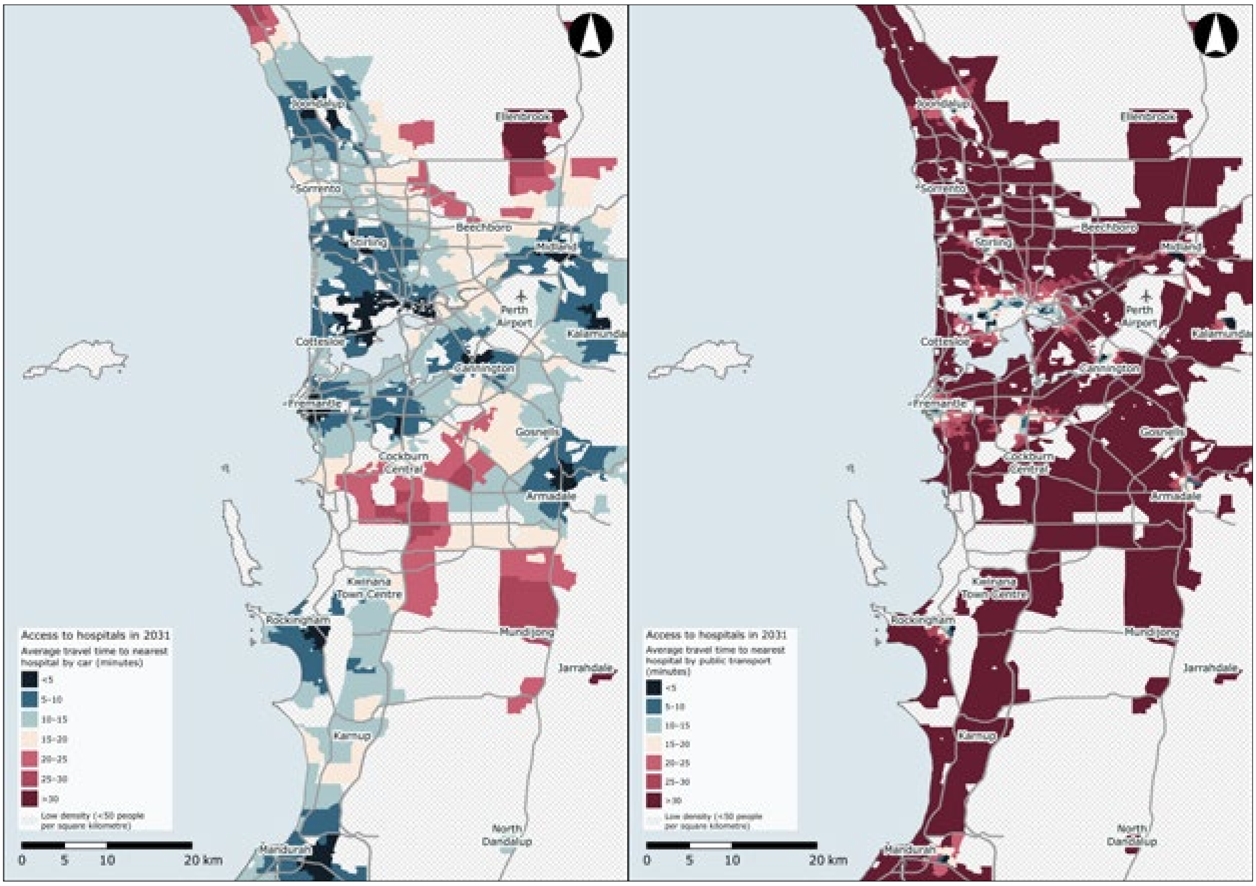
Perth's average travel time by public transport to the nearest public hospital in 2031 will be over 50 minutes. This number reflects the very long travel times modelled for residents of outer or other growth areas where there is limited certainty regarding future public transport connections, including Serpentine–Jarrahdale, Swan and Wanneroo. For residents of middle ring areas, 30–40 minutes will be feasible. This time is reduced further for residents of Perth City, whose nearest public hospital will be accessible in a little over 20 minutes by public transport.

### Access to childcare and schools in Perth – by car and public transport, in 2031

The average resident of the Greater Perth region, if they have the use of a car, can access childcare services (Figure 92), public primary schools (Figure 93) and public secondary schools (Figure 94) within a five-minute trip in 2016. This is expected to extend to a seven-minute trip by 2031.

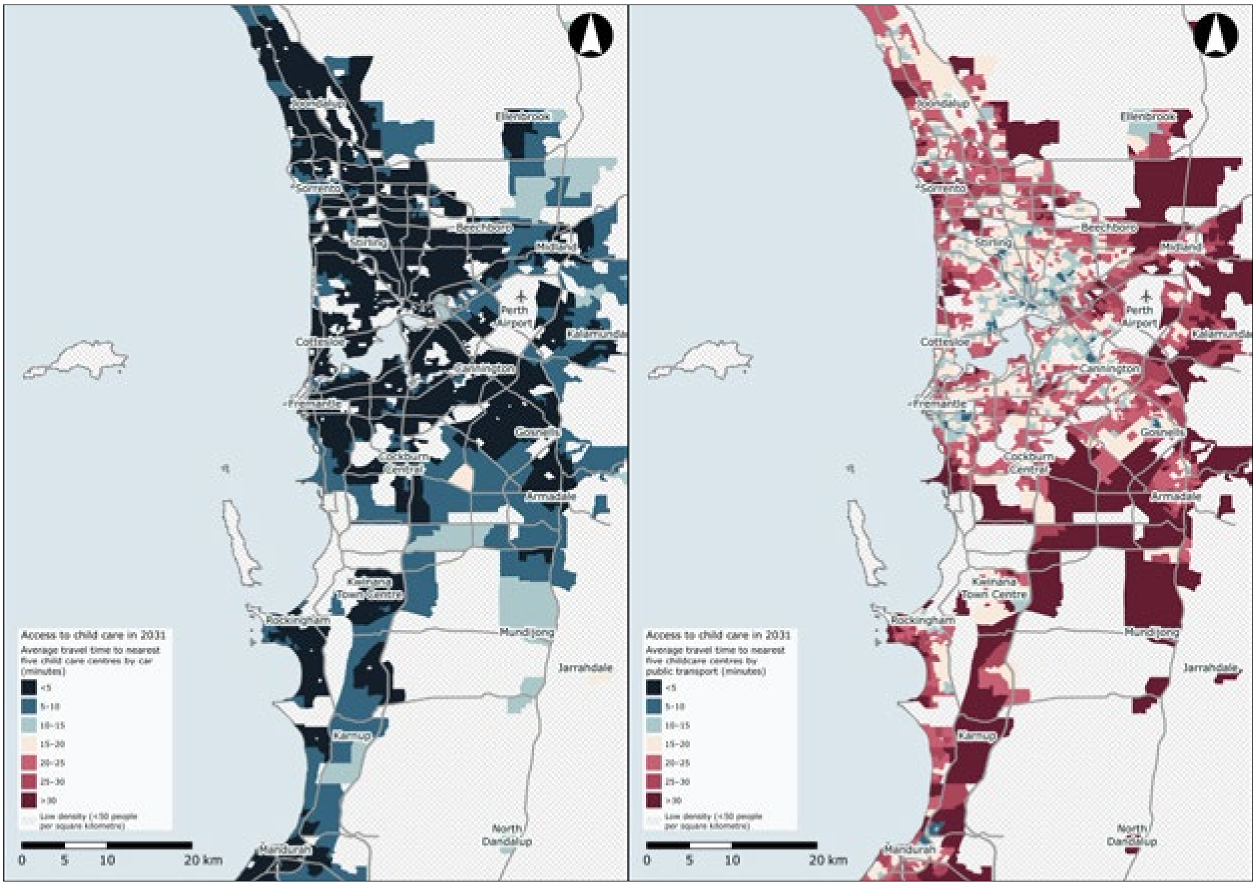
For residents without access to a car, travel times are significantly longer on public transport. Travel times generally average more than 30 minutes for all such destinations, worsening between 2016 and 2031. In some established parts of Perth, public transport offers a realistic alternative to car use, however the urban fringe and areas without direct access to rail services experience much longer travel times. This highlights that while Perth's public transport network effectively facilitates commuting it is less effective at catering for local travel needs.

**Figure 91:** Greater Perth average time to nearest hospital by car (left) and public transport (right), 2031 AM peak



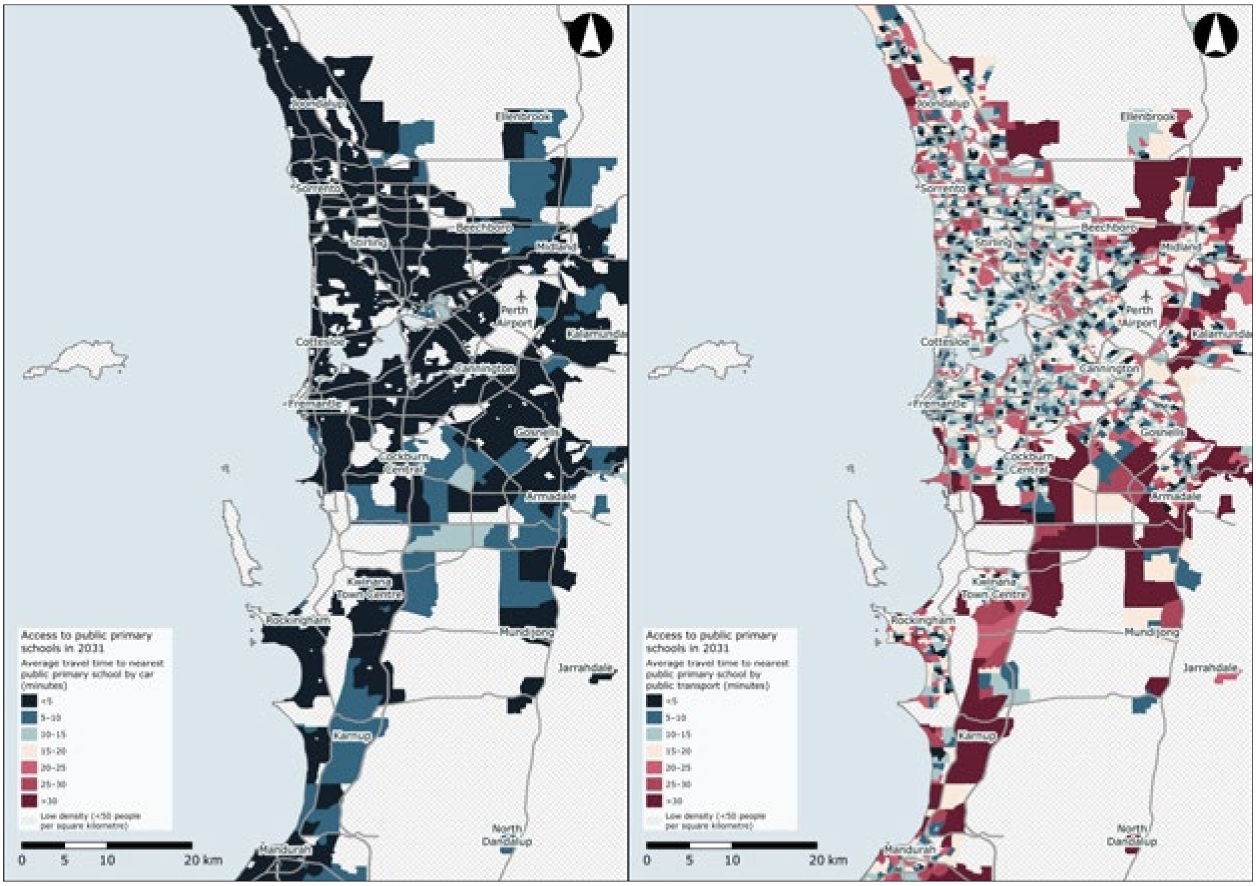

Source: Veitch Lister Consulting (2019)[171]

**Figure 92:** Greater Perth average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



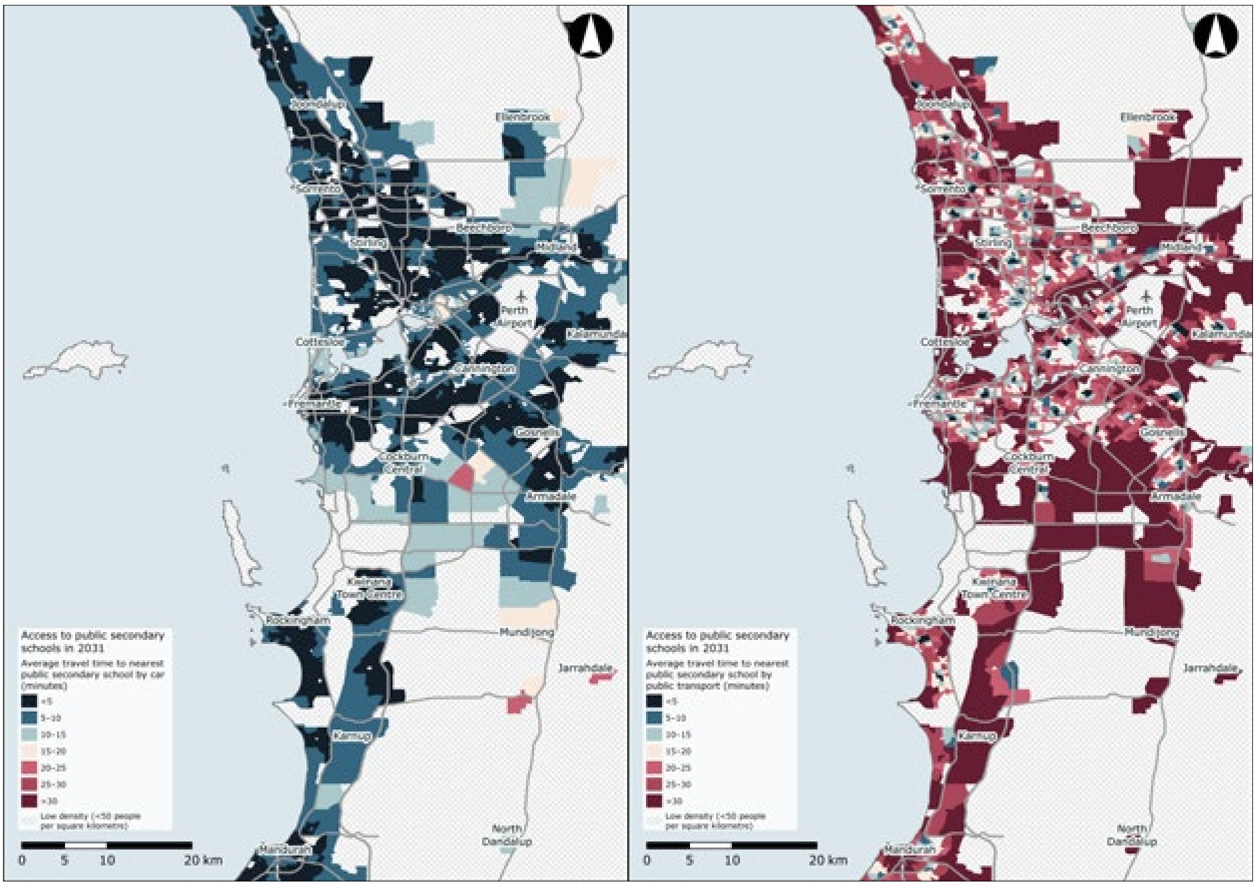

Source: Veitch Lister Consulting (2019)[172]

**Figure 93:** Greater Perth average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[173]

**Figure 94:** Greater Perth average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[174]

### Access to jobs in Perth – by car and public transport, in 2016 and 2031

Employment accessibility has been measured as the percentage of jobs that can be reached in Greater Perth within 30 minutes of home by car (Figure 95) and by public transport (Figure 96) in the two modelled years.

Access to employment across Greater Perth differs based on where a person lives and which mode of transport they opt for. Due to the high current and future concentration of jobs in Perth's city centre, accessibility to this area is the main driver of job accessibility.

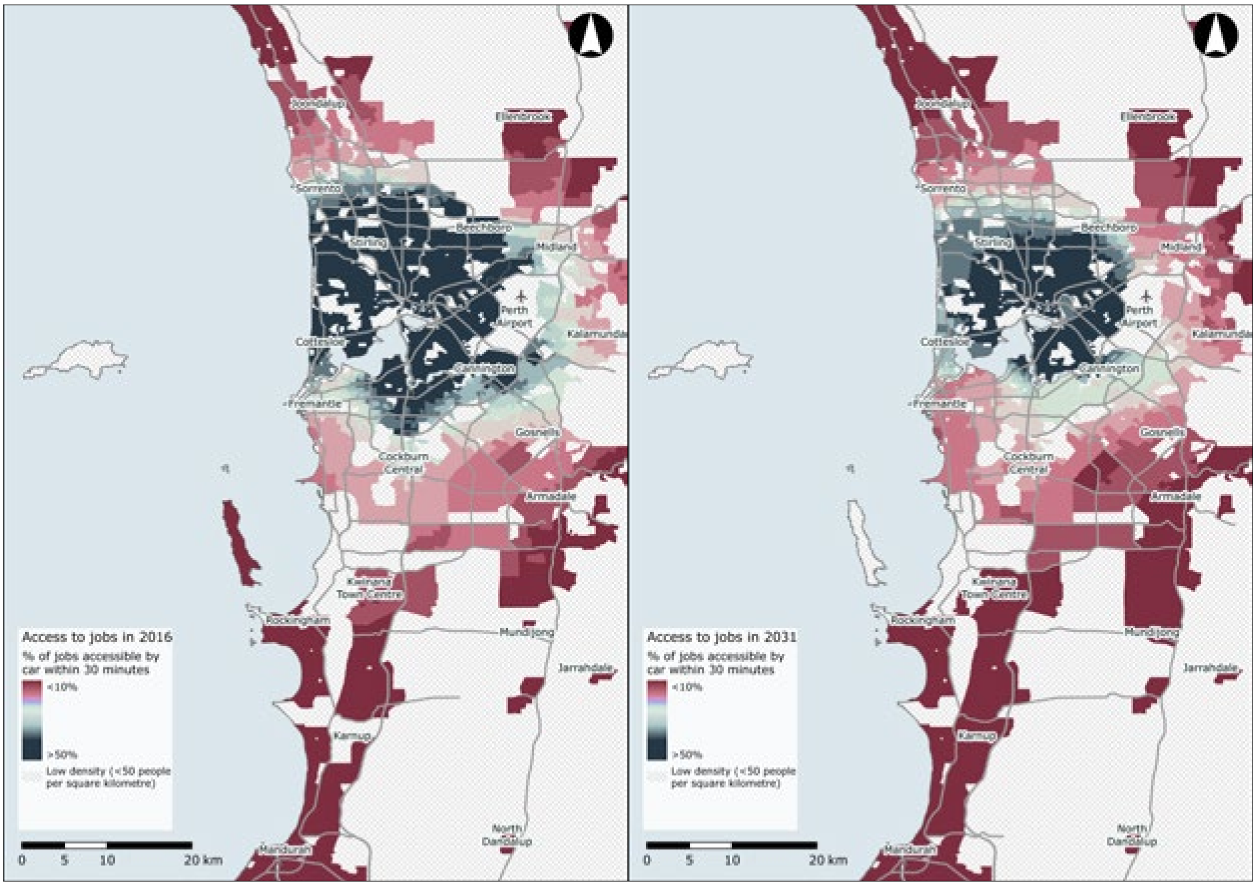
Job accessibility by car is expected to reduce by 2031 due to road congestion. As a result motorists are expected to be able to reach a smaller proportion of jobs by car in 2031 than in 2016. This is particularly the case in areas south of the Swan River, due to the constraints river crossings present to the movement of traffic.

Job accessibility by public transport is forecast as relatively stable between 2016 and 2031. Notwithstanding issues with crowding of bus and rail due to service provision not keeping pace with population growth, in terms of coverage areas that have good accessibility to jobs by public transport in 2016 are forecast to continue to benefit from this in the future. Outer urban areas will still be, as today, relatively disadvantaged in this respect.

## Findings

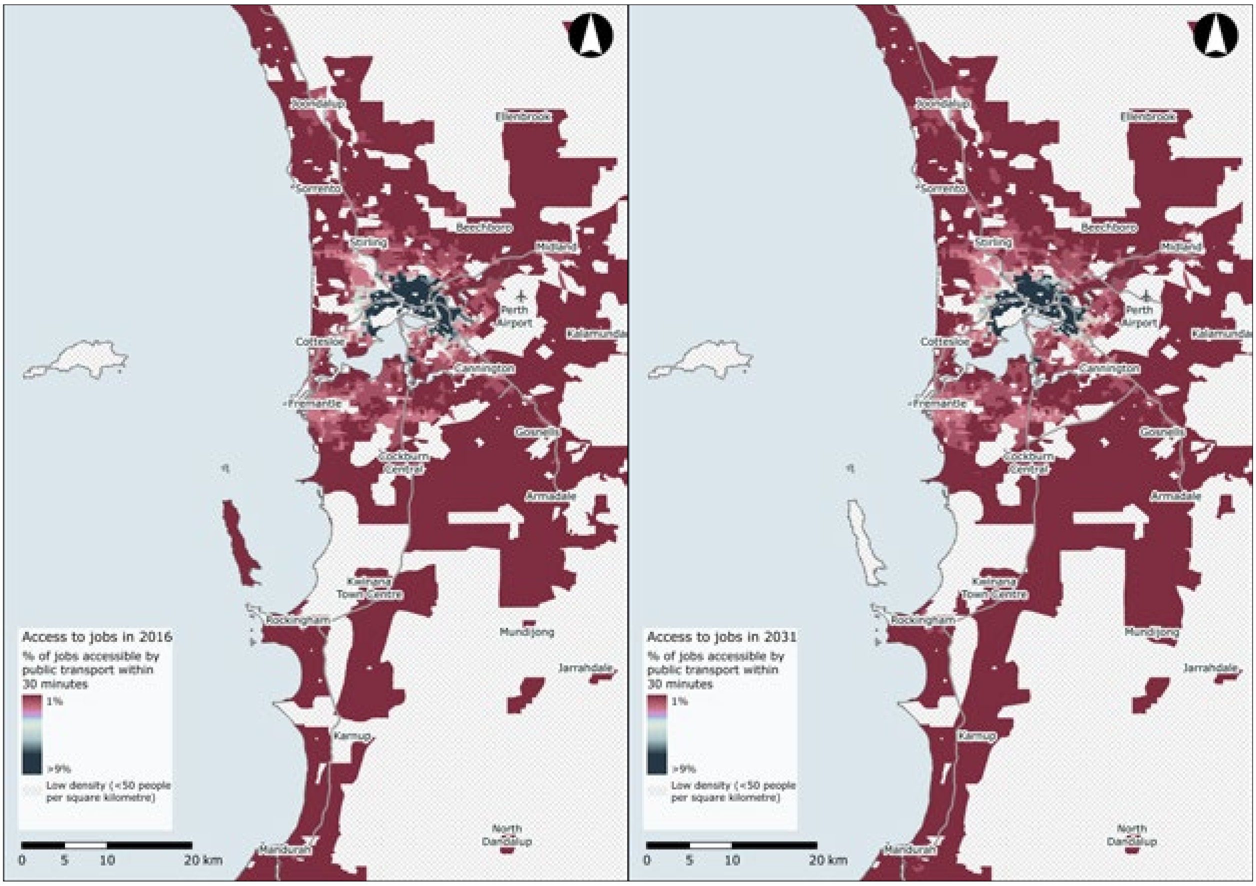
- Perth residents without use of a car have significantly reduced access to social infrastructure today and in the future.
- In central Perth public transport offers a realistic alternative to car ownership and use. However, on the urban fringe and in other outer areas this is not the case.
- Road congestion will generally reduce the proportion of jobs able to be reached by car in 2031.
- The concentration of jobs in Perth's city centre means residents of central areas have significantly more employment options within a 30-minute commute, especially by public transport, than residents of outer areas.

**Figure 95:** Greater Perth access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[175]

**Figure 96:** Greater Perth access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[176]

9

# Greater Adelaide

## 9.1 Adelaide has grown, and so has its transport task

### Adelaide's transport network performance over the past decade

Between 2006 and 2016, Adelaide's population rose from 1.1 million to 1.3 million residents. Growth during this period was particularly focused in Adelaide's inner suburbs, while also involving some development on the city's fringes.[177] Adelaide's primary urban areas sit between the coast and the Adelaide Hills to the city's east, extending from there generally in a north-south direction.

Adelaide's population growth during this period has greatly increased the city's transport task. In 2016, residents of Adelaide collectively travelled 66 million kilometres further on the city's road network than in 2006.[178]

## 9.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit inputs and assumptions

Since the 2015 Audit, Adelaide's forecast cost of road congestion has decreased by 30% (Table 37 and Figure 97). This is due to changes in model calibration to reflect actual journey to work data.

**Table 37:** The cost of road congestion and public transport crowding in Greater Adelaide, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| **2016 (2019 Audit)** | 1 | 1,444 | 1,445 |
| **2031 (2019 Audit)** | 4 | 2,619 | 2,623 |
| 2031 (2015 Audit) | N/A | 3,747 | N/A |
| 2031 (change from 2015 Audit) | | -1,128 (-30%) | |

Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[179]

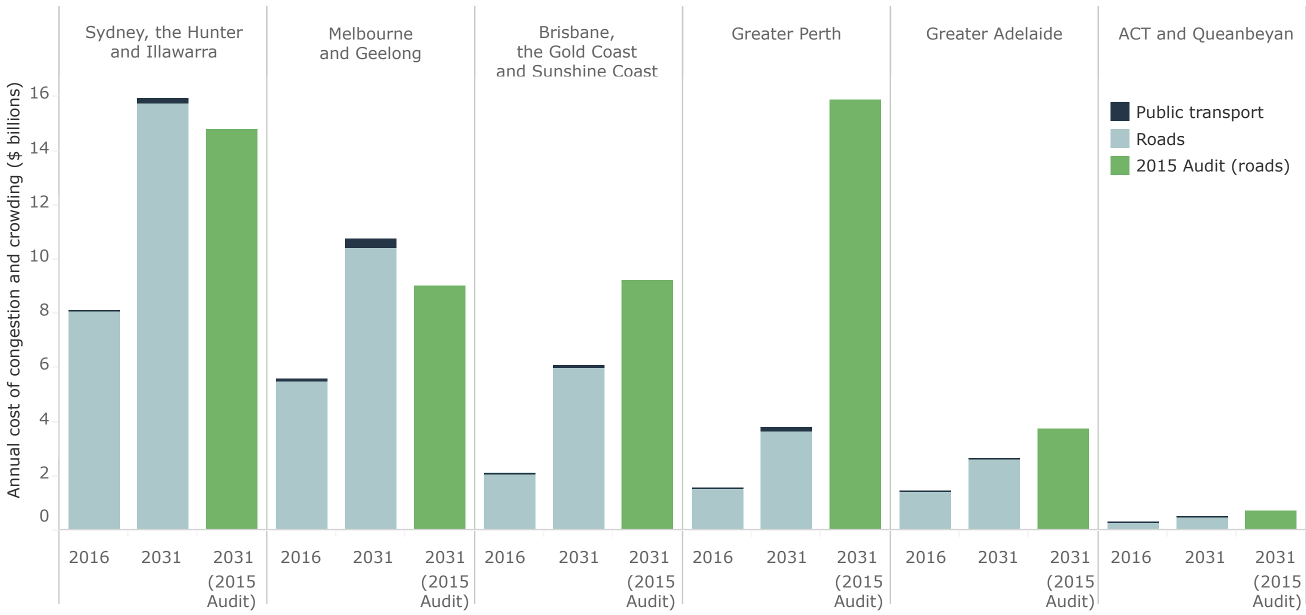
In the 2015 Audit, 2031 population projections for Adelaide were extracted from ABS Series B projections. In the latest work, projections have been provided by the South Australian Government. Overall the demographic forecasts used in the 2019 Audit were fairly similar to those used in the 2015 Audit. Both audits forecast approximately 1.6 million people will live in the Adelaide Greater Capital City Statistical Area in 2031. How population is distributed is also largely aligned in both audits.

By contrast, the proportion of forecast employment in the modelled areas is forecast to drop from 0.8 million to 0.7 million.

The largest single contributor to the decreased forecast cost of road congestion in 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.

Table 38 reflects changes in model inputs and key outputs between 2015 and 2019 Audit modelling.

**Figure 97:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[180]

**Table 38:** Changes in key model inputs and outputs between 2015 and 2019 modelling in Greater Adelaide

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | — Population forecasts are similar (-%) | ⇩ Employment forecasts have reduced (-12%), however the proportion of jobs in Adelaide City SA3 remains stable | ⇧ More investment in the road network (+10% network lane km) | ⇧ More investment in the PT network (+27% service kms) | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | |
| Impact on output (AM peak) | Total trips (-41%) | — As population forecasts are similar, this would have minimal impact on model results | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| | Car trips (-17%) | — As population forecasts are similar, this would have minimal impact on model results | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| | Car vehicle kms travelled (-%) | — As population forecasts are similar, this would have minimal impact on model results | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | |
| | Public transport trips (-35%) | — As population forecasts are similar, this would have minimal impact on model results | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | |

Source: Veitch Lister Consulting (2019)[181]

## New network assumptions

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. For Adelaide, there are two key differences in network assumptions. The City Tram extension and the Port Dock Railway Line are included in the 2019 Audit but not the 2015 Audit.

## Variation between road network capacities in 2031

Traffic volumes on the most delayed corridors are broadly consistent between both audits. The top four most congested corridors at AM peak (South Rd/Main South Rd Corridor, Outer Main North Rd Corridor, Port Wakefield Rd/Main North Rd Corridor, Princess Hwy (M1)/Glen Osmond Rd Corridor) are the same in both audits. Results for the PM peak show a similar outcome.

Sections of the M2 near Reynella, Reynella East and Sheidow Park are forecast to have higher congestion in the 2019 Audit. Similarly, the Northern Expressway in Penfield Gardens is also forecast to have higher traffic volumes.

Table 39 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

**Table 39:** Most congested roads ranked by total delay hours, 2031 AM Peak and ranking in 2015 Audit in Greater Adelaide

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes: | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Main South Road / South Road corridor | N/B | 1,800 | 2,000 | 9% | 4,000 | 3,600 | -10% | 2 |
| 2 | Outer Main North Road corridor | S/B | 2,800 | 2,600 | -5% | 3,800 | 2,800 | -28% | 3 |
| 3 | Port Wakefield Road / Main North Road corridor | S/B | 2,500 | 2,100 | -18% | 6,600 | 2,400 | -63% | 1 |
| 4 | Princes Highway (M1) / Glen Osmond Road corridor | N/B | 3,200 | 3,200 | 1% | 2,900 | 2,300 | -18% | 4 |
| 5 | South Road / Main South Road corridor | S/B | 1,200 | 1,400 | 23% | 1,200 | 2,300 | 94% | 17 |
| 6 | North East Road corridor | S/B | 2,400 | 2,300 | -2% | 2,300 | 2,200 | -4% | 8 |
| 7 | Commercial Road / Dyson Road / Lonsdale Road / Brighton Road / Tapleys Hill Road corridor | N/B | 1,700 | 1,700 | 4% | 2,400 | 2,100 | -14% | 7 |
| 8 | Marion Road corridor | N/B | 2,000 | 1,900 | -6% | 2,400 | 1,900 | -23% | 6 |
| 9 | Port Road corridor | E/B | 2,700 | 2,700 | 1% | 1,700 | 1,800 | 7% | 11 |
| 10 | Lower North East Road / Payneham Road corridor | W/B | 1,900 | 1,800 | -5% | 2,100 | 1,800 | -15% | 9 |

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

Source: Veitch Lister Consulting (2019)[182]

### Variation between public transport capacities in 2031

Similar levels of public transport demand are identified in the 2015 and 2019 Audits.

Both audits identify that the majority of the Gawler Line as well as parts of the Seaford and Tonsley lines will be operating well above seated capacity, but below crush capacity, in the AM peak. The 2019 Audit identifies that the worst levels of crowding are forecast to the south of Salisbury, as opposed to the 2015 Audit that identified lines south of the Adelaide CBD would have the highest demand.

Both audits project that Adelaide's bus routes will be more crowded by 2031.

## 9.3 Commuters in Adelaide experience substantial levels of road congestion and public transport crowding every day

### Snapshot of Adelaide's road network in 2016

Adelaide's drivers already experience significant levels of congestion, particularly in the AM peak (Figure 98). Our modelling indicates the annualised cost of road congestion was approximately $1.4 billion in 2016.

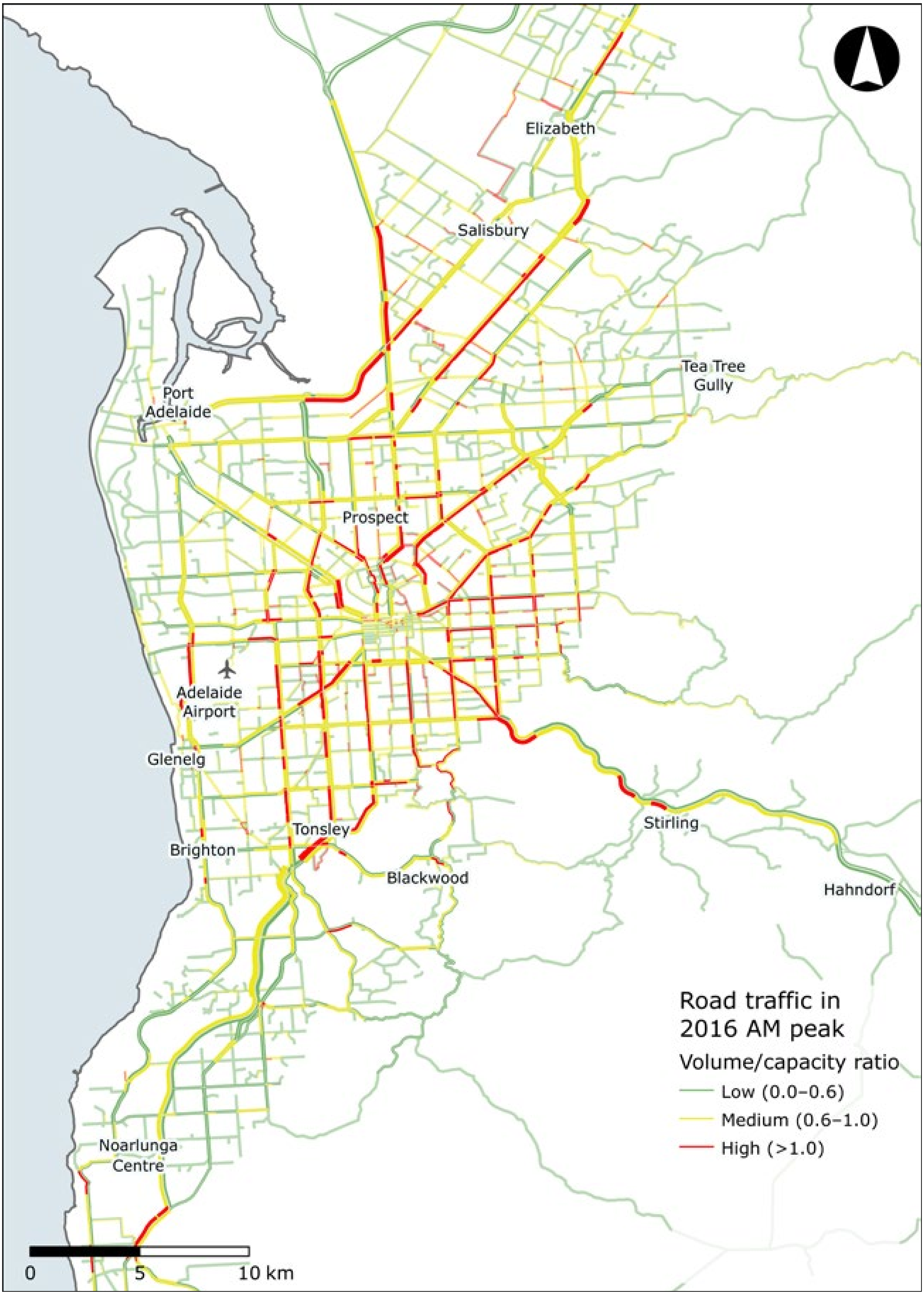
Adelaide's most congested roads are those that accommodate north-south travel, with more severe levels of congestion experienced closer to the CBD. These roads provide access to Adelaide's central employment cluster from surrounding suburbs.

### Adelaide's most congested roads in 2016: what the driver experiences

Infrastructure Australia has measured the most congested corridors in Adelaide using several customer-focused metrics. The ten most congested corridors in the AM and PM peaks from a user's perspective are shown in Table 40 and Figure 99.

Adelaide's most congested road corridors from a driver's perspective in 2016 were the Fullarton Road and Goodwood Road corridors. While these roads are relatively short, under 10km in length, peak period drivers can expect to spend around 60% of their travel time in congested traffic. Both of these corridors carry north-south movements close to the CBD.

**Figure 98:** Adelaide weekday traffic volume/ capacity ratio, 2016 AM peak




Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019)[183]

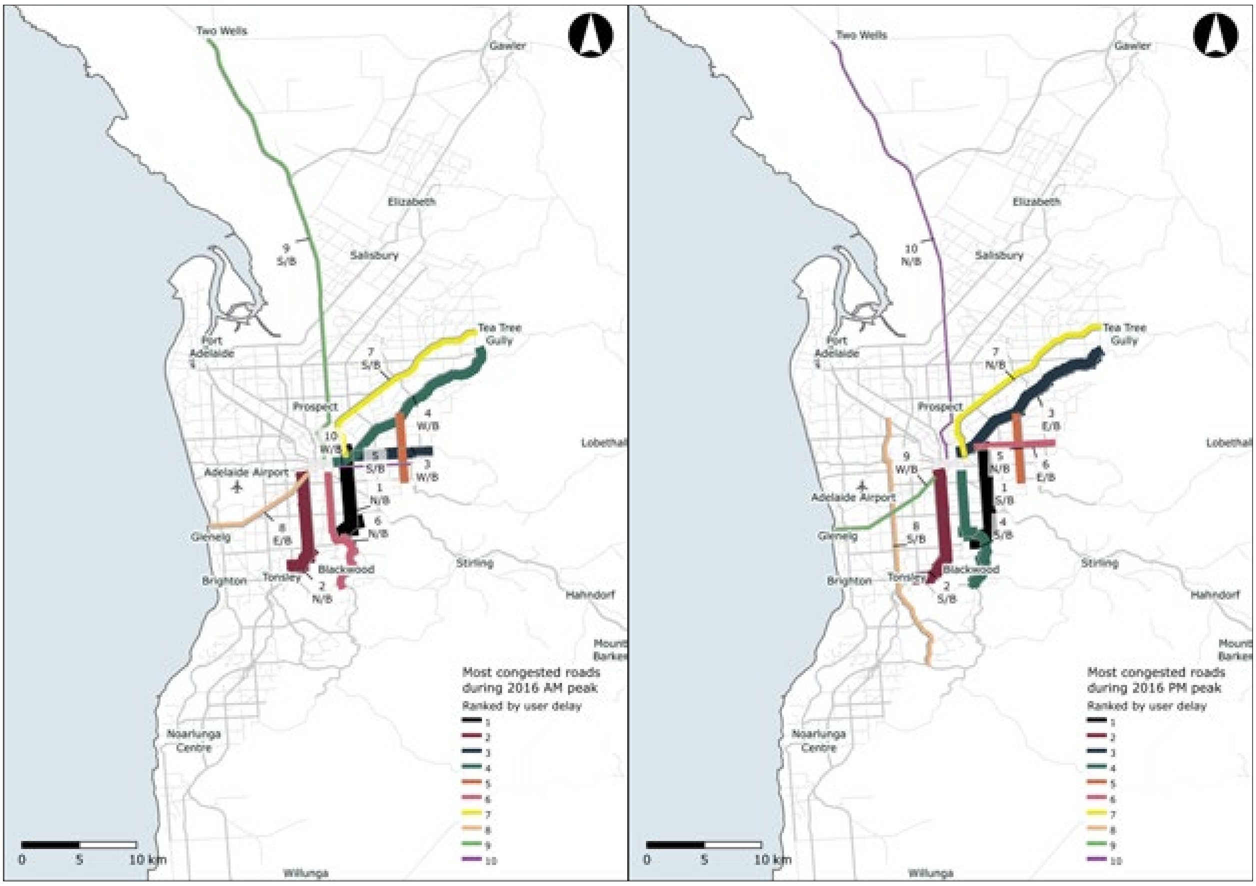
**Table 40:** Adelaide's most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Fullarton Road corridor (N/B) | 8 | 60% | 13 | $3.59 | $15.47 |
| 2. | Goodwood Road corridor (N/B) | 9 | 59% | 15 | $4.14 | $17.85 |
| 3. | Magill Road corridor (W/B) | 5 | 55% | 8 | $2.21 | $9.52 |
| 4. | Lower North East Road / Payneham Road corridor (W/B) | 14 | 55% | 20 | $5.52 | $23.79 |
| 5. | Glynburn Road corridor (S/B) | 5 | 55% | 8 | $2.21 | $9.52 |
| 6. | Belair Road / Unley Road corridor (N/B) | 11 | 54% | 17 | $4.69 | $20.22 |
| 7. | North East Road corridor (S/B) | 16 | 50% | 19 | $5.25 | $22.60 |
| 8. | Anzac Highway corridor (E/B) | 9 | 49% | 11 | $3.04 | $13.09 |
| 9. | Port Wakefield Road / Main North Road corridor (S/B) | 39 | 48% | 28 | $7.73 | $33.31 |
| 10. | Kensington Road corridor (W/B) | 5 | 47% | 6 | $1.66 | $7.14 |
| PM peak | | | | | | |
| 1. | Fullarton Road corridor (S/B) | 8 | 57% | 12 | $3.31 | $14.28 |
| 2. | Goodwood Road corridor (S/B) | 9 | 56% | 14 | $3.87 | $16.66 |
| 3. | Payneham Road / Lower North East Road corridor (E/B) | 14 | 52% | 18 | $4.97 | $21.41 |
| 4. | Unley Road / Belair Road corridor (S/B) | 11 | 51% | 15 | $4.14 | $17.85 |
| 5. | Glynburn Road corridor (N/B) | 5 | 51% | 7 | $1.93 | $8.33 |
| 6. | Magill Road corridor (E/B) | 5 | 50% | 6 | $1.66 | $7.14 |
| 7. | North East Road corridor (N/B) | 16 | 48% | 18 | $4.97 | $21.41 |
| 8. | Marion Road corridor (S/B) | 23 | 47% | 22 | $6.08 | $26.17 |
| 9. | Anzac Highway corridor (W/B) | 9 | 46% | 10 | $2.76 | $11.90 |
| 10. | Main North Road / Port Wakefield Road corridor (N/B) | 39 | 45% | 26 | $7.18 | $30.93 |

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

Source: Veitch Lister Consulting (2019)[184]

**Figure 99:** Adelaide's most congested roads (user experience), 2016 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[185]

## Adelaide's most congested roads in 2016: the cost to the community of total vehicle delays

As a measure of the whole-of-system impacts of congestion, Infrastructure Australia has also identified the most congested road corridors in Greater Adelaide by aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors under this approach are shown in Table 41 and Figure 100, for the AM and PM peak.

In 2016, Adelaide's most congested road corridors carried CBD-bound movements. The worst-performing corridor was the South Road / Main South Road corridor, which serves travel between the city's south and its centre. In 2016 this corridor contributed approximately 2,500 delay hours in both the AM and PM peak, and was congested along most of its length.

The Tapleys Hill Road / Brighton Road / Lonsdale Road / Dyson Road / Commercial Road corridor also contributed significantly to total delays in 2016. This corridor runs north-south along the coast and contributed 1,400 delay hours in both peak periods. Delays on this road highlight how demand for north-south access is the primary driver of congestion on Adelaide's road network.

## Adelaide's public transport system in 2016

Use of public transport in Adelaide has grown in recent years, partly due to progressive improvements to service levels and frequencies, and also as a result of population growth. Adelaide's public transport is mostly radial to the CBD. Most train, bus and tram routes provide access to central areas either directly, or through feeder services to train stations. Consequently, peak periods are dominated by city-centric movements.

Adelaide's rail network serves the far north and south of the city. Adelaide's most crowded rail lines in the AM peak are the northern and southern lines from Gawler and Seaford to the CBD, respectively. As they reach the city, trains on these lines exceed or have reached their seated capacity but, on average, are still under maximum or crush capacity (Figure 101).

Buses perform the majority of Adelaide's public transport task and carry the greatest number of passenger kilometres, passenger hours and boardings. Adelaide's bus network includes high-capacity trunk routes, feeder services and local services. Adelaide's most crowded bus corridors in 2016 are on the south-eastern corridor, particularly beyond Stirling where high volume/capacity ratios may reflect low levels of service provision and limited alternative public transport options. In addition, some routes in the north-east also experience crowding beyond seated capacity (Figure 102).

Adelaide currently has a single tram corridor connecting Glenelg in the city's south west to the CBD and the Entertainment Centre at Hindmarsh. This corridor experiences low average crowding even in peak periods (Figure 103).

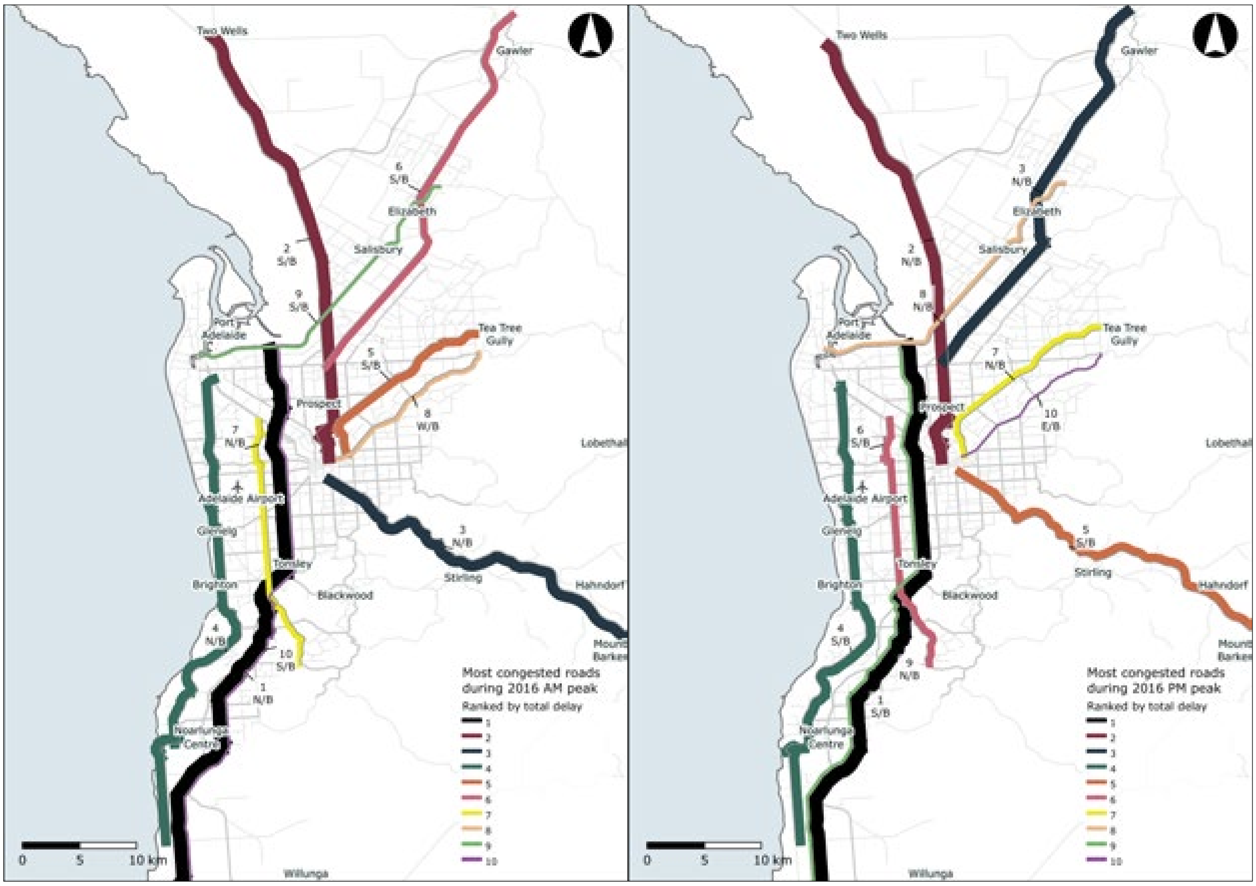
**Table 41:** Adelaide's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Main South Road / South Road corridor | N/B | 2,300 | $44,000 |
| 2. | Port Wakefield Road / Main North Road corridor | S/B | 2,200 | $44,000 |
| 3. | Princes Highway (M1) / Glen Osmond Road corridor | N/B | 1,400 | $26,000 |
| 4. | Commercial Road / Dyson Road / Lonsdale Road / Brighton Road / Tapleys Hill Road corridor | N/B | 1,400 | $27,000 |
| 5. | North East Road corridor | S/B | 1,300 | $24,000 |
| 6. | Outer Main North Road corridor | S/B | 1,300 | $25,000 |
| 7. | Marion Road corridor | N/B | 1,300 | $24,000 |
| 8. | Lower North East Road / Payneham Road corridor | W/B | 1,100 | $20,000 |
| 9. | Phillip Highway / Salisbury Highway corridor | S/B | 1,100 | $22,000 |
| 10. | South Road / Main South Road corridor | S/B | 1,000 | $20,000 |
| PM peak | | | | |
| 1. | South Road / Main South Road corridor | S/B | 2,500 | $47,000 |
| 2. | Main North Road / Port Wakefield Road corridor | N/B | 2,200 | $43,000 |
| 3. | Outer Main North Road corridor | N/B | 1,500 | $28,000 |
| 4. | Tapleys Hill Road / Brighton Road / Lonsdale Road / Dyson Road / Commercial Road corridor | S/B | 1,400 | $26,000 |
| 5. | Glen Osmond Road / Princes Highway (M1) corridor | S/B | 1,300 | $24,000 |
| 6. | Marion Road corridor | S/B | 1,300 | $24,000 |
| 7. | North East Road corridor | N/B | 1,300 | $23,000 |
| 8. | Salisbury Highway / Phillip Highway corridor | N/B | 1,100 | $21,000 |
| 9. | Main South Road / South Road corridor | N/B | 1,100 | $21,000 |
| 10. | Payneham Road / Lower North East Road corridor | E/B | 1,100 | $20,000 |

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

Source: Veitch Lister Consulting (2019)[186]

**Figure 100:** Adelaide's most congested roads (total vehicle delays), 2016 AM (left) and PM (right) peak periods

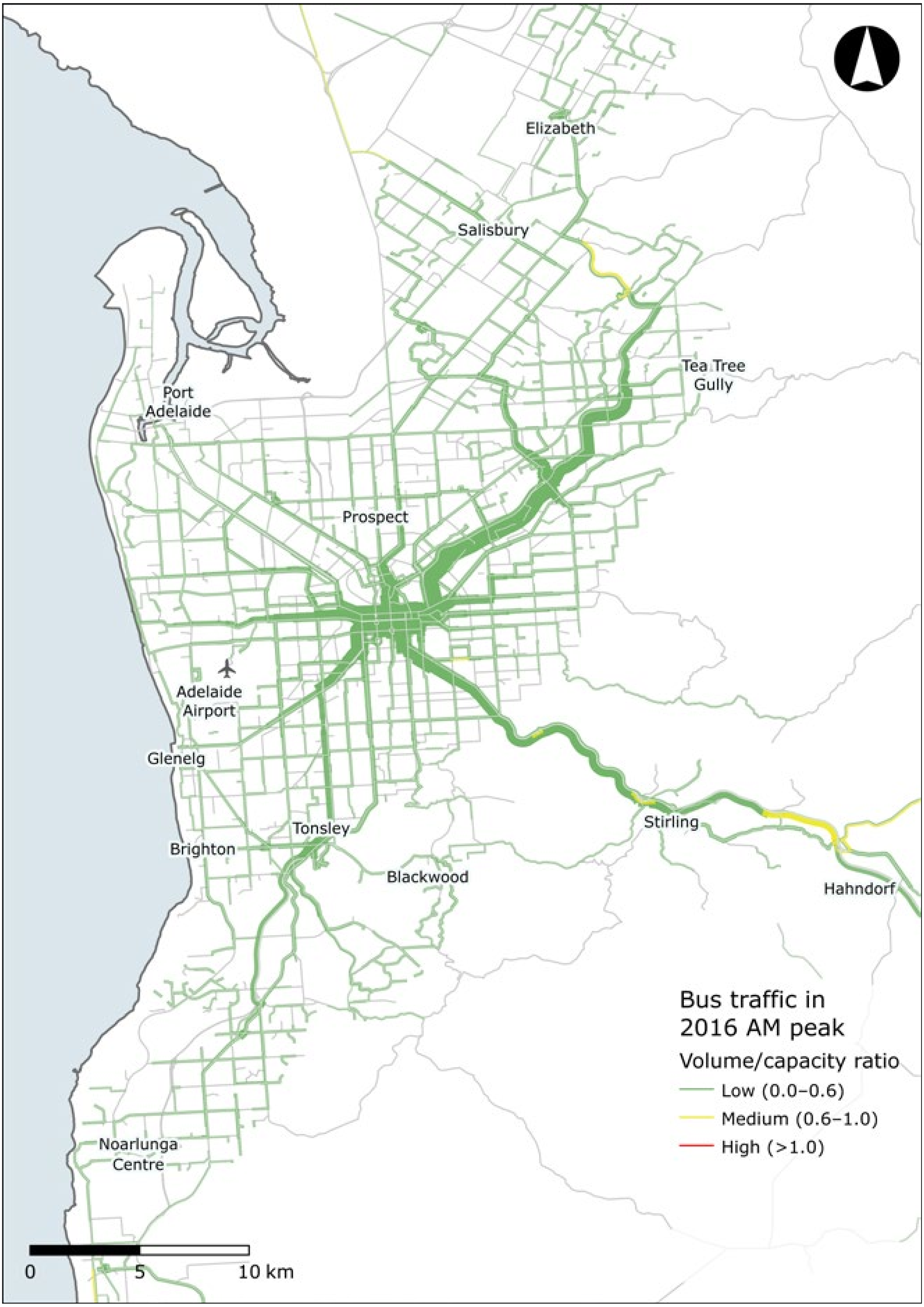



Source: Veitch Lister Consulting (2019)[187]

**Figure 101:** Adelaide weekday train passenger volume / capacity ratio, 2016 AM peak

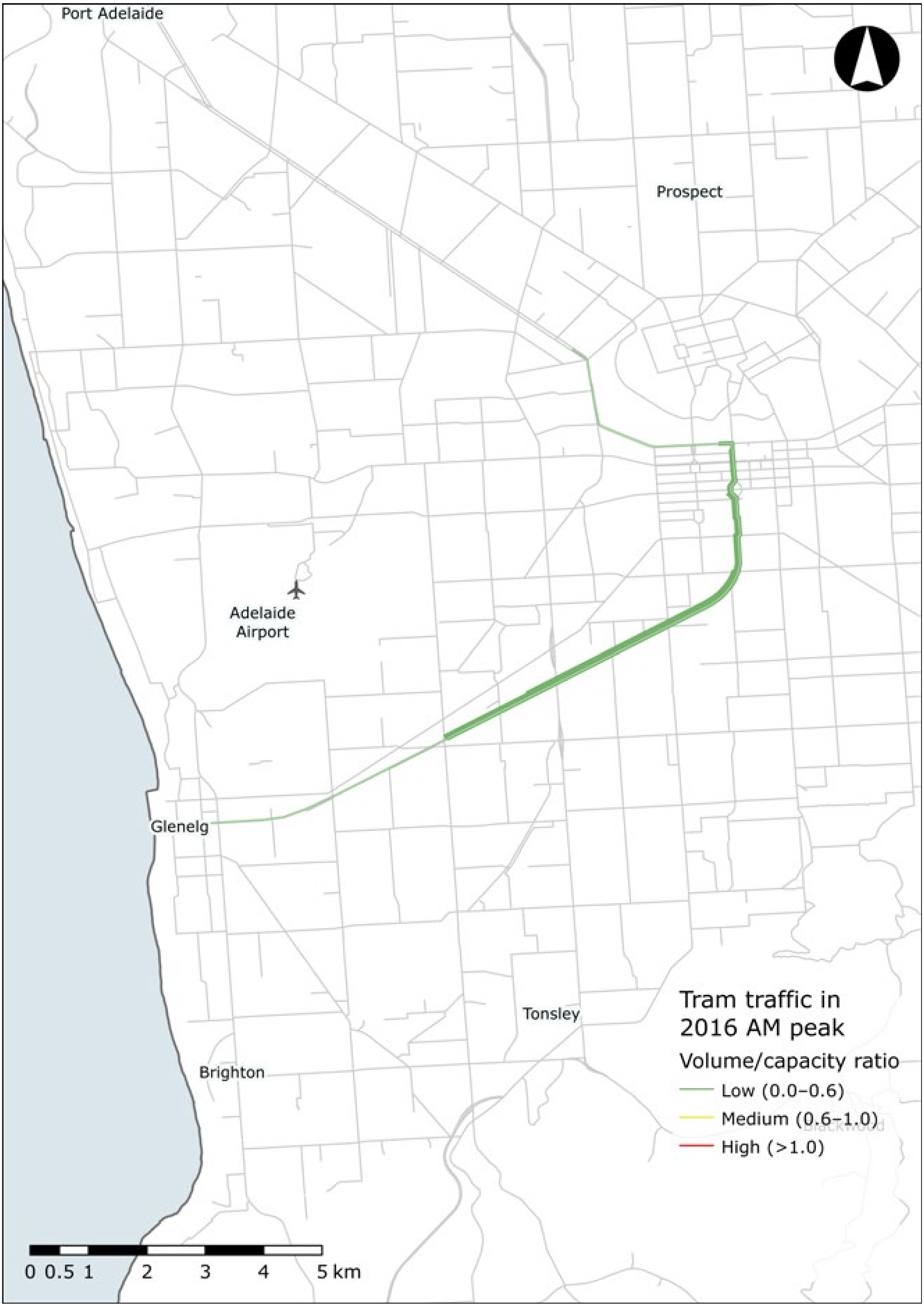

Source: Veitch Lister Consulting (2019)[188]

**Figure 102:** Adelaide weekday bus passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[189]

**Figure 103:** Adelaide weekday tram passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[190]

## Findings

- Consistent with its coastal urban form Adelaide's north-south road corridors are the heaviest-used and most congested corridors in the city. Congested conditions extend over 20km to the north and over 15km to the south.
- With the high concentration of Adelaide's employment in the CBD, the worst congestion is seen in the inner city.
- Small sections of the arterial road network see bi-directional congestion in the AM peak. This is more severe in the PM peak, especially on South Road and other arterial routes to the north-west of the city centre.
- Most of Adelaide's bus network currently operates without capacity issues. The O-Bahn corridor servicing the inner to middle north-eastern suburbs carries a large volume of passengers in conditions of low crowding. Some lower-volume bus routes serving Adelaide's outer suburbs are seeing low levels of crowding, as a function of the limited service frequencies typical of outer urban areas.
- Gawler train line services used by passengers commuting from the Elizabeth and Salisbury corridor to the north of Adelaide are reaching seated capacity as they approach the CBD.

## 9.4 Even with programmed investment, Adelaide's transport networks are forecast to become more congested

### Snapshot of Adelaide's transport networks in 2031

Looking out to 2031, Adelaide's roads and public transport will have to handle a significantly larger transport task. The city's population is predicted to grow from 1.3 million to 1.6 million, an 18% increase. Population distribution is expected to remain relatively similar to today, with higher densities in the city centre and lower relative densities on the urban fringe.

Demand for transport in Adelaide is predicted to increase by a rate slightly higher than projected population growth by 2031. Trips on Adelaide's transport network will increase by 24%, to over 4 million daily trips. This comparatively higher rate of trip growth results from a projected decrease in the size of the average household.

Trips by public transport will grow slightly faster than by car, which suggests a shift towards public transport in the city as Adelaide's population grows. Trips on public transport will increase by 31% and will increase by car by 24%.

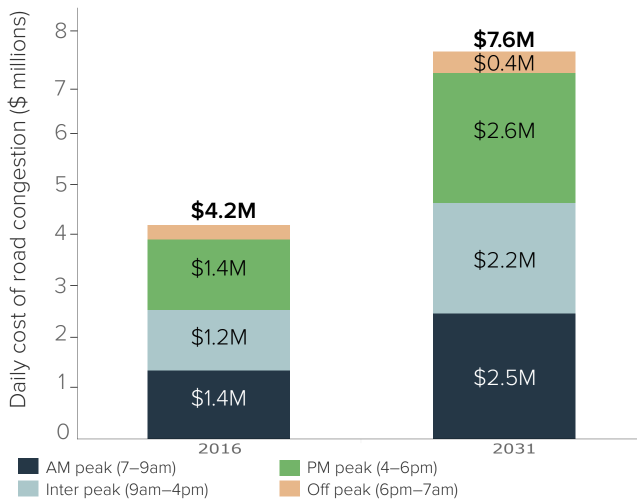
Adelaide's road congestion and public transport crowding are forecast to grow considerably. Our modelling indicates the annualised cost of road congestion and public transport crowding will be approximately $2.6 billion in 2031. This will result in more time spent stuck in traffic and standing on delayed public transport services.

The daily cost of road congestion on Adelaide's roads is expected to almost double, from about $4.2 million to $7.6 million in 2031 (Figure 104).

The modelled cost of public transport crowding is significantly less than for road congestion in Adelaide, reflecting the high reliance on private vehicles. While the cost of public transport crowding in 2016 is negligible, it increases to $4.4 million per year by 2031. This comparatively small cost reflects the residual capacity available in Adelaide's public transport network, and the city's smaller population.

These forecast outcomes account for projects that were either under construction, under procurement or had funding for construction committed from all relevant governments at the time of modelling for the *Australian Infrastructure Audit*[191]

**Figure 104:** Adelaide's average weekday cost of road congestion, 2016 and 2031




Source: Veitch Lister Consulting (2019)[192]

Major projects included in Adelaide's 2031 forecast comprise:

- Northern Connector Freeway
- Darlington Upgrade Project
- Flinders Link
- Port Dock Railway Line.

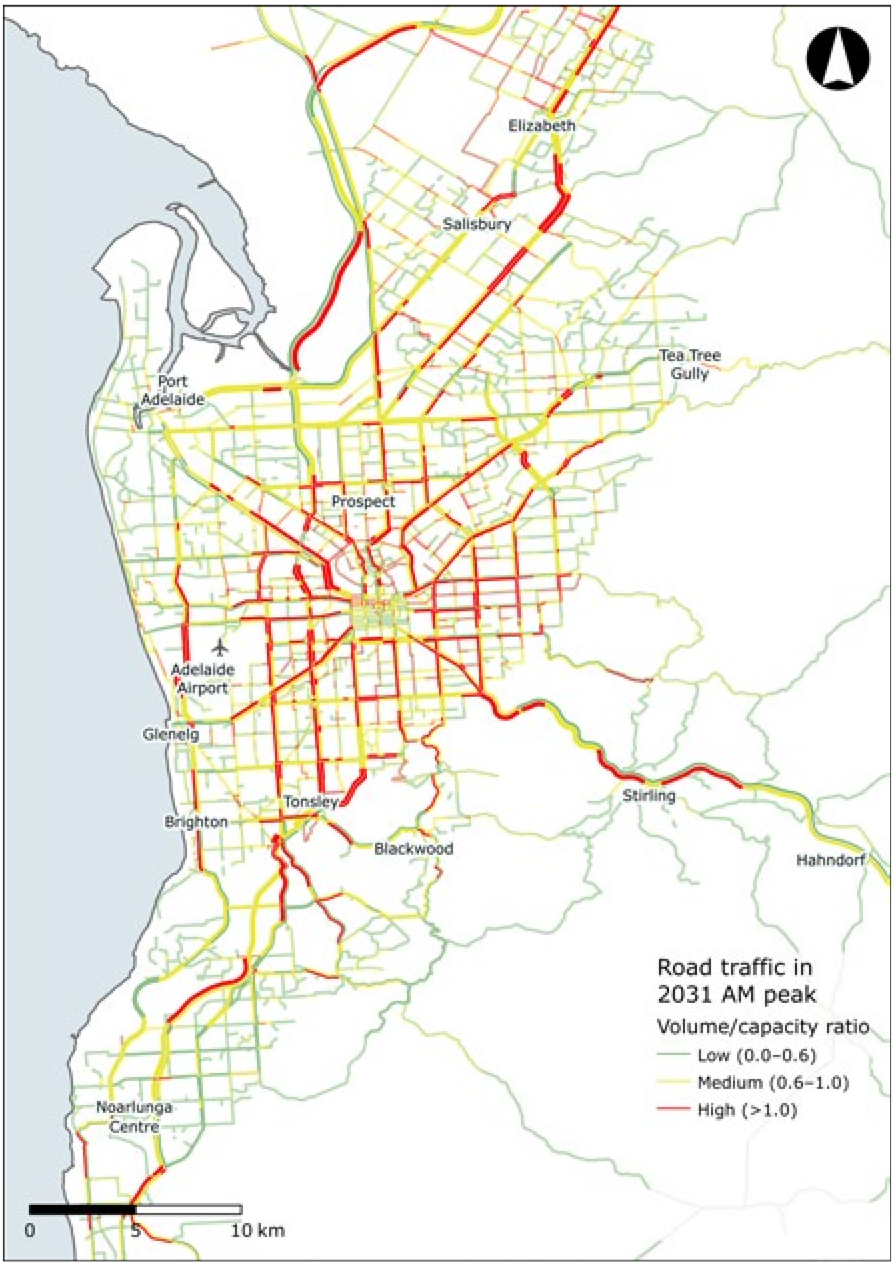
Following the completion of the modelling for this report, the South Australian Government cancelled the Port Dock Railway Line. The modelling and the complementary analysis within this paper therefore underestimates congestion and crowding on parallel roads or bus services.

## Adelaide's most congested roads in 2031: what the driver will experience

Despite the mode shift from cars to public transport, congestion on Adelaide's roads will continue to grow substantially. Adelaide's most congested roads in 2031 are similar to those in 2016 (Figure 105), while the proportion of travel time attributable to congestion is forecast to generally increase from 50–60% in 2016 to 60–70% in 2031.

The worst performers in both 2016 and 2031 are the Fullarton Road, Goodwood Road, Glynburn Road, Magill Road and Lower North East Road / Payneham Road corridors, while some of their relative standings interchange between the two modelled years. Based on estimating the percentage of journey time that will be spent in congestion on Adelaide's road network in 2031, Table 42 and Figure 106 show the ten most congested corridors in the AM and PM peak periods, respectively.

**Figure 105:** Adelaide weekday traffic volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[193]

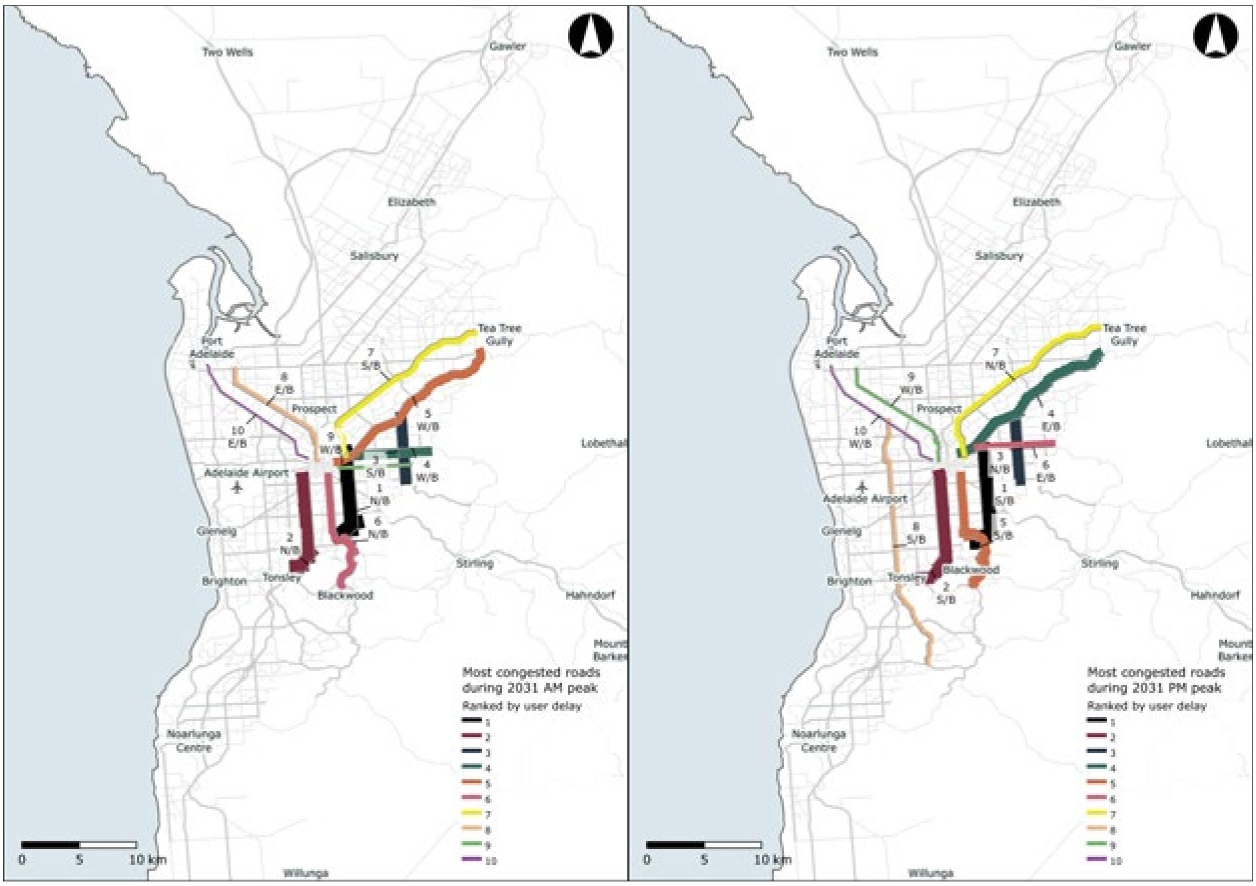
**Table 42:** Adelaide's most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Fullarton Road corridor (N/B) | 8 | 67% | 18 | $4.97 | $21.41 |
| 2. | Goodwood Road corridor (N/B) | 9 | 66% | 20 | $5.52 | $23.79 |
| 3. | Glynburn Road corridor (S/B) | 5 | 66% | 12 | $3.31 | $14.28 |
| 4. | Magill Road corridor (W/B) | 5 | 66% | 12 | $3.31 | $14.28 |
| 5. | Lower North East Road / Payneham Road corridor (W/B) | 14 | 64% | 30 | $8.29 | $35.69 |
| 6. | Belair Road / Unley Road corridor (N/B) | 11 | 63% | 24 | $6.63 | $28.55 |
| 7. | North East Road corridor (S/B) | 16 | 60% | 29 | $8.01 | $34.50 |
| 8. | Torrens Road corridor (E/B) | 11 | 59% | 20 | $5.52 | $23.79 |
| 9. | Kensington Road corridor (W/B) | 5 | 59% | 9 | $2.49 | $10.71 |
| 10. | Port Road corridor (E/B) | 11 | 57% | 19 | $5.25 | $22.60 |
| PM peak | | | | | | |
| 1. | Fullarton Road corridor (S/B) | 8 | 65% | 17 | $4.69 | $20.22 |
| 2. | Goodwood Road corridor (S/B) | 9 | 65% | 20 | $5.52 | $23.79 |
| 3. | Glynburn Road corridor (N/B) | 5 | 63% | 11 | $3.04 | $13.09 |
| 4. | Payneham Road / Lower North East Road corridor (E/B) | 14 | 62% | 27 | $7.46 | $32.12 |
| 5. | Unley Road / Belair Road corridor (S/B) | 11 | 61% | 22 | $6.08 | $26.17 |
| 6. | Magill Road corridor (E/B) | 5 | 60% | 10 | $2.76 | $11.90 |
| 7. | North East Road corridor (N/B) | 16 | 58% | 26 | $7.18 | $30.93 |
| 8. | Marion Road corridor (S/B) | 23 | 57% | 33 | $9.11 | $39.26 |
| 9. | Torrens Road corridor (W/B) | 11 | 56% | 18 | $4.97 | $21.41 |
| 10. | Port Road corridor (W/B) | 11 | 56% | 17 | $4.69 | $20.22 |

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

Source: Veitch Lister Consulting (2019)[194]

**Figure 106:** Adelaide's most congested roads (user experience), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[195]

Between 2016 and 2031, vehicle congestion in Adelaide is expected to worsen and spread. The heaviest congestion is expected to occur within about 5km of the CBD. Adelaide's motorists can expect longer traffic delays and to spend a larger share of their journey time in congestion. Users of Adelaide's most delayed roads can expect to spend between 55% and 70% of their trip duration in dense traffic during peaks. Despite road upgrades to parts of Adelaide's north-south corridor stretching from Noarlunga to Gawler, this will remain one of the city's most congested routes, compromising its role in facilitating north-south travel.

Efforts to strengthen Adelaide's primary road spine will include improvements such as the new Northern Connector and the Darlington Upgrade near Bellevue Heights. These upgrades will provide additional capacity for commuters entering the city centre from northern and southern suburbs, and are expected to provide some congestion relief. While the Northern Connector is forecast to redirect traffic from the Port Wakefield Road and Salisbury Highway corridor, by 2031 these corridors are expected to still be significantly congested during peak periods.

Population growth to the city's south is expected to increase traffic substantially on northbound roads during the AM peak. By 2031 key access routes are expected to be operating over capacity. The Princes Highway / South Eastern Freeway corridor, as well as the arterial roads that connect to it, is expected to be most affected by northbound traffic congestion during this period.

Generally, it is expected that by 2031 many of Adelaide's roads will be operating over their design capacity, causing delays to bus passengers, motorists and freight operators. Many of the worst-performing corridors in 2031 are marked as National Key Freight Routes by the Australian Government.[196]

## Adelaide's most congested roads in 2031: the forecast cost to the community of total vehicle delays

Modelling has forecast the most congested road corridors in Greater Adelaide for 2031, as for 2016, based on aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors in the AM and PM peak periods under this approach are shown in Table 43 and Figure 107.

Planned responses forecast substantial traffic growth on Adelaide's road network and see additional motorway-standard capacity provided to service the city's growing northern suburbs. The Northern Connector is predicted to attract some traffic from the Port Wakefield Road and Salisbury Highway routes. Sections of the North-South Corridor, which includes South Road and Main South Road, will also be upgraded to motorway standard, relieving traffic on remaining surface road sections, such as the section crossing Port Road.

In the context of Adelaide's well-established grid street layout, these projects will provide an opportunity for urban domain improvements on surface roads. As with other capital cities, realising such opportunities in Adelaide will require 'link and place' road planning and operation principles.

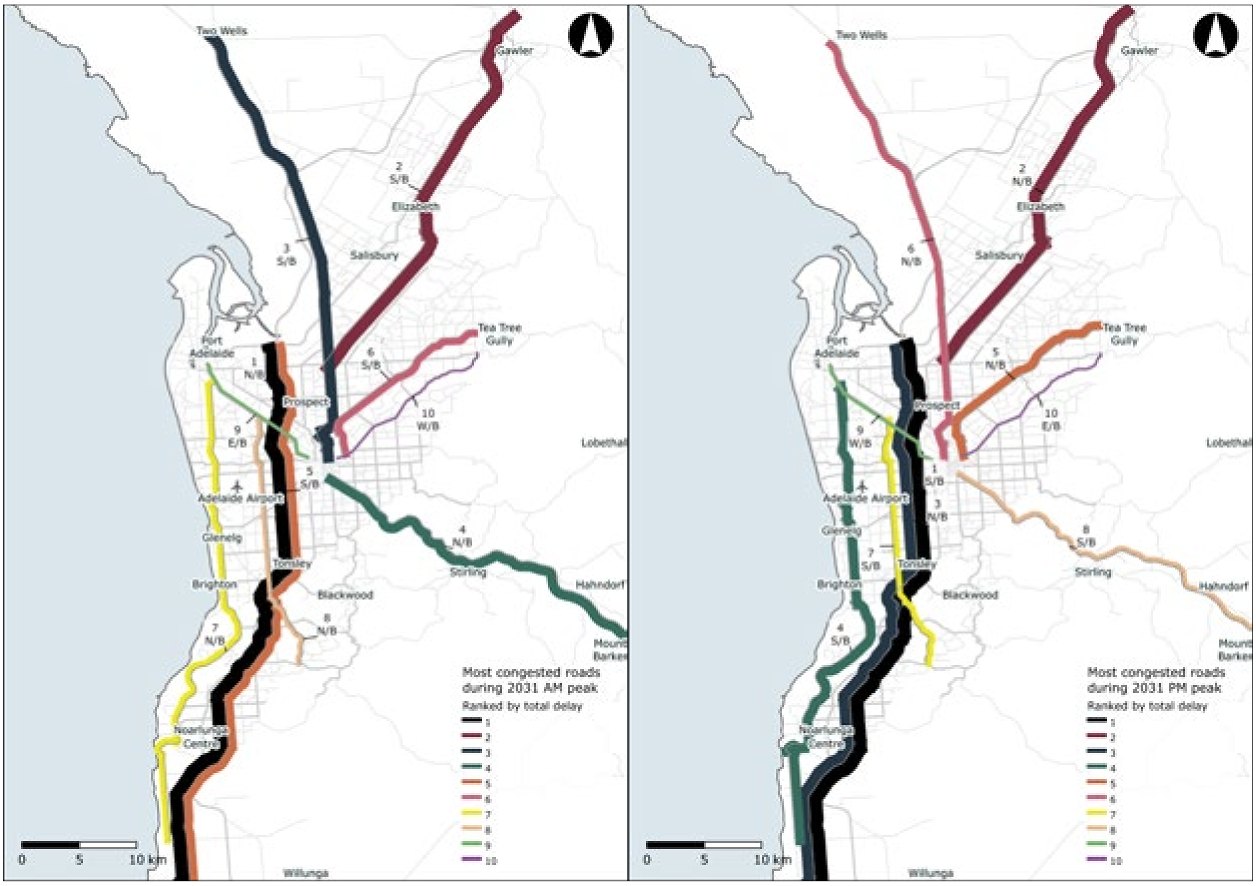
**Table 43:** Adelaide's most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Main South Road / South Road corridor | N/B | 3,600 | $69,000 |
| 2. | Outer Main North Road corridor | S/B | 2,800 | $52,000 |
| 3. | Port Wakefield Road / Main North Road corridor | S/B | 2,400 | $46,000 |
| 4. | Princes Highway (M1) / Glen Osmond Road corridor | N/B | 2,300 | $42,000 |
| 5. | South Road / Main South Road corridor | S/B | 2,300 | $45,000 |
| 6. | North East Road corridor | S/B | 2,200 | $41,000 |
| 7. | Commercial Road / Dyson Road / Lonsdale Road / Brighton Road / Tapleys Hill Road corridor | N/B | 2,100 | $40,000 |
| 8. | Marion Road corridor | N/B | 1,900 | $36,000 |
| 9. | Port Road corridor | E/B | 1,800 | $35,000 |
| 10. | Lower North East Road / Payneham Road corridor | W/B | 1,800 | $33,000 |
| PM peak | | | | |
| 1. | South Road / Main South Road corridor | S/B | 3,800 | $71,000 |
| 2. | Outer Main North Road corridor | N/B | 2,800 | $51,000 |
| 3. | Main South Road / South Road corridor | N/B | 2,600 | $50,000 |
| 4. | Tapleys Hill Road / Brighton Road / Lonsdale Road / Dyson Road / Commercial Road corridor | S/B | 2,400 | $44,000 |
| 5. | North East Road corridor | N/B | 2,100 | $38,000 |
| 6. | Main North Road / Port Wakefield Road corridor | N/B | 2,100 | $40,000 |
| 7. | Marion Road corridor | S/B | 2,100 | $39,000 |
| 8. | Glen Osmond Road / Princes Highway (M1) corridor | S/B | 2,100 | $39,000 |
| 9. | Port Road corridor | W/B | 1,800 | $34,000 |
| 10. | Payneham Road / Lower North East Road corridor | E/B | 1,700 | $31,000 |

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

Source: Veitch Lister Consulting (2019)[197]

**Figure 107:** Adelaide's most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak periods




Source: Veitch Lister Consulting (2019)[198]

## 'Link and place': balancing the dual roles of city streets

A major new direction in integrated road network and land-use planning involves the application of a 'link and place' (also called 'movement and place') framework. This is used to categorise roads according to their relative importance both as corridors, or links in a network, for the movement of people, goods and services, and as places where people shop, live, work, socialise, walk and so on.

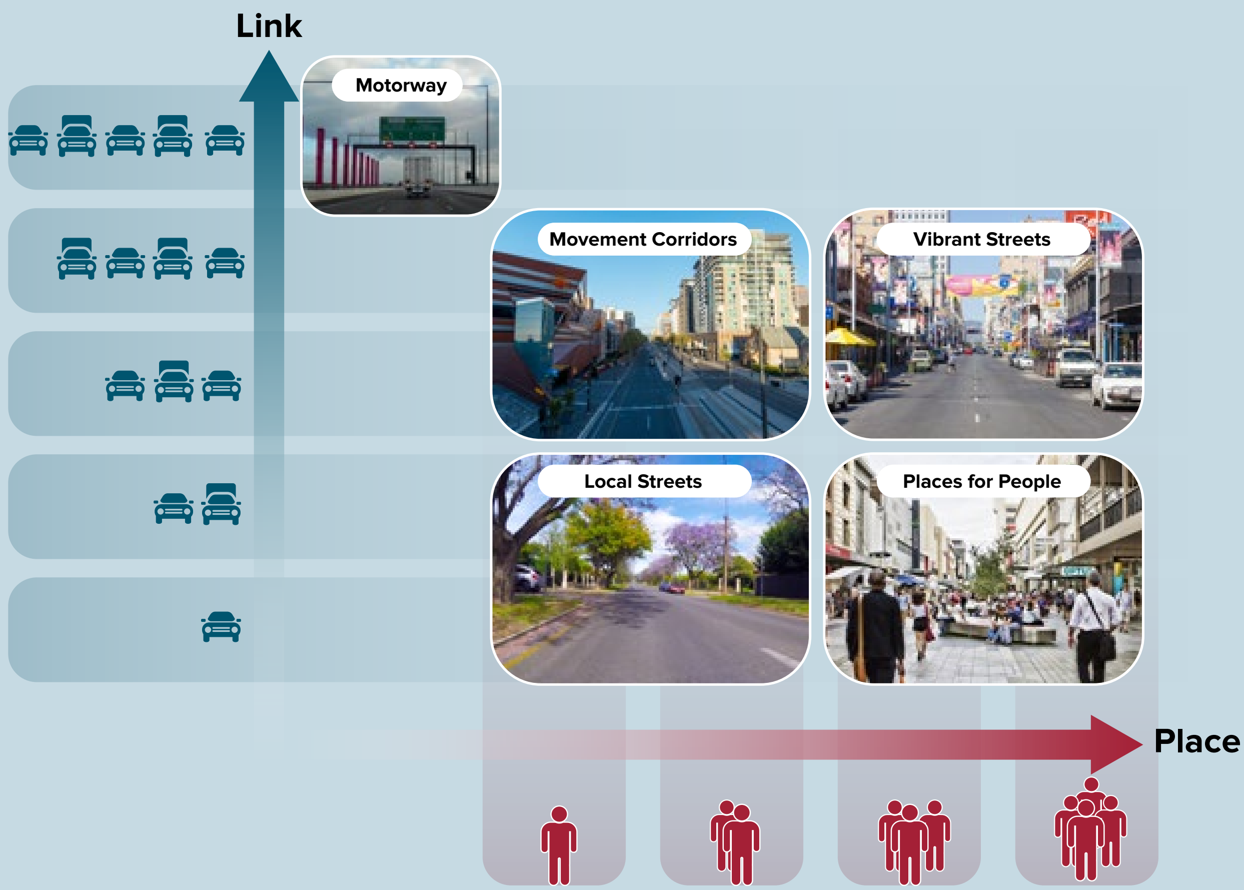
As one of the Australian cities noted for the connected grid layout of its 19th century establishment, Adelaide is well placed to understand the need for and to use such an approach.

Compared with other city road systems that are constrained by ridge-and-valley topography or the need to cross waterways, grid street networks can have the advantage of offering multiple parallel movement corridors. However, secondary network links will lose their amenity as places to live and play if the movement of motor vehicles along those place-rich corridors is not carefully managed.

The South Australian Government has recognised the importance of 'link and place' in planning for Adelaide's growth.[199] Establishing a balance between these two functions is essential to designing and managing streets that otherwise could be overwhelmed by population growth-generated traffic.

An array of tools (Figure 108) is now available to guide future urban planning and transport decisions for large Australian cities, such as Adelaide, where increased traffic flows need to be managed to protect the amenity of the places that motor vehicles are trying to reach. 'Link and place' solutions developed using these tools will be as diverse as a city's streets. In the long term, for example, the upgrade of a motorway or other major movement corridor could be balanced against the traffic calming of a parallel surface street. This could create both a link which moves large numbers of people on foot or by bike, and a high-amenity place that supports the expansion of local business.

**Figure 108:** 'Link and place' framework




"Signage at the interchange of the M2 North South Motorway/A9 Port River Expressway/A13 Salisbury Highway. Adelaide, South Australia" by Alexczarn is licensed under CC BY-SA 4.0.

Source: Based on Austroads (2016)[200]

## Adelaide's public transport system in 2031

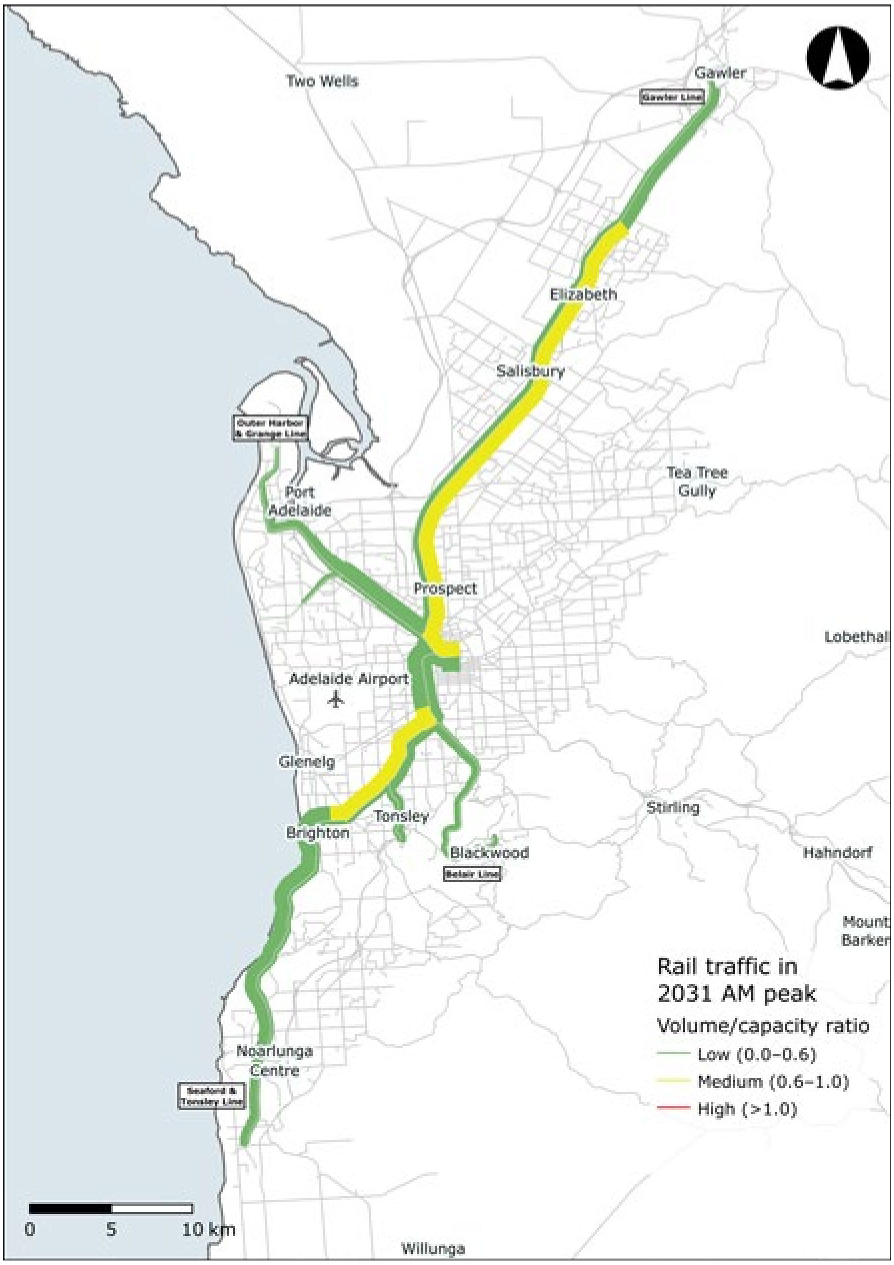
By 2031 car travel is predicted to remain the dominant form of travel in Adelaide, although the use of public transport will significantly increase. Public transport use is forecast to grow by 31% between 2016 and 2031, influenced by the increased time and monetary costs of car travel. As a result, crowding on Adelaide's public transport network is expected to increase.

For Adelaide's rail network, usage is forecast to increase particularly on lines linking the outer suburbs to the north and south with the city centre, driven by population growth on the urban fringe. The majority of the Gawler Line as well as parts of the Seaford and Tonsley lines will be operating well above seated capacity, but below crush capacity, in the AM peak. The worst levels of crowding expected on the rail network are forecast to the south of Salisbury. Other parts of the train network will still offer spare capacity in 2031 (Figure 109).

Adelaide's bus routes are projected to become incrementally more crowded by 2031. Some routes are expected to become busy in growth areas  between Elizabeth, Tea Tree Gully and Salisbury in the north. Routes feeding the O-Bahn are also expected to experience moderate levels of crowding (Figure 110).

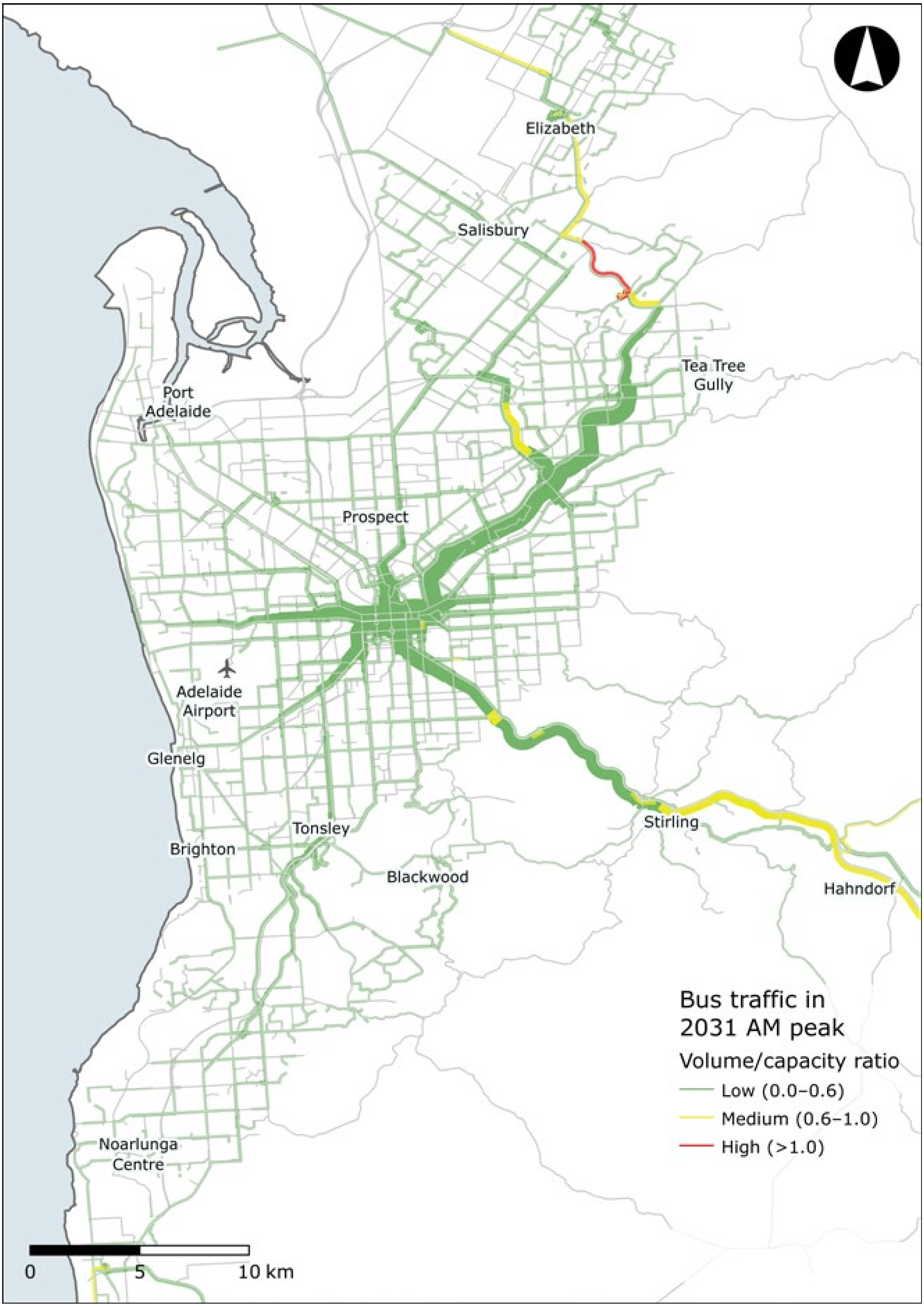
Adelaide's Glenelg tram currently experiences low levels of crowding. Light crowding is forecast to be the case to 2031, for both peak periods (Figure 111), which suggests that there is  opportunity for passenger growth. As the tram currently serves both the dense CBD and areas with high levels of recreational activity, the service could be integrated into active travel networks to increase passenger use.

**Figure 109:** Adelaide weekday train passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[201]

**Figure 110:** Adelaide weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[202]

**Figure 111:** Adelaide weekday tram passenger volume / capacity ratio, 2031 AM peak


Source: Veitch Lister Consulting (2019)[203]

## Findings

- The 2019 Audit forecasts that the annualised cost of road congestion for Greater Adelaide will grow from approximately $1.4 billion in 2016 to $2.6 billion in 2031. This is 31% lower than the 2031 forecast cost of road congestion in the 2015 Audit.
- North-south travel is the movement for which there is expected to be the strongest demand. This demand will be relatively evenly distributed across Adelaide’s north-south arterial network.
- Traffic volumes on the North-South Corridor are expected to grow particularly strongly. The new Northern Connector feeding the North-South Motorway section of this corridor provides additional capacity to Adelaide’s growing northern suburbs and will attract some traffic from the Port Wakefield Road and Salisbury Highway corridor.
- Other sections of the North-South Corridor (including South Road and Main South Road), when upgraded to motorway standard, will similarly relieve traffic on remaining surface road sections.
- These improvements, along with the Darlington Upgrade near Bellevue Heights, strengthen the North-South Corridor as Adelaide’s primary road spine. The corridor will also experience the effects of population growth to the city’s south, evident in the substantial increase in traffic forecast for the Southern Expressway.
- Strong traffic growth is forecast on the arterial roads serving Adelaide’s emerging employment hubs in Elizabeth and areas south of Bellevue Heights.
- In terms of demand from the south-east, traffic on the South Eastern Freeway is predicted to increase, reflecting both projected population growth in the Adelaide Hills as well as the fact that it is the only major highway providing passage through the region.
- Although the highest concentration of heavily utilised roads is around the CBD, the Tapleys Hill corridor - which runs north-south along the coast - is also forecast to carry substantial additional traffic.
- Because CBD-bound travel is better served by public transport, it is north-south travel that is primarily driving an increase in demand on Adelaide’s roads. As such, some of the demand on radial routes such as Port Road, North East Road and Anzac Highway is driven by cross-city travel.
- Congestion of Adelaide’s road network will not only affect commuting drivers and bus passengers, but also disrupt the city’s function by delaying commercial vehicles. Adelaide’s north-south train lines will be operating above their seated capacity for longer sections close to the CBD during peak periods. As will the Gawler Line, the Seaford and Tonsley Line will see this effect on the section north-east of Brighton.
- Many bus routes, particularly in outer growth areas, will become significantly more crowded by 2031. The most severely affected routes are forecast to be services connecting Salisbury to the high-patronage north-eastern bus corridor that feeds the O-Bahn.
- As of today, Adelaide’s single suburban tram route is forecast to still offer significant unused capacity in 2031.

## 9.5 Transport decisions impact access to jobs and services

### Hospital access in Adelaide – by car and public transport, in 2031

Greater Adelaide's access to critical healthcare is measured by the travel time to their nearest public hospital, or hospital with an emergency department, by car versus public transport (Figure 112).

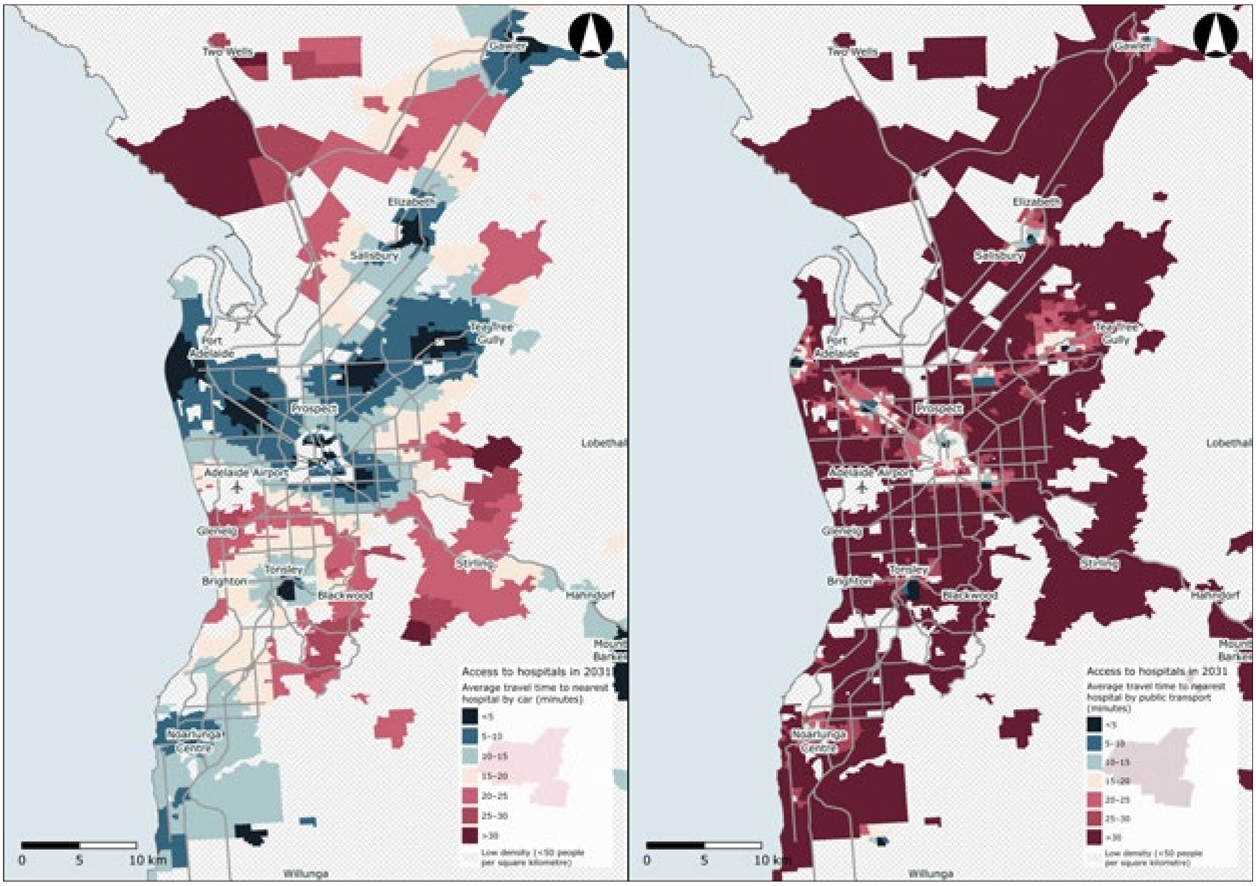
Access to public hospitals in Adelaide is substantially quicker by car than by public transport. For residents of the inner city, travel times are relatively short by both transport choices. However, travel times become more extended for residents of outer areas such as Gawler-Two Wells and Playford. On average, access to a public hospital in Greater Adelaide in 2031 is forecast to take 13 minutes by car, and 47 minutes by public transport, both slightly increased from 2016. For people living in Adelaide City (and along trunk public transport corridors further out) these travel times are significantly reduced, to five minutes by car and 21 minutes by public transport, in 2031.

### Access to childcare and schools in Adelaide – by car and public transport, in 2031

With access to a car, the average resident of the Greater Adelaide region can reach childcare services, public primary schools and public secondary schools within a six-minute trip in 2016. This is expected to extend to a seven-minute trip by 2031 (Figure 113, Figure 114 and Figure 115). For residents without access to a car, travel times are significantly longer by public transport. Travel times generally average just under 30 minutes for childcare and public primary school services, and over 30 minutes for public secondary schools.

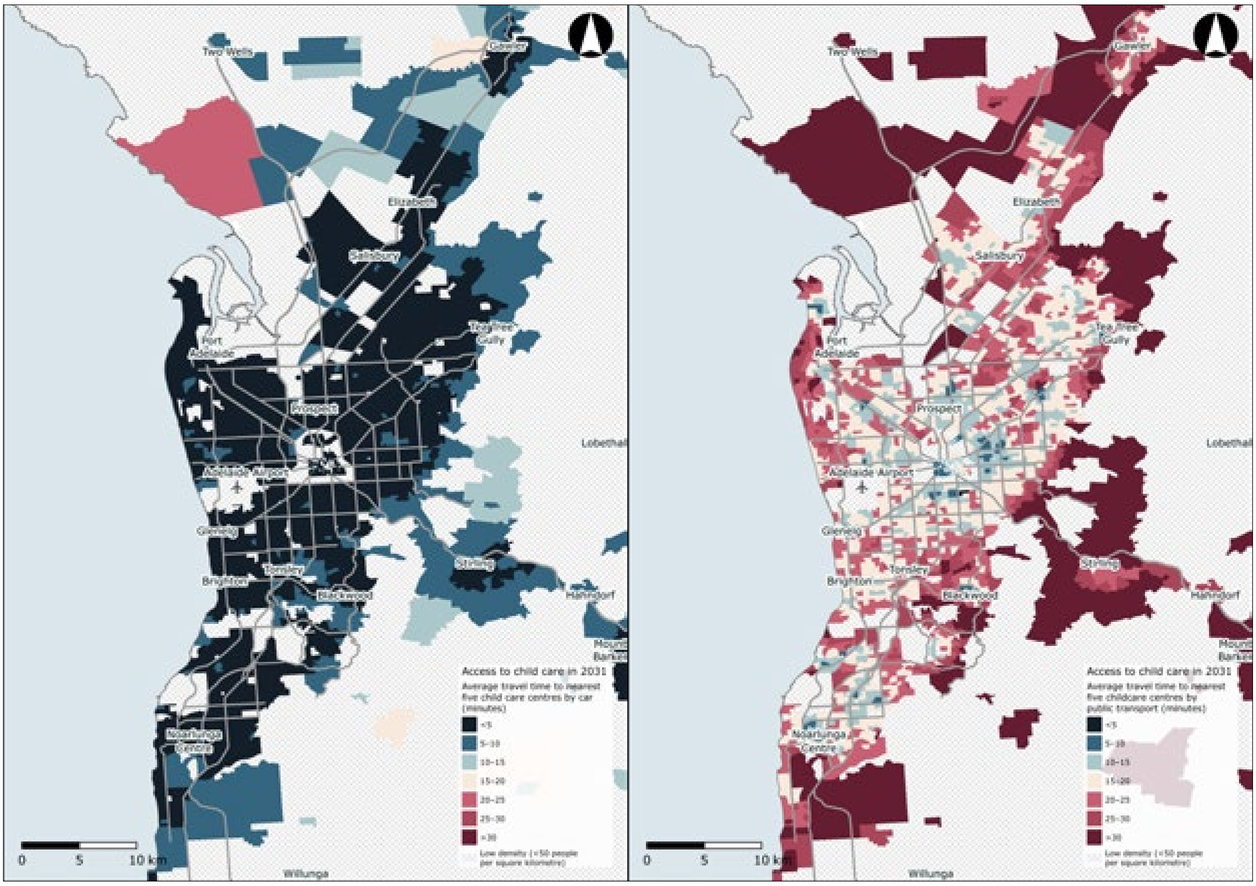
Travel times by car are expected to worsen between 2016 and 2031 due to increased traffic congestion. By public transport, travel times are expected to reduce. While slightly reduced by 2031, travel times by public transport to these social infrastructure services will remain comparatively much less attractive for most of Greater Adelaide. This is one result of the radial nature of Adelaide's public transport system. It is effective in carrying people from outer areas to the centre, but less effective at servicing local travel.

**Figure 112:** Greater Adelaide average time to nearest hospital by car (left) and public transport (right), 2031 AM peak



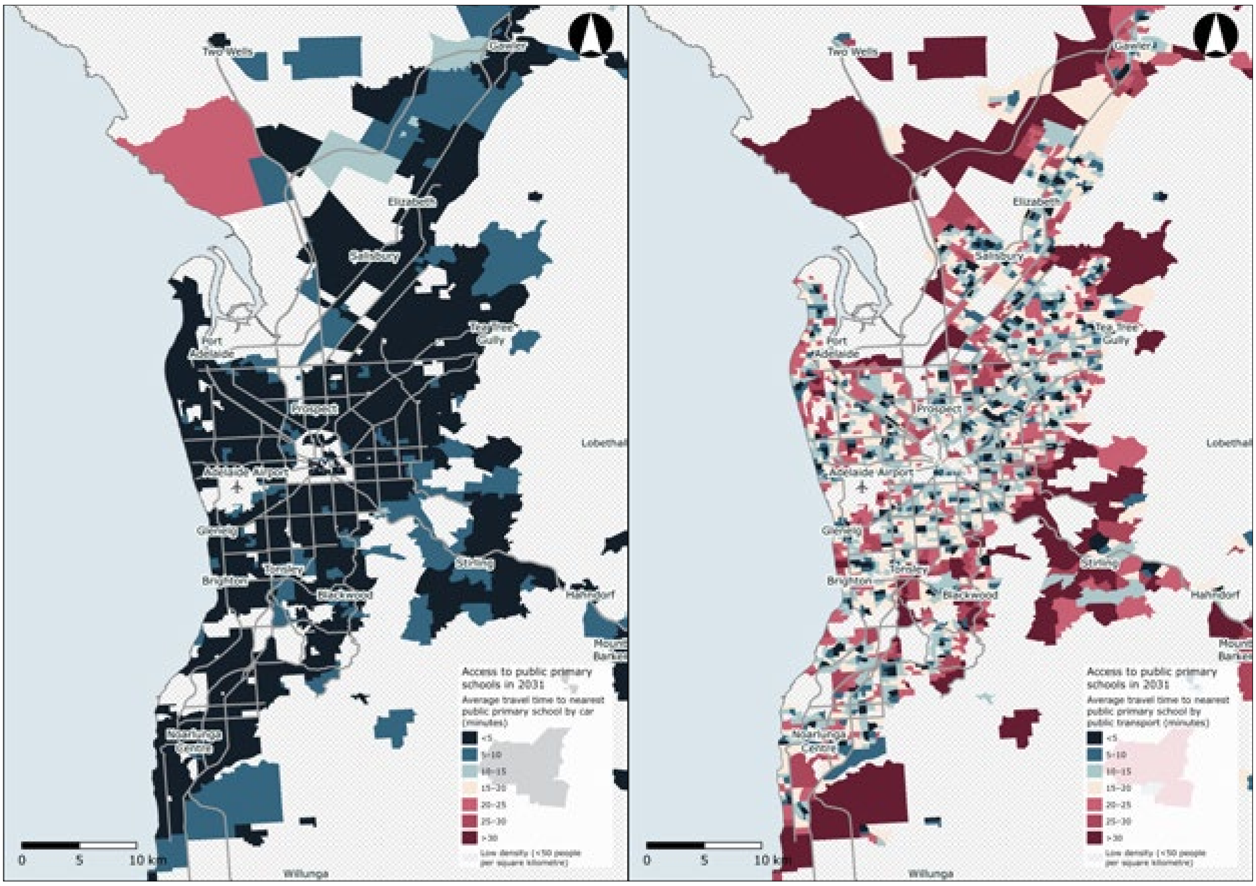

Source: Veitch Lister Consulting (2019)[204]

**Figure 113:** Greater Adelaide average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



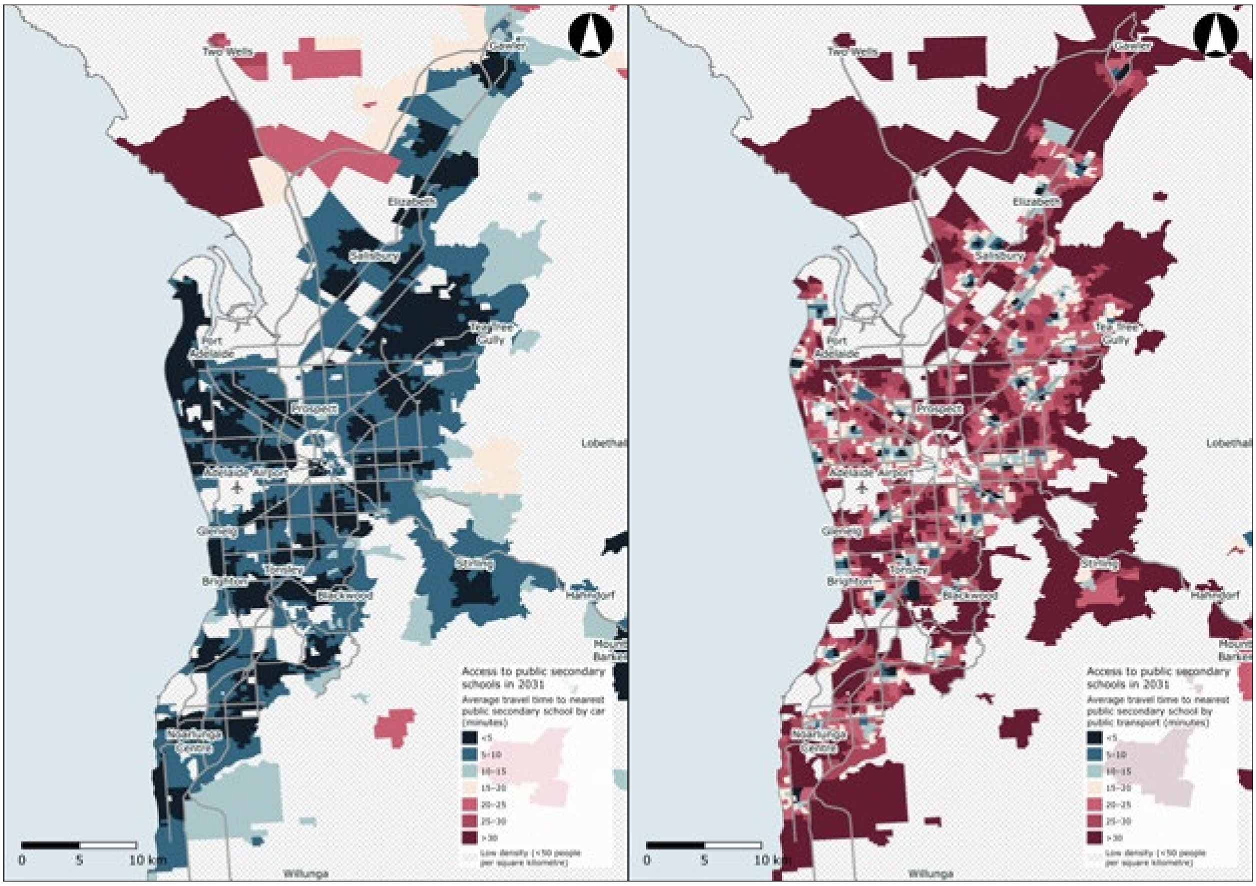

Source: Veitch Lister Consulting (2019)[205]

**Figure 114:** Greater Adelaide average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[206]

**Figure 115:** Adelaide average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[207]

## Access to jobs in Adelaide – by car and public transport, in 2016 and 2031

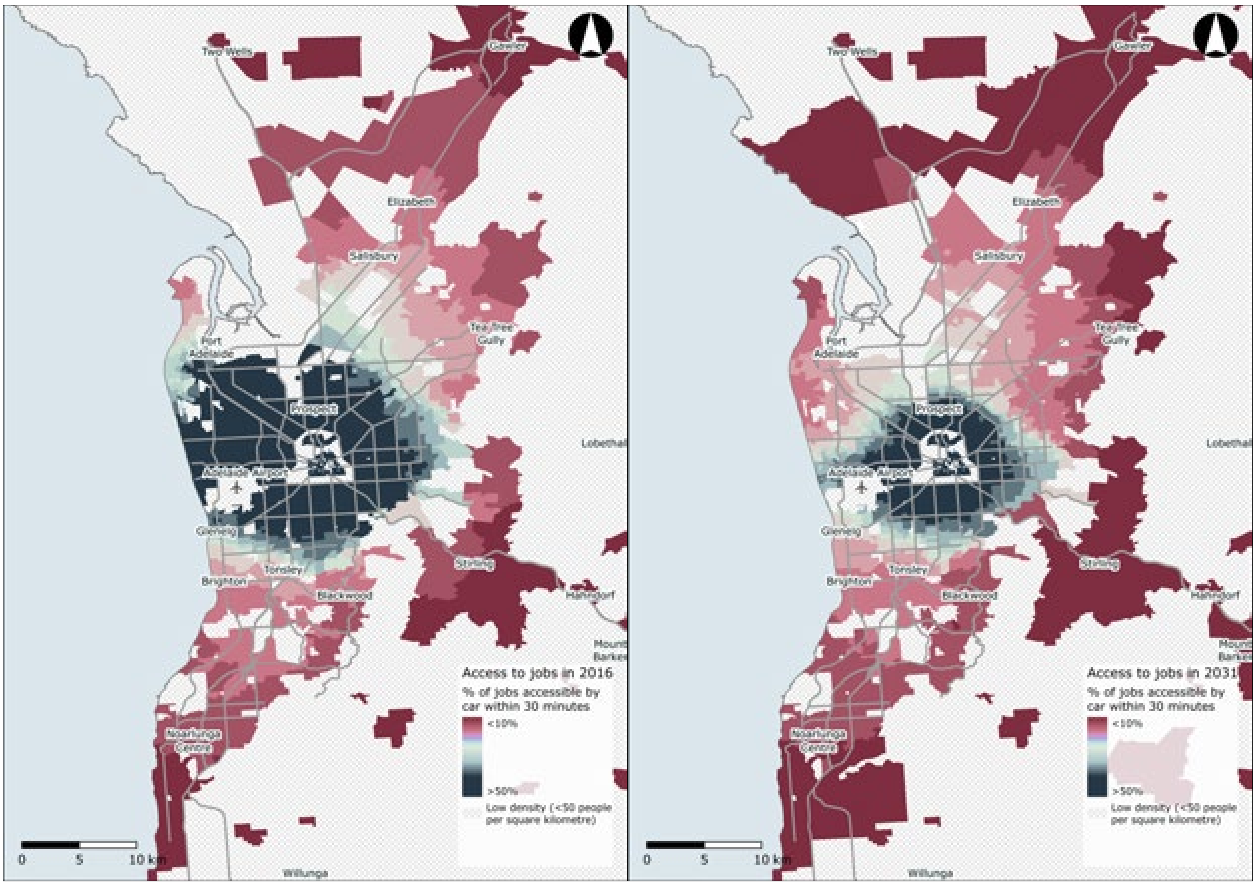
Employment accessibility has been measured as the percentage of jobs that can be reached in Greater Adelaide within 30 minutes of home by car (Figure 116) and by public transport (Figure 117) in the two modelled years.

Access to employment across Greater Adelaide differs based on where a person lives and which mode of transport they opt for. Due to the high current and future concentration of jobs in Adelaide's city centre, accessibility to this area is the main driver of employment advantage.

Job accessibility by car is expected to reduce by 2031 due to road congestion. As a result, motorists are expected to be able to reach a smaller proportion of jobs in 30 minutes by car in 2031 than in 2016. As the location of job opportunities in Adelaide is expected to stay relatively constant, reduced accessibility to employment will most affect the residents of outer suburbs, and inner city dwellers will continue to have access to a wide variety of opportunities.

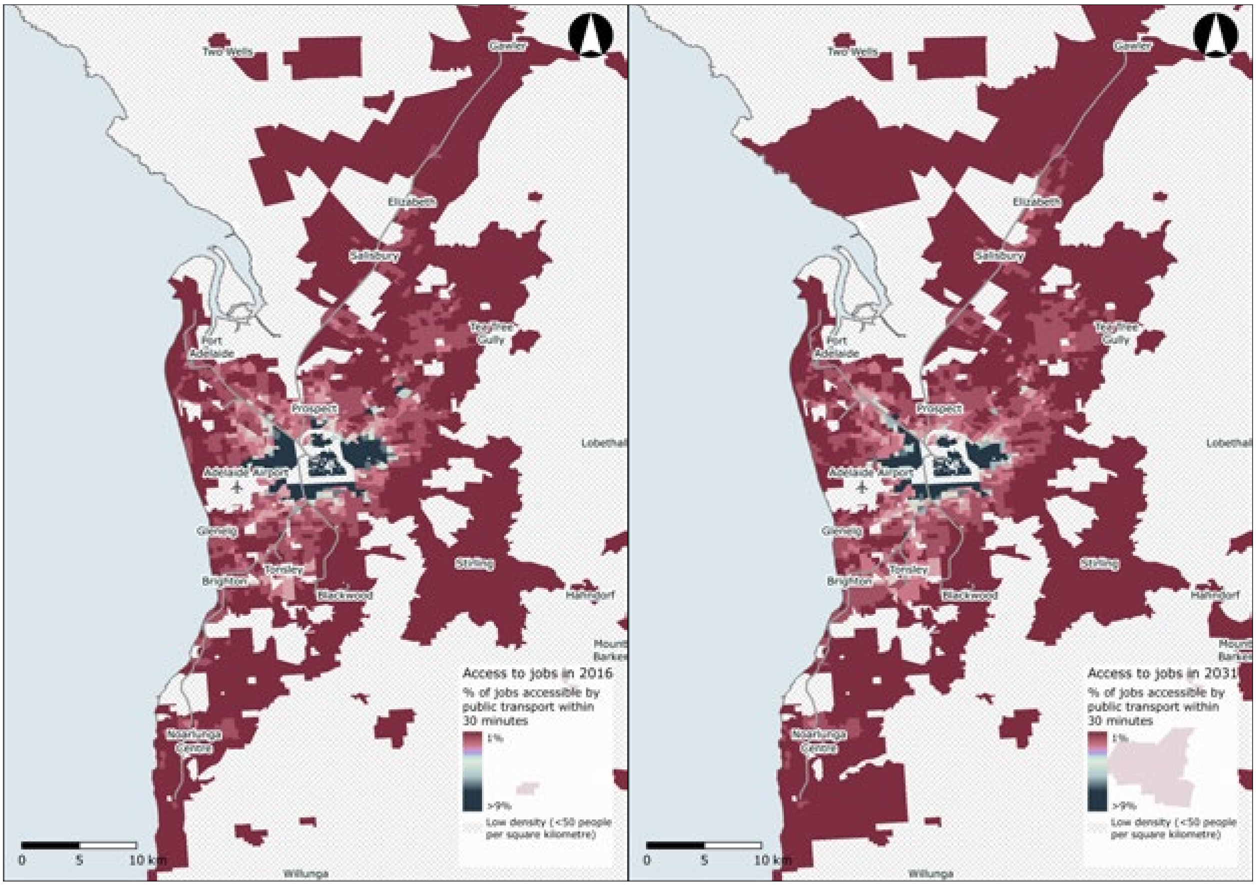
Job accessibility by public transport is forecast to remain relatively stable between 2016 and 2031. This is partially a result of the fairly consistent location of jobs over the 15-year horizon. Areas with good accessibility to jobs by public transport in 2016 are forecast to remain in this situation in the future. Access to jobs for Adelaide's growing northern population will be enhanced for areas with access to the Gawler rail line, but other areas without direct access to trains will see a decline in job accessibility due to the impact of road congestion on bus services.

**Figure 116:** Greater Adelaide access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[208]

**Figure 117:** Greater Adelaide's access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[209]

## Findings

- Car access to Adelaide's social infrastructure will remain universally faster than travel by public transport, despite the impacts of road congestion and public transport upgrades expected by 2031.
- Adelaide's public transport network is effective at supporting the movement of people into and out of the CBD, but less effective at catering for local travel needs.
- Inner city residents will continue to have much greater access to a wide variety of job opportunities by both car and public transport, compared to the residents of outer suburbs.
- Traffic congestion will cause delays to buses, diminishing access to jobs within 30 minutes by public transport for residents of Adelaide's outer suburbs that are not serviced by rail.

10

# The ACT and Queanbeyan

## 10.1 The population of the ACT and Queanbeyan has grown, and so has the region's transport task

### ACT and Queanbeyan transport network performance over the past decade

Between 2006 and 2016, the population of the Australian Capital Territory and the adjacent NSW town Queanbeyan grew from 369,000[210] to around 445,000. In 2016, the most densely populated areas were Belconnen and Gungahlin in the region's north, as well as Tuggeranong in the south. Queanbeyan, located 15 km to Canberra's west, also supports a significant share of the regional population, increasingly playing a role as a commuter settlement for people working in Canberra.

The outcome of more people living and working in the ACT and Queanbeyan has been a greater transport task. Over the past decade the distance travelled by users of Canberra's roads has increased by 7%. In 2016, Canberrans drove the most car kilometres per person of any Australian city.[211] In comparison, public transport patronage has not increased significantly, reflecting the city's continued dependence on cars as a primary mode of transport.

As a result of increased demand and heavy dependence on car transport, the performance of Canberra's roads has suffered, affecting all road users including commercial operators and bus passengers.

## 10.2 There are variations between the 2015 and 2019 Audit forecasts

### There have been substantial changes to the 2019 Audit inputs and assumptions

Since the 2015 Audit, ACT and Queanbeyan's forecast cost of road congestion has decreased by 28% (Table 44 and Figure 118). This is largely due to a decrease in the forecast population compared to the 2015 Audit.

**Table 44:** The cost of road congestion and public transport crowding in the ACT and Queanbeyan, 2016 and 2031

| | Cost of public transport crowding ($ millions) | Cost of road congestion ($ millions) | Total ($ millions) |
|---|---|---|---|
| 2016 (2019 Audit) | 1 | 289 | 290 |
| 2031 (2019 Audit) | 8 | 504 | 512 |
| 2031 (2015 Audit) | N/A | 703 | N/A |
| 2031 (change from 2015 Audit) | | -199 (-28%) | |

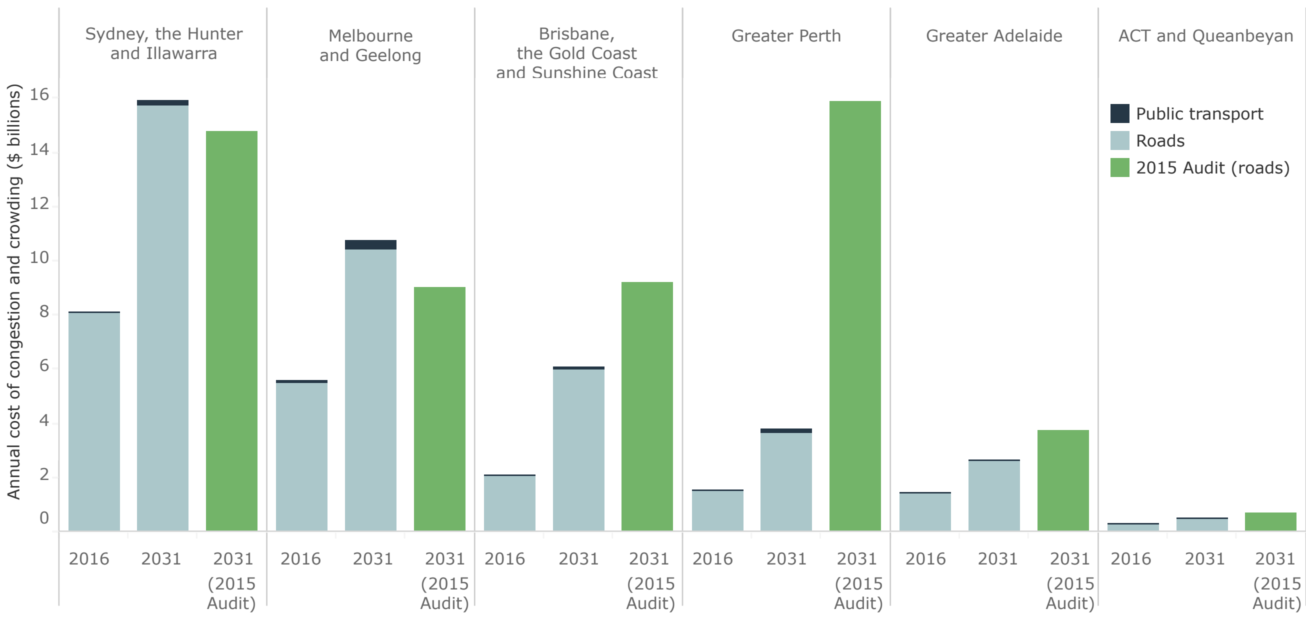
Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[212]

In the 2015 Audit, 2031 population projections for ACT and Queanbeyan were extracted from ABS Series B projections. In this latest Audit, projections have been provided by the ACT Government. The population forecast used in the 2019 Audit finds there will be 8% fewer people than forecast in the 2015 Audit. This population is also distributed slightly differently. Population is higher in Woden Valley (an extra 7,600 residents) and Western Creek (an extra 2,600 residents). However, population forecasts are much lower in Queanbeyan (25,500 fewer residents) and Gungahlin (20,500 fewer residents). Of particular note is Molonglo, which had zero population in the 2015 Audit, and 32,000 residents in the 2019 Audit. A map reflecting these changes is shown in Figure 119.

Forecast employment in the ACT and Queanbeyan is expected to be six percent less in the 2019 Audit. However, the proportion of employment in North and South Canberra is projected to be 2 percent more.

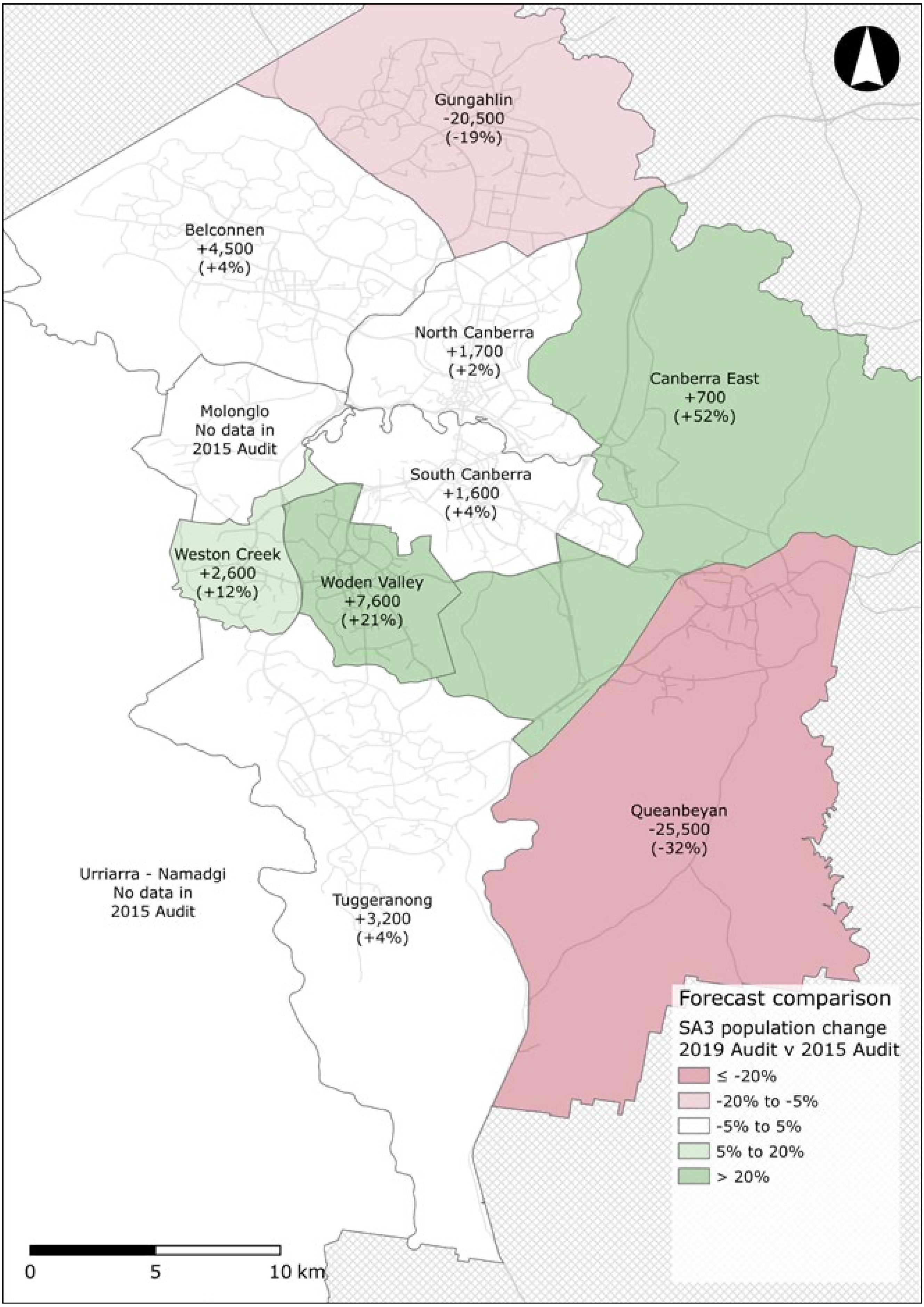
Table 45 reflects changes in model inputs and key outputs between 2015 and 2019 Audit modelling.

**Figure 118:** The cost of road congestion and public transport crowding, 2016 and 2031




Source: Infrastructure Australia (2015) and Veitch Lister Consulting (2019)[213]

**Figure 119:** 2031 population forecast for the ACT and Queanbeyan: 2019 Audit compared to the 2015 Audit




Source: Veitch Lister Consulting (2019)[214]

**Table 45:** Changes in key model inputs and outputs between 2015 and 2019 modelling in the ACT and Queanbeyan

| | | Demographic assumptions | | Network assumptions | | Travel cost assumptions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Population | Jobs | Road investment | Public transport investment | Fuel | PT fares | Parking | Tolls |
| Change in inputs | | ⇩ Population forecasts have reduced (-8%) | ⇧ Employment forecasts have reduced (-6%), however the proportion of jobs in North and South Canberra SA3s remains stable | ⇧ More investment in the road network (+12% network lane km) | ⇧ More investment in the PT network (+31% service kms) | ⇩ Reduction in fuel price (140 c/L to 104 c/L AUD 2011) | — No change in other transport costs | | |
| Impact on output (AM peak) | Total trips (-6%) | ⇩ Lower total population reduces total modelled trips | — Total trips are generated by population assumptions and model parameters only | | | | | | |
| | Car trips (-10%) | ⇩ Lower total population reduces total modelled car trips. | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car trips | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | — Negligible impact |
| | Car vehicle kms travelled (-4%) | ⇩ An overall reduction in population reduces car kilometres | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇧ Better roads encourage car travel | ⇩ Better PT can encourage more PT travel and fewer car kms | ⇧ Lower fuel prices encourage car travel | — No change = no impact | | — Negligible impact |
| | Public transport trips (+1%) | ⇩ Lower total population should reduce total PT trips, but there appears to have been a slight mode shift away from car in favour of PT | — The distribution of employment is similar between the audits, as such a decline in overall employment does not substantially alter the balance between car and PT travel | ⇩ Better roads encourage car travel and fewer PT trips | ⇧ Better PT can encourage more PT travel | ⇩ Lower fuel prices encourage car travel and reduce PT travel | — No change = no impact | | — Negligible impact |

Source: Veitch Lister Consulting (2019)[215]

## New network assumptions

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. In the ACT and Queanbeyan major project assumptions are largely consistent between the audits. However, incremental impacts of more minor projects have results in higher in-service kilometres on public transport and more lane kilometres on the road network in the 2019 Audit compared with the 2015 Audit.

## Variation between road network capacities in 2031

Across the vast majority of the ACT and Queanbeyan network, forecast traffic volumes are lower in the 2019 Audit in the 2031 AM and PM peaks.

Congestion is still forecast for sections of major highways in the 2019 Audit, however it is lower and less widespread than in the 2015 Audit. For example, the 2019 Audit shows small sections of congestion on the Drakeford Drive, Tuggeranong Parkway and Parkes Way Corridor in the 2031 AM peak. By contrast, the 2015 Audit forecasts medium to high congestion across the entirety of this road in the 2031 AM peak. This trend is mirrored on the Monaro Highway, the Majura Parkway, the Federal Highway, Northbourne Avenue, the Barton Highway, Canberra Avenue and Commonwealth Avenue.

The 2019 Audit's road network volume over capacity is also significantly reduced in most arterial and local roads across the network. This change is most apparent in the CBD, Capital Hill, Gungahlin, Belconnen, Queanbeyan and Phillip.

Table 46 compares corridor-level average traffic and delay hours for the AM peak for the ten most delayed corridors in the 2019 Audit.

## Variation between public transport capacities in 2031

The outcomes of the public transport modelling in the 2019 Audit is different those forecast in the 2015 Audit.

Public transport trips increase marginally (+1%) between 2015 and 2019 Audit forecasts. This is due to incremental improvements to the public transport network that results in in-service kilometres being 31% higher in the 2019 Audit relative to the 2015 Audit. A lower total population also results in less total public transport trips.

In the 2019 Audit, the weekday bus passenger volume is far more concentrated in approaching the CBD from Barry Drive and Belconnen Way compared to the 2015 Audit. Conversely, much of the public transport forecast demand in the 2015 Audit was forecast to occur from around the CBD, along Northbourne Avenue towards Bonner, Amaroo, Gungahlin and Ngunnalwal's arterial and local roads. This level of high congestion is largely absent in the 2019 Audit.

**Table 46:** Most congested roads ranked by total delay hours, 2031 AM Peak and ranking in 2015 Audit in the ACT and Queanbeyan

| City rank (2019 Audit) | Corridor | Direction | Average peak hour traffic volumes | | | Total delay hours | | | City rank (2015 Audit) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 Audit | 2019 Audit | Difference | 2015 Audit | 2019 Audit | Difference | |
| 1 | Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor | N/B | 2,400 | 2,200 | -7% | 1,700 | 1,000 | -43% | 1 |
| 2 | Canberra Avenue corridor | W/B | 2,000 | 1,900 | -8% | 1,300 | 900 | -27% | 5 |
| 3 | Monaro Highway corridor | N/B | 3,000 | 2,600 | -15% | 900 | 700 | -18% | 9 |
| 4 | Barton Highway / Northbourne Avenue corridor | S/B | 2,200 | 1,900 | -14% | 1,400 | 600 | -54% | 3 |
| 5 | Canberra Airport to Civic corridor | W/B | 2,000 | 1,400 | -26% | 1,300 | 600 | -51% | 4 |
| 6 | Athllon Drive / Commonwealth Avenue corridor | N/B | 1,900 | 1,600 | -13% | 1,100 | 600 | -51% | 7 |
| 7 | Gungahlin Drive corridor | S/B | 2,600 | 2,300 | -10% | 1,300 | 500 | -59% | 6 |
| 8 | Kingsford Smith Drive / William Hovell Drive corridor | S/B | 1,500 | 1,800 | 23% | 900 | 500 | -46% | 8 |
| 9 | Belconnen Way / Barry Drive corridor | E/B | 2,500 | 1,900 | -27% | 1,400 | 400 | -70% | 2 |
| 10 | East-west corridor via Hindmarsh Drive | E/B | 800 | 1,700 | 128% | 0 | 300 | 985% | 34 |

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

Source: Veitch Lister Consulting (2019)[216]

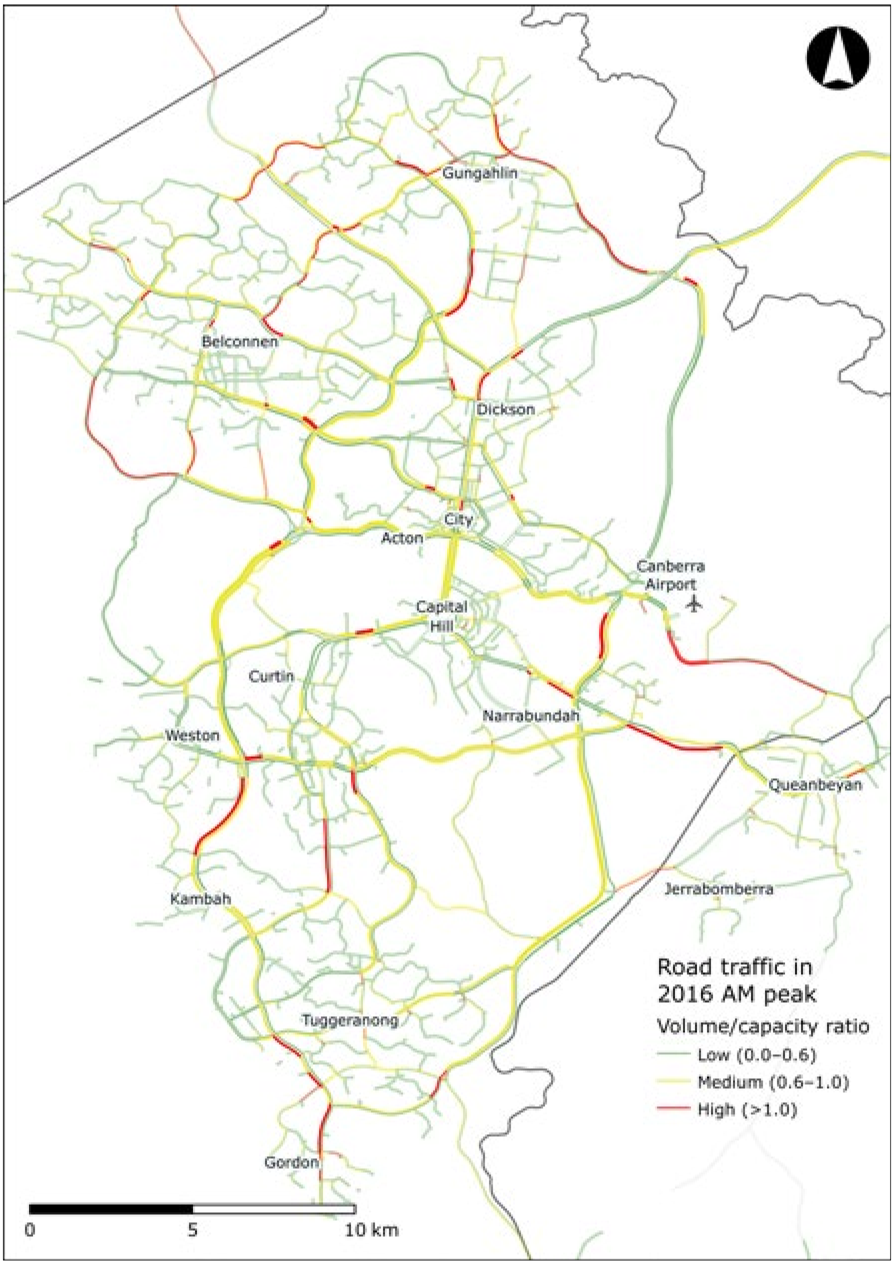
## 10.3 Commuters in the ACT and Queanbeyan experience little road congestion and public transport crowding

### Snapshot of the ACT and Queanbeyan road network in 2016

In 2016, while drivers in the ACT and Queanbeyan experienced moderate levels of congestion at peak periods, their road network continued to offer a relatively high level of service. Our modelling indicates the annualised cost of road congestion and public transport crowding in the ACT and Queanbeyan was approximately $290 million in 2016.

Roads radiating out from the ACT's urban centres have the city's highest levels of congestion (Figure 120), with routes connecting Civic, Canberra's CBD, with outer areas experiencing  the most delay. Roads in Canberra's east, connecting the city centre with Queanbeyan, also experience peak congestion, exceeding design capacity on some corridors. Other congested corridors connect Tuggeranong in the region's south, and major northern suburbs such as Gungahlin and Belconnen, to its centre; some links are congested in both directions during a peak period.

**Figure 120:** ACT and Queanbeyan weekday traffic volume / capacity ratio, 2016 AM peak




Note: Volume / capacity ratios show the quantity of traffic relative to a road's capacity. Any link operating at a VCR above 1.0 is coloured red, indicating that more vehicles are using the road than it was designed to accommodate under free-flow conditions.

Source: Veitch Lister Consulting (2019)[217]

## The ACT and Queanbeyan region's most congested roads in 2016: what the driver experiences

Canberra's drivers experience congestion in the AM and PM peaks. Canberra was designed and has developed as a polycentric city, and congestion is unsurprisingly greatest on the arterial roads that connect its centres.

Infrastructure Australia has measured the most congested corridors in Canberra using several customer-focused metrics. The ten most congested corridors in the AM and PM peak periods from a user's perspective are shown in Table 47 and  Figure 121.

Canberra's most congested roads as experienced by a driver in 2016 were arterials providing a north-south connection through the ACT. Canberra's most congested road corridor in both peak periods was the William Slim Drive / Coulter Drive Corridor. This corridor carries traffic to and from the north of Belconnen. Users of this corridor can expect to spend 40% of their journey time in congested conditions. Canberra's next most congested corridors in 2016 connect across Gungahlin, feeding Gungahlin Drive and Tuggeranong Parkway.

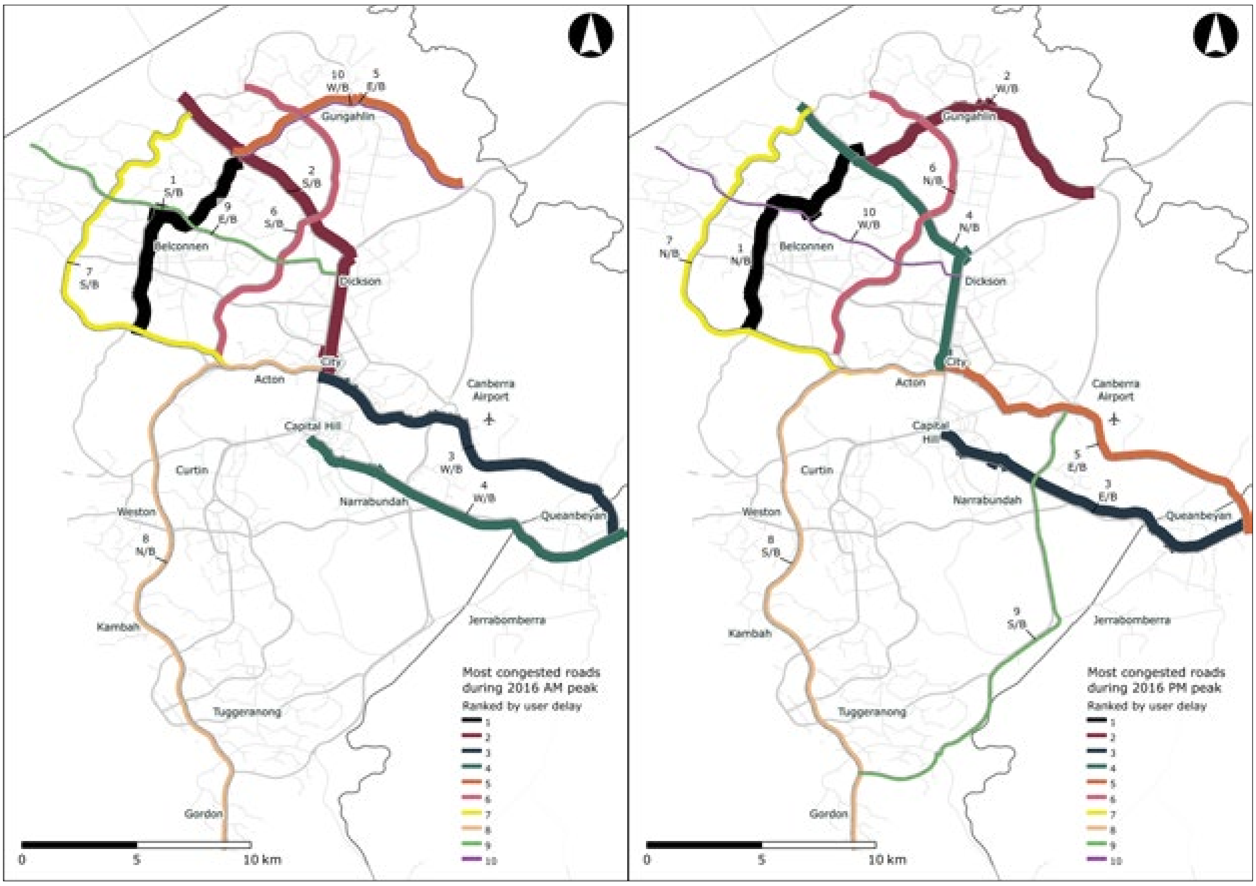
**Table 47:** ACT and Queanbeyan most congested roads (user experience), 2016

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | William Slim Drive / Coulter Drive corridor (S/B) | 10 | 40% | 6 | $1.66 | $7.14 |
| 2. | Barton Highway / Northbourne Avenue corridor (S/B) | 14 | 39% | 9 | $2.49 | $10.71 |
| 3. | Canberra Airport to Civic corridor (W/B) | 15 | 39% | 8 | $2.21 | $9.52 |
| 4. | Canberra Avenue corridor (W/B) | 13 | 39% | 8 | $2.21 | $9.52 |
| 5. | Gundaroo Drive / Horse Park Drive corridor (E/B) | 11 | 39% | 6 | $1.66 | $7.14 |
| 6. | Gungahlin Drive corridor (S/B) | 15 | 38% | 7 | $1.93 | $8.33 |
| 7. | Kingsford Smith Drive / William Hovell Drive corridor (S/B) | 18 | 38% | 9 | $2.49 | $10.71 |
| 8. | Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor (N/B) | 33 | 33% | 12 | $3.31 | $14.28 |
| 9. | Ginninderra Drive corridor (E/B) | 13 | 32% | 5 | $1.38 | $5.95 |
| 10. | Horse Park Drive / Gunaroo Drive corridor (W/B) | 11 | 29% | 4 | $1.10 | $4.76 |
| PM peak | | | | | | |
| 1. | Coulter Drive / William Slim Drive corridor (N/B) | 10 | 39% | 6 | $1.66 | $7.14 |
| 2. | Horse Park Drive / Gundaroo Drive corridor (W/B) | 11 | 37% | 6 | $1.66 | $7.14 |
| 3. | Canberra Avenue corridor (E/B) | 13 | 35% | 7 | $1.93 | $8.33 |
| 4. | Northbourne Avenue / Barton Highway corridor (N/B) | 14 | 35% | 7 | $1.93 | $8.33 |
| 5. | Civic to Canberra Airport corridor (E/B) | 15 | 34% | 7 | $1.93 | $8.33 |
| 6. | Gungahlin Drive corridor (N/B) | 15 | 33% | 6 | $1.66 | $7.14 |
| 7. | William Hovell Drive / Kingsford Smith Drive corridor (N/B) | 18 | 33% | 7 | $1.93 | $8.33 |
| 8. | Parkes Way / Tuggeranong Parkway / Drakeford Drive corridor (S/B) | 32 | 30% | 11 | $3.04 | $13.09 |
| 9. | Monaro Highway corridor (S/B) | 21 | 29% | 6 | $1.66 | $7.14 |
| 10. | Ginninderra Drive corridor (W/B) | 13 | 27% | 4 | $1.10 | $4.76 |

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

Source: Veitch Lister Consulting (2019)[218]

**Figure 121:** ACT and Queanbeyan most congested roads (user experience), 2016 AM (left) and PM (right) peak




Source: Veitch Lister Consulting (2019)[219]

## The ACT and Queanbeyan region's most congested roads in 2016: the cost to the community of total vehicle delays

As a measure of the whole-of-system impacts of congestion, Infrastructure Australia has also identified the most congested road corridors in the ACT and Queanbeyan region by aggregating the total delay hours experienced by all vehicles using the congested road during the modelled period. The ten most congested corridors under this approach are shown in Table 48 and Figure 122 for the AM and PM peak periods.

Based on an aggregated metric – total hours of vehicle delay experienced by all corridor users – the worst performer in 2016 was the Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor, which connects Tuggeranong to the north of Civic. This corridor is the most delayed in both peak periods, but especially in the morning. Drivers on the Gungahlin Drive and Monaro Highway corridors also experienced significant delays in 2016.

High levels of congestion on Canberra's busiest roads is driven by people commuting to the region's main employment clusters from the outer northern and southern  residential suburbs.

## The ACT and Queanbeyan region's public transport system in 2016

Demand for public transport in Canberra has grown in the last 10 years, but (uniquely among the six conurbations examined by this Audit) at a lower rate than for cars. In 2016, public transport use in the ACT and Queanbeyan accounted for just 3% of total daily trips, compared to the use of cars (75%) and active transport including walking and bike-riding (22%).[220]

The ACT and Queanbeyan region's public transport services connect surrounding areas with its urban centres, primarily Civic. In 2016, the region's public transport system was operated by buses providing mainly local services and some longer-distance connections. Service demand is modest and as a result low passenger crowding is experienced on most of the network. Demand is higher during peak periods and in peak directions.

The region's buses operate well below crush capacity on most routes in the AM peak period (Figure 123). Crowding does approach crush capacity on Belconnen Way services between Belconnen and Macquarie, as well as on Ginninderra Drive, towards the University of Canberra. In general, buses become more crowded in the areas surrounding Civic. Passenger volumes exceed seated capacity on the Barton Highway approach into North Canberra.

Very few commuters use bus transport between Queanbeyan and Canberra CBD. This reflects infrequent bus services in this area, the region's general reliance on car use, and cross-border differences between the ticketing and fare systems for ACT and regional NSW bus operations.[221]

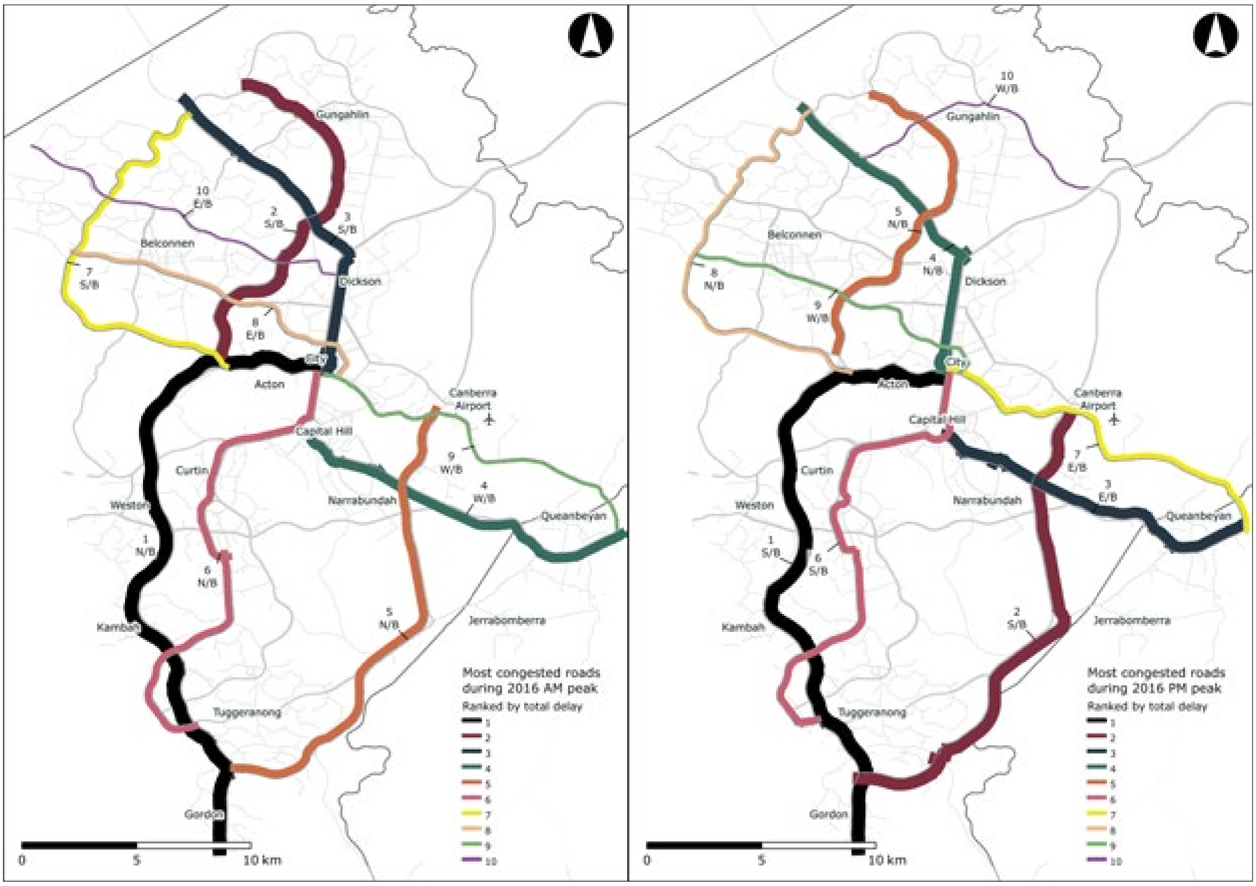
**Table 48:** ACT and Queanbeyan's most congested roads (total vehicle delays), 2016

| City rank | Corridor | Direction | Total delay hours | Cost of congestion (daily) |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor | N/B | 800 | $14,000 |
| 2. | Gungahlin Drive corridor | S/B | 500 | $9,000 |
| 3. | Barton Highway / Northbourne Avenue corridor | S/B | 500 | $10,000 |
| 4. | Canberra Avenue corridor | W/B | 500 | $9,000 |
| 5. | Monaro Highway corridor | N/B | 500 | $10,000 |
| 6. | Athllon Drive / Commonwealth Avenue corridor | N/B | 400 | $7,000 |
| 7. | Kingsford Smith Drive / William Hovell Drive corridor | S/B | 300 | $5,000 |
| 8. | Belconnen Way / Barry Drive corridor | E/B | 300 | $5,000 |
| 9. | Canberra Airport to Civic corridor | W/B | 300 | $6,000 |
| 10. | Ginninderra Drive corridor | E/B | 200 | $4,000 |
| PM peak | | | | |
| 1. | Parkes Way / Tuggeranong Parkway / Drakeford Drive corridor | S/B | 700 | $13,000 |
| 2. | Monaro Highway corridor | S/B | 500 | $10,000 |
| 3. | Canberra Avenue corridor | E/B | 400 | $8,000 |
| 4. | Northbourne Avenue / Barton Highway corridor (N/B) | N/B | 400 | $8,000 |
| 5. | Gungahlin Drive corridor | N/B | 400 | $7,000 |
| 6. | Commonwealth Avenue / Athllon Drive corridor | S/B | 300 | $5,000 |
| 7. | Civic to Canberra Airport corridor | E/B | 300 | $6,000 |
| 8. | William Hovell Drive / Kingsford Smith Drive corridor | N/B | 200 | $4,000 |
| 9. | Barry Drive / Belconnen Way corridor | W/B | 200 | $4,000 |
| 10. | Horse Park Drive / Gundaroo Drive corridor | W/B | 200 | $4,000 |

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

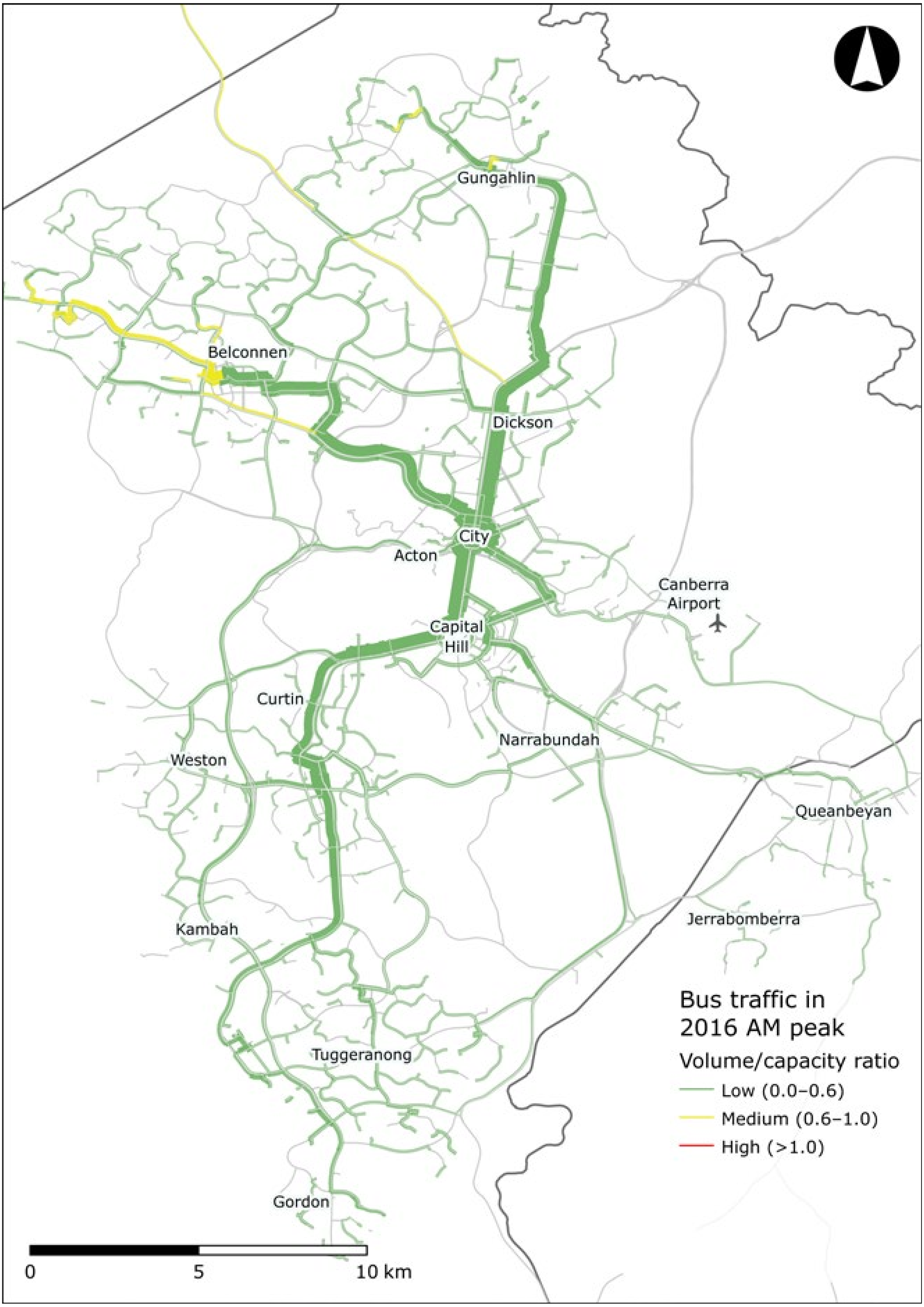
Source: Veitch Lister Consulting (2019)[222]

**Figure 122:** ACT and Queanbeyan most congested roads (total vehicle delays), 2016 AM (left) and PM (right) peak




Source: Veitch Lister Consulting (2019)[223]

**Figure 123:** ACT and Queanbeyan weekday bus passenger volume / capacity ratio, 2016 AM peak




Source: Veitch Lister Consulting (2019)[224]

## Findings

- Road congestion affects key arterial routes connecting Canberra's city centre with surrounding residential areas and other urban centres.
- Regional highways experience high levels of congestion, delaying regional access.
- Bus services are delayed by traffic congestion, and public transport does not compete with car use for commuter travel to the same degree seen in Australia's other largest cities.
- Some bus services do experience peak period crowding in Canberra's north-western suburbs and close to Canberra's CBD.
- Cross-border issues reduce the attractiveness of bus access to Canberra for Queanbeyan commuters.

## 10.4 The ACT and Queanbeyan region's transport networks are forecast to become more congested

### Snapshot of Canberra's transport networks in 2031

By 2031, travel demand in the ACT and Queanbeyan is expected to increase significantly as a result of population growth. Between 2016 and 2031, the region's population is expected to increase by 25% to approximately 558,000 people. The strongest growth is forecast in the Molonglo Valley, in Canberra's west, as a result of greenfield development. Consequently, transport infrastructure connecting Molonglo Valley with central Canberra is expected to be challenged by a significant increase in demand. Population growth will also be concentrated in Canberra's inner suburbs, with North and South Canberra expected to accommodate over 35% more residents in 2031.

Due primarily to this population growth, by 2031 the region will generate 27% more trips, seeing close to 3 million daily trips. Travel by public transport will grow at a significantly faster rate than car use, reversing recent trends and bringing the region into line with the other major cities considered by this Audit. This is forecast to result in an increase in public transport mode share, from 3% to a still modest 4%.

The expected increase in public transport use will result from numerous influences. Significant investment in Canberra's Capital Metro light rail network will be complemented by improved bus services. In addition, higher urban densities, particularly in the inner city and along light rail corridors, will increase the proportion of Canberrans for whom the decision not to use or even own a car, and to use public and active transport instead, will be a natural one.

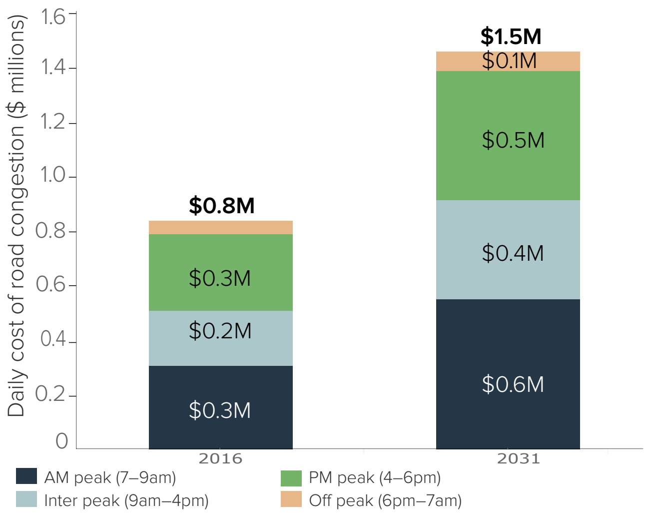
Notwithstanding this change, the congestion of Canberra's roads is forecast to grow substantially to 2031, while crowding will be experienced on more public transport services than today. The daily cost of Canberra's road congestion is expected to almost double, from about $800,000 per day to $1.5 million in 2031 (Figure 124). Our modelling indicates the annualised cost of road congestion in ACT and Queanbeyan will be approximately $504 million in 2031. While the cost of public transport crowding will be significantly less than for road congestion, it is expected to increase at a rapid rate, from $600,000 in 2016 to $7.8 million in 2031.

These forecast outcomes account for projects that were either under construction, under procurement or had funding for construction committed from all relevant governments at the time of modelling for the *Australian Infrastructure Audit*.[225]

Major projects included in the ACT and Queanbeyan region's 2031 forecast comprise:

- Capital Metro
- Duplication of Ashley Drive
- Duplication of Aikman Drive
- Widening of Gungahlin Drive
- Duplication of Gundaroo Drive.

**Figure 124:** ACT and Queanbeyan average weekday cost of road congestion, 2016 and 2031



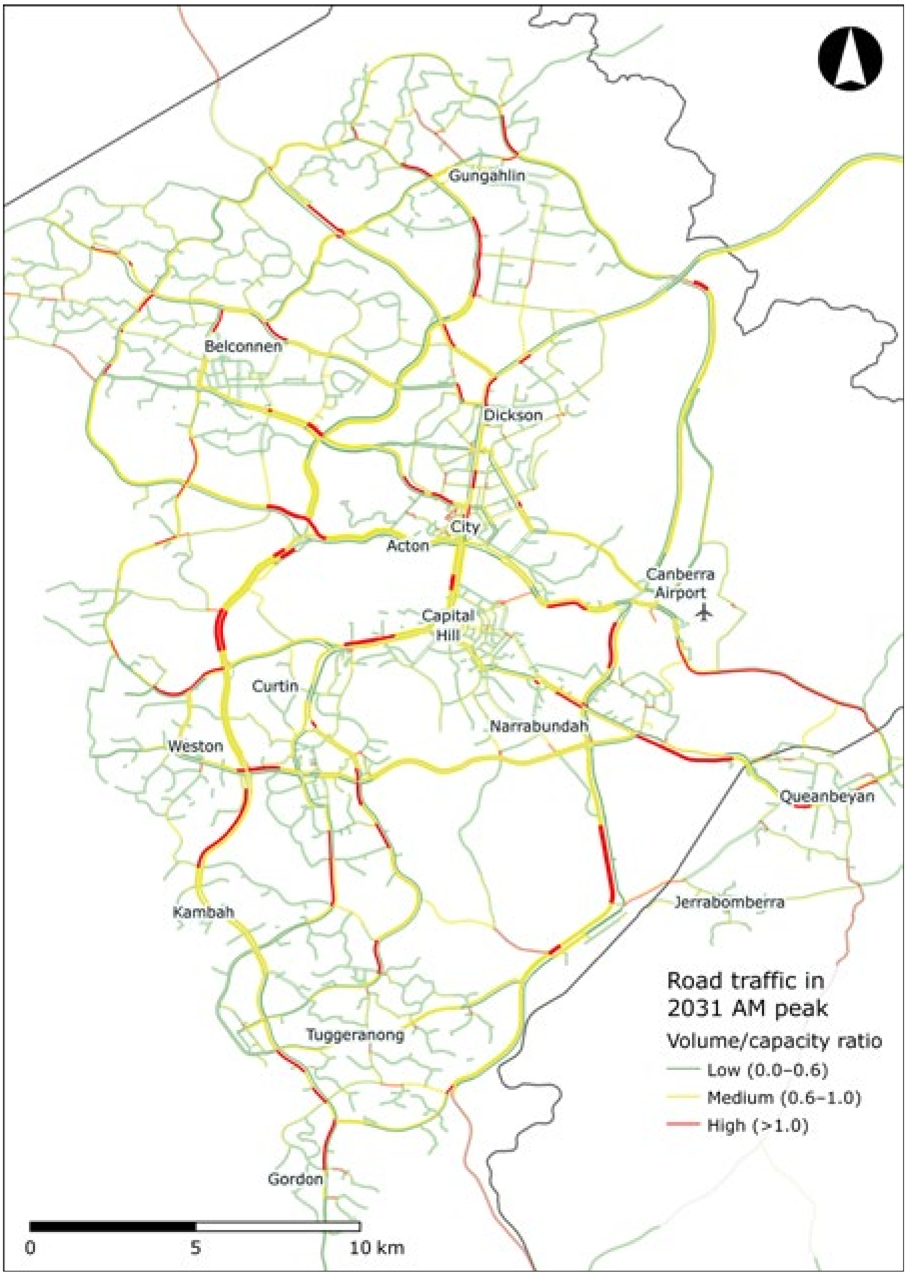

Source: Veitch Lister Consulting (2019)[226]

## The ACT and Queanbeyan region's most congested roads in 2031: what the driver will experience

With population growth generating additional car use that will overwhelm some mode shift from cars to public transport, road congestion will continue to grow in the ACT and Queanbeyan (Figure 125). As for 2016, 2031 modelling has forecast the most congested road corridors in the region based both on an average individual driver's peak period experience of driving on the busiest roads, and on aggregating the total delay hours experienced by all vehicles using an extended road corridor during the modelled time period.

Table 49 and Figure 126 show forecast 2031 outcomes under the first metric. Along the worst-performing routes, drivers can expect to spend close to half of their travel time in congested traffic (as opposed to about 40% in the 2016 base year). Many of the poorest performing routes in 2016 are forecast to occupy a similar position in 2031.

**Figure 125:** ACT and Queanbeyan weekday traffic volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[227]

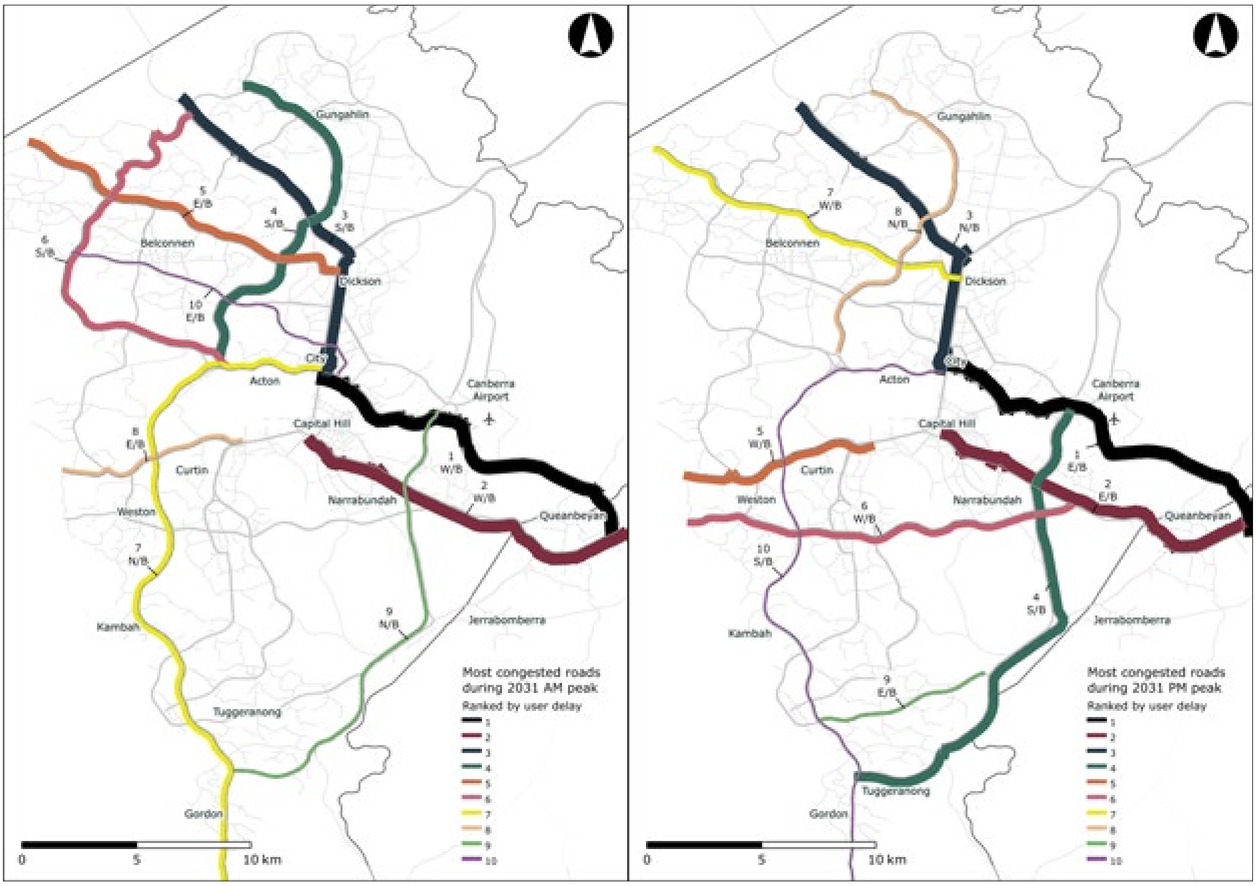
**Table 49:** ACT and Queanbeyan most congested roads (user experience), 2031

| City rank | Corridor including origin / destination connected (direction) | Length (km) | Share of journey time due to congestion | Delay per vehicle (mins) | Cost of congestion for a car | Cost of congestion for a heavy commercial vehicle |
|---|---|---|---|---|---|---|
| AM peak | | | | | | |
| 1. | Canberra Airport to Civic corridor (W/B) | 15 | 54% | 15 | $4.14 | $17.85 |
| 2. | Canberra Avenue corridor (W/B) | 13 | 51% | 12 | $3.59 | $15.47 |
| 3. | Barton Highway / Northbourne Avenue corridor (S/B) | 14 | 45% | 11 | $3.04 | $13.09 |
| 4. | Gungahlin Drive corridor (S/B) | 15 | 38% | 7 | $1.93 | $8.33 |
| 5. | Ginninderra Drive corridor (E/B) | 13 | 38% | 7 | $1.93 | $8.33 |
| 6. | Kingsford Smith Drive / William Hovell Drive corridor (S/B) | 18 | 35% | 8 | $2.21 | $9.52 |
| 7. | Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor (N/B) | 33 | 35% | 13 | $3.59 | $15.47 |
| 8. | Cotter Road corridor (E/B) | 7 | 35% | 3 | $0.83 | $3.57 |
| 9. | Monaro Highway corridor (N/B) | 20 | 34% | 8 | $2.21 | $9.52 |
| 10. | Belconnen Way / Barry Drive corridor (E/B) | 12 | 34% | 6 | $1.66 | $7.14 |
| PM peak | | | | | | |
| 1. | Civic to Canberra Airport corridor E/B | 15 | 50% | 13 | $3.59 | $15.47 |
| 2. | Canberra Avenue corridor E/B | 13 | 46% | 11 | $3.04 | $13.09 |
| 3. | Northbourne Avenue / Barton Highway corridor (N/B) | 14 | 39% | 9 | $2.49 | $10.71 |
| 4. | Monaro Highway corridor (S/B) | 21 | 35% | 8 | $2.21 | $9.52 |
| 5. | Cotter Road corridor (W/B) | 7 | 34% | 3 | $0.83 | $3.57 |
| 6. | East-west corridor via Hindmarsh Drive (W/B) | 14 | 33% | 6 | $1.66 | $7.14 |
| 7. | Ginninderra Drive corridor (W/B) | 13 | 33% | 5 | $1.38 | $5.95 |
| 8. | Gungahlin Drive corridor (N/B) | 15 | 32% | 6 | $1.66 | $7.14 |
| 9. | East-west corridor via Isabella Drive (E/B) | 6 | 31% | 2 | $0.55 | $2.38 |
| 10. | Parkes Way / Tuggeranong Parkway / Drakeford Drive corridor (S/B) | 32 | 31% | 11 | $3.04 | $13.09 |

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

Source: Veitch Lister Consulting (2019)[228]

**Figure 126:** ACT and Queanbeyan most congested roads (user experience), 2031 AM (left) and PM (right) peak




Source: Veitch Lister Consulting (2019)[229]

The ACT and Queanbeyan region's key corridors are expected to carry much greater demand in 2031, causing delays for all road users, including motorists, commercial vehicle operators and bus passengers. One of the worst-performing roads in 2016, Gundaroo Drive, is expected to become even more congested by 2031. This population growth-driven forecast is in spite of plans for the road's duplication. This is expected to be completed by 2021, and to attract road users to this corridor in preference to other, even less attractive routes.

Queanbeyan regional growth, particularly in Tralee and Googong, is expected to increase congestion and delays on the Canberra Airport to Civic and Canberra Avenue corridors. By 2031, these corridors are forecast to be the worst performing in the region and will contribute nearly 900 hours of total delay in each peak period. Additionally, employment growth in Tuggeranong, in Canberra's south, is forecast to drive increased delays on both the Drakeford Drive and Monaro Highway corridors.

Conversely, congestion on the William Slim Drive / Coulter Drive corridor is forecast to improve as a result of duplication improvements to a parallel section of Gungahlin Drive. This is expected to encourage drivers to switch routes away from the William Slim Drive / Coulter Drive corridor, resulting in this no longer appearing among the ACT and Queanbeyan region's top ten most delayed corridors.

## The ACT and Queanbeyan region's most congested roads in 2031: the forecast cost to the community of total vehicle delays

The ACT and Queanbeyan region's ten most congested road corridors in the 2031 AM and PM peak periods, based on aggregating the total delay hours experienced by all vehicles using an extended corridor during the modelled time period, are shown in Table 50 and Figure 127.

Between 2016 and 2031 aggregate delays are expected to worsen substantially on some key roads. Traffic volumes will exceed capacity on more sections of the Tuggeranong Parkway, which runs north-south to Canberra's west past the Molonglo Valley growth area. Severe AM peak congestion is predicted in both directions. Similarly, bi-directional peak congestion will affect the north-south Monaro Highway, which skirts Canberra's east. The Barton Highway and William Hovell Drive are also forecast to be highly congested in both peak directions.

Generally, motorists traveling from outer areas to inner areas can expect by 2031 to encounter congestion earlier on their morning commute and for longer on the way home. These delays will have an impact on bus passengers as well as on travel time for motorists.

## The ACT and Queanbeyan region's public transport system in 2031

By 2031, the use of public transport in the ACT and Queanbeyan is expected to increase. This will occur as a result of population growth, the expansion of the public transport network and the introduction of more frequent services. Increased levels of road congestion and higher car parking charges will also contribute to greater public transport use, especially for light rail in its own right-of-way, and bus priority services which are protected from traffic delays.

Public transport boardings, in-vehicle passenger kilometres and in-vehicle passenger hours are all predicted to double between 2016 and 2031. Buses are expected to remain the most heavily used public transport mode, even after the construction of Canberra Metro light rail (with the first line operating in 2019). The Canberra Metro light rail will replace bus routes between Gungahlin and Civic. This will facilitate improvements to the broader bus network also programmed for 2019, including the introduction of the Rapid network of routes with extended operating hours and more frequent services. Canberra's bus services are expected to see a 66% increase in boardings by 2031.

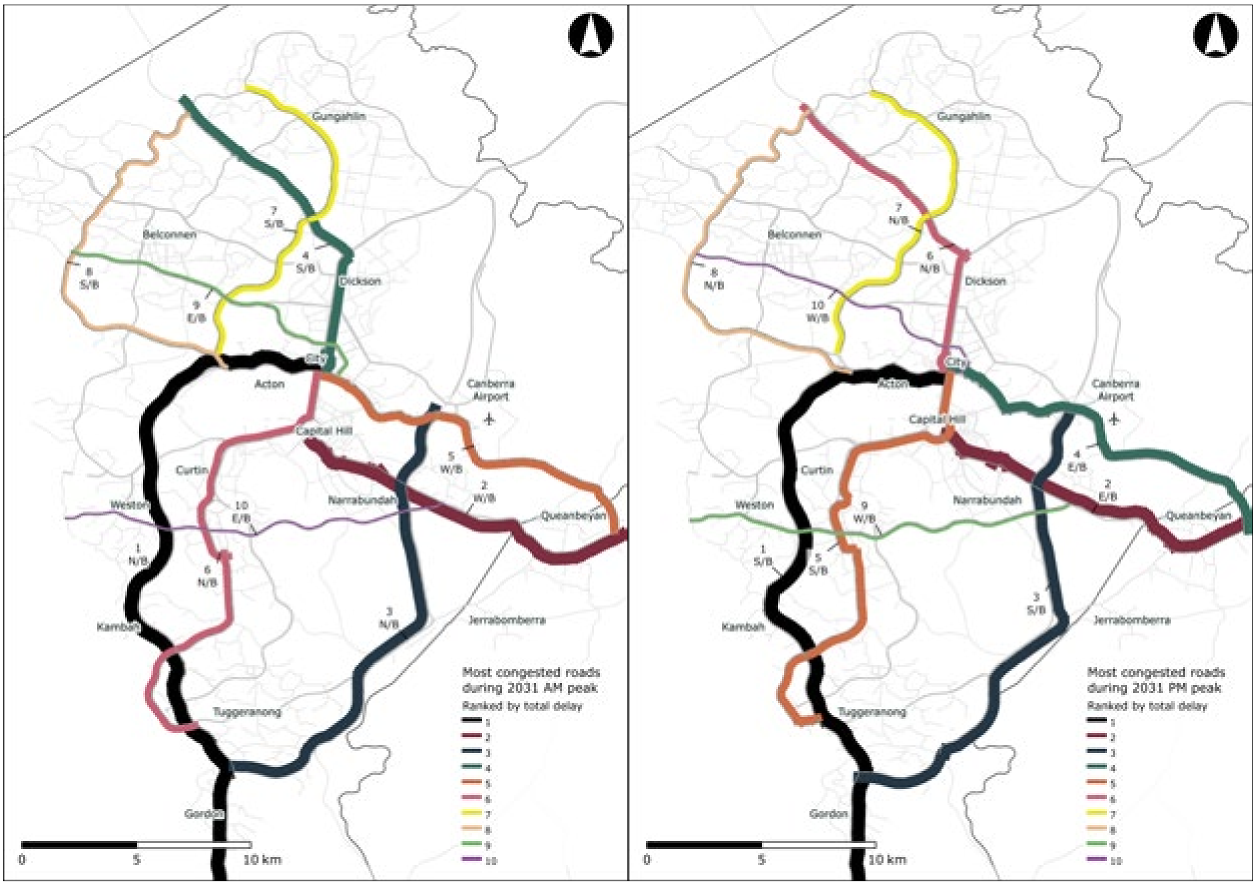
**Table 50:** ACT and Queanbeyan most congested roads (total vehicle delays), 2031

| City rank | Corridor | Direction | Total delay hours | Cost of congestion |
|---|---|---|---|---|
| AM peak | | | | |
| 1. | Drakeford Drive / Tuggeranong Parkway / Parkes Way corridor | N/B | 1,000 | $18,000 |
| 2. | Canberra Avenue corridor | W/B | 900 | $17,000 |
| 3. | Monaro Highway corridor | N/B | 700 | $14,000 |
| 4. | Barton Highway / Northbourne Avenue corridor | S/B | 600 | $12,000 |
| 5. | Canberra Airport to Civic corridor | W/B | 600 | $11,000 |
| 6. | Athllon Drive / Commonwealth Avenue corridor | N/B | 600 | $11,000 |
| 7. | Gungahlin Drive corridor | S/B | 500 | $9,000 |
| 8. | Kingsford Smith Drive / William Hovell Drive corridor | S/B | 500 | $9,000 |
| 9. | Belconnen Way / Barry Drive corridor | E/B | 400 | $7,000 |
| 10. | East-west corridor via Hindmarsh Drive | E/B | 300 | $6,000 |
| PM peak | | | | |
| 1. | Parkes Way / Tuggeranong Parkway / Drakeford Drive corridor | S/B | 800 | $15,000 |
| 2. | Canberra Avenue corridor | E/B | 800 | $15,000 |
| 3. | Monaro Highway corridor | S/B | 800 | $16,000 |
| 4. | Civic to Canberra Airport corridor | E/B | 600 | $12,000 |
| 5. | Commonwealth Avenue / Athllon Drive corridor | S/B | 500 | $9,000 |
| 6. | Northbourne Avenue / Barton Highway corridor (N/B) | N/B | 500 | $10,000 |
| 7. | Gungahlin Drive corridor | N/B | 400 | $7,000 |
| 8. | William Hovell Drive / Kingsford Smith Drive corridor | N/B | 400 | $7,000 |
| 9. | East-west corridor via Hindmarsh Drive | W/B | 300 | $6,000 |
| 10. | Barry Drive / Belconnen Way corridor | W/B | 300 | $5,000 |

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

Source: Veitch Lister Consulting (2019)[230]

**Figure 127:** ACT and Queanbeyan most congested roads (total vehicle delays), 2031 AM (left) and PM (right) peak



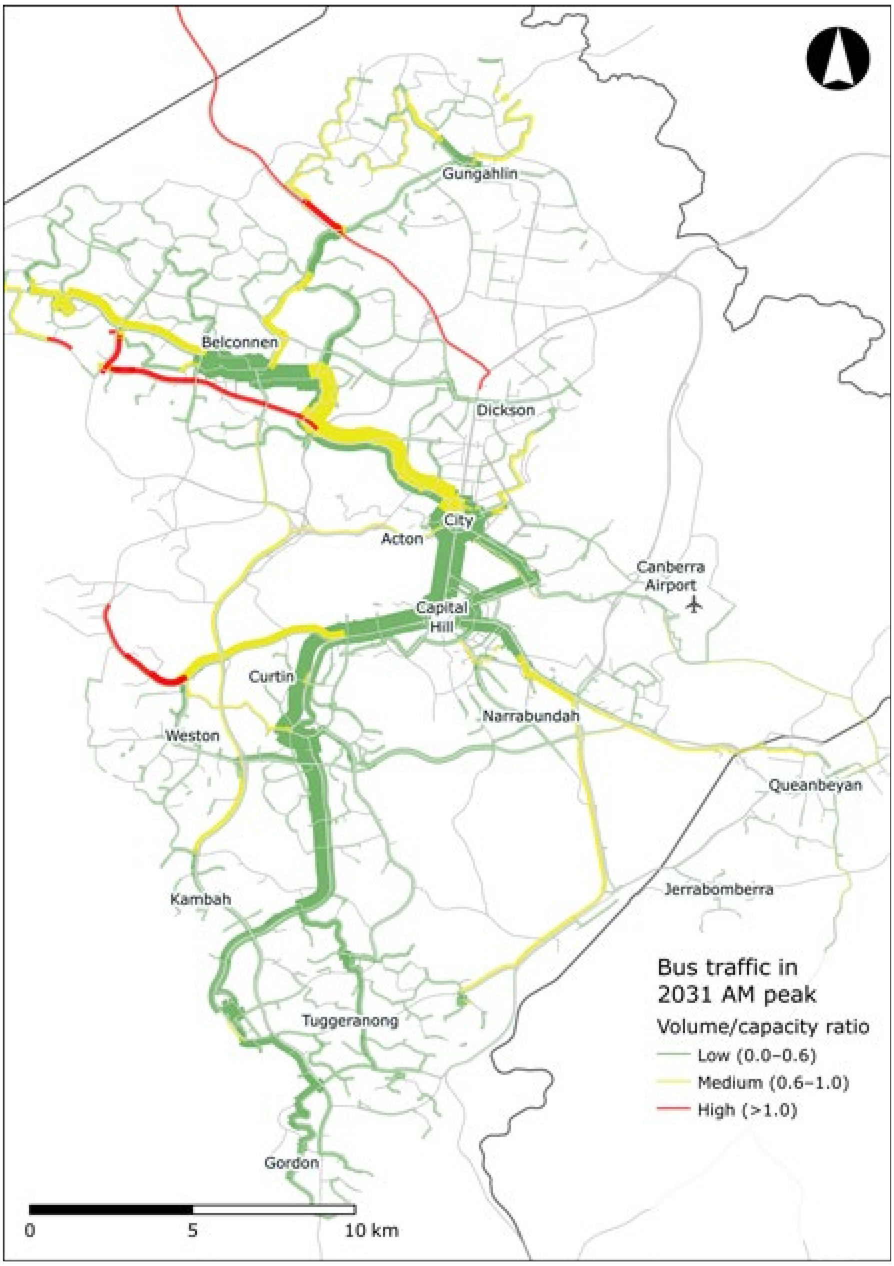

Source: Veitch Lister Consulting (2019)[231]

As a result of heightened demand, the region's bus network is forecast to become increasingly crowded (Figure 128). Services along John Gorton Drive near Molonglo, Belconnen Way and some routes in outer Belconnen, in particular, are expected to exceed crush capacity by 2031. Higher levels of crowding than in 2016 are also forecast for commuters travelling by bus on the Monaro Highway, Canberra Avenue (between the city and Queanbeyan), Tuggeranong Parkway and on the local road network in Gungahlin. These outcomes will occur as a result of strong population growth in outer areas, and employment growth in Canberra's urban centres, not being matched by an increase in the frequency and capacity of public transport services.

Decreased bus patronage is forecast on Northbourne Avenue in the 2031 scenario as a result of passengers using the Canberra Metro light rail. Small decreases on other routes into Dickson and Lyneham in Canberra's north-east will result from the associated realignment of bus routes.

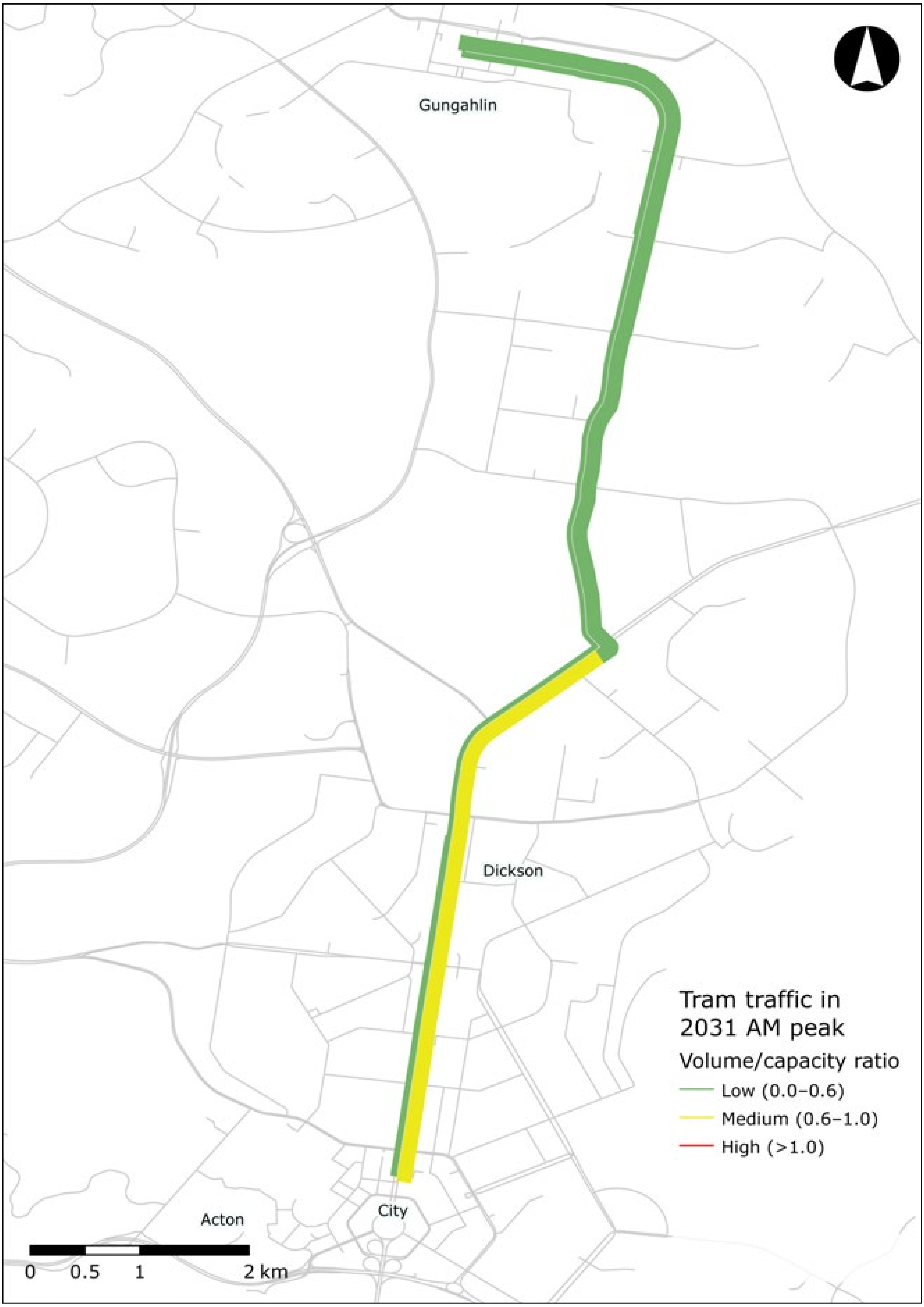
The Canberra Metro light rail will provide access to the CBD for residents in Canberra's northern suburbs. The light rail is forecast to attract significant patronage, with particularly heavy usage predicted close to Civic. Between Gungahlin Place and Phillip Avenue light rail users can expect low levels of crowding in 2031. However, between Phillip Avenue, Dickson Interchange and Civic, passengers can expect moderate crowding as more citybound passengers join the service closer to the CBD, including those who transfer from buses at the Dickson Interchange (Figure 129).

**Figure 128:** ACT and Queanbeyan weekday bus passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[232]

**Figure 129:** ACT and Queanbeyan weekday light rail passenger volume / capacity ratio, 2031 AM peak




Source: Veitch Lister Consulting (2019)[233]

## Findings

- The 2019 Audit forecasts that the annualised cost of road congestion for the ACT and Queanbeyan will grow from approximately $289 million in 2016 to $504 million in 2031. This is 28% lower than the 2031 forecast cost of road congestion in the 2015 Audit.
- Roads connecting Canberra to western and north-western development areas are expected to become increasingly congested by 2031.
- Residents of the ACT and Queanbeyan will spend more time in traffic and crowded public transport by 2031.
- By 2031 drivers on the region's worst-affected routes are expected to spend half their journey time in congestion.
- Despite road improvements, congestion on Gundaroo Drive will increase due to population growth.
- Congestion is expected to increase on roads connecting Queanbeyan with Canberra's centre.
- The region's bus network is forecast to become increasingly crowded, with some parts of the network exceeding crush capacity.
- The construction of the Canberra Metro light rail will improve travel between Canberra's city centre and the north, however by 2031 peak crowding can be expected close to the CBD on this line.

## 10.5 Transport decisions impact access to jobs and services

### Hospital access in the ACT and Queanbeyan region – by car and public transport, in 2031

Access to critical healthcare is measured by the travel time to their nearest public hospital, or hospital with an emergency department, by car versus public transport (Figure 130).

Access to public hospitals in Canberra is significantly faster by car than by public transport. In 2031, the average travel time to a public hospital by car in the ACT and Queanbeyan was 12 minutes, a small increase from 2016.

By public transport, the average time to a public hospital is forecast to be 48 minutes in 2031, three minutes longer than in 2016. This is partly due to the very long travel times modelled (in the absence of information on the location of new hospitals or the provision of public transport links) for the residents of fringe areas including Molonglo Valley. Residents of North and South Canberra, and Woden Valley, are forecast to have the shortest public transport travel time of around 30 minutes.

### Access to childcare and schools in the ACT and Queanbeyan region – by car and public transport, in 2031

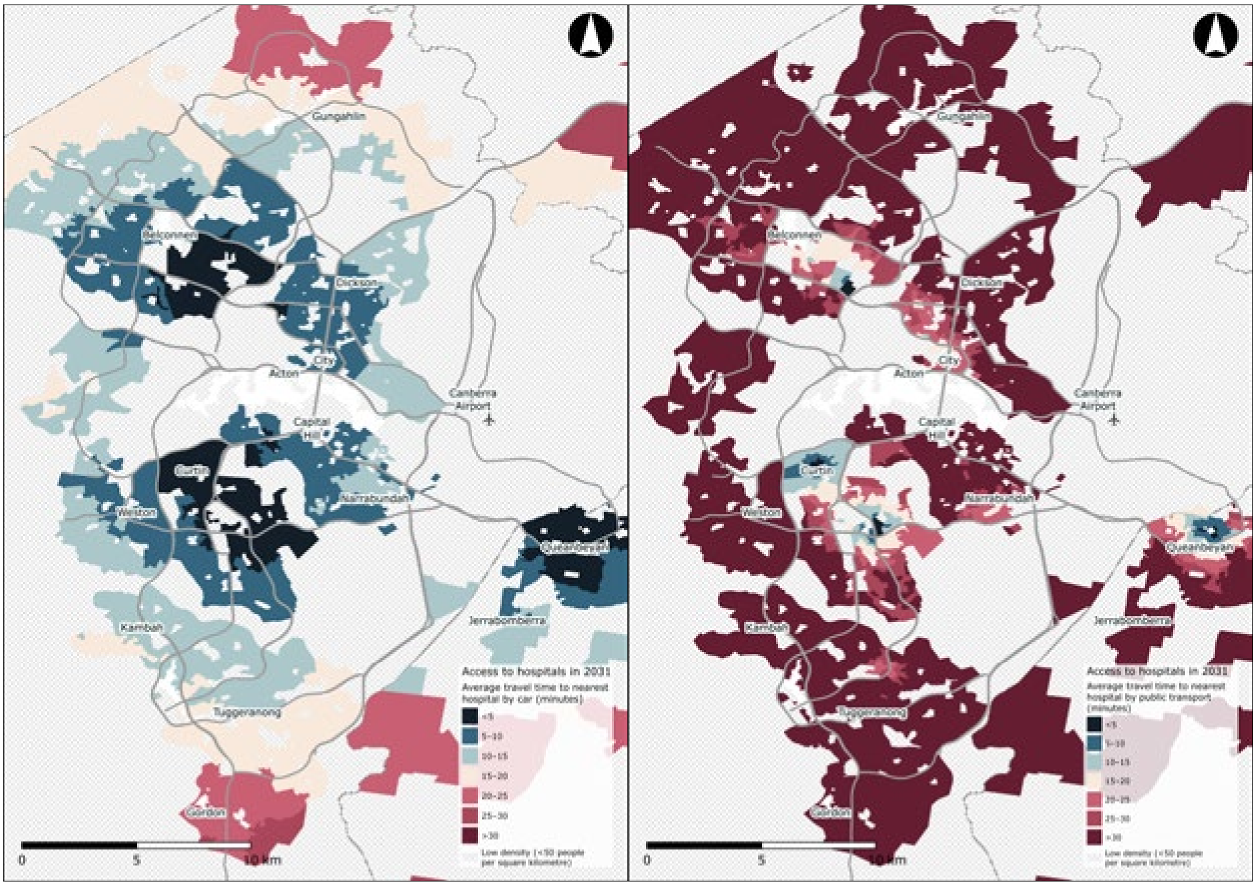
The average resident of the ACT and Queanbeyan region with access to a car can reach childcare services, public primary schools and public secondary schools within a five-minute trip in 2016. This is expected to extend to a six-minute trip by 2031 (Figure 131, Figure 132 and Figure 133).

For residents without access to a car, travel times are significantly longer on public transport. In 2031, forecast travel times generally average just over 25 minutes for childcare and public primary school services, and over 30 minutes for public secondary schools. These travel times are predicted to have increased from 2016.

While public transport may offer a realistic alternative for residents of the region's central areas, this is not the case for outer areas. Residents of Canberra East, Queanbeyan and Molonglo Valley are expected to approach 50 minutes of travel time, reflecting the limited public transport service improvements assumed for these regions compared to population growth.

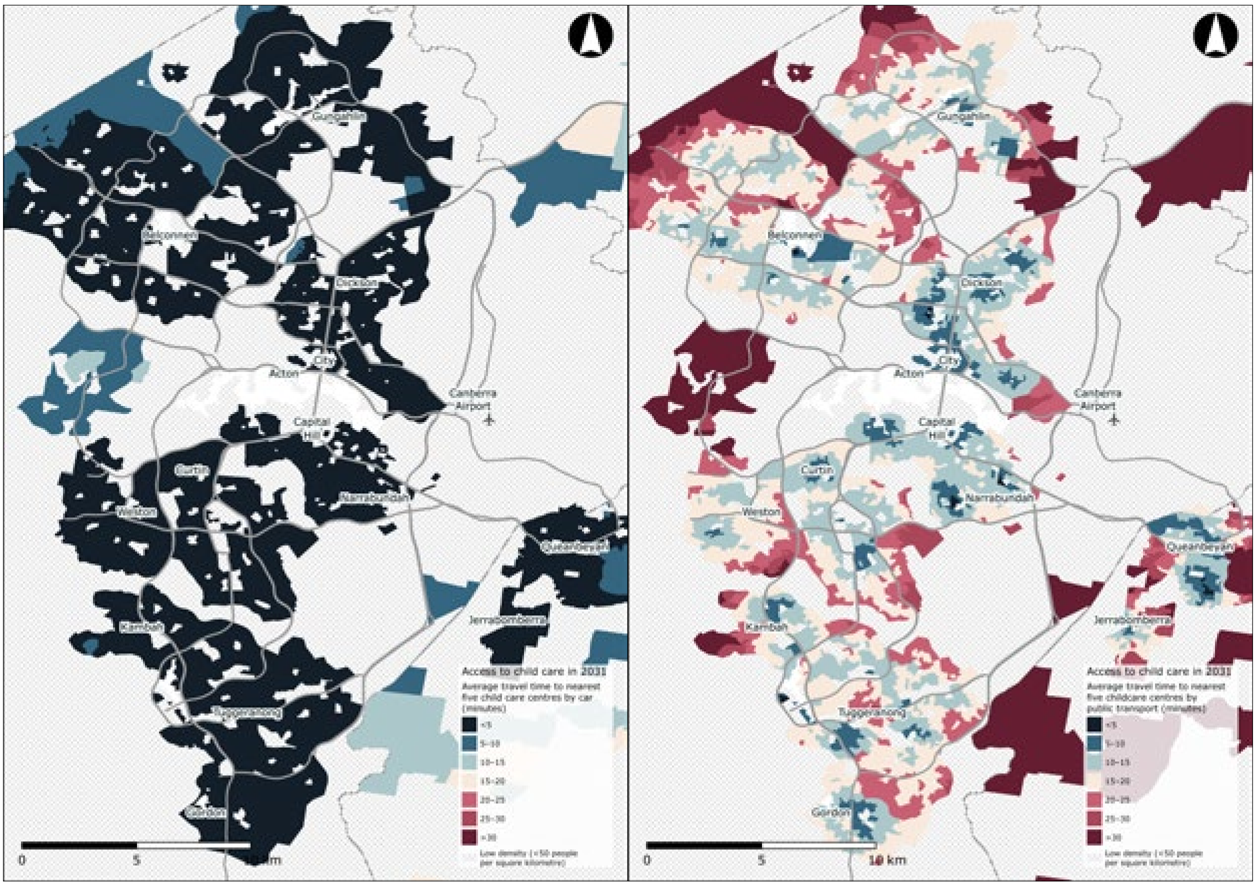
In contrast, public transport access to local social infrastructure in North and South Canberra, Tuggeranong and Woden Valley is forecast to improve slightly by 2031, reflecting improved bus service frequencies provided by an integrated public transport network.

**Figure 130:** ACT and Queanbeyan average time to nearest hospital by car (left) and public transport (right), 2031 AM peak



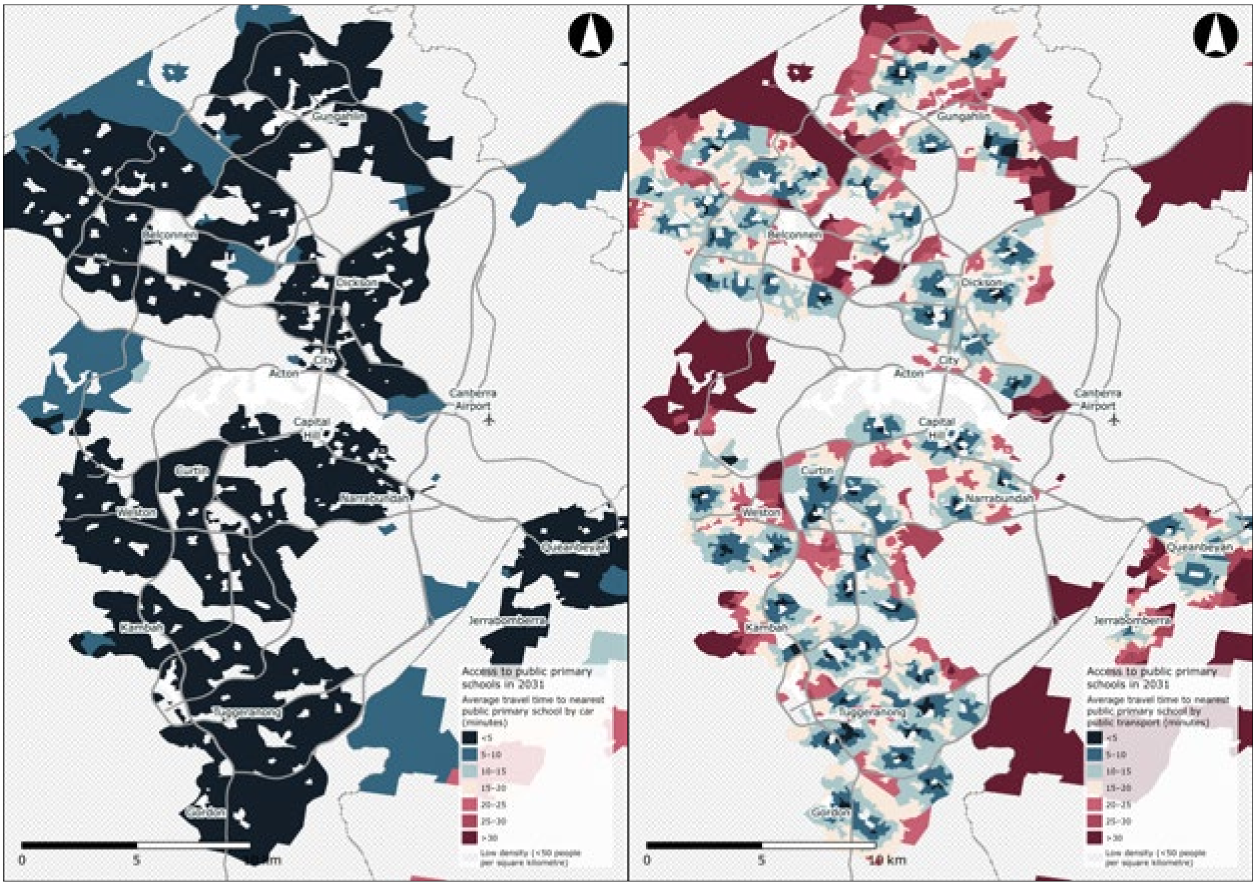

Source: Veitch Lister Consulting (2019)[234]

**Figure 131:** ACT and Queanbeyan average time to nearest five childcare centres by car (left) and public transport (right), 2031 AM peak



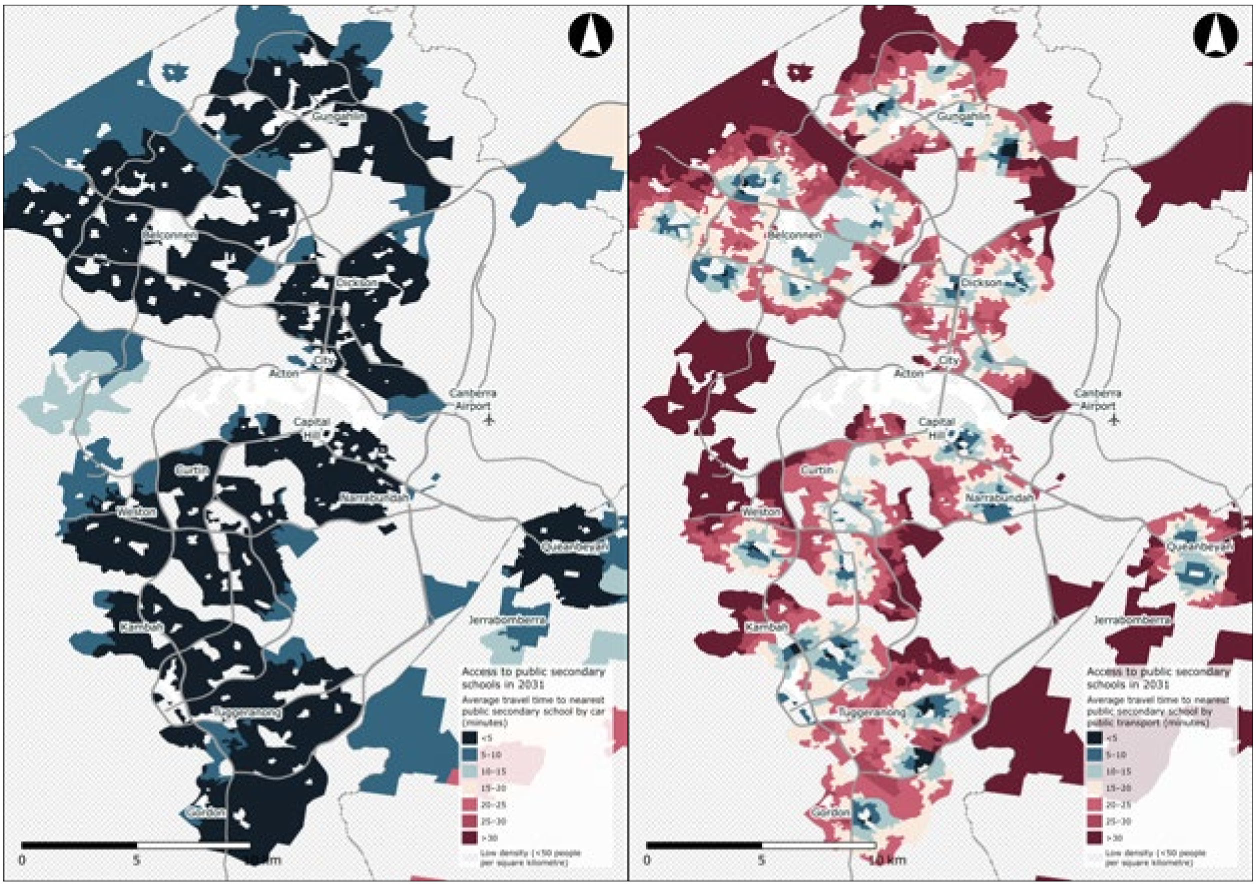

Source: Veitch Lister Consulting (2019)[235]

**Figure 132:** ACT and Queanbeyan average time to nearest public primary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[236]

**Figure 133:** ACT and Queanbeyan average time to nearest public secondary school by car (left) and public transport (right), 2031 AM peak




Source: Veitch Lister Consulting (2019)[237]

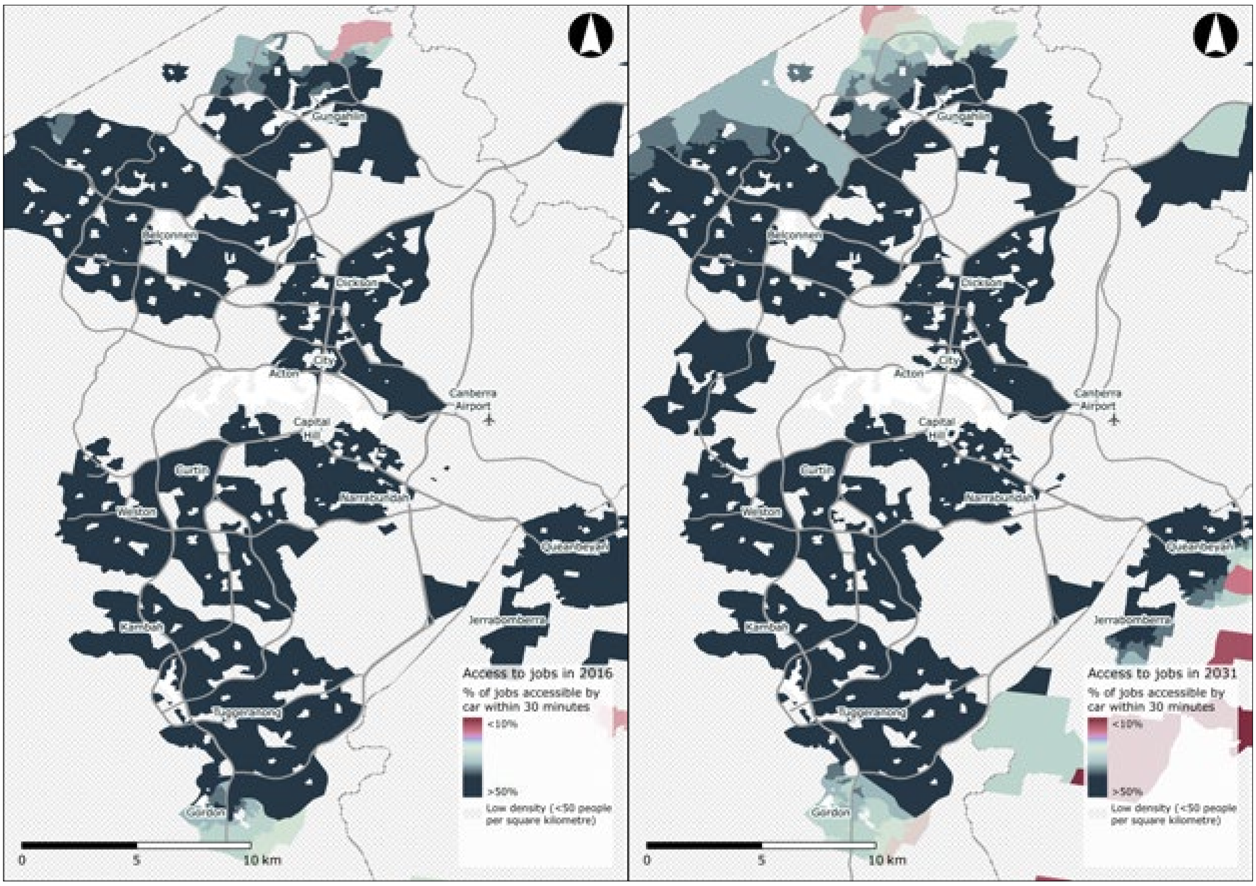
## Access to jobs in the ACT and Queanbeyan region – by car and public transport, in 2016 and 2031

Employment accessibility has been measured as the percentage of jobs that can be reached by ACT and Queanbeyan residents within 30 minutes of their home by car (Figure 135) and by public transport (Figure 135) in the two modelled years.

Access to employment across the ACT and Queanbeyan region differs based on where a person lives and which mode of transport they opt for. Given the region's smaller geographical area compared to other Australian cities, as well as its well-developed road network, most jobs can be reached within a 30-minute drive from all urban areas, with some exceptions in outer suburbs.

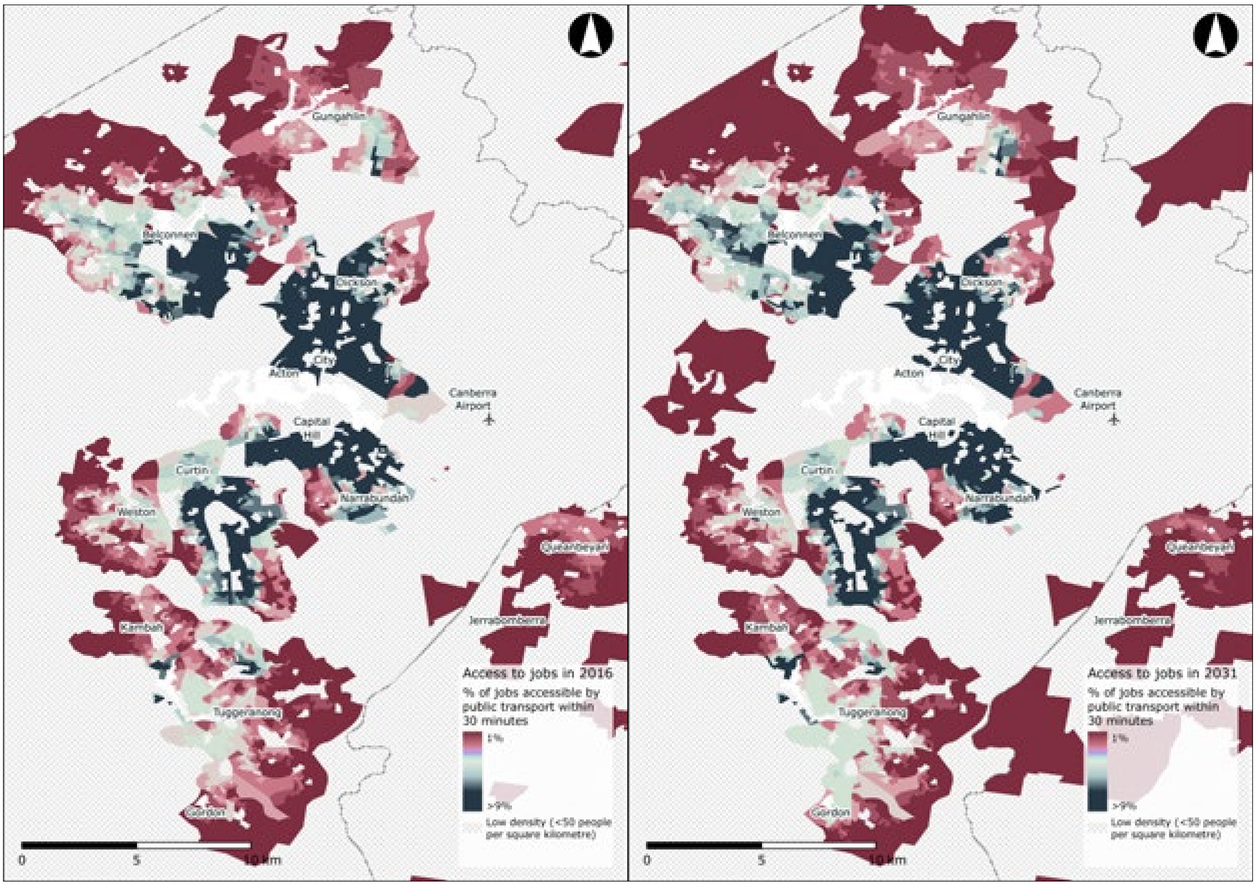
Job accessibility by public transport is forecast to be relatively stable, staying low, between 2016 and 2031. Many residents will continue to be unable to reach a significant choice of jobs within a 30-minute public transport commute. Residents of inner areas such as North and South Canberra, as well as Woden Valley and Belconnen, are forecast to have better access than those in outer ACT suburbs and Queanbeyan.

**Figure 134:** ACT and Queanbeyan access to jobs by car, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[238]

**Figure 135:** ACT and Queanbeyan access to jobs by public transport, 2016 and 2031 AM peak




Source: Veitch Lister Consulting (2019)[239]

## Findings

- Travel by car will continue to be the quickest means to access the region's social infrastructure in 2031, especially for residents of newer areas.
- Residents of Queanbeyan and outer ACT suburbs have significantly poorer access to jobs by public transport than the residents of inner suburbs, and this will not change over the next 15 years.

11

# Future of modelling

## At a glance

This section of the report considers the commonly used, four-step approach to strategic transport modelling and the scope and limitations of existing models.

This section goes on to examine the potential to improve strategic models through:

- The consideration of new mobility and the implications of new technology
- Improved data accuracy and consistency
- Use of scenarios to look beyond averages
- New and emerging data sets
- Enhancing model capability.

## 11.1 Our approach to modelling

The Zenith model used for the *Australian Infrastructure Audit* is consistent with contemporary best practice in terms of strategic transport models. However, like any modelling exercise, there are limitations to the accuracy of its findings and their application.

Transport models need to adapt to changes in the way that people live, work and move. New technology and data present opportunities to improve the way that infrastructure and services are planned for communities. The following sections discuss some of the current limitations of strategic models and explore opportunities for developing the next generation of predictive models.

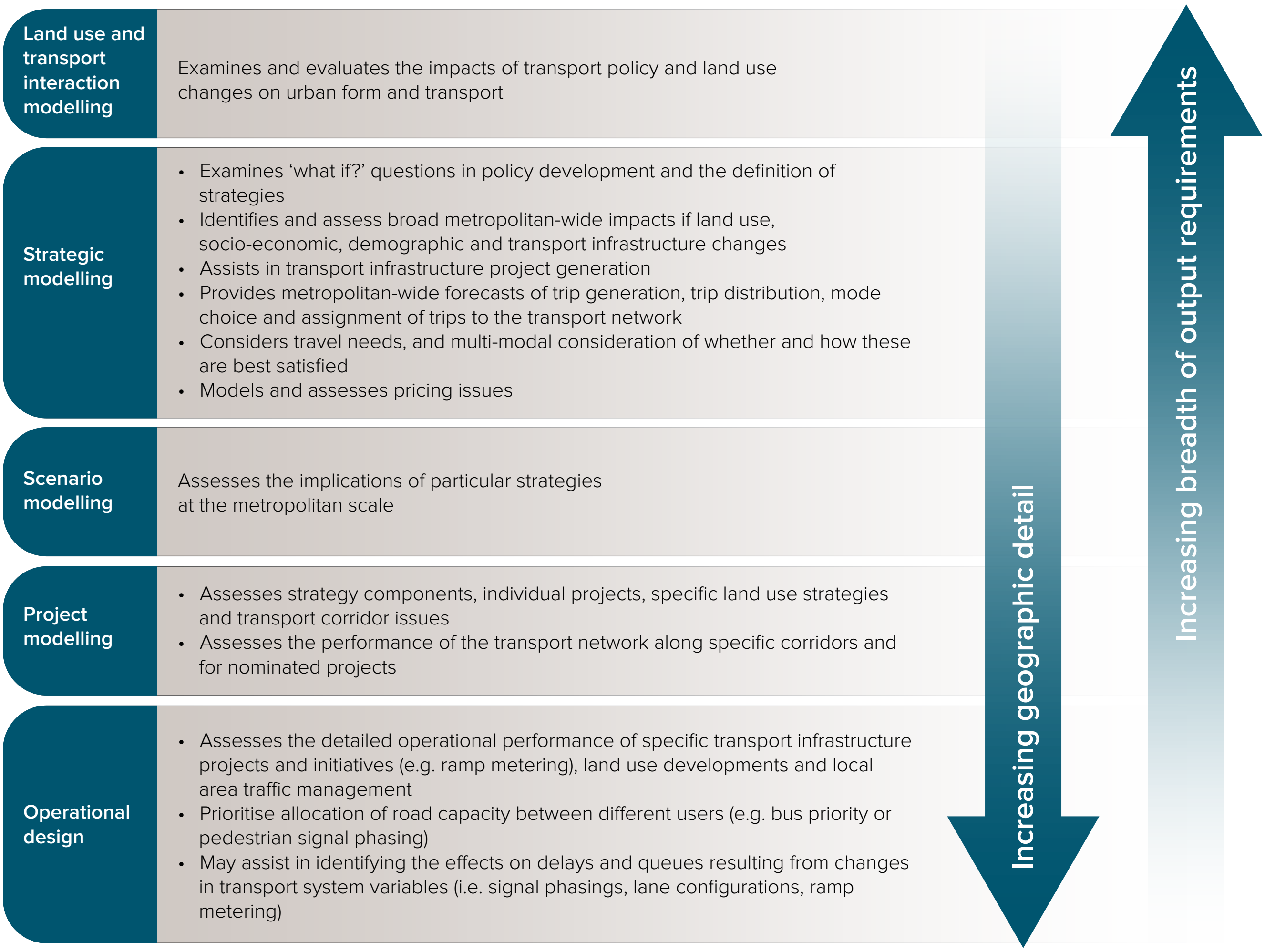
## 11.2 Overview of strategic models

Transport models consist of demand models and supply models. Demand models predict travel patterns and demand for infrastructure and services, while supply models simulate passenger and vehicle flows and determine their level of service.[240] Various types of models are used by transport planners (Figure 136). These include strategic metropolitan-scale transport models (referred to hereafter as strategic models) which estimate levels of travel activity within a metropolitan area, and models that consider demand within smaller geographic areas, including the impacts of changes in infrastructure, services and operations for individual modes (often referred to collectively as 'project-specific' models). This discussion focuses on strategic transport models – a best practice tool used by governments across Australia and internationally for evaluating transport policy and planning transport infrastructure and services.

Strategic models, including the Zenith Model, tend to follow a consistent methodology, often referred to as 'four-step' modelling. Strategic transport models are used for long term strategic planning and to assess projects and services. Strategic models are also used for a more detailed analysis of project proposals in cases where the development of more customised, project specific applications to model smaller parts of a wider network, a project, bus route or a road corridor (such as mesoscopic traffic models) is not available. This approach is not ideal. Microsimulation, or operational design, models provide an even more granular perspective of a network, focusing on an intersection or localised road link.

Strategic models therefore have a critical influence on the infrastructure planning process. The following sections discuss some of the main limitations of strategic models and established processes of modelling transport demand and simulating network flows. Advances in technology and data provide opportunities to overcome these challenges and gain new insights into travel behaviour.

**Figure 136:** The hierarchy of transport models and their uses




Source: Australian Transport Assessment and Planning (2016)[241]

## 'Four step' modelling

The 'four step' model is a commonly used type of strategic transport model. The model involves the following steps:

**1. Trip generation** estimates the number of trips that originate in particular spatial zones through land use, population and economic forecasts.

**2. Trip distribution** draws links between trip origins and destinations, forming an origin-destination (OD) pattern or matrix of trips. This pattern is based on the logic that a person is most likely to preference travel to nearby areas of high activity (e.g. services and employment opportunities) rather than low activity.

**3. Modal split** predicts the travel modes used to complete origin-destination trips, based on trip purpose. The characteristics of the trip maker, the trip itself and travel mode are considered in this step.

**4. Trip assignment** allocates trips by purpose, mode, origin and destination to a certain transport route and simulates these trips on the network and determines the level of service. This provides an indication of the likely distribution of travel and traffic across the network.

Steps 1 through 3 are part of the demand model while Step 4 describes the supply model. Feedback from the supply model in terms of generalised travel costs (travel times, congestion, toll costs, crowding, etc.) influences travel demand in Steps 1 through 3.[242]

Tour-based modelling, where travel events are defined as starting in one location and returning to the same location, is an alternative to the four-step modelling process, which generates individual trips.[243] Tour-based modelling is a step towards activity-based modelling, which focuses more on how demand arises from the desire for activities[244] (see 'New types of models' section).

Source: Australian Transport Assessment and Planning (2016).[245]

## 11.3 Scope and limitations of existing models

Modelling for the *Australian Infrastructure Audit* provides a perspective on future network performance that helps to allow the comparison of changes in network design and operations. These models provide an insight into the future to inform decision making and to provide the basis for the comparison of different reforms or investment decisions.

However, like all models Infrastructure Australia's modelling was subject to a series of limitations that are common to most contemporary transport models used in Australia. For instance, the modelling was undertaken for a typical weekday and assumed no unplanned disruptions. This meant that congestion was likely to be underestimated, as very few days have no incidents on the transport network. In addition, peak spreading or activity rescheduling could not be tested in the modelling. This meant that trips could not be reallocated outside of the peak, despite high levels of congestion and crowding during the peaks and differential fares in some cities.

The modelling typically undertaking by Australian transport agencies also faces limitations. These limitations can include both access to accurate and consistent data inputs, and the capacity of models to extract insightful results. While large jurisdictions currently operate complex, well-developed models, access to skilled and experienced modellers can be a constraint. The necessary knowledge and experience of models is a critical component of optimising their use and interpretation of results.

Access to relatively modest resources to improve model use is often not adequately prioritised, thereby compromising decisions on multi-billion dollar projects with multi-generational impacts.

Critical to improved decision making must also be an openness to current model capabilities and limitations, as well as the opportunity for enhancement.

As a key component of infrastructure decision making, the limitations in the capacity of transport models also naturally also limit the capacity of infrastructure planners to reach informed, reliable conclusions about future transport network performance. Infrastructure Australia has therefore identified a significant opportunity to improve infrastructure decision making by strengthening existing models and evolving them to respond to future uncertainty.

### Focus on network impacts

Over many years, strategic models have been a foundational decision-making tool used by transport agencies for metropolitan transport planning. Fundamentally, they are designed to predict the network flows of people and vehicles between different geographic zones. These models have been designed to meet the needs of transport agencies in their traditional role as network planning authorities, focused on planning and building infrastructure to meet demand.

Strategic models are often used for testing the point at which demand for transport exceeds capacity during peak periods. After the initial step of estimating the total number of trips by origin and destination, that demand is then manually distributed across different time periods (usually split into AM peak, inter peak, PM peak and off peak) as an input to the model.

This is useful for ensuring there is sufficient network capacity to cope with peak demand, and for determining network pinch points and crowding caused by too many people using a particular road or service. Strategic models are particularly useful for estimating aggregate changes in travel activity on networks, such as changes in fuel prices, transport costs or significant changes to the network. Key metrics generated by strategic models include traffic/passenger volume, traffic/passenger volume to capacity ratio, delay hours and average speed.

The ability to test future changes in networks and services against a base case or 'without project' scenarios has made these models well suited to use in cost benefit appraisal (CBA) of major projects.

The models provide a consistent means to assess the network wide impacts of changes in projects and services (e.g. new and improved network links, increased services), controlling for expected future changes in population, workforce and factors that influence decision making. The models have also allowed planners to test the implications of changes in the growth and distribution of people and jobs on the use of transport networks.

For appraisal purposes, it is necessary to compare model outcomes where the model and demand and supply models are in equilibrium.[246] This is achieved through iterative uses of the model with varying inputs, allowing feedback on its sensitivities to understood and tested, until a satisfactory level of convergence is reached.[247]

These measures are helpful for network planning and project business cases, but do not always provide insights into the customer experience of using transport or to the detailed performance of individual projects or infrastructure assets.

For instance, the level of service experienced by travellers during rush hours is often not accurately reflected in model outputs due to the fact that many strategic transport models (including Zenith) do not simulate queues, such as waiting in front of traffic lights, in heavy congestion on motorways, or when boarding public transport. Typically, this type of behaviour is produced as an output from project (meso) or link (micro) models and is then fed into the strategic model as a fixed (static) input.

Other relevant level of service outputs may also be missing. For example, the reliability of arrival times often ranks as the most important attribute of travel from the user's perspective,[248] but is not considered in most strategic models because they generally model a normal weekday, with no unplanned disruptions. The importance of travel time reliability is increasingly being considered a key attribute of assessing transport networks[249] and various researchers and transport agencies have an interest in how reliability can be incorporated into models.[250] Although forecasting travel time reliability is challenging,[251] this is an opportunity area for future modelling, and could allow decision makers to develop new kinds of solutions to meet demand, in addition to increasing infrastructure capacity.

Another opportunity is to better model customer behaviour, and in particular peak spreading and activity scheduling. Strategic models are able to allocate demand within a time period by mode, however unless specific time of day choice models are included, models do not account for how people may change their time of travel in response to policy (such as differential fares), infrastructure constraints (such as crowded services or incidents), or if they decide not to travel (for instance working from home on a rainy day).[252]

## Focus on work trips and weekdays

Most strategic models have a focus on work trips given these comprise a large portion of total travel in most metropolitan areas.

Non-work trips generally focus on travel which is relatively predictable, and based on observed patterns and available spatial data e.g. education and shopping. Remaining trips are often classified into a residual category of 'other'. As the way that people live, work and move evolves in our cities, there is an opportunity to expand strategic models to consider other periods and a greater diversity of activities.

The application of strategic models is generally focused on weekday peak hour journeys as they were historically the times of greatest congestion on the network. This approach also allows the complexity of models to be reduced, typically to focus on a small period of time, traditionally AM peak, such as 7–9am. This approach provides little opportunity to consider peak-spreading and other forms of journey avoidance during congested periods.

Hence transport planners have generally assumed that new infrastructure and services provided for the peak will be sufficient for meeting long term demand across the full period of the day and across the week.

However, growth in weekend travel has led to increasing congestion on Saturdays and Sundays, especially key holidays. In Sydney, weekend transport demand increased by 68% between 2013 and 2016.[253] Furthermore, in 2016, weekend travel time delays across Australia and New Zealand accounted for between 15% and 25% of total weekly travel time, with the slowest and most delayed period around midday.[254] Customers in major capital cities are increasingly frustrated with congestion on weekends and expect policy makers to take action to address it.

Modelling weekends and holidays can be more complex than weekdays, as a result they are also more difficult to predict. A lack of data compounds these issues, with sample sizes of weekend travel activity from Household Travel Surveys are usually low compared to samples of weekday/peak period travel. Household travel surveys have historically focused on trips made 'on an average weekday', rather than on weekends.[255]

The focus of models on weekdays and commuting has obvious consequences for transport planning requiring the use of tailored project models to assess the impacts of projects designed to cater for weekend or holiday impacts. This can be particularly relevant for major event impacts on transport networks.

More dynamic forms of modelling could allow for greater consideration of the performance of the network throughout the day and across weekends and weekends. This approach, while more complex, could provide the opportunity for the performance of the network under a broader range of circumstances to be understood, including the compounding impacts of congestion across the day.

## 11.4 New mobility and the implications of new technology

Most strategic models assume that in the future, people will behave in similar ways to today. This is common practice in forecasting and reflects the lack of information modellers have about how society will change. However, with technology increasingly changing the way that people travel, assumptions about future customer behaviour and services are becoming more important.

Mode choice in most major strategic models is usually limited to traditional modes of transport rather than newer ones.[256] However, advances in technology are changing the way that people travel and have enabled new kinds of transport services. Car sharing, ridesharing, and on-demand transport services are changing the way Australians move around our cities today, the cost to travel and could potentially alter long held ideas of car ownership. These new modes have the potential to reduce congestion and improve accessibility however they may also lead to an increase in the use of cars as rideshare and car share reduce their per journey cost. Technology also enables working from home[257] and shopping online,[258] which directly affects travel demand.

There is an opportunity to consider the role that new transport services, as well as travel replacements, can play when planning major projects and services, either through new models, or through enhancements to existing models.

## Changes in transport services

Transport service and network providers such as Uber are changing Australian cities by offering new forms of ridesharing, or more appropriately ride-hailing, services. While in February 2015, these services accounted for 10% of taxis, hire cars and rideshare services, by February 2017 this had increased to 37%.[259] It is estimated that Uber now delivers approximately 14.5 million trips per year across Australia in its low-cost ridesharing option UberX.[260]

Car share schemes have become increasingly popular in densely populated parts of Australian cities, made attractive as a result of increasing congestion and limited parking availability. It has been estimated that the global market for car sharing grew 27% per annum between 2014 and 2019.[261] Technology is presenting opportunities for the expansion of the car sharing market by allowing schemes to be better integrated into our cities. For example, in 2012 Brisbane became the first Australian city to integrate car sharing services with public transport, providing car-share members with much greater convenience.

Technology has also enabled trials of 'on-demand' public transport services, offering more flexible alternatives of improving accessibility within low density urban areas and services which bridge the gap between mass transport and point to point services. From October 2017, the NSW Government has conducted trials of on-demand bus services across Sydney. Patronage has grown from an initial level of less than 200 trips in the first month with the introduction of the first pilot service in Bankstown, to over 27,000 trips in November 2018 across nine service providers in NSW.[262] In Brisbane, Demand Responsive Transport trials are currently being carried out across selected suburbs of the Logan City area while in regional South Australia, Dial-A-Ride, on-demand services have been established for more than a decade.

While rapidly growing, it is crucial to consider the overall role of these services in the context of total transport movements. The 14.5 million trips made nationally using UberX each year pale in comparison to use of mass public transport which in Greater Sydney alone supported more than 750 million trips in 2017–18.[263] Car share membership levels in the City of Sydney are now substantial in absolute terms but still a relatively modest percentage of the 233,000 people living in that area.[264] The 27,000 trips made using on-demand bus services in November 2018 compares to over 26 million bus trips across the greater metropolitan area for the same period. However, as these services grow in importance it will be important to understand how they impact on the number and type of trips undertaken.

In the medium to long term, connected and automated vehicles are also likely to change the way we move around and within cities and regions.

Major trials of automated vehicles are being progressed by mobility service providers, car manufacturers and other technology providers in cities across the world. All Australian mainland states and territories now have trialled connected and automated vehicles at level 4 operations. It is estimated that the global autonomous driving market will grow significantly over the next few decades, leading to global revenue of USD $173 billion by 2030.[265] While the long-term implications of automated vehicles are being debated, change is certain. There is an opportunity for modellers to develop and enhance the way automated vehicles are modelled, and the impact they could have on our transport networks.

For most strategic models, 'model estimation' – the process of determining model parameters and coefficients based on survey and other input data – occurs on an irregular basis and usually involves updating existing variables rather than making fundamental changes to incorporate new ones. As a starting point, regular re-estimation of model parameters and updates to variables in response to observed changes in travel behaviour, can allow transport models to evolve and the impact of technological change to be better understood. Given that revealed preference data (observations in the current transport system) are not yet available with respect to new transport modes, understanding preferences towards future transport will require the use of stated preference techniques that analyse responses to hypothetical scenarios.[266]

## 11.5 Improved data consistency

### Land-use data – practical challenges

Developing and maintaining strategic models is complicated and involves combining data from many different sources. Strategic transport models rely heavily on population and employment forecasts (generally referred to as land-use data) as input data. Strategic transport models are sensitive to land-use data and changes in assumptions can have a significant impact on model outputs.[267] Changes in population and employment projections resulted in notable changes in outputs from modelling conducted for the 2015 and 2019 Audits.

Preparing land-use data is a time-consuming process and usually requires breaking down population and employment projections for large spatial zones into smaller units to allow models to provide a more comprehensive picture of transport movements. The number of zones used in strategic transport models across Australia varies according to the size of the metropolitan area and scope of the model, ranging from several hundred to several thousand.[268]

The process and timing for updating models is heavily influenced by when land-use data is prepared and released by other agencies including the Australian Bureau of Statistics (ABS) and demography units within planning agencies. Agencies that generate land-use data projections may not need to break data into smaller units meaning that the responsibility for developing land-use models may fall to transport and infrastructure planning agencies. With some exceptions, most agencies do not publish underlying land-use data sets.[269] The frequency of updates to land-use data can also be a challenge. In modelling undertaken for the 2019 *Australian Infrastructure Audit,* some underlying land-use data sets had been updated to reflect the 2016 Census while other data sets pre-dated this.

Current practice generally involves land-use data sets being prepared by government agencies. While consistency of use is important, external providers present an opportunity to provide strategic models with more regularly updated data, similar to the way in which there are multiple groups which provide GDP and other economic forecasts. Provided agencies adopt a common case which is used consistently in government planning, data from external providers could provide an opportunity for achieving greater accuracy when forecasting demand through allowing the definition of a range of scenarios. The Council of Australian Governments (COAG), through the Inaugural Treasurers Forum on Population has identified the need for improved data accuracy and consistency, subsequently forming the Data and Forecasting Working Group.[270]

### Making assumptions more transparent

Given the complexity of this process and the involvement of multiple agencies, ensuring consistency of land-use data and key assumptions in modelling can be a major challenge. A key issue is what, if any, assumptions are made in relation to future policies and projects and whether predictions are forecasts (predicting the future based on an expectation of what will happen) or projections (future values if existing patterns and trends continue).

As an example, population forecasts may assume future changes in the distribution and rate of growth as a result of land-use policy (e.g. encouraging development around a particular corridor), whereas projections will assume patterns based on past trends without consideration of policy.

Within the context of this report, the variation between the Queensland Statisticians projections and ShapingSEQ's forecasts are discussed on page 84.

Projections and forecasts may be produced separately by different government agencies for valid reasons and used concurrently for planning purposes. For example, projections may be used within an intergenerational report produced by a treasury department for the purpose of considering the long-term sustainability of current projects and policies. A regional land-use plan, on the other hand, may assume the implementation of current policies and projects to increase future population and employment growth within specific areas.

These data sets will obviously have vastly different implications for travel demand. A data set which assumes future transit-oriented development around a particular road corridor or train line may produce lower estimates of future congestion compared to data sets that assume fewer people live near public transport services. Similarly, if population is assumed to increase in a particular area, transport services in that area are likely to need to be upgraded (and these upgrades may have been assumed when the population forecasts were being developed). This highlights the importance of ensuring that the key assumptions used to develop population forecasts are publicly available.

The essential requirement is to ensure clarity about which type of data is used in a model informing a business case or policy and that preferably a consistent, common projection is used as one scenario to allow different approaches, projects or reforms to be compared. The distinctions between similar data sets can quickly become lost during the process of developing policy and planning projects if documentation is limited and project managers are under pressure to use data sets which are most readily available at the time of planning.

Related to this issue, project development teams often identify issues with land-use projections which do not incorporate future effects of projects that they are developing. Ignoring these effects could result in underestimating the benefits of a project, meaning planners often revise land-use projections to incorporate these impacts. Effective governance and documentation are needed to prevent inconsistencies and ensure that modifications and assumptions are formally adopted within future land-use data sets at an appropriate time.

### Common planning assumptions

In NSW, a set of common planning assumptions have been prepared to collect and document the fundamental assumptions that underpin the development of key government strategies. This cross-agency initiative is aimed at ensuring the alignment and consistency of assumptions in strategies and plans prepared by different NSW government agencies and departments. It was established to minimise the risk of some agencies using different assumptions and projections for service and infrastructure planning – a situation which could contribute to suboptimal decision making.[271]

Source: Bureau of Infrastructure, Transport and Regional Economics (2018)[272]

## 11.6 Using scenarios to look beyond averages

### Making scenario and sensitivity testing easier

Scenario modelling is the process of investigating and evaluating different possible events in the future. Scenario modelling is an effective way to consider the potential effects that social and economic changes could have on the way that people live and work. This can help us understand the possible impact that new technology and transport services can have on the movement of people and the need for future infrastructure, how changes to housing and jobs can improve cities, and possible outcomes of future changes in the economy and key sectors such as health, education and the environment.

The use of models to demonstrate network performance under a range of scenarios can support better decision making. Better consideration of planned and unplanned events, ranging from the impacts of major periods of construction on network performance to the impacts of varying rates of population growth, changing consumer preferences and the impacts of technology.

While strategic models have the capacity to evaluate scenarios, there are practical limitations to the extent to which this can be achieved. Models were not necessarily designed with this purpose in mind. Major changes in behaviour and technology may be approximated by changing certain underlying assumptions and model parameters. For example, testing the possible impacts of connected and automated vehicles by reducing average headways between vehicles and/or increasing road capacities as a proxy for how such vehicles may operate.

Other changes in transport, such as the growth of on-demand services and Mobility-as-a-Service, may be much more difficult to consider within existing models. Crude scenario testing within existing models has value, but new types of models or separate modules may enable scenarios to be evaluated and reassessed on a regular basis.

Similar issues apply for sensitivity analysis which consider changes in factors which influence project design and investment decisions. With the pace of technological and geo-political change increasing, amending models to give better regard for uncertainty should be considered. Making simple variations in key assumptions, such as the population in each travel zone, the value of time and elasticities can provide significant insights for planning but is often an expensive and time-consuming process as it requires repeated re-runs of models.

## 11.7 New and emerging data sets

### New data sources can address gaps and supplement survey data

Most strategic travel models have been designed around household travel survey data. These surveys have played an important role in transport planning for a number of decades, providing detailed information on travel by households across metropolitan areas. These surveys are conducted at regular intervals for most major metropolitan areas. Survey samples usually align with spatial units and other key attributes of strategic models. Data is often combined across multiple years for the purpose of transport modelling.

While household travel survey data is essential for transport modelling and planning, surveys are very expensive, particularly for face-to-face data collection. Response rates for traditional interview-based surveys are declining in most countries, meaning that the cost per completed survey is increasing. A 2018 Australasian Transport Research Forum study of travel survey responses across 24 countries concluded that non-response was a significant issue.[273] Over 50% of study participants indicated an unwillingness to complete a survey regardless of delivery method.[274] The high cost of surveys inhibits annual data collection for many agencies and requires modellers to decide which aspects of travel are most important for the purpose of modelling. Data may provide a statistically representative picture of overall travel by households within a metropolitan area, but become less representative at finer spatial levels, or when looking at specific variables. Survey costs usually preclude the collection of statistically representative data on regional travel, which is one of the key reasons why most transport agencies do not have regional passenger transport models.

Advances in technology provide unprecedented insights into travel behaviour and opportunities to improve transport planning. Data from electronic ticketing systems represented a large initial step forward for most government agencies, providing vastly improved information on public transport use.[275] GPS/smartphone and other transactional and mobility data from telecommunications companies, app vendors, financial institutions and other sources can provide insights into aspects of passenger travel - such as the use of active transport and regional travel - which have been largely invisible to planners in the absence of time consuming and costly data collection. In the short term, these data sets can help to address gaps in survey data and/or reduce sample sizes needed for modelling applications. In the long term, these data sources could replace survey data altogether.

A barrier for using this type of data in forecasting is the level of manipulation required for it to be useable. Data is collected for a purpose other than transport modelling (e.g. billing a customer) meaning it offers insights into a highly specific part of transport use.

Many major government transport and planning agencies are now trialling the use of third-party transactional data sets. Commercialisation of these data sets is now advancing rapidly. Consideration will need to be given to regulators longer term regarding the ownership of this data and its potential for use. Innovative data sharing platforms and service providers are well established, allowing agencies to gain insights from multiple sources of linked data without compromising privacy requirements.

These data sets provide opportunities to improve existing strategic transport models and allow the development of new more customer-centric models.

## 11.8 Enhancing model capability

### Providing a customer-centric view of transport needs

Since the 1950s, trip-based models have primarily been used to model demand.[276] However, new technology and better data provide the opportunity to move beyond these conventional models to focus on the travel purpose and pattern (daily travel plan) of specific types of people. This new approach is often referred to as an activity-based model.

While trip-based models use origin and destination-based trips as the unit of analysis, activity-based models provide further insight, with trips being undertaken as part of a more comprehensive linked travel plan. Due to the additional detail, activity-based models typically use a day or week as the unit of analysis.[277] This approach theoretically allows the generation of more realistic outputs, however the quality of the outputs is highly reliant on the stability and performance of the model.

Activity models involve the generation of synthetic populations (households) which are then given activity-travel schedules, these are often known as daily travel plans.[278] These schedules provide linkages between trips, nature of the journey and duration of stay. By linking these features, the fixed and variable characteristics of a journey can be better understood and accommodated.[279] For instance, a journey to school may have a fixed time to ensure arrival for 9am, however the model of travel could vary based on whether a parent can accommodate the drop-off as part of their own time-critical journey to work.

The addition of these schedules gives activity-based models a more complex structure than traditional four-step models. These models therefore require significant longer run times and require additional microsimulations. As a result they may not converge to an equilibrium in practical applications.[280] Therefore, it is important to balance model realism with model stability.

While activity-based models are challenging and expensive to build, they hold the potential to more accurately discern how households and individuals make choices that drive activity and travel patterns than conventional trip-based models. Activity-based models are therefore generally considered to have a greater capacity to assess how travel behaviour might be affected by new transport projects or policies.

The use of models developed by private organisations varies by jurisdiction. Their use is often limited to strategic studies,[281] with in-house models sometimes favoured for project planning.[282] While having independent and consistent in-house models will continue to be important, in-house models should be viewed as just one of many decision-making tools that can be used to plan infrastructure and services. Greater contestability in modelling and advice, particularly during early stages of policy and project planning may improve the development of solutions and outcomes for customers. Economic appraisal guidelines can support this.[283] New types of partnerships and alternate models (e.g. open sourcing) may help government agencies maximise value for money and innovation while ensuring that they do not become dependent on single external model or vendors.

## Recent examples of activity-based models

### *KPMG Melbourne Activity and Agent Based Model*

The primary purpose of strategic models is to assess how travel behaviour and traffic flows might change in response to changes like new transport projects or policies. Traditionally, strategic transport models in Victoria use a trip-based approach, which considers the characteristics of individual trips.

The Melbourne Activity and Agent Based Model is a customer centric model that considers the characteristics and behaviours of individuals, rather than trips. The model represents each person in Melbourne and their daily travel plans, including when, where and how they will access their various activities. It also includes their demographic characteristics such as age, income and household composition. This means that the model is well suited to understanding user profiles and therefore equity impacts of transport interventions. It was recently used by Infrastructure Victoria to examine the future impacts of automated and zero emission vehicles.

Unlike traditional models, Melbourne Activity and Agent Based Model uses a continuous timescale. As congestion grows people tend to change the times that they travel to avoid congestion (known as 'peak spreading'). It can also model behavioural responses to connected and automated vehicles, zero emission vehicles, car sharing services, ride-hailing services and demand responsive transport and Mobility-as-a-Service.

Traditional models seek to optimise the travel choice (mode or route) for each individual trip. As a result, these models do not consider how trip choices made across the entire day are interrelated. The Melbourne Activity and Agent Based Model considers all journeys and activities taken by an individual in a day. This means that it is able to more realistically represent traveller behaviour. For example, if you need to pick your child up from school after work, you might bring your car even if public transport would have been faster.

Source: KPMG (2018).[284]

### *PwC Customer Transport Simulator*

PwC Australia has developed a multi-modal transport simulation model that provides a more customer-centric view of public transport services and helps understand the impact of incidents on networks. The model was initially developed for a rail operator and has been expanded to include buses, ferries and light rail.

Input data for the model was obtained from various sources, including the transport company, government, and publicly available sources. The main metric collected was Lost Customer Minutes (LCM), calculated as sum of delay minutes for all individual journeys within a particular mode or on multiple modes across a broader network. The model allows the users to obtain a passenger-centric LCM calculation, which is more precise than traditional vehicle-centric methods that were considered to over- or underestimate LCM.

Using an agent-based approach, the different components of the network (e.g. vehicles, network topography, stations, stops) are added into the simulation. Behavioural rules are assigned to each agent (e.g. trains will follow a specific timetable, they need to stay a minimum distance from the train in front). Customers are added as a specific layer of agents in the simulation. Using anonymised public transport ticketing data or assumed customer journey information, the model can simulate an individual's journey through the network including use of interchanges.

The model includes a reporting layer which provides a view of the historical performance of the transport network against a variety of performance measures. The dashboard provides a snapshot view of the overall network and each individual mode's performance on a day. Measures such as customer punctuality, vehicle crowding, average journey time and lost customer minutes, provide insights to support decisions from the customers' perspective. Measures such as vehicle punctuality and patronage give the more traditional insight used to make more operationally focused decisions. The simulation engine provides the ability to ask what-if scenario questions of complex networks and understand customer and operational impacts.

Source: Anylogic (2019).[285]

## Better accounting for the impacts of asset performance

Since the 1950s, commonly used strategic transport models have taken a prescriptive approach to route choice within the model. As a result they have limitations in their capacity to accommodate delays from intersection queueing and other aspects of asset design.

Typically strategic transport models use assumptions regarding the capacity of infrastructure derived from the high level characteristics of the asset, e.g. lane numbers, speed and historical usage levels, or derive inputs from mesoscopic or microsimulation models. While these inputs provide a view of network performance, these mostly static supply models do not account for time-varying conditions and can understate queuing delays, for instance at intersections or due to planned impacts, such as road works or construction. Subsequently, they are most accurate in study areas with light congestion.[286]

Given that queues can have a significant impact on network flows and travel times,[287] there is an opportunity to better account for network capacity through the incorporation of asset performance into strategic models, such as through the use of dynamic capacity constrained traffic assignment and simulation models.

The transfer of outputs created within strategic city-wide models to project (mesoscopic) or link (microsimulation) models, or vice versa, is traditionally used to allow refinement of the understanding network performance and improvements to accuracy. In addition to the incorporation of dynamic asset performance, there is scope to strengthen to improve information flow between established models in many jurisdictions.

The United States Transportation Research Board published a primer on dynamic traffic assignment[288] to facilitate informed decision making by practitioners regarding these more sophisticated models. The KPMG Melbourne agent-based model described above for example, adopts the MATSim, an open-source multi-agent dynamic transport simulator.[289] Dynamic models require more computation time and an equilibrium solution may no longer be unique,[290] hence just like activity-based models it is important to balance model realism with model stability.

Most strategic models consider trips by either private transport or public transport and perform traffic assignment more or less separately for private and public transport. However, due to the presence of ride-hailing and shared bicycle schemes as well as automated vehicles in the future, the lines between public and private transport are blurring. As such, intermodal trips that use a mix of private and public transport modes may need to be considered. TRANSIMS[291] is an example of an open-source intermodal traffic simulator to conduct transportation system analyses for a region. Like MATSim, it models individual travellers based on a synthetic population.

## Integrating transport and land-use models

For most forms of software, risks and development timeframes often increase in response to product complexity and features. Forecasting models which meet multiple needs can be useful but are more complicated and costly to develop compared to models developed for a single purpose. If the development of apps is anything to go by, the future may involve decision makers using more models rather than less.

With this aside, there is significant scope to better integrate transport and land-use models. Transport models focus on passenger transport with freight considered indirectly through the category of light commercial vehicles (LCVs) or through separate applications which consider LCVs and heavy vehicles.[292] There are currently few applications that allow trade-offs between passengers and freight to be easily tested.[293] This is important within environments which road space is constrained (e.g. major arterials and activity centres), and where planners need to consider options for maximising productivity.

There has traditionally been a large disconnect between transport and land-use models. While transport models usually include significant functionality for testing land-use changes, they can sometimes be developed with little input from planning agencies who may use separate analytical tools.

Integrated transport and land-use (ITLU) planning models can potentially address a city or region's long-term challenges and create a shared vision of what the space aspires to be in the future by coordinating investments and policy decisions to achieve that vision.[294] An example of this is DELTA, a transport model developed by various consultancies and the Institute for Transport Studies (ITS) of the University of Leeds in 1995–96.[295] The land-use model was designed to model a variety of different processes of change in an urban system.[296] By aligning core functions between models through ITLU models, scenarios involving changes in transport and land use may be more easily tested.

In the context of Australia, the University of Wollongong developed TransMob, an agent-based model for South East Sydney that simulates interdependencies between transport and land use[297] where TRANSIMS was adopted as the traffic simulator. MetroScan[298] is a fully operational integrated model developed at the University of Sydney for the Sydney Greater Metropolitan area that describes the interaction between transport and land use, passenger movement with freight movement, and work location choice with firm location.[299]

12

# Next steps

## 12.1 The modelling is an input to the Audit

The strategic transport modelling undertaken for the *Australian Infrastructure Audit 2019* provides an insight into the impacts to cost, access and quality of transport services in our major cities over the coming years in response to changing population, land-use and projects currently planned.

Under this scenario, congestion in our major cities is expected to grow, especially in our large fast growing cities of Sydney and Melbourne, with pressure in Perth and South East Queensland, especially Brisbane. The impacts of congestion on Adelaide and Canberra will be less pronounced, however will be significant in their local context.

While congestion will increase, changes to inputs and the approach to modelling has presented a new perspective on future network pressures when compared to our inaugural *Australian Infrastructure Audit* in 2015. The discrepancies between results show the importance of high quality data and the need to continue to plan, especially within a highly uncertain and rapid changing period in Australia's history. There are also opportunities to improve strategic modelling as a result of access to new data and new approaches to modelling.

The 2019 *Australian Infrastructure Audit* is written in this context and provides a view of the impact of uncertainty on the impacts on infrastructure services for users across our diverse country. The Audit analyses this transport modelling and reflects its findings both in terms of transport network performance and with regard to the second impacts on the accessibility of employment and services, especially social infrastructure like schools and hospitals.

The Audit presents these considerations in a series of *Challenges*, impediments to maintaining Australia's quality of life and productivity, and *Opportunities*, the potential to provide step-change improvements. The future presented by this modelling is one potential view of the future under a do-little approach to further reform and infrastructure investment.

Infrastructure Australia would like to invite submissions on the Urban Congestion and Crowding Report as well as the *Australian Infrastructure Audit 2019*.

## 12.2 Our targets and priorities

### Your feedback will guide our infrastructure decisions

Completing this Audit, and the supporting technical papers, was the first step of Infrastructure Australia's program of work. We will next use the findings to build a package of recommended reform and investment priorities.

To set these priorities, we will work intensively for the next three months to engage with governments, community and industry. Your feedback will inform our work in developing two key documents:

- The Australian Infrastructure Plan will respond to each policy challenge and opportunity. It will give recommendations for reform and set a path for measuring progress.
- The Infrastructure Priority List will continue to evolve with new initiatives added to reflect nationally significant problems and opportunities that have been identified by the Audit. Existing Projects and Initiatives will, where relevant, link to the challenges and opportunities identified by the Audit, and Initiatives may be removed where the Audit findings do not support them.

The process does not end there. Once the reform and investment priorities are set, Infrastructure Australia will track and publically report on progress. We will track Australia's progress against meeting the reform targets set by the Plan and progressing the potential investments highlighted in the *Infrastructure Priority List.*

## 12.3 We want your input

To help us shape the future, we want to know what you think about this Audit. There will likely be differing views, and there may also be gaps in our evidence. We don't have all the answers, so we need your help to get this right.

To give feedback on our Audit, you can:

- **Make a submission** to tell us what we got right, what we missed, and what responses may be needed – such as policy reform or project investment. When you give this feedback, please respond directly to a relevant challenge or opportunity.
- **Provide new evidence**, if it is available and not reflected in the Audit. Please do this in a submission, or over time as evidence becomes available. Your contribution will ensure our evidence base stays as up to date as possible.

## 12.4 Your feedback

### Anyone can make a submission

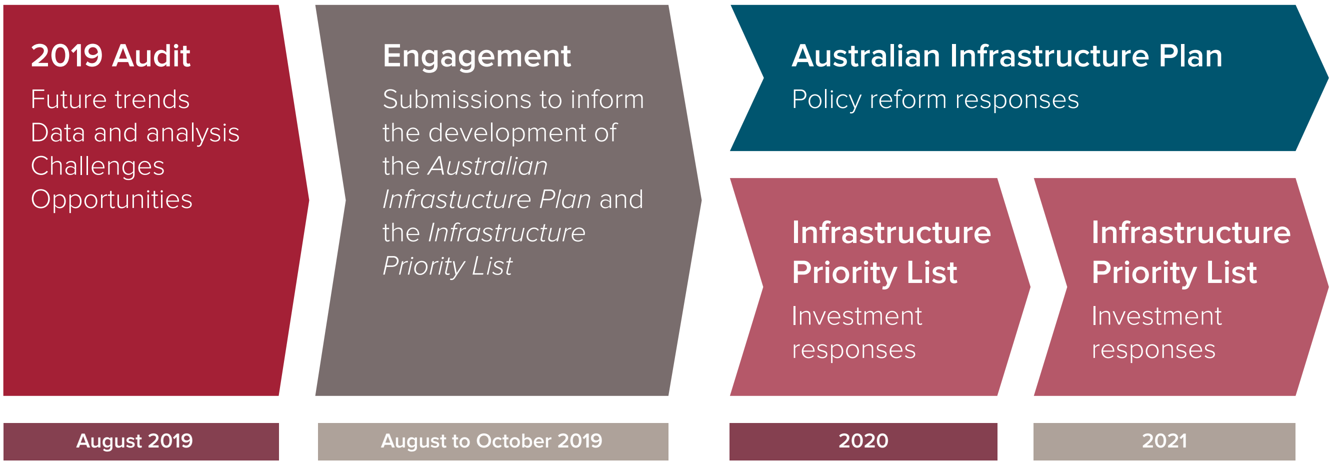
We encourage everyone to get involved, from governments, industry experts and peak bodies, to academics, community groups and individual Australians. This is your chance to have a say on our infrastructure for the next 15 years and beyond.

To comment on individual challenges and opportunities, or download a longer template with room for more supporting evidence, visit the Infrastructure Australia website: www.infrastructureaustralia.gov.au

If your submission includes a specific investment proposal, you should provide supporting documents through the separate *Infrastructure Priority List* submissions process, which closes on 31 August 2019 for this round. If you submit after this date, we will consider your submission in early 2021, along with the next *Australian Infrastructure Plan*. Figure 137 summarises the submission process and identifies indicative dates.

Your submission should identify which challenge or opportunity from the Audit it seeks to address.

**Figure 137:** We invite submissions to help shape our future advice



## References


1. Office of the Chief Economist 2018, *Industry Insights – Flexibility & Growth*, Department of Industry, Innovation and Science, Canberra, p 50, available via: www.publications.industry.gov.au/publications/industryinsightsjune2018/documents/IndustryInsights_1_2018_ONLINE.pdf.
2. Australian Bureau of Statistics 2016, *2016 Census: National capital cities*, media release, Australian Bureau of Statistics, Canberra, 27 June 2017, available via: www.abs.gov.au/ausstats/abs@.nsf/lookup/Media%20Release10.
3. Bureau of Infrastructure, Transport and Regional Economics 2018, *Australian Infrastructure Statistics Yearbook*, Bureau of Infrastructure, Transport and Regional Economics, Canberra, p 88, available via: www.bitre.gov.au/publications/2018/files/infrastructure-statistics-yearbook-2018.pdf.
4. Bureau of Infrastructure, Transport and Regional Economics 2018, *Australian Infrastructure Statistics Yearbook*, Bureau of Infrastructure, Transport and Regional Economics, Canberra, p 88, available via: www.bitre.gov.au/publications/2018/files/infrastructure-statistics-yearbook-2018.pdf; Australian Bureau of Statistics 2018, 3218.0 - Regional Population Growth, Australia, 2016-17, Australian Bureau of Statistics, Canberra, viewed 30 May 2019, https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3218.0Main+Features12016-17?OpenDocument.
5. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne, Brisbane*, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide, Brisbane*, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.
6. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.
7. Bureau of Infrastructure, Transport and Regional Economics 2015, *Traffic and congestion cost trends for Australian capital cities*, Bureau of Infrastructure, Transport and Regional Economics, Canberra, pp 2-3, available via: www.bitre.gov.au/publications/2015/is_074.aspx.
8. Johnston K 2016, *Understanding the causes of congestion*, speech, Engineering Technology Forum 2016, Brisbane, 24 August 2016, available at: https://www.tmr.qld.gov.au/About-us/Events/Engineering-Technology-Forum-2016/Presentations24August.
9. Rosier, K and McDonald, M 2011, *The relationship between transport and disadvantage in Australia*, Australian Institute of Family Studies, Melbourne, p 4, available via: www.aifs.gov.au/cfca/sites/default/files/publication-documents/rs4.pdf.
10. Hensher, D 2007, 'Social exclusion: Informed reality thinking on accessibility and mobility in an ageing population' in *No way to go: Transport and social disadvantage in Australian communities*, Currie, G, Stanley, J, and Stanley, J (eds), Monash University ePress, Melbourne, pp 5.1–5.11.
11. Infrastructure Australia 2018, *Outer urban public transport: Improving accessibility in lower-density areas*, Infrastructure Australia, Sydney, p 4, available via: www.infrastructureaustralia.gov.au/policy-publications/publications/files/Outer-Urban-Public-Transport_WEB_FA-hi_res.pdf.
12. Energeia 2018, *Australian Electric Vehicle Market Study*, Australian Renewable Energy Agency, Canberra, p 7, available via: www.arena.gov.au/assets/2018/06/australian-ev-market-study-report.pdf.
13. Transport for NSW 2018, *Future Transport Strategy*, Transport for NSW, Sydney, p 16, available via: https://future.transport.nsw.gov.au/plans/future-transport-strategy.
14. IBISWorld 2018, *Ridesharing Services - Australia market research report*, IBISWorld, viewed 6 May 2019, www.ibisworld.com.au/industry-trends/specialised-market-research-reports/consumer-goods-services/ridesharing-services.html.
15. INRIX 2017, *London Congestion Trends*, INRIX, Kirkland, p 15, available via: www.inrix.com/wp-content/uploads/2017/09/INRIX-London-Congestion-Trends-May16.pdf.
16. Australian Institute of Health and Welfare 2018, *Physical activity across the life stages*, Australian Institute of Health and Welfare, Canberra, p 21, available via: www.aihw.gov.au/getmedia/c249ef97-e219-44df-a8bd-f5e50d04064c/aihw-phe-225.pdf.aspx?inline=true.
17. Transport Accident Commission Victoria 2018, *Older drivers – Road safety for ageing road users*, Transport Accident Commission Victoria, viewed 1 May 2019, www.tac.vic.gov.au/road-safety/safe-driving/older-drivers.
18. Department of the Environment and Energy 2017, *Australia's emissions projections 2017*, Department of the Environment and Energy, p 23, available via: www.environment.gov.au/system/files/resources/eb62f30f-3e0f-4bfa-bb7a-c87818160fcf/files/australia-emissions-projections-2017.pdf.
19. Department of the Environment and Energy 2017, *Australia's emissions projections 2017*, Department of the Environment and Energy, p 23, available via: www.environment.gov.au/system/files/resources/eb62f30f-3e0f-4bfa-bb7a-c87818160fcf/files/australia-emissions-projections-2017.pdf.
20. Veitch Lister Consulting 2019, *Zenith*, Veitch Lister Consulting, viewed 1 May 2019, www.veitchlister.com.au/our-company/zenith/.
21. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 97, available via: www.infrastructureaustralia.gov.au.

22. Infrastructure Australia 2015, Australian Infrastructure Audit Volume 1, Infrastructure Australia, Sydney, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 94, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 73, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 63, available via: www.infrastructureaustralia.gov.au.

23. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 111, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 155, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 150, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 109, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 109, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 92, available via: www.infrastructureaustralia.gov.au.

24. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 65, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 90, available via: www.infrastructureaustralia.gov.au.

25. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 66, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 91, available via: www.infrastructureaustralia.gov.au.

26. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 62, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 67.

27. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 63, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 84, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 68.

28. Greater Sydney Commission 2018, *Greater Sydney Region Plan: A Metropolis of Three Cities*, Greater Sydney Commission, Sydney, p 27, available via: www.greater.sydney/file/12064/download?token=ZvBYYNxK.

29. Transport for NSW 2018, *Household Travel Survey – Data by Region*, NSW Government, viewed 1 May 2019, www.transport.nsw.gov.au/performance-and-analytics/passenger-travel/surveys/household-travel-survey-hts/household-travel-1.

30. Transport for NSW 2018, *All modes historical patronage – Top Level Chart*, NSW Government, viewed 1 May 2019, www.transport.nsw.gov.au/data-and-research/passenger-travel/all-modes-patronage-historical/all-modes-historical-patronage.

31. Transport for NSW 2018, *NSW Freight and Ports Plan 2018-2023*, NSW Government, Sydney, p 34, available via: www.transport.nsw.gov.au/system/files/media/documents/2018/TNSW%20Freight%20and%20Ports%20Plan%202018-2023_0.pdf.

32. Charting Transport 2017, *Trends in journey to work mode shares in Australian cities to 2016 (second edition)*, Charting Transport, viewed 1 May 2019, https://chartingtransport.com/2017/10/24/trends-in-journey-to-work-mode-shares-in-australian-cities-to-2016/.

33. Department of Infrastructure, Regional Development and Cities, *2018 Inquiry into National Freight and Supply Chain Priorities: Analysis of capital city key freight route performance*, Australian Government, p 7, available via: www.infrastructure.gov.au/transport/freight/freight-supply-chain-priorities/supporting-papers/files/Supporting_Paper_No4_Analysis_of_Capital_City_Key_Freight.pdf.

34. Transport for NSW 2018, *Average and maximum AM peak train loads by line*, NSW Government, viewed 1 May 2019, www.transport.nsw.gov.au/data-and-research/passenger-travel/train-patronage; Audit Office of NSW 2018, *Report on Transport 2018*, Audit Office of NSW, p 26, available via: www.audit.nsw.gov.au/sites/default/files/pdf-downloads/Transport%202018%20Website%20PDF%20version%201.pdf; Transport for NSW 2017, *Inner West Light Rail Line Short-Term Capacity Enhancements: Final Business Case*, NSW Government, p 14, available via: www.scribd.com/document/386930470/Final-Business-Case.

35. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au.

36. Infrastructure Australia 2015, Australian Infrastructure Audit Volume 1, Infrastructure Australia, Sydney, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide, Brisbane*, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.

37. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 114, available via: www.infrastructureaustralia.gov.au.
38. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 115, available via: www.infrastructureaustralia.gov.au.
39. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 30, available via: www.infrastructureaustralia.gov.au.
40. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 65, available via: www.infrastructureaustralia.gov.au.
41. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 65, available via: www.infrastructureaustralia.gov.au.
42. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 62, available via: www.infrastructureaustralia.gov.au.
43. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 62, available via: www.infrastructureaustralia.gov.au.
44. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 38, available via: www.infrastructureaustralia.gov.au.
45. Transport for NSW 2018, *Future Transport Strategy 2056*, NSW Government, p 27, available via: www.future.transport.nsw.gov.au/.
46. Austroads 2016, *Congestion and Reliability Review*, Austroads, p 30, available via: www.onlinepublications.austroads.com.au/items/AP-R534-16.
47. TomTom 2017, *Traffic Index*, TomTom, viewed 13 January 2019, www.tomtom.com/en_gb/trafficindex/; Infrastructure Partnerships Australia 2017, *Australian Travel Time Index*, Infrastructure Partnerships Australia, viewed 13 January 2019, http://infrastructure.org.au/chart-group/travel-time-index-chart/.
48. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 42, available via: www.infrastructureaustralia.gov.au.
49. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for* Sydney, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au.
50. Roads and Maritime Services 2018, *Traffic Volume Viewer,* NSW Government, viewed 30 May 2019, www.rms.nsw.gov.au/about/corporate-publications/statistics/traffic-volumes/aadt-map/index.html#/?z=6.
51. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.
52. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 82, available via: www.infrastructureaustralia.gov.au.
53. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 32, available via: www.infrastructureaustralia.gov.au.
54. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 66, available via: www.infrastructureaustralia.gov.au.
55. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 66, available via: www.infrastructureaustralia.gov.au.
56. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 63, available via: www.infrastructureaustralia.gov.au.
57. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 63, available via: www.infrastructureaustralia.gov.au.
58. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 67, available via: www.infrastructureaustralia.gov.au.
59. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, p 68, available via: www.infrastructureaustralia.gov.au.
60. Australian Bureau of Statistics 2011, *Census of Population and Housing 2011*, TableBuilder, Findings based on use of TableBuilder data.
61. Australian Bureau of Statistics 2016, *Census of Population and Housing 2016*, TableBuilder, Findings based on use of TableBuilder data.
62. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, pp 126-127, available via: www.infrastructureaustralia.gov.au.
63. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, pp 132-133, available via: www.infrastructureaustralia.gov.au.
64. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, pp 130-131, available via: www.infrastructureaustralia.gov.au.
65. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, pp 126-127, available via: www.infrastructureaustralia.gov.au.
66. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney,* Brisbane, pp 130-131, available via: www.infrastructureaustralia.gov.au.
67. Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney, Brisbane, pp 132-133, available via: www.infrastructureaustralia.gov.au.
68. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 60, available via: www.infrastructureaustralia.gov.au.
69. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 49, available via: www.infrastructureaustralia.gov.au.
70. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 50, available via: www.infrastructureaustralia.gov.au.

71. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 51, available via: www.infrastructureaustralia.gov.au.
72. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 57, available via: www.infrastructureaustralia.gov.au.
73. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 58, available via: www.infrastructureaustralia.gov.au.
74. Australian Bureau of Statistics 2007, *2006 Census QuickStats*, Australian Bureau of Statistics, viewed 3 May 2019, http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2006/quickstat/205.
75. Charting Transport 2017, *Summarised ABS data – trends in journey to work mode shares in Australian cities to 2016*, Charting Transport, viewed 3 May 2019, https://chartingtransport.com/2017/10/24/trends-in-journey-to-work-mode-shares-in-australian-cities-to-2016/.
76. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au.
77. Department of Land, Water and Planning 2016, *Victoria in Future 2016*, Victorian Government, viewed 3 May 2019, www.planning.vic.gov.au/land-use-and-population-research/victoria-in-future-2016.
78. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.
79. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 159, available via: www.infrastructureaustralia.gov.au.
80. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 160, available via: www.infrastructureaustralia.gov.au.
81. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 33, available via: www.infrastructureaustralia.gov.au.
82. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au.
83. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au.
84. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 83, available via: www.infrastructureaustralia.gov.au.
85. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 83, available via: www.infrastructureaustralia.gov.au.
86. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne,* Brisbane, p 47, available via: www.infrastructureaustralia.gov.au.
87. Veitch Lister Consulting 2019, *Transport Planning for the Australian* Infrastructure Audit: Transport Modelling Report for Melbourne, Brisbane, p 62, available via: www.infrastructureaustralia.gov.au.
88. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 57, available via: www.infrastructureaustralia.gov.au.
89. Victorian Government 2019, *Level Crossing Removal Project*, Victorian Government, viewed 3 May 2019, https://levelcrossings.vic.gov.au/about.
90. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 52, available via: www.infrastructureaustralia.gov.au.
91. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 93, available via: www.infrastructureaustralia.gov.au.
92. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 16, available via: www.infrastructureaustralia.gov.au.
93. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au.
94. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au.
95. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 33, available via: www.infrastructureaustralia.gov.au.
96. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 36, available via: www.infrastructureaustralia.gov.au.
97. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 84, available via: www.infrastructureaustralia.gov.au.
98. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 84, available via: www.infrastructureaustralia.gov.au.
99. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 39, available via: www.infrastructureaustralia.gov.au.

100. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 26, available via: www.infrastructureaustralia.gov.au.
101. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit:* Transport Modelling Report for Melbourne, Brisbane, p 64, available via: www.infrastructureaustralia.gov.au.
102. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 59, available via: www.infrastructureaustralia.gov.au.
103. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 54, available via: www.infrastructureaustralia.gov.au.
104. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 169, available via: www.infrastructureaustralia.gov.au.
105. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 171-173, available via: www.infrastructureaustralia.gov.au.
106. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 176-178, available via: www.infrastructureaustralia.gov.au.
107. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 169, available via: www.infrastructureaustralia.gov.au.
108. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 80, available via: www.infrastructureaustralia.gov.au.
109. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 69, available via: www.infrastructureaustralia.gov.au.
110. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.
111. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 52, available via: www.infrastructureaustralia.gov.au.
112. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 184, available via: www.infrastructureaustralia.gov.au.
113. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, p 185, available via: www.infrastructureaustralia.gov.au.
114. Australian Bureau of Statistics 2007, *2006 Census QuickStats*, Australian Bureau of Statistics, viewed 3 May 2019, http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2006/quickstat/205.
115. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au.
116. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.
117. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 153, available via: www.infrastructureaustralia.gov.au.
118. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 154, available via: www.infrastructureaustralia.gov.au.
119. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 37, available via: www.infrastructureaustralia.gov.au.
120. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 90, available via: www.infrastructureaustralia.gov.au.
121. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 90, available via: www.infrastructureaustralia.gov.au.
122. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au.
123. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 86, available via: www.infrastructureaustralia.gov.au.
124. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 50, available via: www.infrastructureaustralia.gov.au.
125. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 93, available via: www.infrastructureaustralia.gov.au.
126. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 95, available via: www.infrastructureaustralia.gov.au.
127. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 16, available via: www.infrastructureaustralia.gov.au.
128. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 91, available via: www.infrastructureaustralia.gov.au.

129. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 91, available via: www.infrastructureaustralia.gov.au.
130. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 52, available via: www.infrastructureaustralia.gov.au.
131. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au.
132. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 87, available via: www.infrastructureaustralia.gov.au.
133. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 20, available via: www.infrastructureaustralia.gov.au.
134. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 58, available via: www.infrastructureaustralia.gov.au.
135. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, pp 164-166, available via: www.infrastructureaustralia.gov.au.
136. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland,* Brisbane, pp 61-63, available via: www.infrastructureaustralia.gov.au.
137. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, pp 164-166, available via: www.infrastructureaustralia.gov.au.
138. Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland, Brisbane, pp 61-63, available via: www.infrastructureaustralia.gov.au.
139. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 83, available via: www.infrastructureaustralia.gov.au.
140. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 71, available via: www.infrastructureaustralia.gov.au.
141. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au.
142. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 73, available via: www.infrastructureaustralia.gov.au.
143. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 78, available via: www.infrastructureaustralia.gov.au.
144. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 79, available via: www.infrastructureaustralia.gov.au.
145. Australian Bureau of Statistics 2007, *2006 Census QuickStats*, Australian Bureau of Statistics, viewed 3 May 2019, http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2006/quickstat/505.
146. Australian Bureau of Statistics 2017, *2016 Census QuickStats*, Australian Bureau of Statistics, viewed 3 May 2019, http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2017/quickstat/505.
147. Australian Bureau of Statistics 2017, *2016 Census QuickStats*, Australian Bureau of Statistics, viewed 3 May 2019, http://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2017/quickstat/505.
148. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au.
149. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.
150. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 110, available via: www.infrastructureaustralia.gov.au.
151. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 112, available via: www.infrastructureaustralia.gov.au.
152. Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth, Brisbane, p 113, available via: www.infrastructureaustralia.gov.au.
153. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 29, available via: www.infrastructureaustralia.gov.au.
154. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 69, available via: www.infrastructureaustralia.gov.au.
155. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 69, available via: www.infrastructureaustralia.gov.au.
156. LEK Consulting 2018, *Australian Public Transport Barometer – June 2018*, LEK Consulting, p 3, available via: www.lek.com/sites/default/files/insights/pdf-attachments/TTF-LEK-Public-Transport-Barometer.pdf.
157. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 67, available via: www.infrastructureaustralia.gov.au.

158. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 67, available via: www.infrastructureaustralia.gov.au.

159. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 45, available via: www.infrastructureaustralia.gov.au.

160. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 74, available via: www.infrastructureaustralia.gov.au.

161. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 39, available via: www.infrastructureaustralia.gov.au.

162. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 14, available via: www.infrastructureaustralia.gov.au.

163. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.

164. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.

165. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 32, available via: www.infrastructureaustralia.gov.au.

166. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 22, available via: www.infrastructureaustralia.gov.au.

167. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 68, available via: www.infrastructureaustralia.gov.au.

168. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 68, available via: www.infrastructureaustralia.gov.au

169. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 42, available via: www.infrastructureaustralia.gov.au.

170. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 48, available via: www.infrastructureaustralia.gov.au.

171. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 64, available via: www.infrastructureaustralia.gov.au.

172. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 54, available via: www.infrastructureaustralia.gov.au.

173. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 55, available via: www.infrastructureaustralia.gov.au.

174. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 56, available via: www.infrastructureaustralia.gov.au.

175. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 61, available via: www.infrastructureaustralia.gov.au.

176. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, p 62, available via: www.infrastructureaustralia.gov.au.

177. Charting Transport 2017, *Summarised ABS data – trends in journey to work mode shares in Australian cities to 2016*, Charting Transport, viewed 3 May 2019, https://chartingtransport.com/2017/10/24/trends-in-journey-to-work-mode-shares-in-australian-cities-to-2016/.

178. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au.

179. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney*, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne*, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland*, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth*, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.

180. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 114, available via: www.infrastructureaustralia.gov.au.

181. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 115, available via: www.infrastructureaustralia.gov.au.

182. Bureau of Infrastructure, Transport and Regional Economics 2015, *Traffic and congestion cost trends for Australian capital cities*, Bureau of Infrastructure, Transport and Regional Economics, p. 14, available via: www.bitre.gov.au/publications/2015/is_074.aspx.

183. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 69, available via: www.infrastructureaustralia.gov.au.

184. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 69, available via: www.infrastructureaustralia.gov.au.

185. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 30, available via: www.infrastructureaustralia.gov.au.

186. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 66, available via: www.infrastructureaustralia.gov.au.

187. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 66, available via: www.infrastructureaustralia.gov.au.

188. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 41, available via: www.infrastructureaustralia.gov.au.

189. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 46, available via: www.infrastructureaustralia.gov.au.

190. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 73, available via: www.infrastructureaustralia.gov.au.

191. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 15, available via: www.infrastructureaustralia.gov.au.

192. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 50, available via: www.infrastructureaustralia.gov.au.

193. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.

194. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 70, available via: www.infrastructureaustralia.gov.au.

195. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 33, available via: www.infrastructureaustralia.gov.au.

196. Transport and Infrastructure Council 2016, *National Key Freight Route Maps*, Department of Infrastructure and Regional Development and Cities, p 1, available via: www.transportinfrastructurecouncil.gov.au/publications/files/freight_route_maps/SA_Adelaide_Urban_Map_A3_ROAD.pdf.

197. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 67, available via: www.infrastructureaustralia.gov.au.

198. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 67, available via: www.infrastructureaustralia.gov.au.

199. Department of Planning, Transport and Infrastructure, *The 30-Year plan for Greater Adelaide 2017 update*, Government of South Australia, p 89, available via: http://livingadelaide.sa.gov.au/__data/assets/pdf_file/0003/319809/The_30-Year_Plan_for_Greater_Adelaide.pdf.

200. Austroads 2016, *Guide to Traffic Management Part 4: Network Management*, Austroads, p 7, available via: https://austroads.com.au/publications/traffic-management/agtm04/media/AGTM04-16_Guide_to_Traffic_Management_Part_4_Network_Management.pdf.

201. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 43, available via: www.infrastructureaustralia.gov.au.

202. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 48, available via: www.infrastructureaustralia.gov.au.

203. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 50, available via: www.infrastructureaustralia.gov.au.

204. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 65, available via: www.infrastructureaustralia.gov.au.

205. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 56, available via: www.infrastructureaustralia.gov.au.

206. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 57, available via: www.infrastructureaustralia.gov.au.

207. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 58, available via: www.infrastructureaustralia.gov.au.

208. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 62, available via: www.infrastructureaustralia.gov.au.

209. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide*, Brisbane, p 63, available via: www.infrastructureaustralia.gov.au.

210. Australian Bureau of Statistics 2012, *3218.0 Regional population growth*, Australia, 2011, Australian Bureau of Statistics, viewed 3 May 2019, www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3218.0Main+Features12011?OpenDocument.

211. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.

212. Infrastructure Australia 2015, *Australian Infrastructure Audit Volume 1*, Infrastructure Australia, Sydney, p. 83, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Sydney, Brisbane, p 72, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Melbourne, Brisbane, pp 94-95, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for South East Queensland, Brisbane, p 98, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Perth, Brisbane, pp 73-75, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for Adelaide, Brisbane, pp 72-74, available via: www.infrastructureaustralia.gov.au; Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan, Brisbane, pp 63-65, available via: www.infrastructureaustralia.gov.au.

213. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 93, available via: www.infrastructureaustralia.gov.au.

214. Veitch Lister Consulting 2019, Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan, Brisbane, p 95, available via: www.infrastructureaustralia.gov.au.

215. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 96, available via: www.infrastructureaustralia.gov.au.

216. Charting Transport 2017, *Summarised BITRE data – Update on Australian transport trends (December 2018)*, Charting Transport, viewed 3 May 2019, https://chartingtransport.com/tag/bitre/.

217. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 60, available via: www.infrastructureaustralia.gov.au.

218. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 58, available via: www.infrastructureaustralia.gov.au.

219. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 60, available via: www.infrastructureaustralia.gov.au.

220. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 36, available via: www.infrastructureaustralia.gov.au.

221. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 27, available via: www.infrastructureaustralia.gov.au.

222. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 58, available via: www.infrastructureaustralia.gov.au.

223. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 18, available via: www.infrastructureaustralia.gov.au.

224. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 64, available via: www.infrastructureaustralia.gov.au.

225. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 30, available via: www.infrastructureaustralia.gov.au.

226. NSW Planning and Environment 2017, *South East and Tablelands Regional Plan*, NSW Government, p 44, available via: www.planning.nsw.gov.au/-/media/Files/DPE/Plans-and-policies/south-east-and-tableland-regional-plan-2017-07.pdf.

227. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 61, available via: www.infrastructureaustralia.gov.au.

228. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 61, available via: www.infrastructureaustralia.gov.au.

229. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 14, available via: www.infrastructureaustralia.gov.au.

230. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 59, available via: www.infrastructureaustralia.gov.au.

231. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 59, available via: www.infrastructureaustralia.gov.au.

232. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 38, available via: www.infrastructureaustralia.gov.au.

233. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 41, available via: www.infrastructureaustralia.gov.au.

234. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 56, available via: www.infrastructureaustralia.gov.au.

235. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan,* Brisbane, p 46, available via: www.infrastructureaustralia.gov.au.

236. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 47, available via: www.infrastructureaustralia.gov.au.

237. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 48, available via: www.infrastructureaustralia.gov.au.

238. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan*, Brisbane, p 53, available via: www.infrastructureaustralia.gov.au.

239. Veitch Lister Consulting 2019, *Transport Planning for the Australian Infrastructure Audit: Transport Modelling Report for ACT and Queanbeyan,* Brisbane, p 54, available via: www.infrastructureaustralia.gov.au.

240. Australian Transport Assessment and Planning 2016, *Overview of transport modelling*, Australian Government, Canberra, viewed 29 May 2019, available at: www.atap.gov.au/tools-techniques/travel-demand-modelling/2-overview.aspx.

241. Transport and Infrastructure Council 2015, *National Guidelines for Transport System Management in Australia*, Transport and Infrastructure Council, p 11, available via: https://atap.gov.au/tools-techniques/travel-demand-modelling/files/T1_Travel_Demand_Modelling.pdf.

242. Transport and Infrastructure Council 2015, *National Guidelines for Transport System Management in Australia*, Transport and Infrastructure Council, p 24, available via: https://atap.gov.au/tools-techniques/travel-demand-modelling/files/T1_Travel_Demand_Modelling.pdf.

243. Rossi, T and F, Shiftan, Y 1997, *Tour Based Travel Demand Modeling in the US*, IFAC Transportation Systems, p 382, available via: www.sciencedirect.com/science/article/pii/S1474667017438535/pdf?md5=dce0ac99687564da3c82199c5922f80e&pid=1-s2.0-S1474667017438535-main.pdf.

244 Rossi, T and F, Shiftan, Y 1997, *Tour Based Travel Demand Modeling in the US*, IFAC Transportation Systems, p 382, available via: www.sciencedirect.com/science/article/pii/S1474667017438535/pdf?md5=dce0ac99687564da3c82199c5922f80e&pid=1-s2.0-S1474667017438535-main.pdf.

245. Australian Transport Assessment and Planning 2016, *Model Design*, Department of Infrastructure, Regional Development and Cities, viewed 11 March 2019, https://atap.gov.au/tools-techniques/travel-demand-modelling/3-model.aspx#mdfigure-19-373.

246. Rogerson, M and Carnovale, F 2007, *Introducing convergent feedback in the Melbourne Integrated Transport Model*, VicRoads, p 2, available via: http://atrf.info/papers/2007/2007_Rogerson_Carnovale.pdf.

247. Australian Transport Assessment and Planning 2016, *Model Design*, Department of Infrastructure, Regional Development and Cities, viewed 10 April 2019, www.atap.gov.au/tools-techniques/travel-demand-modelling/5-model-development.aspx.

248. Hojati, A, Ferreira, L and Charles, P 2009, *Assessing the major causes of travel time reliability on urban freeways*, The University of Queensland, p 2, available via: www.researchgate.net/publication/43515784_Assessing_the_major_causes_of_travel_time_reliability_on_urban_freeways.

249. Hojati, A, Ferreira, L and Charles, P 2009, *Assessing the major causes of travel time reliability on urban freeways*, The University of Queensland, p2, available via: www.researchgate.net/publication/43515784_Assessing_the_major_causes_of_travel_time_reliability_on_urban_freeways.

250. International Transport Forum 2017, *Quantifying the Socio-economic Benefits of Transport*, OECD, p 19, available via: www.itf-oecd.org/sites/default/files/docs/summary-round-table-socio-economic-benefits-transport.pdf.

251. De Jong, G and Bliemer, M C J 2015, 'On including travel time reliability of road traffic appraisal', *Transport Research Part A: Policy and practice*, vol. 73, pp 80-95.

252. Hess, S, Daly, A, Rohr, C and Hyman, G 2007, 'On the development of time period and mode choice models for use in large scale modelling forecasting systems', *Transport Research Part A: Policy and practice*, vol 41, pp 802-826.

253. Transport for NSW 2017, *Rail Revolution: busting weekend congestion with hundreds more train services*, media release, NSW Government, 11 July 2017, available via: www.transport.nsw.gov.au/newsroom-and-events/media-releases/rail-revolution-busting-weekend-congestion-hundreds-more-train-0.

254. Austroads 2016, *Congestion and Reliability Review*, Austroads, Sydney, p 2, available via: www.onlinepublications.austroads.com.au/items/AP-R534-16.

255. Stopher, P and Zhang, Z 2010, *Is Travel Behaviour Repetitive from Day to Day?*, Institute of Transport and Logistics Studies, Sydney, p 12, available via: https://atrf.info/papers/2010/2010_Stopher_Zhang_B.pdf.

256. Transport for NSW 2018, *Strategic Travel Model (STM) Overview*, NSW Government, viewed 25 March 2019, www.transport.nsw.gov.au/data-and-research/forecasts-and-projections/travel; Veitch Lister Consulting 2014, *Zenith Model Framework Papers version 3.0.1 Paper G – Mode Choice Model*, Veitch Lister Consulting, p 3, available via: https://veitchlister.com.au/wp-content/uploads/2018/08/ZenithFramework_G_ModeChoice-1.pdf.

257. Moeckel, R 2017, 'Working from home: modeling the impact of telework on transportation and land use', *Transportation Research Procedia*, vol. 26, pp 207-214.

258. Suel, E and Polak, J W 2017, 'Incorporating online shopping into travel demand modelling: challenges, progress, and opportunities', *Transport Reviews*, vol. 38, pp 576-601.

259. Taverner Research 2017, *Comparing Surveys of Point to Point Transport Use, November 2014 to February 2017*, Independent Pricing and Regulatory Tribunal, p 16. available via: www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/investigation-administrative-taxi-passenger-survey/taverner-research-comparing-surveys-of-point-to-point-transport-use-november-2014-to-february-2017.pdf.

260. Deloitte Access Economics 2016, *Economic effects of ridesharing in Australia*, Deloitte Access Economics, p 22, available via: www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-economic-effects-of-ridesharing-australia-150216.pdf.

261. IBISWorld 2019, *Car sharing providers in Australia – Australian Market Research Report*, IBISWorld, viewed 6 May 2019, www.ibisworld.com.au/industry-trends/specialised-market-research-reports/consumer-goods-services/car-sharing-providers.html.

262. Transport for NSW, *Opendata – On demand pilots patronage,* NSW Government, viewed 3 May 2019, https://opendata.transport.nsw.gov.au/dataset/on-demand-pilots-patronage/resource/e6bff099-fa37-423e-ab6b-02d76ec2bb74.

263. Transport for NSW 2019, *All modes historical patronage –Top Level Chart*, NSW Government, viewed 9 March 2019, www.transport.nsw.gov.au/data-and-research/passenger-travel/all-modes-patronage-historical/all-modes-historical-patronage.

264. City of Sydney 2019, *The city at a glance*, City of Sydney, viewed 9 March 2019, www.cityofsydney.nsw.gov.au/learn/research-and-statistics/the-city-at-a-glance.

265. Frost and Sullivan 2018, *Global Autonomous Driving Market Outlook*, Frost and Sullivan, available via: https://go.frost.com/EU_PR_KMenzefricke_K24A_AutonomousDriving_Apr18.

266. Ben-Akiva, M, McFadden, D and Train, K 2019, 'Foundations of stated preference elicitation: consumer behavior and choice-based conjoint analysis', *Foundations and Trends in Econometrics*, vol. 10, no. 1-2, pp 1-144.

267. Planning and Transport Research Centre 2014, *Independent Transport Modelling Review*, University of Western Australia, Perth, pp 17-22, available via: www.patrec.uwa.edu.au/__data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.

268. Planning and Transport Research Centre 2014, *Independent Transport Modelling Review*, University of Western Australia, Perth, pp 25-36, available via: www.patrec.uwa.edu.au/__data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.

269 Transport for NSW 2019, *Open data: Travel Zone Projections for Population, Workforce and Employment in the Greater Sydney Metropolitan Area*, NSW Government, viewed 3 May 2019, https://opendata.transport.nsw.gov.au/search/type/dataset.

270. Frydenberg J, Tudge A and Coleman D 2019, *Inaugural Treasurers' Forum on Population*, media release, Canberra, 8 February 2019, available via: http://jaf.ministers.treasury.gov.au/media-release/010-2019.

271. Bureau of Infrastructure, Transport and Regional Economics 2018, National Data Collection and Dissemination Plan, Bureau of Infrastructure, Transport and Regional Economics, Canberra, p 15, available via: www.bitre.gov.au/data_dissemination/files/National_Infrastructure_Data_Collection_and_Dissemination_Plan.pdf.

272. Stopher, P and Greaves, S 2007, 'Household travel surveys: where are we going?', Transportation Research Part A: Policy and Practice, vol. 41, pp 367-381.

273. Verzosa, N, Greaves, S, Ho, C and Davis, M 2018, *Willingness to participate in travel surveys: A cross-country and cross-methods comparison*, Australasian Transport Research Forum, Darwin, p 5, available via: https://atrf.info/papers/2018/files/ATRF2018_paper_71.pdf.

274. Verzosa, N, Greaves, S, Ho, C and Davis, M 2018, *Willingness to participate in travel surveys: A cross-country and cross-methods comparison*, Australasian Transport Research Forum, Darwin, p 6, available via: https://atrf.info/papers/2018/files/ATRF2018_paper_71.pdf.

275. Shen, L, Fields, S, Stopher, P and Zhang, Y 2016, *The future direction of household travel survey methods in Australia*, Australasian Transport Research Forum, Melbourne, p 1,available via: https://atrf.info/papers/2016/files/ATRF2016_Full_papers_resubmission_115.pdf.

276. Chu, Z, Cheng, L and Chen, H 2012, *A review of activity-based demand modelling*, American Society of Civil Engineers, Reston, p 49, available via: www.researchgate.net/publication/268583253_A_Review_of_Activity-Based_Travel_Demand_Modeling.

277. Chu, Z, Cheng, L and Chen, H 2012, *A review of activity-based demand modelling*, American Society of Civil Engineers, Reston, p 51, available via: www.researchgate.net/publication/268583253_A_Review_of_Activity-Based_Travel_Demand_Modeling.

278. Planning and Transport Research Centre 2014, Independent Transport Modelling Review, University of Western Australia, Perth, pp 25-36, available via: www.patrec.uwa.edu.au/__data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.

279. KPMG and ARUP 2017, *Model Calibration and Validation Report*, Infrastructure Victoria, Melbourne, p 3, available via: www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/KPMG-MABM-Validation-Report-December-2017.pdf.

280. Vovsha, P, Donnelly, R and Gupta, S 2008, 'Network Equilibrium with Activity-Based Microsimulation Models: The New York Experience', *Transportation Research Record*, vol. 2054, no. 1, pp 1-10.

281. Infrastructure Victoria 2018, *Advice on automated and zero emissions vehicle infrastructure*, Infrastructure Victoria, viewed 3 May 2019, www.infrastructurevictoria.com.au/project/automated-and-zero-emission-vehicle-infrastructure/.

282. Planning and Transport Research Centre 2014, *Independent Transport Modelling Review*, University of Western Australia, Perth, p 34, available via: www.patrec.uwa.edu.au/__data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.

283. Department of Treasury and Finance 2013, *The Victorian Economic Evaluation for Business Cases Technical guidelines*, Victorian Government, p 20, available via: www.dtf.vic.gov.au/sites/default/files/2018-03/Economic%20Evaluation%20-%20Technical%20Guide.doc.

284. KPMG 2018, *Transport Modelling: The KMPG Melbourne Activity and Agent Based Model*, KPMG, viewed 6 March 2019, https://home.kpmg/au/en/home/insights/2018/03/transport-modelling-melbourne-activity-based-model.html.

285. Anylogic 2019, *PwC Australia and PwC Customer-Centric Transport Transportation Modelling,* Anylogic, viewed 11 March 2019, www.anylogic.com/customer-centric-transportation-network-modelling/.

286. Bliemer, M C J, Raadsen, M P H, Brederode, L J N, Bell, M G H, Wismans, L J and Smith, M J 2017, 'Genetics of traffic assignment models for strategic transport planning', *Transport Reviews*, vol. 37, no. 1, pp 56-78.

287. Bliemer, M C J and Raadsen, M P H 2019, *Static traffic assignment with residual queues and spillback*, Swiss Transport Research Conference, Monte Veritá, pp 1-33, available via: www.strc.ch/2017/Bliemer_Raadsen.pdf.

288. Transportation Research Board of the National Academies 2011, *Dynamic traffic assignment: a primer,* Transportation Research Board of the National Academies, viewed 6 May 2019, available via: https://onlinepubs.trb.org/onlinepubs/circulars/ec153.pdf.

289 Horni, A, Nagel, K and Axhausen, K W 2016, *The Multi-Agent Transport Simulation MATSim*, MATsim, viewed 11 April 2019, www.matsim.org/the-book.

290. Iryo T 2011, 'Multiple equilibria in a dynamic traffic network', *Transportation Research Part B: Methodological*, vol. 45, no. 6, pp 867-879.

291. Google Code 2019, *TRANSIMS*, Google, viewed 12 April 2019, https://code.google.com/archive/p/transims/.

292. Planning and Transport Research Centre 2014, *Independent Transport Modelling Review*, University of Western Australia, Perth, pp 25-36, vailable via: www.patrec.uwa.edu.au/__data/assets/pdf_file/0003/2578710/2014-Transport-Modelling-Review.pdf.

293. Ellison, R, Teye, C and Hensher D A 2017, 'Modelling Sydney's light commercial service vehicles', *Transportation Research Part A: Policy and Practice*, vol. 96, p 79-89.

294. Australian Transport Assessment and Planning 2016, *F0.2 Integrated transport and land use planning*, Australian Transport Assessment and Planning, viewed 10 April 2019, www.atap.gov.au/framework/integrated-transport-land-use-planning/index.aspx.

295. Simmonds D, C 1999, 'The design of the DELTA land-use modelling package', *Environment and Planning C: Planning and Design*, vol. 26, pp 665-684.

296. Simmonds D, C 1999, 'The design of the DELTA land-use modelling package', *Environment and Planning C: Planning and Design*, vol. 26, pp 665-684.

297. Huynh, N, Perez, P, Berryman, M and Barthelemy, J 2015, 'Simulating transport and land use interdependencies for strategic urban planning – an agent-based modelling approach', *Systems*, vol. 3, no. 4, 177-210.

298. Ho, C, Hensher, D A, Ellison and R 2017, 'Endogenous treatment of residential location choices in transport and land use models: introducing the MetroScan framework', *Journal of Transport Geography*, vol. 64, pp 120-131.

299. Hensher, D A, Ho, C, and Ellison, R 2019 'Simultaneous location of firms and jobs in a transport and land use model', *Journal of Transport Geography*, vol. 75, pp 110-121.

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