AUTOMATED & ZERO EMISSION VEHICLE LAND USE SCENARIOS

PREPARED FOR
Infrastructure Victoria

SGS Economics & Planning | Independent insight.

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Executive Summary

The report is one product in an ecosystem of final products for the automated and zero emission vehicle land use scenarios project. The ecosystem is designed to package the findings and data to meet the needs of a various range of users. The ecosystem contains this report, an interactive online map and a detailed excel data files.

An uncertain future with automated and zero emissions vehicles

Automated and zero emission vehicles have the potential to change how Victoria's transport network operates. Their introduction could increase road capacity, improve safety, provide greater mobility for older people and those with disability, raise productivity during travel time and provide better access to labour markets for business. As identified in *Victoria's 30-Year Infrastructure Strategy*, how and when these technologies will be adopted are two of the biggest questions for the transport system.

It has long been observed that the economic geography and land use patterns adjust over time in response to changes in relative transport accessibility. Substantial shifts in transport accessibility have changed the location choices of firms and households alike. Moving operations to areas of superior accessibility reduces transaction costs in dealing with suppliers and distributors, as well as improving access to workers. These same dynamics apply to households. They adjust location to maximise opportunities for employment, education, recreation and other services.

This, in turn, will signal where new and/or intensified urban development is warranted under commercial market rules. The outcome is a shift in urban form and urban structure. Thus, major transport infrastructure projects (public transport networks, major freeway) have shaped the pattern of urban development.

The uptake of automated and zero emissions vehicles presents an opportunity to change the accessibility profile of Victoria. The complexity of factors driving urban development patterns, the uncertainty of behavioural patterns and the long-time horizon means there is considerable uncertainty around the impact of automated and zero emission vehicles on the future spatial distribution of people and jobs. Nevertheless, it is important to plan for the very likely arrival of automated and zero emission vehicles and testing possible scenarios is a useful way to do so.

To assist in planning for these new technologies, this report for Infrastructure Victoria details the results of testing the land use impact of seven different automated and zero emission vehicles scenarios. It will inform advice to the Victorian Special Minister of State on the infrastructure required to enable the implementation of highly automated and zero emissions vehicles in Victoria.

Historical urban development patterns

Over the past 150 years, major transport infrastructure has set the pattern of Greater Melbourne's urban development. Substantial shifts in accessibility (provided by tram, train and car) have changed the location preferences of firms and households, setting in place a new geography of land values. While, automated and zero emission vehicles represent a form of new transport infrastructure, examining this historical relationship can provide some clues as to what their impact might be.

Melbourne began as a relatively compact settlement largely confined to the inner suburbs. The city grew rapidly along tram and rail networks into the first half of the 20th Century. With rising car ownership and high post-war population growth, an extensive plan for major freeway and arterial road construction was embarked upon in the 1960s. This period was characterised by a dominant model of dispersed population and employment growth, with large scale movement to the suburbs and a strong manufacturing-based economy.

From the mid-1990s, the outward expansion slowed and urban density increased, with the inner city and locations along public transport corridors attracting development. A major driving factor was Melbourne's changing economic structure and the shift in growth towards a service-based and knowledge-based economy. The opening of the City Loop during the early 1980s also had a significant impact. Some sprawling development still occurred on the urban fringe, particularly in the western and north western suburbs. This development was facilitated by transport projects such as the Western Ring Road and CityLink.

Potential future impacts

Into the future, automated and zero emissions vehicles have the potential to change Victoria's transport system and pattern of urban development. Some of these mechanisms could act in different directions or be complementary:

- **Accessibility**: Access to transport and the quality of that transport is a major driver of demand for housing and employment land in a city. Since automated and zero emission vehicle technology will be freely available to everyone, the accessibility impacts will be more dispersed than traditional transport impacts like highways and rail lines. The impacts will likely be felt across Melbourne but probably most strongly in outer urban areas and areas close to major roads.
- **Vehicle ownership patterns:** Presently, it is unclear whether automated and zero emissions vehicles will bring about a rise or decline in vehicle ownership. The lower labour costs for driverless taxis (Robotaxis) could make taxi travel more affordable than private car ownership and even public transport services. Conversely, there may be higher perceived costs of travel because Robotaxi fares are likely to cover the associated costs of registration, insurance and maintenance[1].
- **Cost of travel:** Higher travel costs encourage people to move closer to the city as the higher cost of land (or rent) is offset by the savings in travel cost. Conversely, lower travel costs encourage sprawl by increasing the relative cost of land. Importantly, the marginal utility of travel time (MUTT)[2] could change dramatically when time in an automated vehicle could be spent productively rather than being focussed on the task of driving. For those individuals, the time cost of travel may be greatly reduced.
- **Peak period impacts:** Automated vehicles are likely to alleviate peak period congestion because they will require smaller headways (the stopping distance between cars) and they will be able to make quicker, more consistent and safe road manoeuvres. This 'platooning' will increase the network capacity because cars are able to travel closer together than traditional cars at the same speed.
- **Commercial feasibility of housing development:** Traditionally, a major cost for high density development is providing underground car parking. High take-up of automated vehicles and suitable changes to planning polices, may reduce the need for underground car parking. Eliminating the need for underground parking would lower construction costs and increase commercial feasibility for development in areas which have an existing level of demand.
- **Amenity improvements:** The adoption of automated and zero emission vehicles in the freight industry may help address amenity issues along major road corridors.

Different scenarios for automated and zero emissions vehicles

The scenarios in this report each look at different ownership and market models as well as different travel time utilities. The three key scenarios are Slow Lane, Private Drive and Fleet Street, with some sensitivity tests examined for different utilities of travel time and the degree of empty running in the road network.

- **Slow Lane.** There is a 50/50 mix between private and shared ownership and between automated and zero emission and internal combustion vehicles. Many of the benefits of the former (e.g. increased speeds, reduced accidents) are not fully achieved as half of the vehicles are still driven by humans.
- **Private Drive**. All cars are privately owned, fully automated and create zero emissions. The car knows the best route to take because it is continuously updated with current traffic patterns and road maintenance data.
- **Fleet Street**. Households and business no longer own private cars. Rather companies own fleets of automated, zero emission vehicles and offer a range of transport services at different price points.

Three sensitivities are also examined. The **Private Drive Empty Running** scenario allows empty running of private vehicles which are not in use[3]. The **Private Drive Low MUTT** and **Fleet Street Low MUTT** scenarios use a low marginal utility of travel time.

[1]This compares to private vehicle ownership when at the time of a trip, many of these costs have occurred in the past. Consumers are likely to discount sunk costs and perceive a greater weight for costs that are incurred at the time of travel.

[2]The MUTT reflects how people value travel time (or the utility they derive from that time). A low MUTT indicates people place a lower value on travel time, trips then have a lower cost and individuals are willing to travel longer distances.

[3]Empty running refers to automated vehicles driving while unoccupied, usually to avoid parking. In the private drive scenarios, it means cars remaining driving when not being used by an owner. Under the shared ownership scenarios, it refers to cars remaining moving while in between passengers.

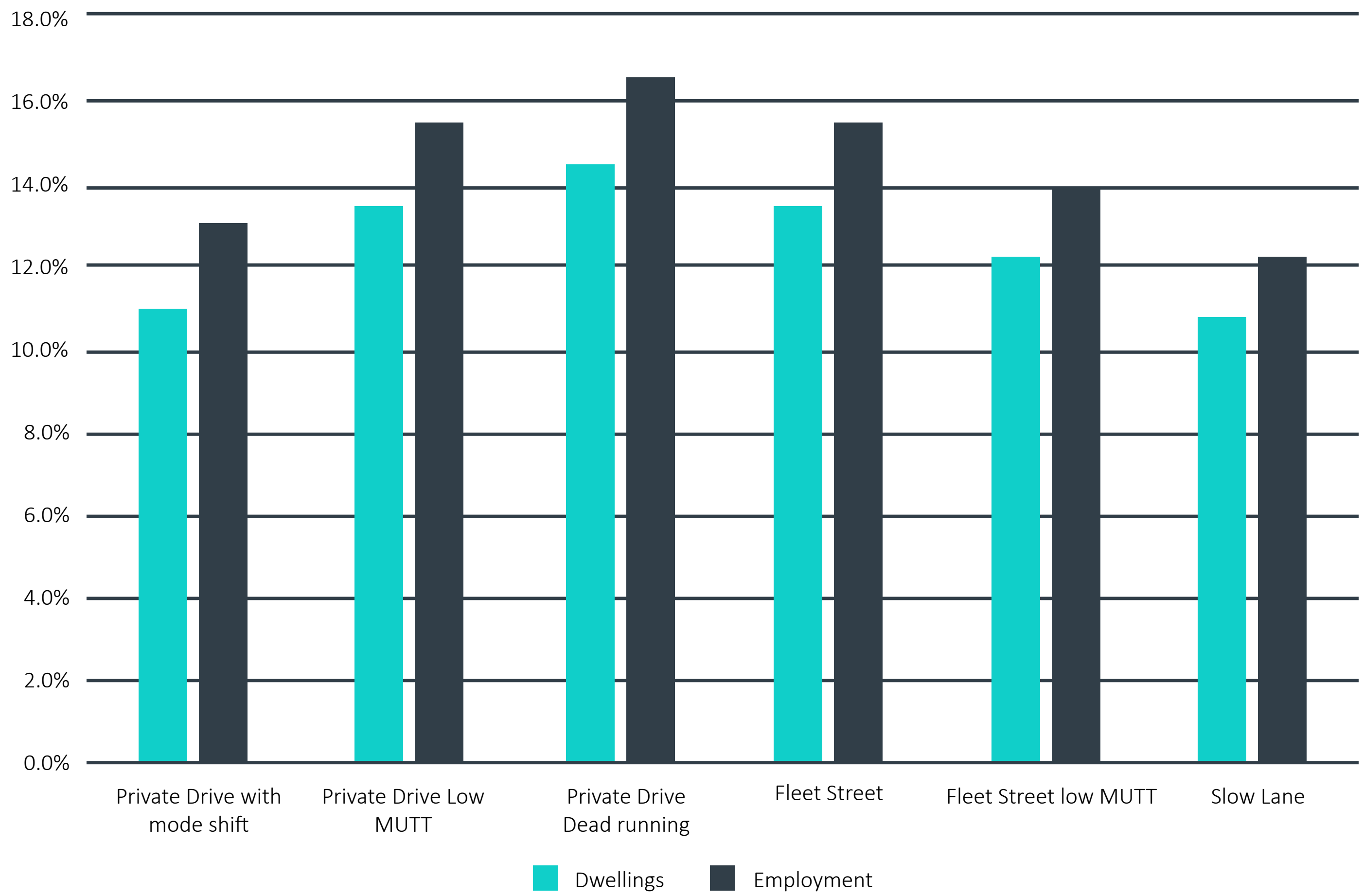
Population and land use impacts of study scenarios

The land use impacts of all the scenarios show a consistent overall pattern of dwellings and jobs being redistributed to the outer suburbs. The changes in relative accessibility with the adoption of automated and zero emissions vehicles cause between 10.8 and 14.5 per cent of dwellings, and between 12.3 and 16.6 per cent of jobs to shift location in Greater Melbourne[4]. This is a significant impact on the urban structure of the city. In comparison, major transport projects such as CityLink, EastLink and rail projects have only shifted 1 to 4 per cent of additional dwellings.

The land use impacts from the scenarios bear many similarities to the development patterns which were observed when car ownership became commonplace during the 1950s, 1960s and 1970s.

While several factors are at play, this large shift can primarily be attributed to the effect that automated and zero emission vehicles have on car use and congestion. Under all the scenarios, the cost of car travel was reduced such that the overall amount of car transport increased. The outcome of this was that while automated and zero emissions vehicles provided increased levels of accessibility, they also increased the level of congestion within already congested parts of the city. This had an offsetting impact on relative accessibility.

FIGURE 1: REDISTRIBUTION OF EMPLOYMENT AND HOUSEHOLD GROWTH UNDER DIFFERENT SCENARIOS



Source: SGS Economics and Planning, 2018

[4]These are dwellings or jobs that shifted location at the Statistical Area 2 level.

Inner city locations and areas surrounding major suburban employment hubs become relatively less attractive for households, while middle ring suburbs with good arterial roads and access to the freeway network become more attractive.

In particular, the Peninsula Link – East Link – North East Link Corridor (Casey – North to Whittlesea – Wallan) has contributed significant additional dwelling and employment growth under all scenarios. Brimbank in the west (at the junction of the Western Ring Road, Western Freeway and the Calder Freeway) also sees additional dwelling and job growth.

This outcome is also supported by a review of the literature, which has shown that automated vehicles are most beneficial to longer trips. In terms of policy implications, the scenarios suggest that automated vehicles will create additional growth fronts across Greater Melbourne. Inner city and fringe greenfields will continue to see significant rates of growth, however, established middle ring and outer suburbs will see a surge in urban development.

While automated and zero emission vehicles cause large shifts in where new dwellings locate (compared to the base case), overall, development is dispersed to the extent that density across the Greater Melbourne remains largely unchanged. The vehicles improve transport accessibility and therefore housing demand across a wide area (a similar pattern is seen with employment).

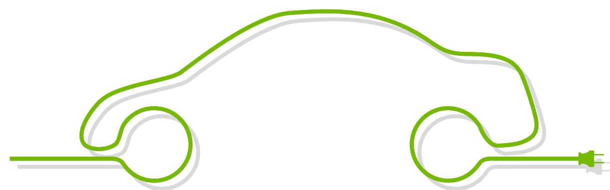
The market responds by providing additional medium density dwellings, but the dispersed nature of the demand means there is only a modest increase in housing densities to accommodate the increasing population. With only modest increases in housing densities, there would be no need to expand the existing urban growth boundary under these scenarios.

In middle ring suburbs, the removal of the need for car parking does not appear to create a change in the likely density of development. Dwellings may become slightly larger or more affordable without the need for onsite car parking under the Fleet Street scenario. In inner suburbs, the removal of the need for carparking will likely result in slightly more affordable dwellings.

Given the high level of growth anticipated in the inner city locations, the decrease in additional population growth would have little impact on the need to provide additional infrastructure (e.g. schools, open space, health services) in this part of Victoria. The middle ring suburbs which will see additional growth which should be able to absorb additional housing without the need for significant additional infrastructure. Additional growth in greenfield areas would only add to the infrastructure challenge on Melbourne's urban fringe. It is still important to note that these conclusions for future infrastructure provision have not been able to consider the very local infrastructure and service provision thresholds would have to be reviewed in the face of changes to population and employment growth.

In Regional Victoria, Greater Geelong sees the strongest growth. Ballarat, Bendigo and other regional cities also see additional growth. Most rural areas see a decline in dwellings and jobs growth. Some parts of Regional Victoria, which are already experiencing stagnant or declining populations, will see even lower levels of population growth.

This impacts in regional areas may create some threshold issues for the provision of some services (e.g. retail and health) and infrastructure (e.g. schools). In the scenarios where there is additional growth in Regional Victoria, small towns and peri-urban residential areas will accommodate this growth via infill development and small increases in residential densities, but there would not be any need to expand urban growth boundaries or encroach on other land uses.



01 Introduction

> Automated and zero emission vehicles have the potential to radically change how Victoria’s transport network operates.

Automated and zero emission vehicles have the potential to significantly change the way people travel and shape the pattern of urban development. Planning for their eventual use will be crucial for maximising their benefits. However, the complexity of the urban system and the long-time horizon associated with their delivery makes doing so difficult. As a result, several scenarios have been developed to help understand their potential impact.

1.1 Purpose

Automated and zero emission vehicles have the potential to radically change how Victoria's transport network operates. For example, their introduction could increase road capacity, improve safety, provide greater mobility for mature age people and those with disability, raise productivity during travel time and provide better access to labour markets for business.

As a result, several land use scenarios (in terms of dwellings, population and employment) have been developed to help understand their potential impact. Detailed in Table 1, the scenarios are based on different models of vehicle ownership, potential variation in human preferences and driver behaviour, as well as different rates of technology uptake.

The land use impacts are based on statistical modelling of historical changes in accessibly which have resulted from transport infrastructure projects (e.g. CityLink, Western Ring Road, EastLink), transport modelling outputs from the Melbourne Activity and Agent Based transport Model and the 2015 *Victoria in Future* population projections.

TABLE 1: LAND USE SCENARIOS

SCENARIO	DESCRIPTION
Slow Lane	There is a 50/50 mix between private and shared ownership and between automated and zero emission and internal combustion vehicles. Many of the benefits of the former (e.g. increased speeds, reduced accidents) are not fully achieved as half of the vehicles are still driven by humans.
Private Drive	All cars are privately owned, fully automated and create zero emissions. The car knows the best route to take because it is continuously updated with current traffic patterns and road maintenance data.
Fleet Street	Households and business no longer own private cars. Rather, companies own fleets of driverless, zero emission vehicles and offer a range of transport services at different price points.

1.2 Project background - request for advice

In October 2017, the Victorian Special Minister of State formally requested that Infrastructure Victoria provide advice on the infrastructure required to enable the implementation of highly automated and zero emissions vehicles in Victoria. As identified in *Victoria's 30-Year Infrastructure Strategy*, how and when these technologies will be adopted are two of the biggest questions for the transport system.

The Minister expects that Infrastructure Victoria will comprehensively engage with industry and other key stakeholders, draw on international comparators and research, and develop their own modelling and analysis.

The advice is to be presented in two parts:

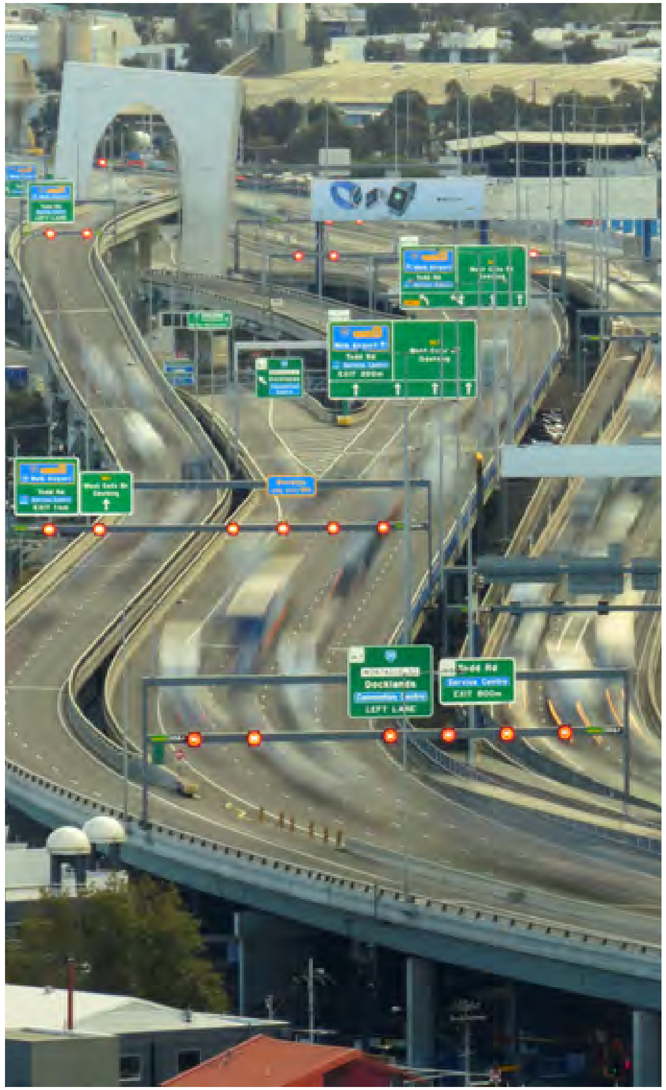
- A scenarios report (published in April 2018), set out potential future scenarios for the uptake of automated and zero emissions vehicles in Victoria that will form the basis of the advice.
- Evidence and analysis, detailing potential infrastructure requirements for automated and zero emissions vehicles will be published in August 2018. The final report will analyse the current situation, recommend delivery pathways and identify key decision or trigger points for infrastructure and will be provided to the Minister in October 2018.

1.3 Report structure

This report is structured as follows:

- Section two provides a short summary of Greater Melbourne urban development patterns;
- Section three provides an overview of some of the literature related to the potential impacts of automated and zero emission vehicles;
- Section four describes the scenarios to be examined;
- Section five presents a simple overview of the various models which are used to produce the land use scenarios. A more detailed explanation of the models in terms of data inputs and assumptions is provided in the Appendix;
- Section six explores some potential impacts on the commercial feasibility of housing;
- Section seven outlines the base case scenario;
- Section eight outlines the land use results for the various automated and zero emissions vehicle scenarios; and
- Section nine contains some conclusions and implications.

The report is one product in an ecosystem of final products for the automated and zero emission vehicle land use scenarios project. The ecosystem is designed to package the findings and data to meet the needs of a various range of users. The ecosystem contains this report, an interactive online map and detailed excel data files.



02
Historical Urban Development Patterns

> "How land uses are arranged can influence all aspects of how a city functions."

Over the past 150 years, major transport infrastructure has set the pattern of urban development. Substantial shifts in accessibility (provided by tram, train and car) have changed the location choices of firms and households, setting in place a new geography of land values. This, in turn, will signal where new and/or intensified urban development is commercially feasible.

2.1 An historical link

Urban development patterns are defined by the relationships of the dominant land uses (residential, commercial industrial etc), and the infrastructure networks that serve them. How land uses are arranged can influence all aspects of how a city functions. The urban development patterns and economic geography influences the social, economic and environmental characteristics of the city. Urban development patterns have long been shaped by the dominant transport mode at the time.

While, automated and zero emission vehicles represent a form of new transport infrastructure, examining this historical relationship can provide some clues as to what their impact might be. This section provides a brief overview of the how Melbourne's urban development patterns have developed in response to changes to transport accessibility.

2.2 Early development

Australia's second largest city, Greater Melbourne has a population of 4.9 million people[5], centred on the meeting of the Yarra River and Port Phillip Bay. European settlement of the city began in the 1830s and soon after the grid layout that still defines the CBD today was laid by surveyor Robert Hoddle (the 'Hoddle Grid').

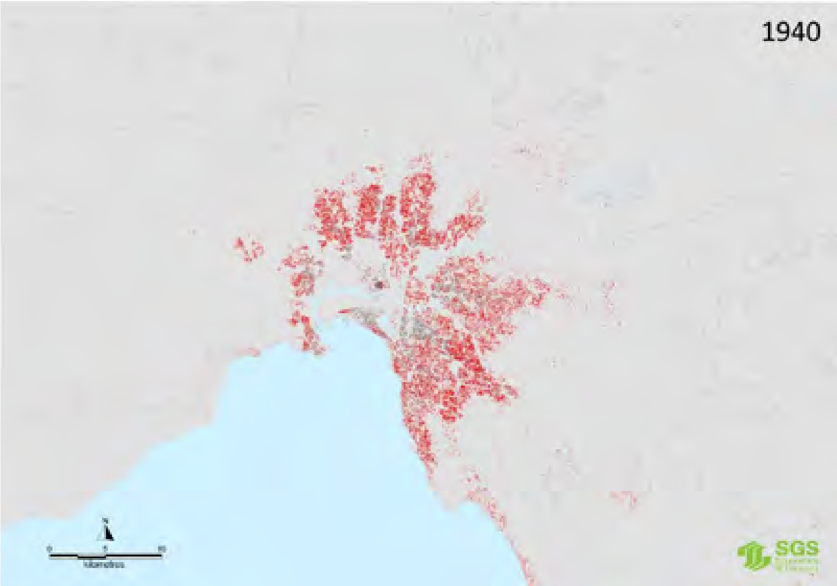
Initially developing either side of the Yarra River, Melbourne began as a relatively compact settlement largely confined to what is now the CBD and inner suburbs. The gold rush of the 1850s and 1860s saw a dramatic increase in the city's wealth, but also the development of large secondary cities in Ballarat, Bendigo, and although not directly related to the gold rush, Geelong.

Rail lines between these secondary cities and Melbourne were established in those early years. Driven by a land boom, numerous tramways then rail lines were built in Melbourne to facilitate land sales, and the city grew rapidly along these tram and rail networks. Development first spread east of the CBD where the topography is undulating, and the soil is fertile, which provided a more desirable environment. The flatlands of the west were initially developed for industrial uses.

By 1940, the urban development patterns of Greater Melbourne still followed the rail and tram lines set out during the 19th Century. This can be seen in Figure 2 below, where the grey properties are those constructed prior to 1900 and the red properties are those constructed between 1900 and 1940.

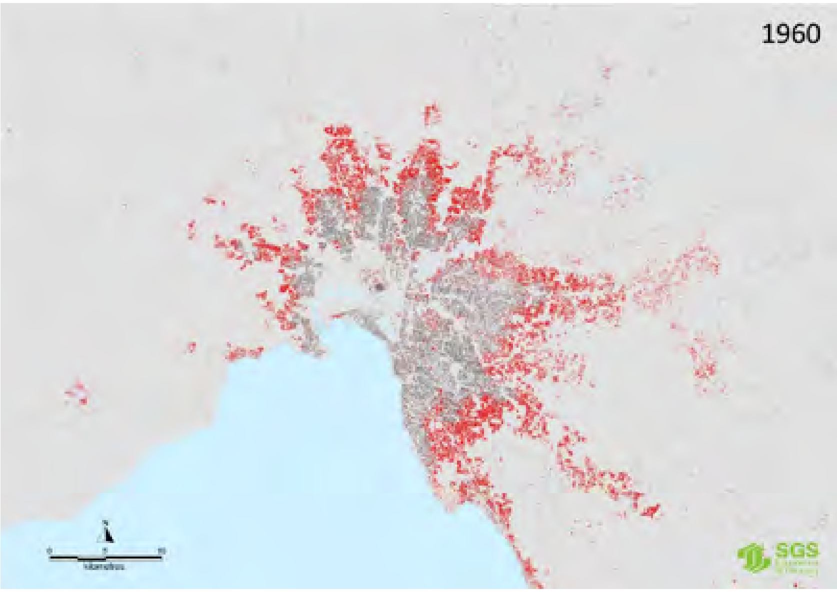
[5]As of 30 June 2017: ABS (2018) cat. no. 3218.0, Regional Population Growth, Australia, 2016-17

FIGURE 2: RESIDENTIAL PROPERTIES CONSTRUCTED BY 1940



Source: SGS Economics & Planning, 2018

FIGURE 4: RESIDENTIAL PROPERTIES CONSTRUCTED BETWEEN 1940 AND 1960



Source: SGS Economics & Planning, 2018

2.3 Post-war period

Developed around the extensive tram and rail network, Melbourne's early urban structure remained largely unchanged until the 1960s when, with rising car ownership (see Figure 4on page 5) and high post-war population growth, an extensive plan for major freeway and arterial road construction was embarked upon. This was also on the back of manufacturing plants setting up across suburban Melbourne. Figure 3 helps to highlight the rapid growth in the importance of the manufacturing industry. [6]

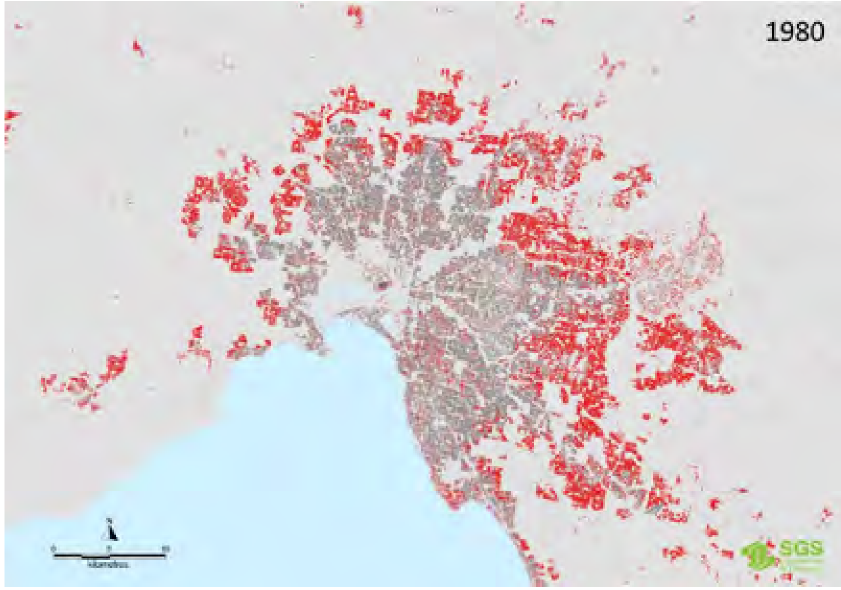
FIGURE 3: SELECTED INDUSTRY SHARE OF AUSTRALIAN GDP

Source: SGS Economics & Planning, 2018 (derived from ABS National Accounts)

While not all components of the 1969 Transport Plan were ultimately constructed, this period of road building led to a dramatic expansion in Melbourne's urban footprint. As seen in Figure 5, the city branched away from the traditional public transport corridors in this period and spread further out into formerly rural and farming land, particularly to the south east.

[6]While the data shown in the figure is for Australia, the same pattern would have been seen in Melbourne, although the share of Manufacturing would have been higher as the city would have had minimal Agricultural or Mining production.

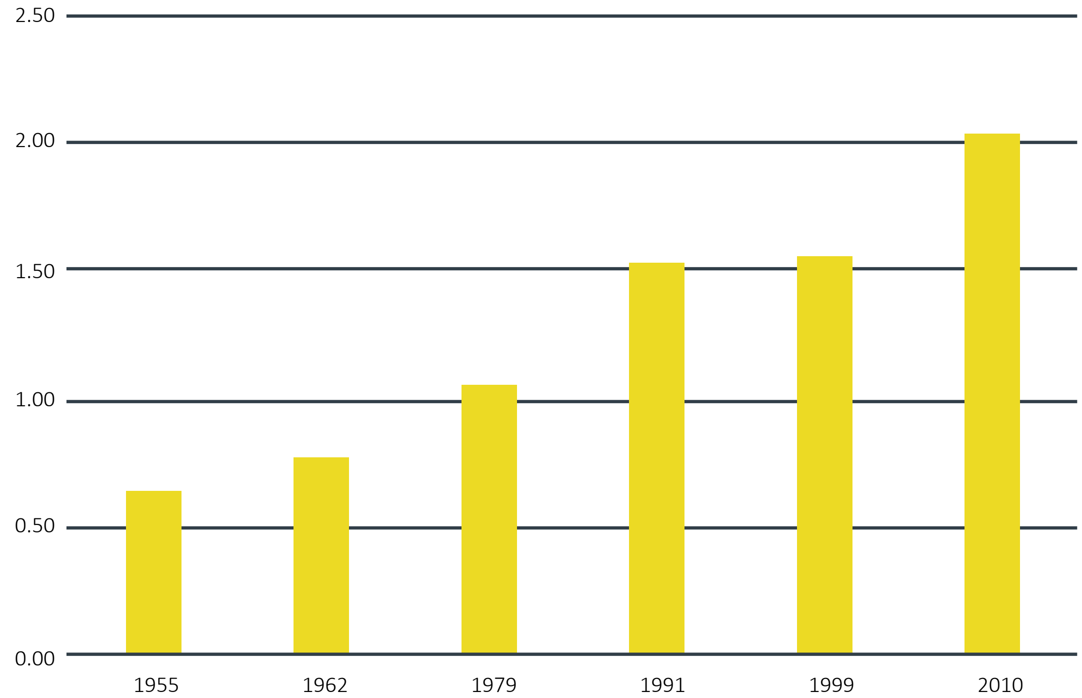
FIGURE 5: RESIDENTIAL PROPERTIES CONSTRUCTED BETWEEN 1960 AND 1980



Source: SGS Economics & Planning, 2018

The period from the late 1960s to the early 1990s was characterised by a dominant model of dispersed population and employment growth, with mass suburbanisation leading to a city today spread over an area of 2,500 square kilometres that is close to 100 kilometres wide and 100 kilometres long. Over this period, the average number of cars per occupied dwelling in Victoria went from around 0.8 cars to over 1.5 cars per occupied dwelling (see Figure 6).

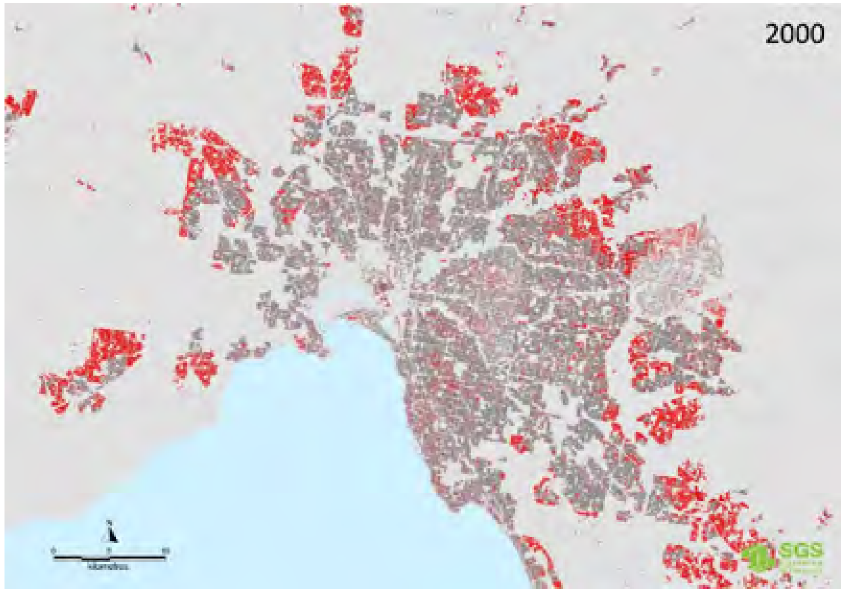
FIGURE 6: AVERAGE NUMBER OF CARS PER OCCUPIED DWELLINGS IN VICTORIA



Source: SGS Economics & Planning, based on Census of Motor Vehicles and Population Census

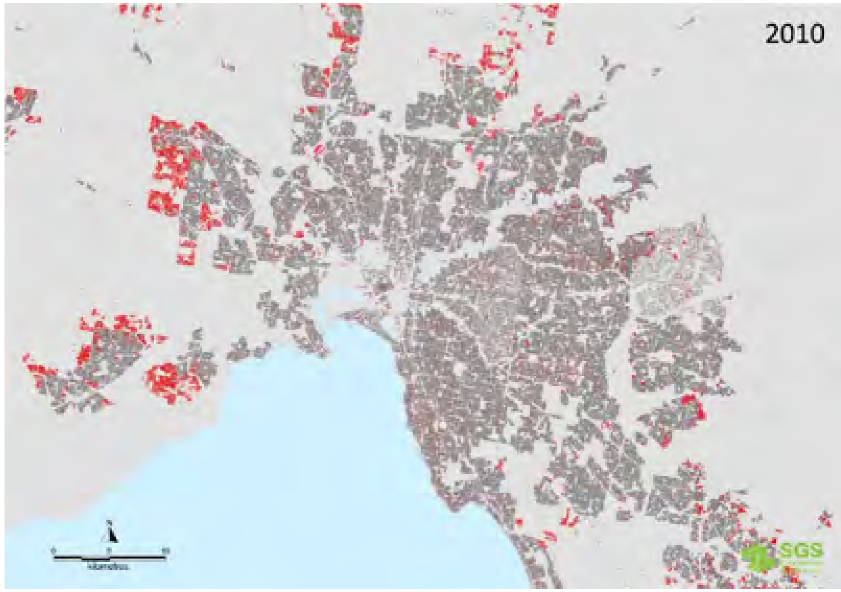
This period of urban expansion was also facilitated by Melbourne's extensive road network which coincided with, and complemented and reinforced, an economy based on manufacturing. With a locational preference for large lots on cheap land close to road networks, manufacturing precincts were spotted around the city. These provided a range of jobs, including high-paying positions to their surrounding resident populations.

FIGURE 7: RESIDENTIAL PROPERTIES CONSTRUCTED BETWEEN 1980 AND 2000



Source: SGS Economics & Planning, 2018

FIGURE 8: RESIDENTIAL PROPERTIES CONSTRUCTED BETWEEN 2000 AND 2010



Source: SGS Economics & Planning, 2018

2.4 Contemporary trends

From the mid-1990s the outward expansion slowed, and urban density increased, with the inner city and locations along public transport corridors attracting development. This was related to an increase in car congestion starting to limit transport options in inner Melbourne[7]. This can be seen in Figure 7 and Figure 8, with fewer red areas on the fringes than earlier periods and more red infill development scattered within the inner and middle ring areas of Melbourne.

While always the largest centre for employment, the CBD began to experience a substantial increase in jobs at this time, while also seeing the productivity of those jobs rise dramatically. In stark contrast to the 1970s and 1980s when the emphasis was on suburban growth, the 1990s saw population and employment growth return to the inner suburbs.

A major driving factor was Melbourne's changing economic structure and the shift in growth towards a service-based and knowledge-based economy. This resulted in a concentration of higher paying employment to the city centre with employment growth in the suburbs being largely in population serving firms and organisations. This shift has raised the value of land with good access to the employment opportunities of the CBD and inner city.

The opening of the City Loop during the early 1980s also had a significant impact on employment growth (in concert with the Southbank and Docklands urban renewal) and residential development (due to planning controls and changing social trends) in the CBD.

Some sprawling development still occurred on the urban fringe, particularly in the western and north western suburbs. This development was facilitated by transport projects such as the Western Ring Road and CityLink.

[7]At this time, Melbourne was served by several freeways that terminated in its inner suburbs, generally five kilometres from the centre. Once traffic left these freeways, it was distributed onto local and arterial roads, resulting in gridlock and some roads of the city, notably King, Spencer and Swanston Streets performing major through road arterial roles. Some inner residential and urban streets were handling volumes up to 80% greater than their planned capacity (Russell, 2000, Audit Review of Government Contracts, Contracting, Privatisation, Probity and Disclosure in Victoria 1992-1999, An Independent Report to Government (Vol. 2 –Case Studies). Melbourne: State Government of Victoria).

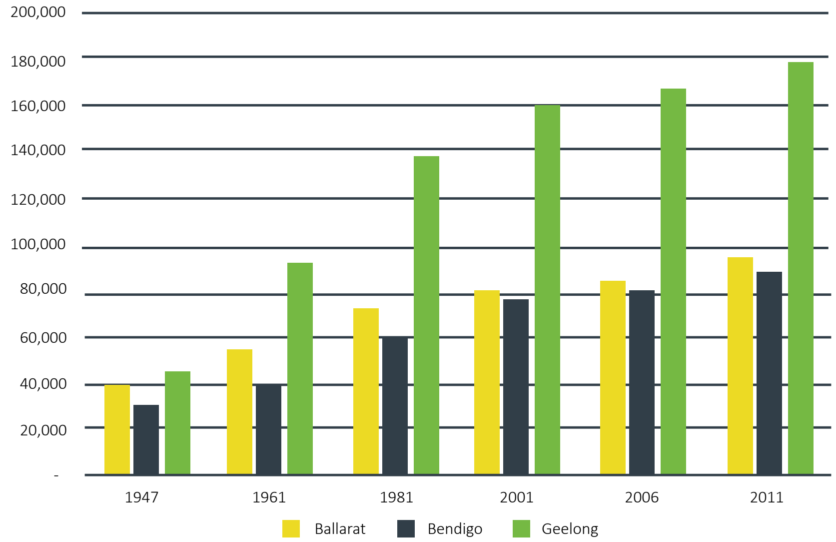
2.5 Regional Victoria

Some similar trends can be seen in the historical growth of Victoria's regional cities. In the late 1940s, Ballarat, Bendigo and Geelong were in the range of 31,000 to 45,000 residents (see Figure 9). By 1961, Geelong was approximately twice the size of Ballarat and Bendigo.

The concentration was driven by a growing manufacturing industry in Geelong (which was closely linked to Melbourne) and investment in roads and suburban development. The natural geography of Geelong also meant that it could sprawl at a much greater rate than Ballarat and Bendigo, which were more challenged by the natural terrain.

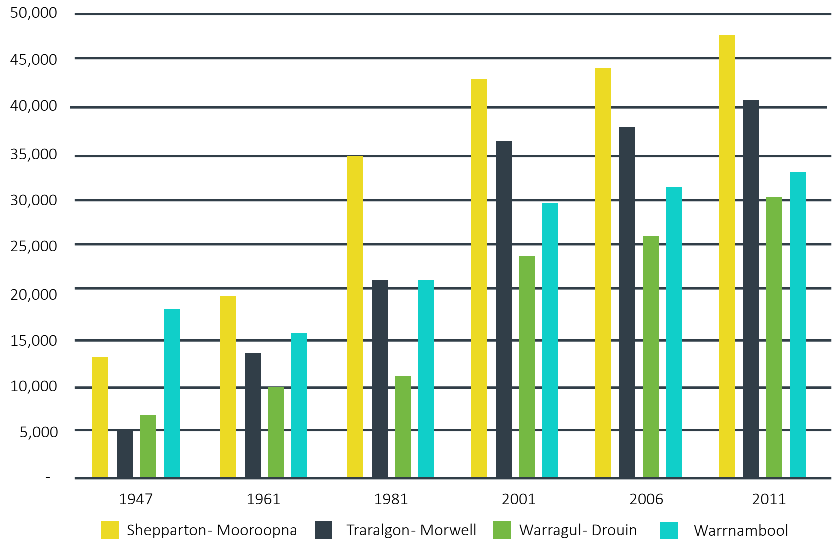
The factors driving the population growth of smaller regional cities (see Figure 10) are more local in nature. For example, local economic strength and proximity to Greater Melbourne.

FIGURE 9: POPULATION OF LARGER REGIONAL CITIES



Source: Australian Historical Population Statistics (Cat. No 3105.0.65.001)

FIGURE 10: POPULATION OF SMALLER REGIONAL CITIES



Source: Australian Historical Population Statistics (Cat. No 3105.0.65.001)

03

Potential Future Impacts

> "Access to transport and quality of that transport is a major driver of demand for housing and employment land in a city."

Automated and zero emissions vehicles have the potential to change Victoria's transport system and pattern of urban development. Some of these mechanisms could act in different directions or be complementary. The role of accessibility, vehicle ownership patterns, the cost of travel, peak period impacts, commercial feasibility, and local amenity are discussed below.

3.1 Accessibility

Access to transport and quality of that transport is a major driver of demand for housing and employment land in a city. Changes to the transport network can shape and reshape the land use development pattern and density of a city; indeed, transport investments can be used to facilitate and encourage a desired urban form.

Changing the accessibility of an area will ultimately result in changes in the land uses of those areas. Initially, a change in accessibility creates a travel-time savings benefit for those living or working in the affected corridor. Developers, households and firms then look to capitalise on this benefit and, as a result, these affected areas tend to see an increase in terms of employment and housing density post-project. This, in turn, will signal where new and/or intensified urban development is warranted under commercial market rules.

This typical pattern of transport accessibility impacts can be seen in the Western Ring Road case study below. The introduction of automated and zero emission vehicles is likely to present somewhat different impacts because the technology will be freely available to everyone. Given this, the impacts will be dispersed and will likely be felt most strongly in outer urban areas and areas close to major roads, particularly under a shared fleet scenario where users do not own their own cars. This possible effect is explored further below in the Vehicle Ownership section on page 12.

Better transport access can bring about many other accessibility benefits. Modelling by KPMG, Arup and Jacobs (2016) found that automated and zero emission vehicles may significantly improve access to employment opportunities, health services, education and central Melbourne[8]. However, the model did not account for future land use changes that will result from better access to transport. Many of these will be further improved as land uses adapt to automated and zero emission vehicles, particularly access to labour market opportunities.

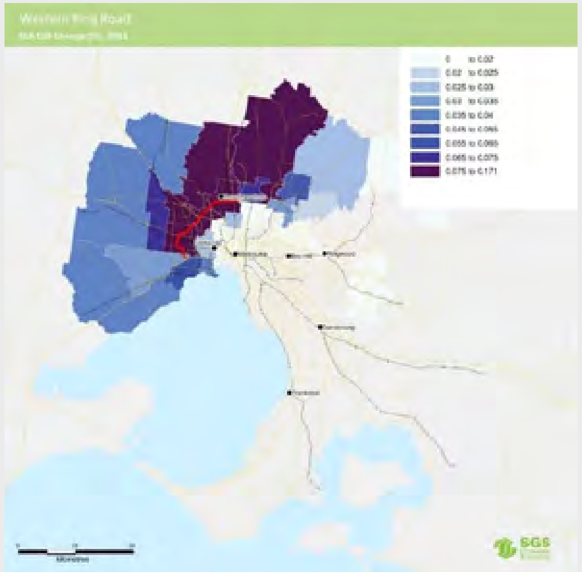
The additional demand created by increased accessibility also drives up the price of the land, indicating that land prices are a function of accessibility (see Figure 11). There will be an underlying rise in land value associated with enhanced accessibility brought about by automated and zero emission vehicles. Assuming that planning controls and commercial feasibility allow it, this will result in an increase in the density of development.

[8]KPMG, Arup and Jacobs (2016) Preliminary Demand Modelling and Economic Appraisal, IV, Melbourne, available at <www.infrastructurevictoria.com.au/document-library>, last viewed 20 March 2018.

CASE STUDY: THE WESTERN RING ROAD IMPACT ON URBAN DEVELOPMENT

The Western Ring Road connects the northern and western suburbs of Melbourne to other Victorian urban and rural freeways. Construction of the Western Ring Road commenced in 1989, with initial works centred around Broadmeadows. Over the next decade, various sections of the route were completed and opened, with the entire route completed by 1999.

Upon its completion, the Ring Road vastly increased the accessibility of Melbourne's outer western and northern suburbs. Increases in both employment and population followed. The maps below show the percent change in effective job density (a measure of the accessibility of an area) and in households in 2011. They suggest a strong relationship between accessibility and development, with the largest relative change in both variables being seen in areas surrounding the road.



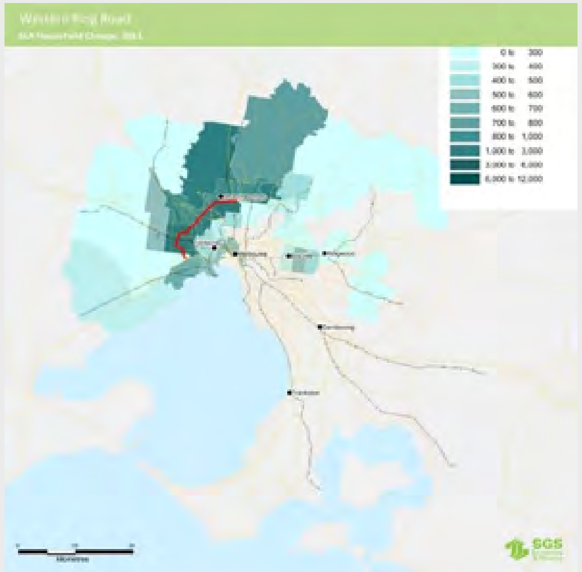
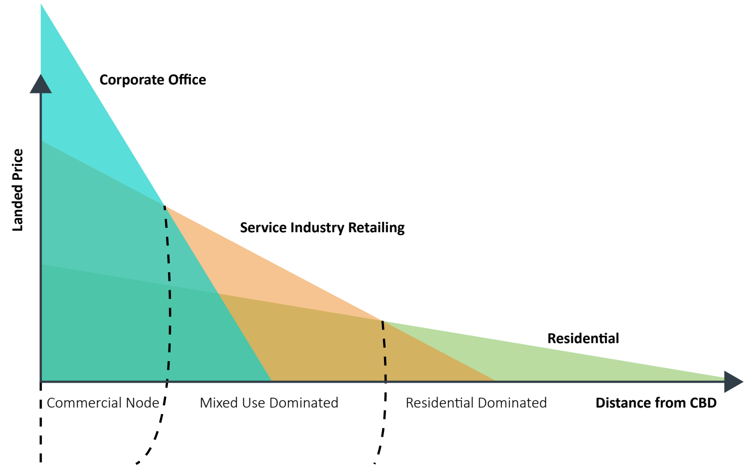
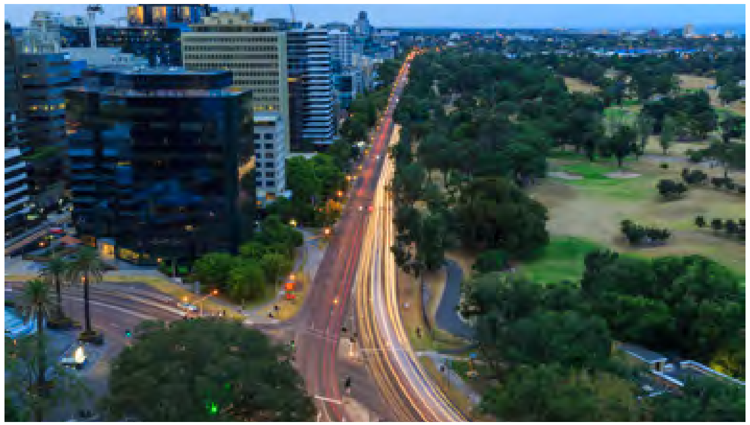


FIGURE 11: DEMAND FOR DIFFERENT LAND USE AS A FUNCTION OF ACCESSIBILITY



Source: SGS Economics and Planning, 2018



3.2 Vehicle ownership

Presently, it is unclear whether automated vehicles will bring about a rise or decline in vehicle ownership. The lower labour costs for Robotaxis could make taxi travel more affordable than private car ownership and even public transport services. This may drive a preference for Robotaxis.

Conversely, there may be higher perceived costs of travel because Robotaxi fares are likely to cover the associated costs of registration, insurance and maintenance[9]. In turn, this may drive a shift towards public transport and a reduction in trip distance and trip times.

The mix of ownership will affect travel behaviour of users and vehicles, including the:

— number of kilometres travelled per vehicle-year
— pattern of vehicle journeys and the demand for parking, and
— location of that parking.

Bruce Shaller (2017) found that ridership of Uber and other apps amounted to 15 million trips per month in October 2016, tripling the amounts of trips from June 2015[10]. These services have been labelled TNCs (Transportation Network Companies). Accounting for a reduction in licensed taxi trips, the study found TNCs generated a net increase of 31 million trips and 52 million passengers from 2013 to October 2016.

Other findings from the study include:

— ridership in TNCs growing faster than the rate of transit
— significant amount of empty running travel
— overall vehicle mileage increasing despite the provision of carpooling services
— potential to integrate with transit to provide door-to-door services.

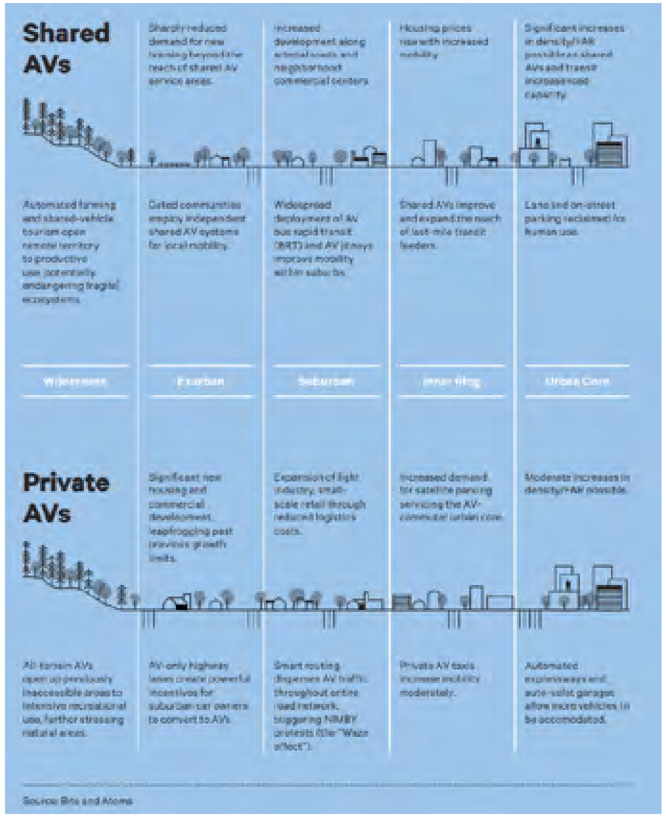
The Fleet Street scenarios in this analysis explore a future where all car travel is through TNCs (as driverless Robotaxis). As such, the trends that have emerged from existing TNC travel – fast uptake, high rates of empty running and an overall increase in car trips – are particularly salient for this analysis.

A 2017 report by the Bloomberg Aspen Institute outlined the potential land use impacts of two broad automated vehicle scenarios – shared and private ownership[11]. These are presented below in Figure 12.

While not modelled in this study, there is also potential for privately-owned automated vehicles to increase the number of smaller public transport vehicles (while not being privately used). This would offer more flexible and widely distributed services in lower population density areas and could reduce the need for car ownership as other transport options become more easily accessible. Alternatively, it could also encourage ownership as cars can be employed profitably when not in use. The increased availability of public transport, especially in previously poorly connected areas would also likely have a significant effect on development patterns, potentially encouraging sprawl.

Like with existing transport options, there is the potential for automated and zero emissions vehicles to further entrench disadvantage. If privately owned automated vehicle fleets become the primary mode of public transport, gaps in coverage or discriminatory pricing may arise in areas where markets are thin, such as in low density outer suburbs and regional and rural Victoria. The extent to which this is a problem will largely depend on the policy and regulatory framework.

FIGURE 12: POSSIBLE LAND USE IMPACTS OF AUTOMATED VEHICLES



Source: Bits and Atoms via the Bloomberg Aspen Institute, 2017

[9]This compares to private vehicle ownership when at the time of taking a trip, many of these costs have occurred in the past. Consumers are likely to discount sunk costs and perceive a greater weight for costs that are incurred at the time of travel.
[10]Bruce Shaller Consulting, (2017). UNSUSTAINABLE? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City.
[11]The Bloomberg Aspen Institute (217). Taming the Autonomous Vehicle. P.75

3.3 Cost of travel

The cost of travel has a significant impact on where people choose to live. Higher travel costs encourage people to move closer to the city as the higher cost of land (or rent) is offset by the savings in travel cost. Conversely, lower travel costs encourage sprawl by increasing the relative cost of land. The perceived marginal cost of travel could vary under different automated and zero emission vehicle scenarios, changing the types of land uses demanded by residents and businesses.

Forces driving down the perceived cost might include: shorter and less volatile travel times from improved reliability of automated and zero emission vehicles (hence, a lower buffer time requirement); use of cleaner and cheaper fuel; the ability to be productive during private travel; and potential use of vehicles as automated taxis between personal trips.

The marginal utility of travel time (MUTT) could change dramatically in an environment where an automated vehicle with good internet connectivity permits time to be spent productively rather than being focussed on the task of driving. For those individuals able to make good use of this time (and derive a higher utility), the time cost may be greatly reduced or even have a positive value. This is most likely for those travelling alone in privately owned automated vehicles, not shared automated vehicles or on crowded public transport.

The marginal cost of travel will also change, depending on vehicle ownership and the technology (automated or zero emission). As noted, people who use an automated taxi or ride share service are likely to perceive a higher marginal cost of travel because capital costs will be incorporated into the fare. On the other hand, total travel costs may be reduced for owners of automated vehicles if they employ their vehicle as an automated taxi between trips[12]. In addition to reducing carbon emissions and air pollution, zero emissions vehicles are likely to have lower marginal costs than traditional internal combustion engine vehicles (ICEs). The current perceived running cost of electric vehicles is already around one third of ICEs[13].

3.4 Peak period impacts

Most network issues in urban transport environments are during morning and afternoon commuter peak periods. And most infrastructure projects and network upgrades are in response to peak period capacity issues.

Automated vehicles are likely to alleviate these issues because they will require smaller headways (the stopping distance between cars) and they will be able to make quicker, more consistent and safe road manoeuvres. This ‘platooning’ will increase the network capacity because cars are able to travel closer together than traditional cars at the same speed.

On a motorway standard road, the assumed lane capacity is approximately 1,800 vehicles per lane in a free-flow state.[14] Lane changing and entry and exit ramps can reduce this capacity. Higher capacities can be achieved, depending on local conditions. In free-flow conditions, if the platooning available with automated vehicles brought about even a half a second reduction in headway (1.5 seconds), it could result in a 33 per cent increase in lane capacity.

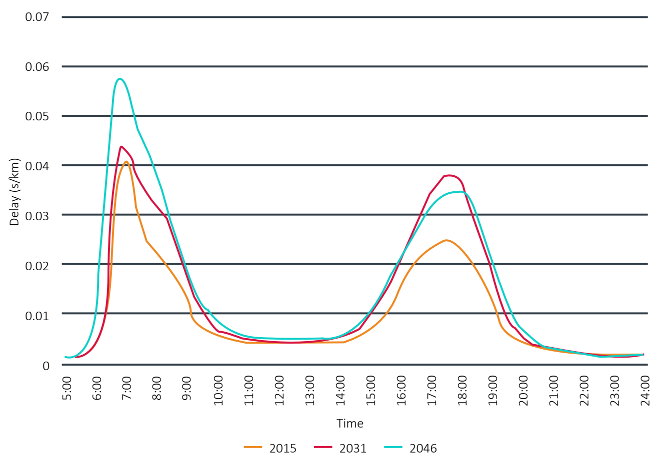
[12]It could be possible that the price offered by shared vehicles will drop down to just above the marginal cost (including maintenance and cleaning) for low demand periods and go above the average cost (or be withdrawn) during peak demand periods. This could damage mainstream taxi providers economics even using automated vehicles.
[13]KPMG, Arup and Jacobs (2016), ibid.
[14]Based on a 2 second gap between vehicles, so 30 vehicles per minute, or 1,800 vehicles per hour.
[15]Car trip delay is defined as the difference between travel times in ‘no traffic’ and actual travel times.
[16]KPMG, Arup and Jacobs (2016), ibid.

Figure 13[15] highlights the intensity of peak period traffic in Melbourne, both now and in the future. Outside of the peak periods, there is very little delay across the road network so there would be limited ability of capacity improvements throughout the day. The capacity benefits are likely to be realised in the 6-7 hours of peak period each day.

If anything, automated vehicles might encourage more travel during peak periods because capacity on major roads will increase and travel times will decrease. This may increase congestion on smaller roads where end-of-journey activities such as parking and off-loading operations take place. The greater capacity on major roads is likely to make outer suburban areas more accessible and, as noted earlier, attract residents and employers to those areas.

The road capacity impacts will also depend on the type of road, passenger behaviour and the proportion of cars on the road that are automated. KPMG identified in 2016[16] that automated vehicles have the greatest potential to increase road capacity of urban roadways, road freeways and motorways where travel is consistent and predictable. However, they may reduce intersection capacity if passengers decide to have lower deceleration and acceleration settings for improved comfort. There may also be issues in mixed traffic environments where cars with and without drivers need to interact.

FIGURE 13: MEDIAN DELAY FOR CAR TRIPS



Source: KPMG (2018) 2046 Scenario and AZEVIA Model Development Final Report

3.5 Commercial feasibility

Many factors determine commercial viability at a site-specific level. These can include but are not limited to planning controls, site size and shape, neighbouring uses, development capacity, and so on. The gross realisation value is driven by demand for dwellings, which is at its highest in suburbs with high levels of accessibility.

Traditionally, a major cost for high density development is providing underground car parking. High take-up of automated vehicles and suitable changes to planning policies may reduce the need for underground carparking. Under a shared ownership scenario, people will not need to keep a car on their property. Even in a private ownership scenario, vehicle owners can send their vehicles to cheaper off-site parking locations or provide Robotaxi services when they are not in use.

Eliminating the need for underground parking would lower construction costs and increase commercial feasibility for development in areas which have an existing level of demand. This would lead to an increase in dwelling supply (or bring forward development in earlier years) and help to change the future land use distribution.

According to the City of Melbourne, there are approximately 49,500 residential and 68,300 commercial off-street parking places in the CBD[17]. This sizable portion of valuable land could be provided for other uses if parking were no longer required.

In most cities, this parking availability will have a significant focus on city centres and areas with higher job densities. The conversion of that land for other uses can greatly increase the ability to provide inner-city housing and services. A proportion of this land in cities will be required for potential charging stations and some vehicle storage.

This will change the requirements for development approval and enable further development of sites with more dwellings, services and amenities.

[17]City of Melbourne (2018). Car Parking Discussion Paper – Transport Strategy Refresh

3.6 Amenity

Local amenity in an area has a strong positive relationship with the intensity and type of land uses. Improving amenity can drive urban development. High traffic volumes in an area can cause noise and visual dis-amenity and discourage urban development, a common problem in inner city locations. The type of traffic on roads can also impact on the local amenity. For example, larger freight vehicles cause a greater impact of local amenity than a passenger car.

Residential areas can suffer from noise and visual dis-amenity, particularly where traffic volumes are expected to increase significantly. There is significant evidence that the residential amenity (noise and visual) along key collector roads within the metropolitan Melbourne is already being compromised due to high heavy commercial traffic volumes on local roads[18]. This is likely to increase in the future as Melbourne grows and population pressures increase.

The adoption of automated and zero emission vehicles in the freight industry may help address some of these amenity issues. In addition to the potential energy and labour cost savings presented by the new technologies, they could also facilitate 24-hour operations and allow out-of-hours deliveries and movements to occur. This can reduce the transport task during peak periods and during the working day. Automated and zero emission vehicles can greatly improve last mile delivery operations with smaller targeted delivery trucks and reduce the impact of large trucks in urban and residential areas.

Residential amenity benefits may include noise, visual and pedestrian amenity improvement, and benefits through reduced severance and improvements to community cohesion. While automated and zero emission vehicles are not noise-free, they are substantially quieter than traditional ICEs. This reduction in car noise may see improvements in amenity along major transport routes and certain corridors, and result in small changes to land use distribution.

3.7 Speed of technology adoption

Due to the dynamic interplay between urban development and available existing technologies, the impact of different technologies will be affected by the speed at which they are taken up. The impacts will be smaller and/or slower in established areas where technology will have to be incorporated into the existing infrastructure as it is renewed or replaced. On the other hand, new areas will be able to include the new technological considerations into their original design. This will have important impacts on the urban fringe and growth corridors of Melbourne in particular.

3.8 Risks and benefits

The likely risks and benefits of automated and zero emissions vehicles are highly dependent on the regulatory and pricing regimes applied to future transport. A transition from ICEs to zero emissions vehicles will reduce fuel excise revenue and new road pricing based on a combination of capital cost recovery, wear and tear, congestion and environmental impact has the potential to dramatically change travel patterns. Zero emission vehicles may also have a significant role in electricity demand management, which in turn may offer incentives that drive both travel patterns and charging/discharging behaviour at the margins.

The response of businesses seeking to attract customers will also influence behaviour, through offering free charging or free shuttle services in lieu of parking or free/very cheap delivery of goods in automated delivery vehicles. The risks and benefits of automated and zero emission vehicle uptake are likely to arise as much from the impacts of the regulatory and pricing regimes adopted as from the technology itself. The assumptions around the regulatory framework will have to be considered when assessing various scenarios on the uptake of automated and zero emissions vehicles.

[18]For example, see Victoria State Government (2017) Level Crossing Removal Project, Program Business Case, accessed 28 June 2018 <https://levelcrossings.vic.gov.au/__data/assets/pdf_file/0005/216329/LXRP-Business-Case.pdf>

04 Scenarios

> "There is significant uncertainty about how automated and zero emissions vehicle technology will be adopted in the future."

Several scenarios have been developed to help understand the potential impact of automated and zero emissions vehicles on land use within Victoria. These scenarios vary according to three important factors: the ownership mix, marginal utility of travel time (MUTT), and degree of empty running in the network.

4.1 Scenario variables

There is significant uncertainty about how automated and zero emissions vehicle technology will be adopted in the future. To inform government, this project will examine future possible scenarios to:

- test different market and ownership levels of automated vehicles
- test potential changes to travel behaviour of transport users (public and private) and the implications to the transport network, and
- understand the likely risks and benefits.

Amongst other factors, the outcomes and implications of the scenarios will depend on the ownership mix, MUTT, and degree of empty running in the network. These three factors are the focus of the scenarios in this study and are tested with different variations across the scenarios. They will have different impacts on trip costs, the number of trips and congestion, the general directions of these impacts are detailed in Table 2 and described further below.

Fleet ownership

Fleet ownership is defined by the share of the fleet that is that is privately owned (rather than shared via Robotaxi services)[19]. Presently, it is unclear whether automated vehicles will bring about a rise or decline in vehicle ownership. To test the extremes of what a rise or fall might look like, the scenarios test a private car fleet (Private Drive) and a share car fleet (Fleet Street).

Marginal utility of travel time

In this analysis, the MUTT is a key input in the generalised cost of travel[20]. The MUTT reflects how travellers perceive the time it takes to complete a trip, and the utility they derive from it. As noted, the MUTT could change dramatically in the future where passengers could be more productive during travel than when focussed on the task of driving. In these scenarios, a higher MUTT means a traveller has a higher cost of travel and vice versa for a lower MUTT. Low MUTT increases a traveller's propensity to take longer trips.

TABLE 2: SENSITIVITY EFFECTS

Sensitivity	Trip cost	Trips	Congestion
Low MUTT	↓	↑	↑
Empty running	↓	↑	↑
Private ownership	↓	↑	↑
Shared ownership	↑	↓	↓

Source: SGS Economics and Planning, 2018

Empty running

Empty running is the running of a driverless car without a passenger. In the case of a Robotaxi, empty running is required between passenger pickups in order to meet people at the start of their trip. In privately owned vehicles, it may be more affordable to allow a car to empty run instead of paying for parking. It is unclear whether empty running will be allowed within the state's road rules in the future because it could potentially have major congestion impacts. For this reason, the scenarios both test whether private vehicles are allowed to empty run between journeys.

[19] It is possible to imagine that some 'private' owners may offer their vehicles for use by others for periods of time, although this is not modelled in the scenarios within this study.
[20] Low MUTT scenarios have half the MUTT value within the generalised cost of travel equation.

4.2 Study scenarios

This study will examine three key scenarios with sensitivity tests for the different values of travel time and the degree of empty running in the network. The results of our modelling will show the likely impact that different scenarios will have on the distribution of land uses in Greater Melbourne and therefore inform further consideration on land planning and infrastructure planning. The scenarios are detailed further below.

Private Drive

All cars are privately owned, have zero emissions technology, and take you anywhere you want to go within the city or the country. You just tell it your destination, then sit back and relax. The car knows the best route to take because it is continuously updated with current traffic patterns and road maintenance data. Your car communicates with other road users and transport infrastructure, so the drive is smooth and accidents are very rare. In the **Private Drive scenario**, the marginal utility of travel is high and cars do not empty run when not in use. To test this scenario, two sensitivity tests are undertaken, **Private Drive Empty Running** which allows automated vehicles to run without passengers to avoid parking costs and **Private Drive Low MUTT**.

Fleet Street

Households and business no longer own private cars. Rather companies own fleets of driverless, zero emission vehicles and offer a range of transport services at different price points. The marginal utility of travel time is high and cars run without passengers between trips. There is also a sensitivity test Fleet Street Low MUTT to understand the impact of a lower MUTT.

Slow Lane

There is a 50/50 mix between private and shared ownership and between automated and zero emission and internal combustion vehicles. Many of the benefits of the former scenarios (for example, increased speeds and reduced accidents) are not fully achieved as half of the vehicles are still driven by humans.

05
Method

> “SGS has developed land use scenarios using its dynamic Transport Impact Model (TIM) and Small Area Model (SAM).”

SGS have employed our established dynamic spatial transport and land use models to understand the impacts of the various scenarios. The models have been developed over the past decade and are constantly being refined to account for new data and changing trends.

5.1 Overview

SGS has developed land use scenarios using its existing dynamic spatial transport and land use models. The Transport Impact Model (TIM) estimates the land use impacts of infrastructure investment and the Small Area Model (SAM) forecasts future dwelling and employment capacity at a travel zone level. These two models are briefly described in the following sections, with a more detailed explanation in the Appendix.

5.2 Transport Impact Model

The TIM forecasts the land use impacts of infrastructure projects using changes to accessibility to predict changes to jobs and population. Spatially, it demonstrates how improving (or reducing) the accessibility of different areas will result in greater (or lesser) demand for employment and housing. SGS has used TIM extensively in previous work to estimate the land use impacts of transport projects, policies and behaviour changes.

TIM has three components:

- **Access improvement**: Changes to travel times (by private car and public transport) in locations affected by new infrastructure are used to estimate the improvement in an area's relative access to housing and employment opportunities.
- **Dwelling redistribution**: Households are attracted to locations where access to employment and services is strong. This relationship is quantified (as explained in the following section) for use in the model and accounts for 'stickiness" in different housing submarkets across Victoria.
- **Employment redistribution**: Improved accessibility and proximity to households lead to growth in certain types of employment. The relationship between employment at an Australian and New Zealand Standard Industrial Classification (ANZSIC) 1-digit industry level and these two factors are quantified for use in the model.

Access improvement

SGS has developed the relative *Effective Job Density (EJD) index* which measures a geographic region's accessibility and the ability to access overall economic activity *relative to other regions* across the wider Melbourne Statistical District (MSD).

EJD considers both the spatial distribution of jobs and the transport network which connects them. An absolute measure of EJD is derived from the density and accessibility of all jobs across a region and is calculated using two variables: travel time from *location A to location B and number of jobs at location B*. Changes to relative accessibility are quantified by translating absolute EJD across the five Census years (1996, 2001, 2006, 2011, 2016) into a 0 to 1 index (i.e. a relative EJD index).

The statistical area (SA) with the highest EJD (in this case the Melbourne SA2) provides the index ceiling and is given a score of one, while the SA with the lowest EJD (in this case Yarra Ranges SA2) provides the index floor and is assigned a score of zero. The TIM uses changes to travel times (by private car and public transport) in locations for each scenario to estimate the improvement in an area's relative EJD.

Relative EJD for Melbourne and Regional Victoria has been calculated based on transport modelling outputs from the Melbourne Activity and Agent Based transport Model (MABM[21]) and the state-wide modelling derived from a combination of MABM and Victorian Integrated Transport Model (VITM) outputs. This is shown for each scenario in Figure 14 and Figure 15. For more details on the transport modelling outputs please refer to the *Automated and Zero Emission Vehicle Infrastructure Advice – 2046 Scenario and AZEVIA Model Development Final Report.*

MABM transport outputs were provided at the SA2 level. The TIM modelling was also undertaken at this level and the results were then aggregated to SA3s (on average an SA3 is made up of eight SA2s). This aggregation of SA3s allowed a clearer understanding of the impacts on the land use patterns under the various scenarios.

[21]http://www.infrastructurevictoria.com.au/sites/default/files/images/KPMG%20-%20MABM%20fact%20sheet.PDF

STATISTICAL AREAS

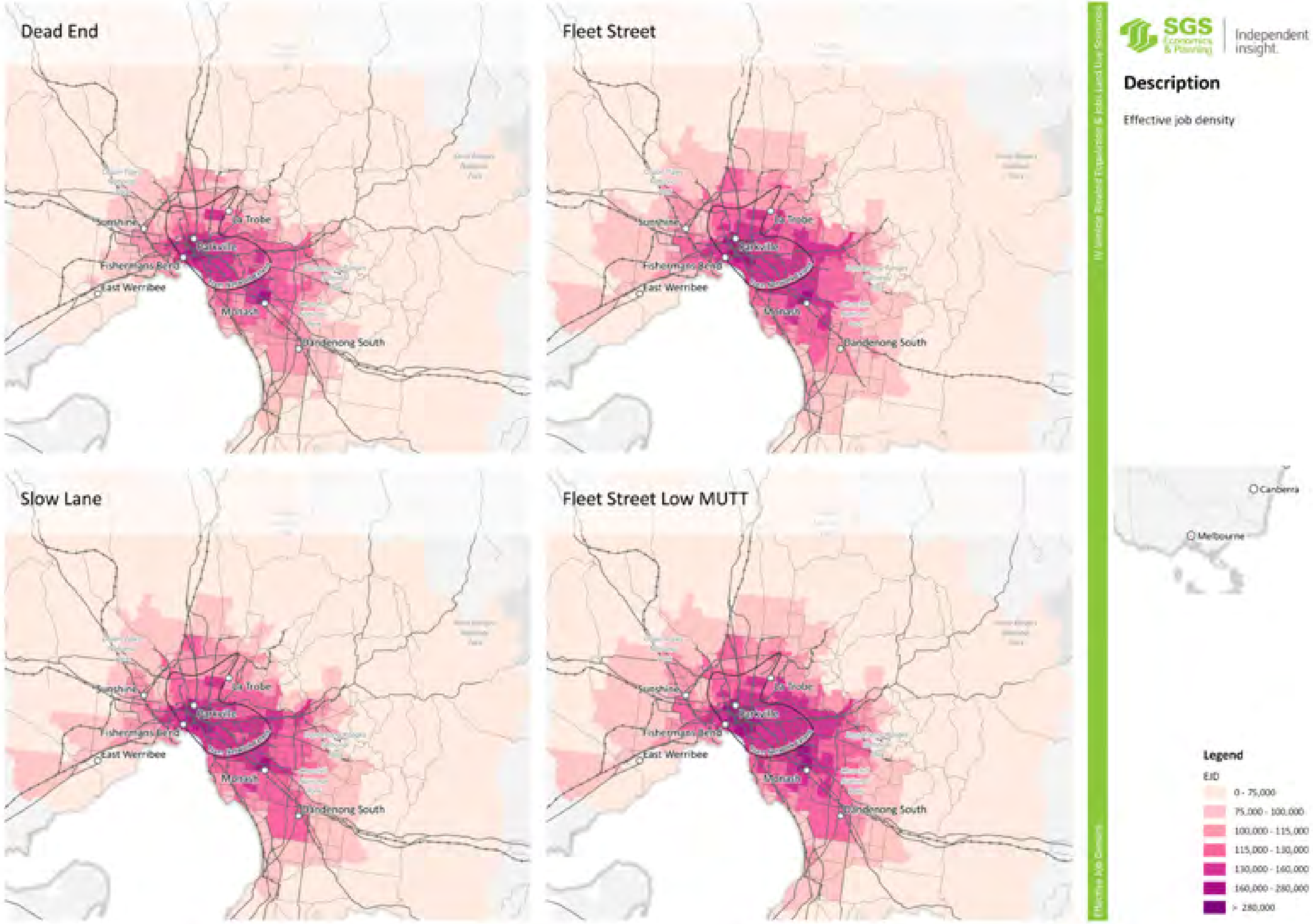
Statistical Areas are geographic units defined by the Australian Bureau of Statistics. The area they cover captures a certain part of the population, the economy and the social landscape.

The SA2 is the third smallest geographic area defined by the ABS. They generally have a population range of 3,000 to 25,000 persons, with an average of 10,000 persons.

Wherever possible, SA2s are based on State suburbs and localities. In urban areas, SA2s largely conform to whole suburbs and combinations of whole suburbs, while in rural areas they cover areas with social and economic links.

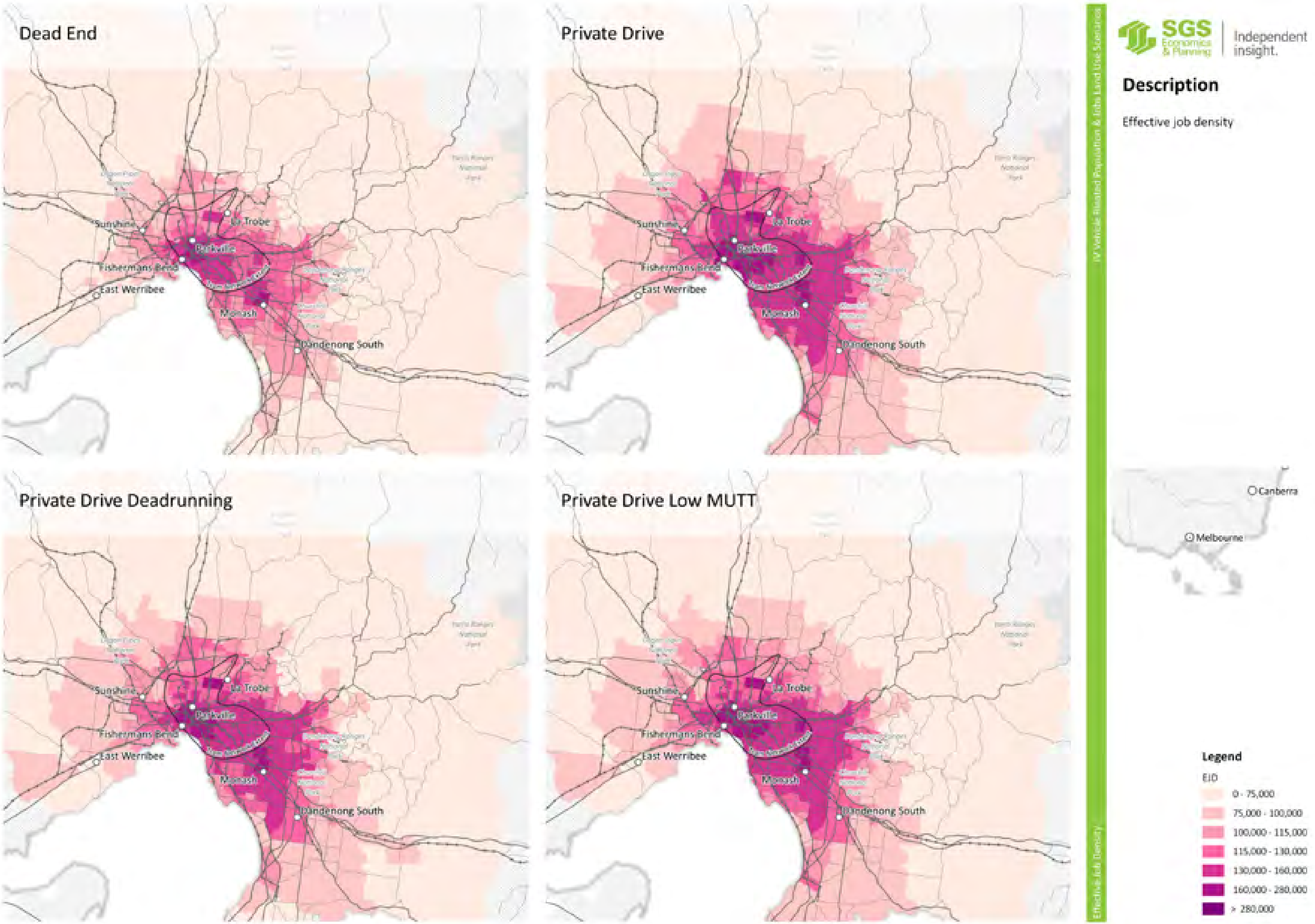
SA3s are the fourth smallest Statistical Area. They contain whole SA2s and represent regions of between approximately 30,000 and 130,00 people.

FIGURE 14: RELATIVE EJD IN THE DEAD END, FLEET STREET AND SLOW LANE SCENARIOS



Source: SGS Economics and Planning, 2018

FIGURE 15: RELATIVE EJD IN THE DEAD END (BASE CASE) AND PRIVATE DRIVE SCENARIOS



Source: SGS Economics and Planning, 2018

Measuring dwelling and employment redistribution

The TIM tests two hypotheses:

- An area's share of employment, is based on its share of dwellings and accessibility.
- An area's share of total housing stock is based on urban land supply and accessibility.

These hypotheses suggest that strong growth within a greenfield area is a result of increased land supply, while strong growth within the inner city is a result of increased accessibility. Furthermore, they suggest that demand will increase if a location's accessibility is improved and that the strength of this relationship varies from industry to industry. Industry variation is due to different requirements and willingness/capacity to pay for more accessible locations.

The hypotheses are tested using a regression analysis of past major road infrastructure projects (such as the Western Ring Road, CityLink and Eastlink) and the distribution of accessibility changes of Melbourne, provided by the ABS Census and Department of Transport.

To undertake the analysis, three key data variables are synthesised by SGS for each SA2 across Greater Melbourne from 1996 to 2016:

- SA2s share of total employment by industry sector and households
- SA2s share of total urban land
- SA2s housing capacity indicators
- SA2s relative accessibility.

The regression coefficients for Relative EJD by ANZSIC 1-digit industries are shown below in Figure 16. The results show the service sector and higher value-added industries such as information and media, professional services, and public administration, exhibit the highest preference for increased accessibility, while agriculture, manufacturing, construction and retail trade exhibit the lowest. The agriculture industry's negative relationship with EJD reflects the industry's requirement for large and relatively cheap land parcels away from major centres and the competition it faces from competing land uses, particularly residential.

Many industries depend on a local population as either customers (product demand) or skilled workers (labour supply). This means that an increase in population in an area often results in a further increase in population-servicing employment such as retail trade, health care, education and training, and accommodation and food services. Figure 17 shows the effect that changes in local population have on an area's share of employment in an industry. It displays the coefficients related to a change in household share for each of the employment industry sectors.

Using the coefficients of the regression analysis, we can estimate the effect of changes in accessibility (relative EJD) on employment and households under the different scenarios. It should be noted, the TIM measures overall household redistribution, it does not measure the movements of individual households. TIM produces a new distribution of dwellings and jobs given a new level of accessibility.

For example, a reduction of one dwelling from Port Phillip and an increase of one dwelling in Casey does not mean that a dwelling has shifted between these two areas. In a real world situation, many households have moved across Melbourne to optimise their travel and household choice. The TIM is merely reflecting the net impact of one less dwelling in Port Phillip and one more in Casey.

FIGURE 16: RELATIVE EJD REGRESSION COEFFICIENTS

Source: SGS Economics & Planning, 2018

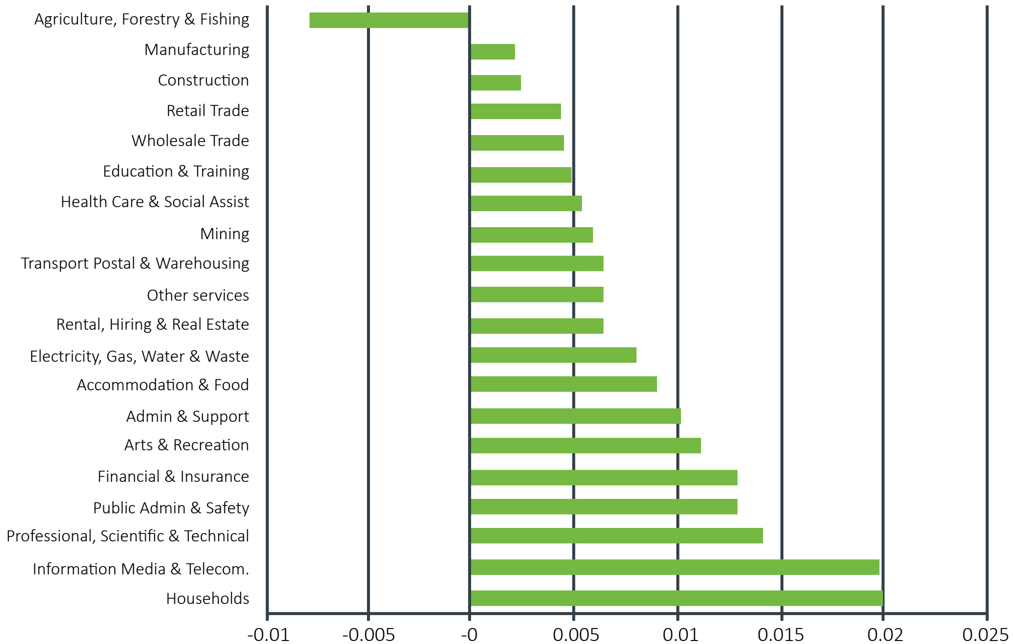
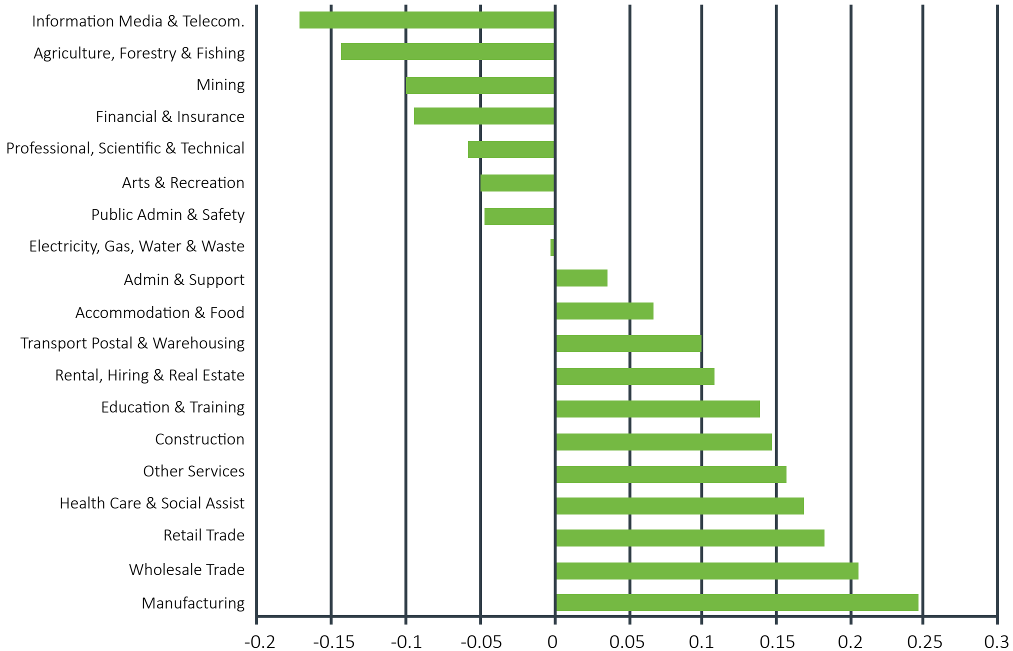


FIGURE 17: HOUSEHOLD SHARE REGRESSION COEFFICIENTS

Source: SGS Economics & Planning, 2018



5.3 Small Area Model

The SAM estimates housing development and employment capacity based on existing and planned housing development controls. It does this using four modules which are described below.

Module 1 – SA2 control totals

Module 1 collates SA2 control totals for all dwelling and population variables, ranging from Structural Private Dwellings (SPD) to Estimated Resident Population (ERP) by age. The control totals were provided by Victoria in Future 2015 (VIF15)[22] data from 2011 to 2046 (at five-year intervals). For 2011, Census data was aligned to create control totals for each of the dwelling and population variables.

Module 2 – Structural private dwellings by travel zone

Module 2 estimates SPDs at a travel zone level by distributing the historical and projected SA2 control totals from Module 1 down to a travel zone level using a staged approach. Travel zones are very small geographic boundaries used in the VITM mode. In the modelling undertaken for this project there are 6644 travel zones in Victoria.

Historical and predicted dwelling datasets are created using a range of data sources, and assumptions are made about the density and growth of locations to manage long term growth where information is missing or unclear.

Forecast SPDs are then estimated using a sequenced allocation approach for 'priority' and 'additional' capacity:

- To accurately calculate the potential number of additional dwellings within an established area requires a comparison of the potential yield for new dwellings with the existing housing stock. Using the outputs of the lot level available land analysis a series of yield and site density assumptions which reflect the zoning controls based on both prescriptive controls (i.e. max 2 dwellings per lot) and the planning intent of each zone (i.e. site density) were applied.
- Priority Capacity (five-year intervals): Includes certain and localised development information, including the 2016 Urban Development Program and approved Precinct Structure Plans (as of June 2017) and previous consultation.
- Additional Capacity (five-year intervals): Includes all other capacity information, some of which have timing components. Sources include incremental infill data from housing capacity assessments, previous consultation, and broad density limit assumptions.

Priority Capacity and Additional Capacity were created for each travel zone across Victoria ad each five-year interval. These capacity measures were then used to distribute the growth in periods at an SA2-level, with priority capacity being allocated first and additional capacity being allocated after. This process is repeated for all SA2s up until 2046 to derive an estimate of SPDs at a travel zone level.

Module 3 – Estimated resident population by travel zone

Module 3 estimates occupied private dwellings (OPDs), persons in OPDs, persons in non private dwellings (NPDs) and estimated resident population by private dwelling using SPD outputs from Module 2 and historical occupancy rates, household sizes and proportion of non-private dwellings.

Module 4 – Estimated resident population by age breakdown by travel zone

Module 4 further disaggregates total population into age groups using Residual Allocation System (RAS), also known as Iterative Proportional Fitting (IPF). RAS involves aligning previous period age structure with the future total population by TZ (from Module 3) and the population by age SA2 control totals (from Module 1). The result is a detailed breakdown of population by age by travel zone which equals the SA2 control totals and reflects the historical distribution of the area as much as possible.

[22]VIF2015 is the most recent population projection that has been broken down to the VITM travel zone level for use in Transport for Victoria's transport model.

06

Housing Commercial Feasibility

> "Autonomous vehicles may influence residential developments by removing the need for car spaces."

This section details the housing feasibility model which explains the mechanisms, enablers, and barriers related to housing development.

Improved transport accessibility adds to the demand for land by increasing accessibility to jobs and services. It can also make it easier for people to visit families and friends, and to participate in recreation activities. There are also benefits for businesses as moving operations to areas of superior accessibility reduces transaction costs in dealing with suppliers and distributors, as well as improving access to workers.

In the past, major transport infrastructure projects such as heavy rail, light rail, major freeways (combined with increased car ownership rates) have significantly increased accessibility of an area. This increases the demand for people and business to locate in this area.

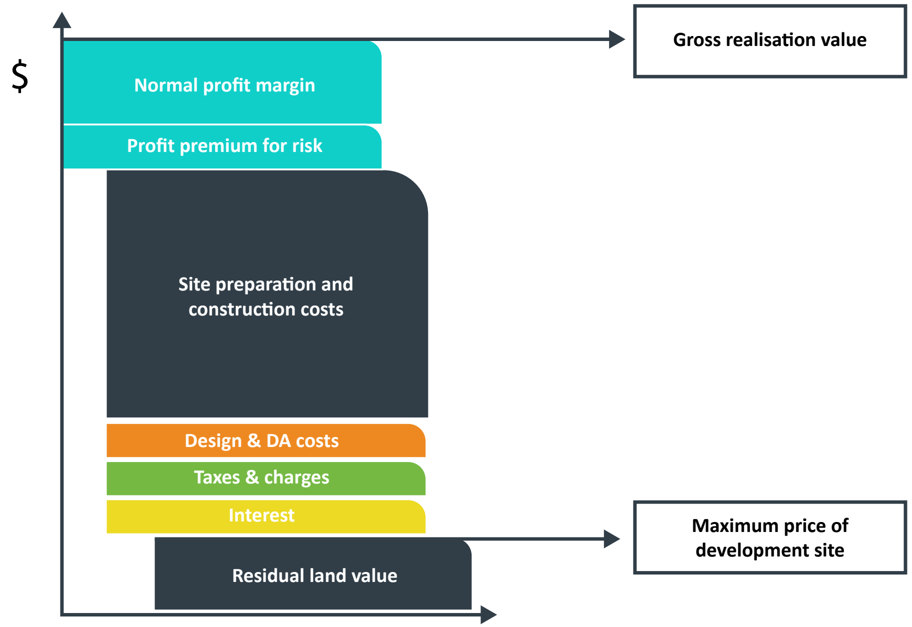
Of course, there are other factors which influence the ability of an area to deal with increased demand for commercial and residential uses. These include:

- **Local level infrastructure provision** reflecting the value of off-site infrastructure such as water and sewerage, stormwater drainage, distributor and collector roads.
- **State level infrastructure provision** reflecting the area's direct access to beneficial or 'social' infrastructure such as schools and hospitals.
- **Amenity values** reflecting the site's locational and natural qualities, its proximity to open space and recreational opportunities, plus the quality of general 'urban upkeep'.
- **Application of planning controls & development rights** to allow for realisation of latent demand for an increase in development approvals.
- **Site characteristics** can also play a role in the amount of housing which a site can yield. E.g. narrow sites are more difficult to develop than a square site with access from multiple sides.
- **Construction costs** include both site preparation and construction of the internal space.
- **Purchasing power** of owner occupiers and investors. Increases in household income, reduction in interest rates and changes to various taxes and subsides increase the budget which households have available to purchase dwellings.

There is very much a dynamic relationship between demand, supply and many of the factors identified above. The commercial feasibility of development is central to establishing the equilibrium between supply and demand in the housing market.

Figure 18 provides an example of a commercial feasible analysis. This highlights the residual land value analysis which identifies the maximum price a developer would pay for a site after allowing for all development costs and their margin for profit and risk. The gross realisation value is driven by demand for dwellings and the cost of land and construction costs.

FIGURE 18: COMMERCIAL FEASIBILITY ANALYSIS



Source: SGS Economics & Planning, 2018

For example, an increase in the market price for a dwelling (driven by increased demand by improved accessibility) can alter the commercial feasibility for developers. Autonomous vehicles may also remove the need for cars to be parked on a property. In this case, the floor area of a dwelling can be reduced (which reduces the construction costs) or that area could be converted into an additional bedroom (which would increase the property value). It could also simply result in the developer having a higher profit margin. In some situations, it could result in a higher density of development.

To demonstrate the potential commercial feasibility of automated vehicles, the local government areas of Whitehorse is used as an example.

The median density (apartment/townhouse) price in Whitehorse is $710,000 which would yield almost $5.0 million (based on seven dwellings) for the developer on a 600 square metre block. After accounting for all the development costs, the developer could offer an existing landholder approximately $1.4 million[25] for the property.

If there was no need to construct an internal car space, the cost of development would fall by around $63,000 (assuming the area was not used for another internal use). This is a 3.5 per cent reduction in overall construction costs. This could flow through to lower housing costs for households, higher profits for developers, or more valuable land for landholders.

TABLE 3: COMMERCIAL FEASIBILITY, SEVEN DWELLINGS WITH INTERNAL CAR SPACE

	PER SQM	VALUE FOR 600M2 BLOCK
Gross realisation value (GRV)	$8,300	$4,980,000
Marketing costs	-$200	-$120,000
Site preparation (demolition/ remediation/services)	-$250	-$150,000
Construction cost (including external features)	-$3,000	-$1,800,000
Professional fees	-$325	-$195,000
Developers margin for profit and risk (per cent of GRV)	-$1,600	-$960,000
Financing/holding costs (per cent of development costs)	-$178	-$107,250
Financing/holding costs	-$100	-$60,000
Developers margin for profit and risk	-$178	-$107,250
Financing/holding costs (per cent of development costs)	-$100	-$60,000
Residual land value	$2,368	$1,420,500

Source: SGS Economics & Planning, 2018

So, there is not a radical change in the commercial feasibility because of not providing internal car parking. There is also the issue of increased density without the need for a carpark and driveway. While the carpark is less likely to be required, there would still be a need for a driveway to access properties.

Figure 19 presents an example of medium density developments. Please note, the internal car spaces are marked with a black arrow. In Case Studies 1-4 there would be no change in the densities due to the automated vehicles. This is due to the driveway access still be required (as is the case in Case Studies 1 and 2). Or in the case of Case Studies 3 and 4 where there is no driveway provided on the property.

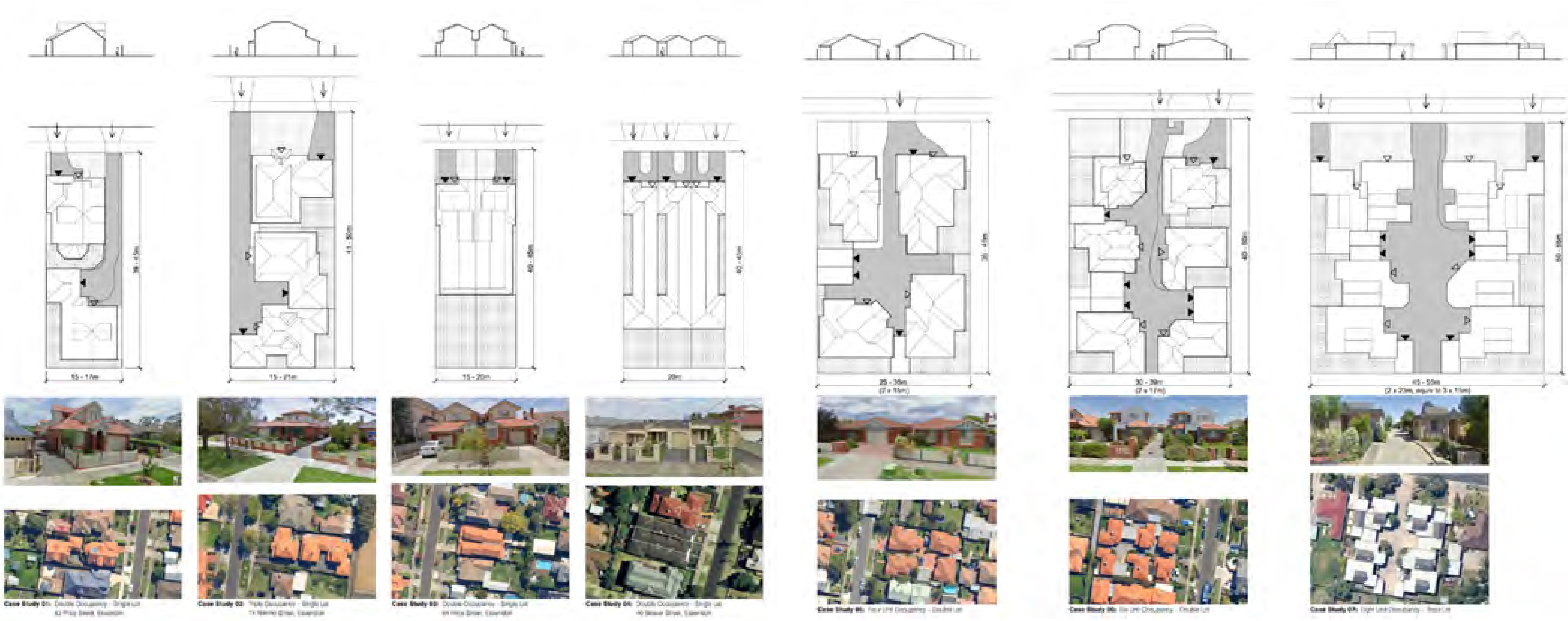
Cased Studies 5-7 would have more scope to possibly increase the number of dwellings on the property. For example, in Case Study 5 and 6, the area for carparking and associated turning circle at the rear of the property (and with some rearranging of other dwellings) could be used to accommodate one additional dwelling. In Case Study 7, the size of the block (2,000m^2) means that the removal of the 8 car spaces and some of driveway space could yield two additional dwellings.

There is also the issue around timing of the uptake of automated vehicles. While traditional vehicles remain commonplace, developers will continue to provide parking spaces. It may still be more than 15 years[26] before the provision of car parking becomes less common.

This analysis highlights that the potential impact on the residential densities of automated vehicles would require a site by site analysis to fully understand the impact of urban development.

[25]The current median for a detached house in Whitehorse is $1.3 million. Hence a development of this kind is feasible in Whitehorse.
[26]Based on the assumptions for this project there would be a 50 per cent uptake of automated vehicles in the early 2030, reaching 100 per cent in 2046.

FIGURE 19: EXAMPLES OF MEDIUM DENSITY DEVELOPMENT



Source: Monash University (2011)

The above type of commercial feasibility holds true in established areas. However, within fringe greenfield housing markets, where large scale developers dominate, commercial feasibility assessment works in a different way.

In these markets developers are also landholders. They are aware of the price points for the buyers of their products and rework the commercial feasibility to meet the buyers' price point. In recent years greenfield developers have met the price points for the buyers by reducing the size of housing lots (see Table 4), while maintaining the internal space of the dwellings. This, in turn, has increased the housing density of Melbourne's greenfields.

Consequently, the impact of automated vehicles on removing the need for internal carparking could continue pushing this lot size towards the average housing lot size[27] of dwelling constructed before high levels of car ownership.

TABLE 4: MEDIAN LAND PRICE AND SIZE IN MELBOURNE GREENFIELD AREAS

YEAR	MEDIAN LOT SIZE (M^2)	MEDIAN PRICE
2010	474	$205,000
2011	448	$219,500
2012	448	$206,500
2013	447	$197,000
2014	448	$210,000
2015	420	$213,000
2016	400	$237,000

Source: Urban Development Institute of Australia National Land Supply Study, 2017

There is also the issue of existing residential car parking. For example, high rise apartment blocks have significant amounts of underground or podium car parking. In the City of Melbourne, there were 193,600 off-street car parking spaces. Of these, 39 per cent (75,800 spaces) are privately used (provided for customers and staff), 35 per cent (68,300 spaces) are commercial car parking spaces and 26 per cent were residential car parking spaces (49,500 spaces).

The number of private and commercial car spaces declined slightly between 2014 and 2016. However, the number of residential car parks has increased by 12 per cent to 49,500 spaces Estimates from the 2016 Census shown in Table 5 suggest that there are only around 44,000 residential vehicles in the City of Melbourne, this indicates that only 89 per cent of the residential car parks are being used[28].

With the ongoing trend of providing parking with inner city apartments, there may be an increasing number of car parks becoming redundant. However, it would be difficult for this internal space to be converted to another use (e.g. residential or commercial use). This is due to lower ceiling heights and a lack of access to utilities (e.g. water and sewage) and the cost to retrofit these services.

As a result, there is a question about the requirement for the large supply of inner city car parking, especially considering that its construction does add to the cost of construction for inner city apartments.

TABLE 5: NUMBER OF VEHICLES IN CITY OF MELBOURNE (2016)

NUMBER OF MOTOR VEHICLES PER DWELLING	DWELLINGS	SUM OF VEHICLES
No motor vehicles	28,138	0
One motor vehicle	21,702	21,702
Two motor vehicles	6,207	12,414
Three motor vehicles	911	2,733
Four or more motor vehicles	327	1,472
Not stated	8,498	5,685
Total	65,783	44,006

Note: "Four or more vehicles" is counted as 4.5 vehicles per dwelling. "Not stated" is counted as 0.7 vehicles per dwelling (the average number of cars per dwellings from reported values).
Source: SGS Economics and Planning, 2018; ABS Census 2016

[27]This is in the order of 300-350 m2 based on average size of housing lots for suburbs like Fitzroy North, Brunswick, St Kilda, and Yarraville.
[28]Recent estimates from the City of Melbourne indicate that the car space utilization could be as low as 77 per cent (City of Melbourne, 2018, ibid.). This assumes that 'not stated' responses from Census 2016 indicates zero vehicles in a dwelling, where SGS's estimates assume the average rate of vehicles per dwelling of 0.7.

07

Base case land use scenario: Dead end

> "By 2046, there are projected to be nearly 5 million jobs and 9.4 million people in Victoria."

The Dead End scenario represents a base case with no adoption of automated or zero emission vehicle technology. This is based on the Victoria in Future 2015 population forecasts and SGS's small area modelling. Victoria's population will grow substantially over the next 30 years and the labour market is set to grow with it. Most of the growth will be concentrated in Melbourne as well as some regional centres such as Geelong, Ballarat and Bendigo.

7.1 Victoria overview

By 2046, there are projected to be nearly 5 million jobs and 9.4 million people in Victoria. The distribution of projected population and employment growth will have a marked impact on how Melbourne and Victoria's regions function. The size and complexity of the Melbourne urban system will be a significant challenge and the future distribution of growth will respond to the provision of future infrastructure, metropolitan strategic planning and evolving demographic, market and economic demands and preferences. The charts in Figure 20 present the projected population and employment growth from 2016 to 2046.

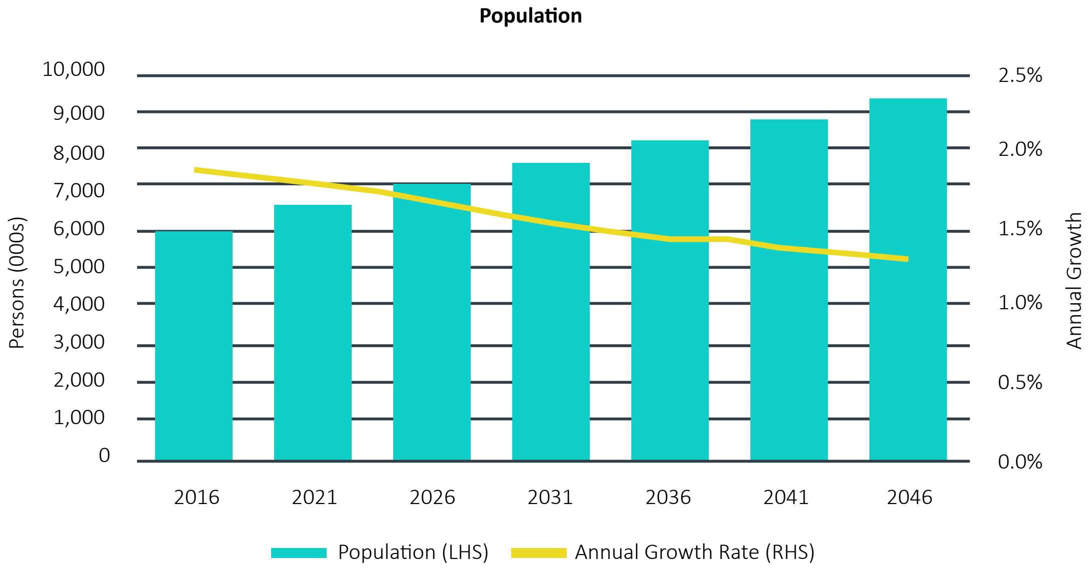
From this, we can see Victoria is forecast to grow by 3.4 million people over the next 30 years. The annual growth rate will slow from 1.9 per cent per annum to 1.3 per cent by 2046. Employment will increase by nearly 2.5 million people. After a dip in the coming five years, the employment growth rate is expected to increase to 1.9 per cent in 2026 and then slow somewhat to 1.6 per cent by 2046.

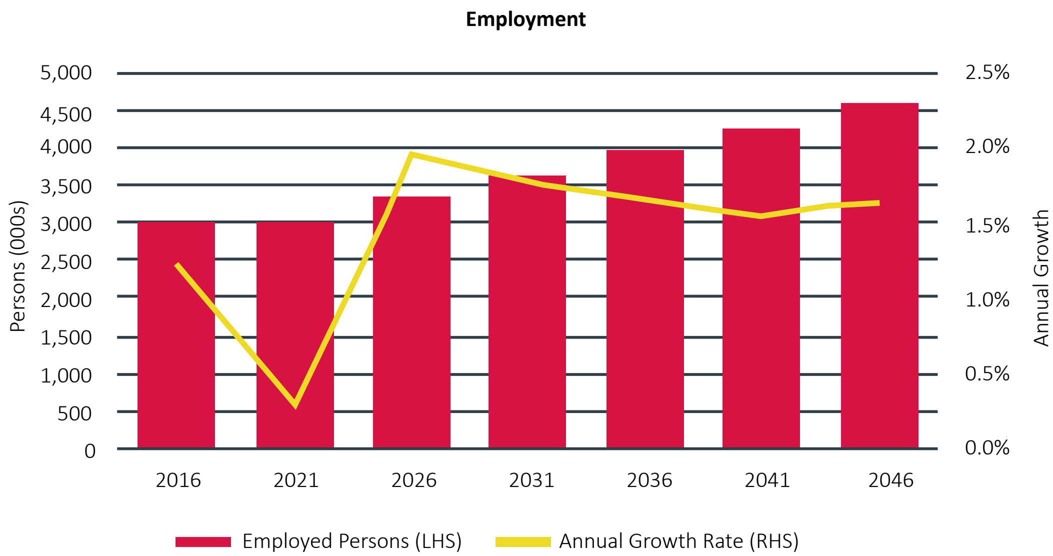
DEAD END: THE LIVED EXPERIENCE

James is recently married. He and his partner, keen to start a family, are deciding where in Melbourne to buy a house and establish themselves for the long term. Both he and his partner work in the centre of Melbourne in industries that, for the most part, require them to be in the office. With a time-consuming and expensive daily commute in mind and a growing family to accommodate, they are looking for a place, preferably a detached house, somewhere within an hour of work and with sufficient space to expand.

Unfortunately, they don't have enough money for a house, so they end up buying an apartment in Reservoir, mostly for its proximity to public transport. Despite being what they can afford, the apartment isn't cheap, and the area is quite crowded. They could have moved out further but as well as costing as much for land, they would have to contend with a long, unproductive, expensive and usually congested car trip to work every day.

FIGURE 20: POPULATION & EMPLOYMENT GROWTH FOR VICTORIA (2016-2046)





Source: SGS Economics and Planning, 2018

7.2 Greater Melbourne

The maps in Figure 21 and Figure 22 show the spatial distribution of the base case population and employment growth across Greater Melbourne. The underlying data for those maps is provided at the SA3 level in Table 6 and Table 7 overleaf.

The population is set to expand the urban footprint of Melbourne as new growth areas establish to the North, West and continue to the South East of Melbourne. Over the next 15 years, 42.6 per cent of Melbourne's population growth will occur within new growth areas; this will decrease over time falling to 29.8 per cent of growth over the period 2031 to 2046. While at the same time infill development through both major redevelopments and small scale incremental developments will provide for significant population growth within the existing urban footprint.

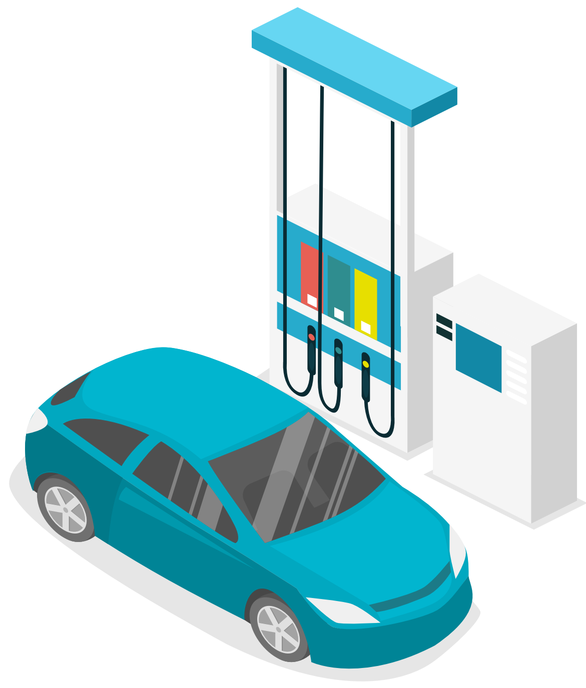


FIGURE 21: BASE CASE POPULATION GROWTH, BY SA3 (2016-2046)

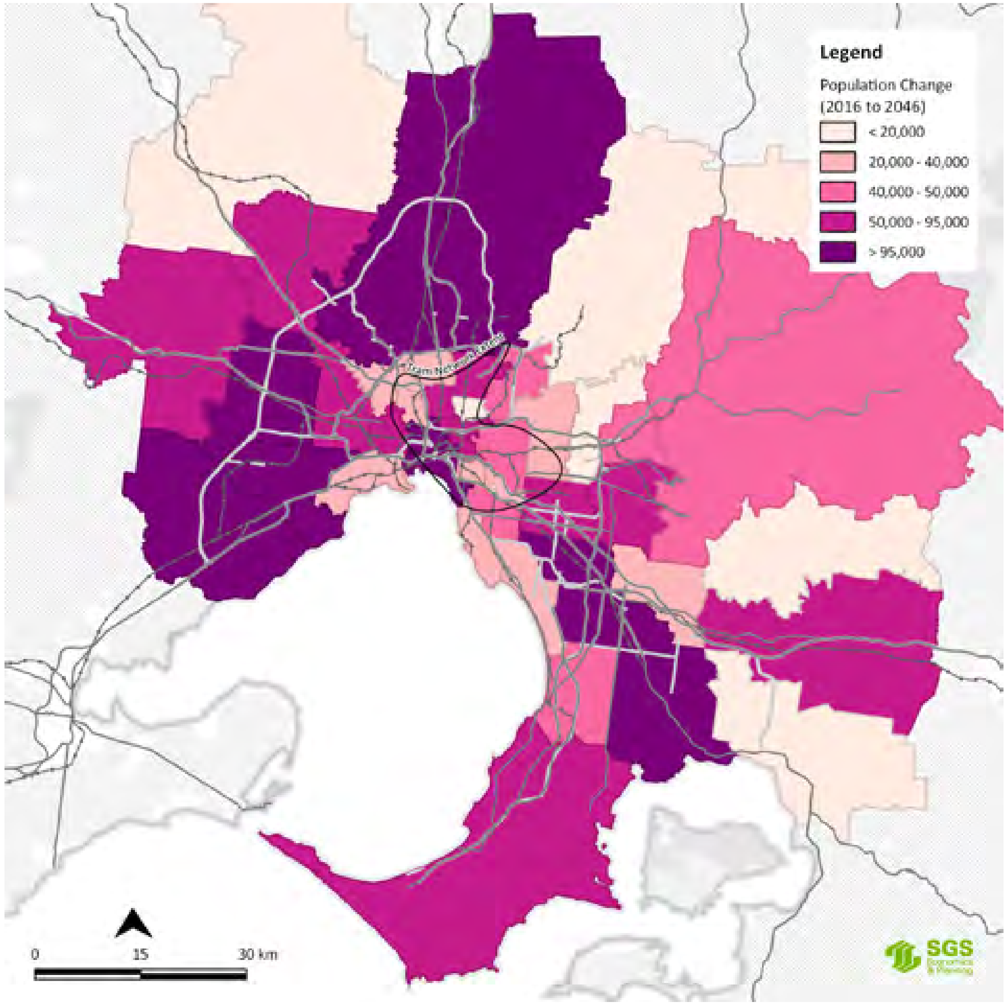
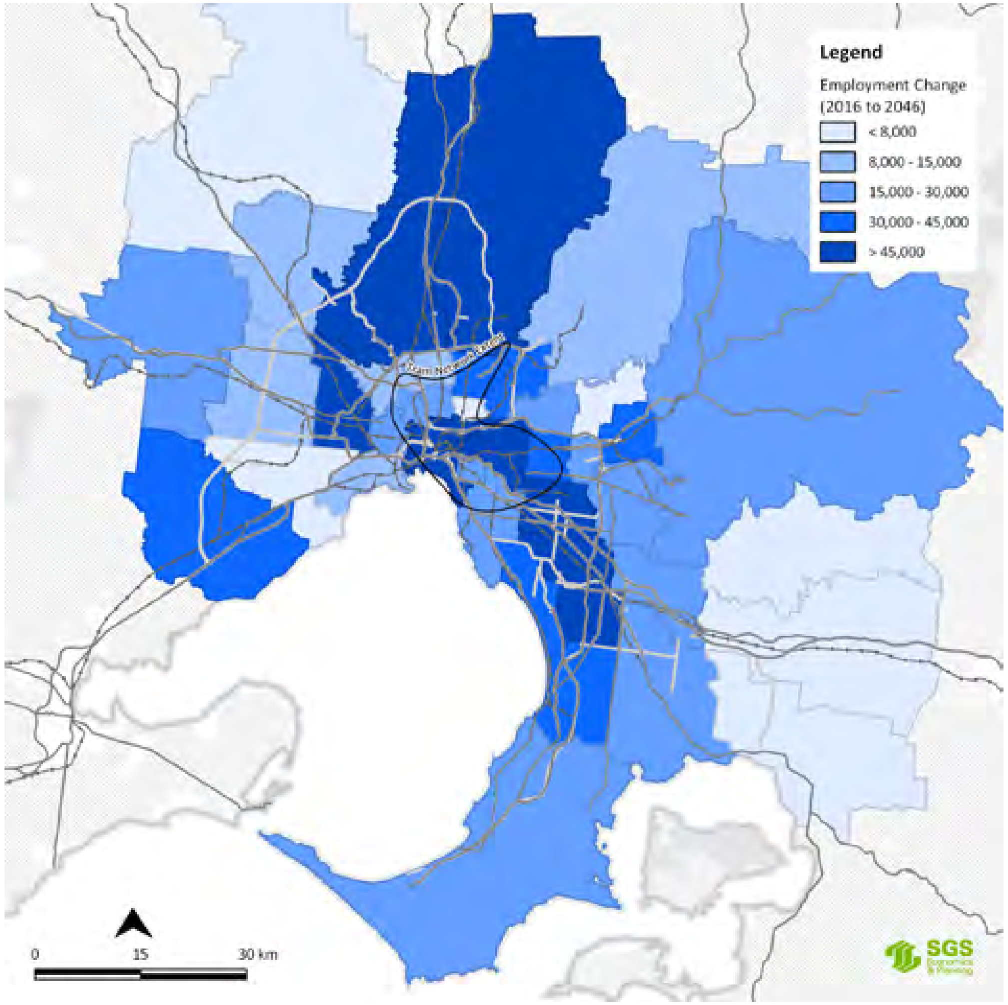


FIGURE 22: BASE CASE EMPLOYMENT GROWTH, BY SA3 (2016-2046)



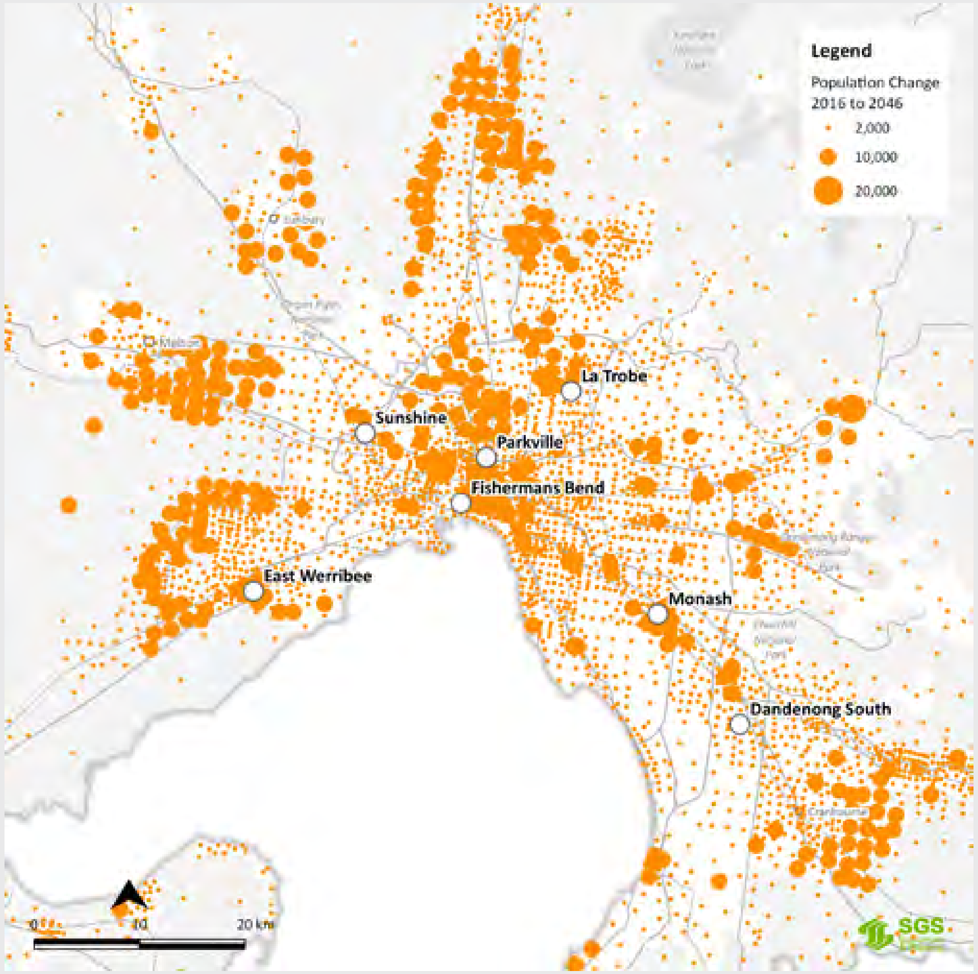
Source: SGS Economics and Planning, 2018

Approximately 9.7 per cent of Melbourne's population growth will occur within Inner City SA3s, with half of that growth occurring within the City of Melbourne over the next 15 years. Middle and Outer ring areas will capture an increasing share of population growth, particularly in later time periods. From 2036 to 2046, 41.8 per cent of Melbourne's population growth is anticipated within Established LGAs. Two-thirds of this growth will occur in the outer areas which, when combined with New Growth Areas, will place substantial strain on infrastructure in outer Melbourne. Middle ring suburbs are forecast to accommodate a relatively small share of future growth, with only 13.2 per cent of the new population. This aligns with the historically difficult task of encouraging urban infill in these areas.

The demographics of the population and where they choose to live will also change. We will see a continued aging of the population over the next few decades and more complex family structures (i.e. share houses, young professionals couples, split families, retirees, lone persons). We also expect to see households make trade-offs on housing type and location to access the dense employment agglomeration of central Melbourne. This will result in more families and other household types living in the inner city and surrounds.

FINE GRAIN PATTERN OF URBAN DEVELOPMENT

The SA3 level is useful for seeing the broad trends of growth. However, at the SA3 level, there is a mix of residential, industrial, green open space and other land uses mixed together. The map below presents the growth of Greater Melbourne at a travel zone level. This map highlights that new growth is focused in key corridors within the larger SA3s.



In terms of employment, the economy will continue to undergo a fundamental restructure away from traditional manufacturing based sectors to one based on services – health, education, professional, retail and other. This transition has fundamental implications on the spatial distribution of new jobs that seek to congregate around major nodes and population growth areas.

Some of the key trends include:

- Continued dominance of Greater Melbourne, in particular, the CBD and inner city driving economic growth through higher order services employment.
- There will still be significant dispersed employment based on existing spatial patterns and continued dispersed population growth. As Melbourne increases in size, more significant employment nodes will establish outside of the central core.
- The Health sector will be the largest employment growth sector over the next few decades. It will continue to broaden its functions ranging from local service functions (for example, a local GP) which will be spread across all population areas, to highly specialised and research functions which will cluster around major health and research nodes.

Key sectors of employment that will experience the largest amount of growth include the Health and Education sectors and Knowledge Intensive sectors. As Table 7 shows, the share of employment in Health and Education is forecast to increase across all regions, most notably in the areas outside of the Inner Region. Employment in Knowledge Intensive industries (i.e. financial and professional services) will also increase substantially, although its share will remain relatively similar across the regions.

Similarly, Population Serving jobs will rise significantly but keep a reasonably stable representation in the employment mix. Industrial employment will fall as share of employment in all regions (although the actual employment level will rise modestly).

TABLE 6: BASE CASE POPULATION AND EMPLOYMENT GROWTH IN GREATER MELBOURNE

Note: The following SA3s have been combined for simplicity: Casey North and South; Darebin North and South; Manningham East and West; Stonnington East and West; and Whitehorse East and West.
Source: SGS Economics and Planning, 2018

		POPULATION			EMPLOYMENT		
PLAN MELBOURNE REGION	SA3	2016	2046	GROWTH	2016	2046	GROWTH
Inner	Melbourne City	137,000	275,000	101.0%	488,000	921,000	88.6%
	Port Phillip	108,000	219,000	102.3%	100,000	156,000	56.9%
	Yarra	93,000	146,000	55.9%	95,000	151,000	58.8%
Western	Brimbank	191,000	243,000	27.3%	59,000	104,000	77.6%
	Essendon	69,000	102,000	48.1%	26,000	46,000	78.7%
	Hobsons Bay	89,000	122,000	37.4%	38,000	51,000	34.9%
	Keilor	61,000	90,000	47.3%	32,000	40,000	25.5%
	Maribyrnong	87,000	152,000	75.0%	41,000	69,000	66.8%
	Wyndham	223,000	500,000	123.9%	66,000	112,000	68.8%
Northern	Banyule	127,000	169,000	32.7%	49,000	84,000	70.8%
	Brunswick- Coburg	92,000	148,000	60.6%	28,000	50,000	75.8%
	Darebin	154,000	238,000	54.9%	55,000	87,000	58.2%
	Moreland- North	77,000	116,000	50.4%	16,000	24,000	51.1%
	Nillumbik- Kinglake	67,000	81,000	21.5%	17,000	27,000	60.5%
	Sunbury	42,000	116,000	174.0%	9,000	18,000	95.6%
	Tullamarine- Broadmeadows	160,000	266,000	66.1%	89,000	141,000	59.6%
	Whittlesea- Wallan	219,000	490,000	123.8%	61,000	116,000	92.2%
Inner South East	Bayside	102,000	129,000	27.0%	34,000	52,000	53.3%
	Boroondara	177,000	225,000	26.5%	82,000	129,000	58.3%
	Glen Eira	156,000	201,000	29.1%	47,000	69,000	46.4%
	Stonnington	112,000	157,000	40.3%	63,000	99,000	56.7%
Eastern	Knox	158,000	210,000	32.5%	73,000	101,000	38.7%
	Manningham	121,000	161,000	32.9%	34,000	54,000	58.4%
	Maroondah	113,000	157,000	39.2%	50,000	85,000	70.6%
	Monash	182,000	240,000	32.0%	122,000	193,000	58.7%
	Whitehorse	170,000	225,000	32.9%	85,000	140,000	64.3%
	Yarra Ranges	151,000	192,000	27.7%	50,000	74,000	50.4%
Southern	Cardinia	96,000	193,000	101.5%	25,000	44,000	74.6%
	Casey	300,000	510,000	69.8%	70,000	118,000	68.6%
	Dandenong	189,000	285,000	50.7%	117,000	191,000	63.0%
	Frankston	138,000	179,000	30.3%	53,000	91,000	72.1%
	Kingston	123,000	161,000	31.3%	73,000	115,000	57.8%
	Mornington Peninsula	158,000	226,000	43.3%	58,000	84,000	43.6%
Central Highlands	Melton- Bacchus Marsh	155,000	404,000	161.6%	33,000	60,000	81.3%
Loddon Campaspe	Macedon Ranges	30,000	46,000	55.1%	9,000	13,000	47.3%

TABLE 7: EMPLOYMENT BY INDUSTRY GROUP AND PLAN MELBOURNE REGION (2016-2046)

Note: Regions do not sum to Greater Melbourne totals because some region boundaries do not fully align with the Greater Melbourne area
Source: SGS Economics & Planning, 2018

	2016		2046	
SUBREGION	JOBS	SHARE OF REGION	JOBS	SHARE OF REGION
Inner Total	683,000		1,228,000	
Knowledge Intensive	340,000	49.8%	616,000	50.2%
Health and Education	96,000	14.1%	203,000	16.5%
Population Serving	167,000	24.5%	292,000	23.8%
Industrial	80,000	11.7%	118,000	9.6%
Inner South East Total	224,000		345,000	
Knowledge Intensive	60,000	26.8%	91,000	26.4%
Health and Education	66,000	29.5%	127,000	36.8%
Population Serving	78,000	34.8%	106,000	30.7%
Industrial	20,000	8.9%	21,000	6.1%
Western Total	288,000		473,000	
Knowledge Intensive	44,000	15.3%	68,000	14.4%
Health and Education	64,000	22.2%	132,000	27.9%
Population Serving	99,000	34.4%	164,000	34.7%
Industrial	82,000	28.5%	108,000	22.8%
Northern Total	320,000		533,000	
Knowledge Intensive	47,000	14.7%	84,000	15.8%
Health and Education	82,000	25.6%	175,000	32.8%
Population Serving	104,000	32.5%	162,000	30.4%
Industrial	87,000	27.2%	112,000	21.0%
Eastern Total	415,000		651,000	
Knowledge Intensive	74,000	17.8%	107,000	16.4%
Health and Education	112,000	27.0%	229,000	35.2%
Population Serving	135,000	32.5%	198,000	30.4%
Industrial	93,000	22.4%	117,000	18.0%
Southern Total	396,000		642,000	
Knowledge Intensive	55,000	13.9%	79,000	12.3%
Health and Education	83,000	21.0%	184,000	28.7%
Population Serving	143,000	36.1%	223,000	34.7%
Industrial	116,000	29.3%	156,000	24.3%
Total Greater Melbourne	**2,346,000**		**3,910,000**	
Knowledge Intensive	**623,000**	**26.6%**	**1,054,000**	**27.0%**
Health and Education	**505,000**	**21.5%**	**1,058,000**	**27.1%**
Population Serving	**736,000**	**31.4%**	**1,162,000**	**29.7%**
Industrial	**481,000**	**20.5%**	**636,000**	**16.3%**

7.3 Regional Victoria

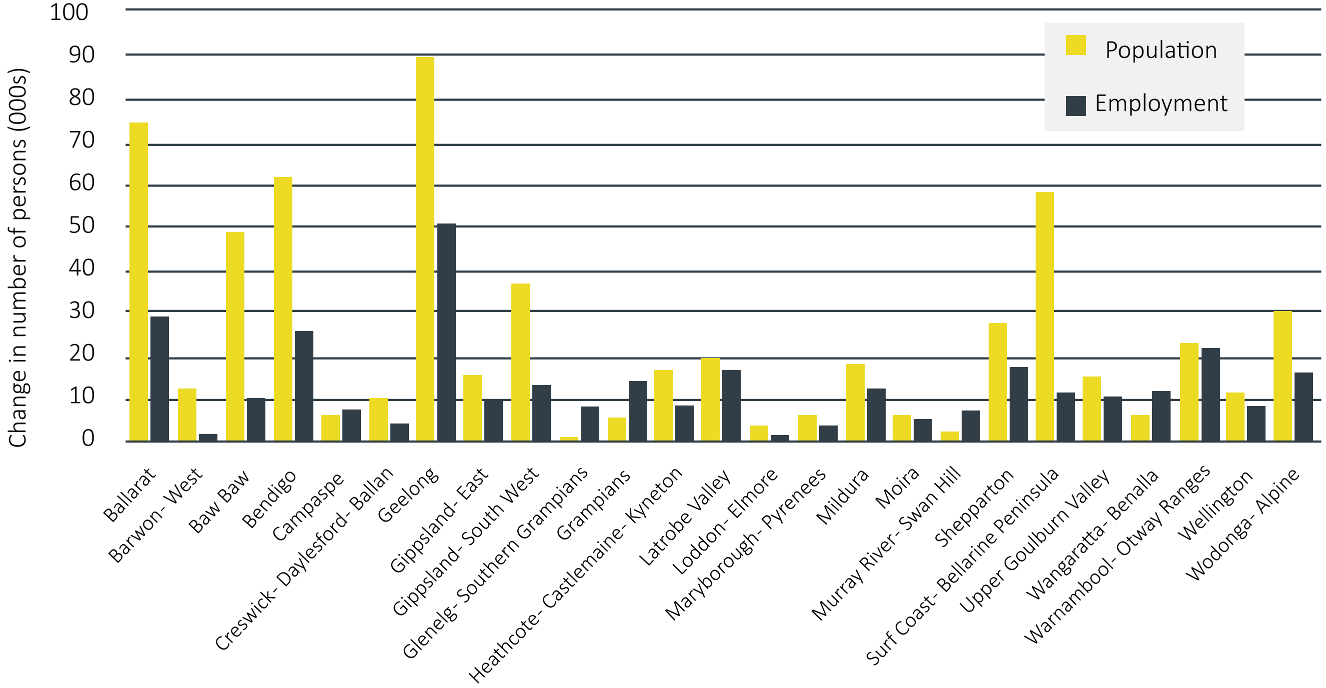
The base case population and employment growth in regional Victoria is broken down by SA3 in Figure 23–Figure 25 and Table 8 below. Growth will be focused in two different types of regional area:

— Major regional centres, namely Ballarat, Bendigo and Geelong, and
— Peri-urban areas of Melbourne, such as Baw Baw and Gippsland- South West.

While aggregate growth is seen in all regional SA3s, some smaller rural areas and small towns will experience a decline in population and jobs. Many remote/agricultural areas while still growing in terms of output will likely experience declining or stagnant employment.

Regional areas will develop a more diversified economy with more services based employment. This is seen in Table 9, where there is strong growth in the Knowledge Intensive sectors and Health and Education sectors, resulting in a rising share of employment. By contrast, there is a falling share of employment in Population Serving and Industrial sectors. This diversification trend is greatest in the major regional centres and peri-urban areas where employment growth will be strongest.

FIGURE 23: REGIONAL BASE CASE POPULATION AND EMPLOYMENT GROWTH (2016-2046)



Source: SGS Economics and Planning, 2018

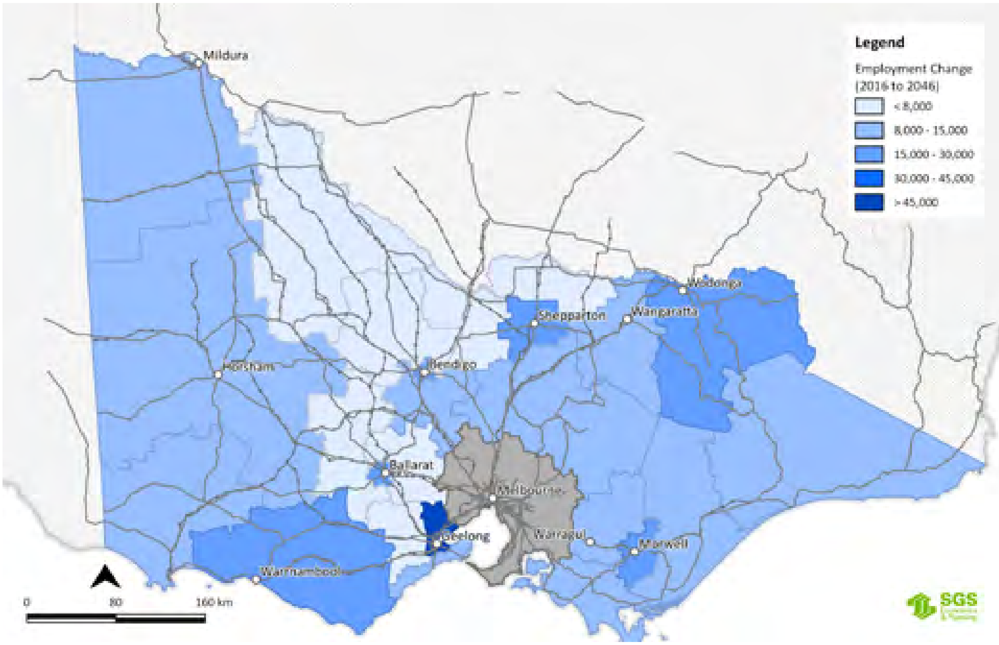


FIGURE 24: SA3 BASE CASE EMPLOYMENT GROWTH IN REGIONAL VICTORIA (2016-2046)

Source: SGS Economics and Planning, 2018

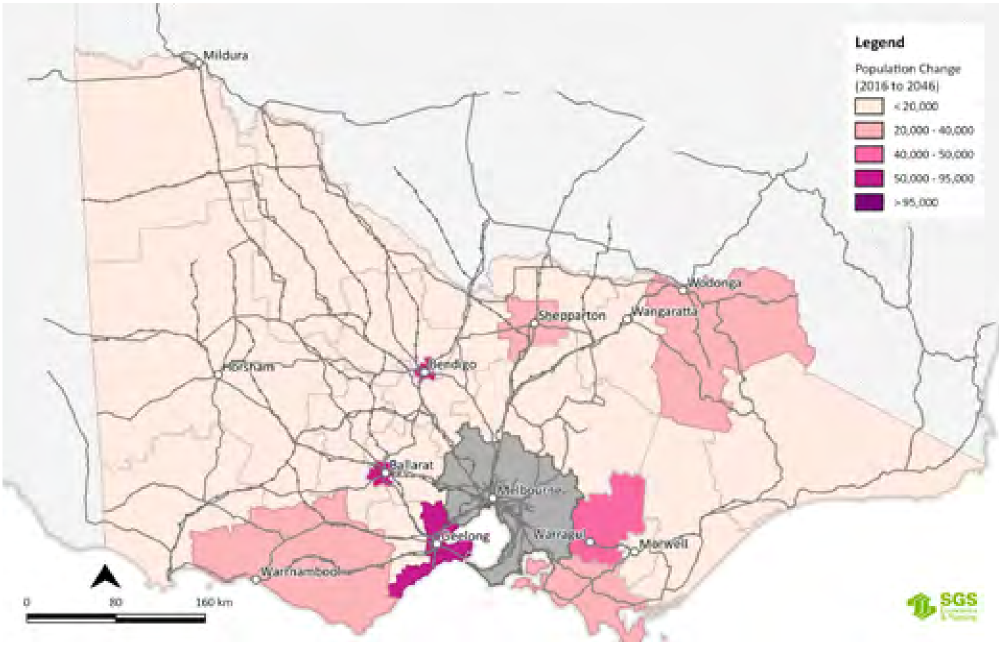


FIGURE 25: SA3 BASE CASE DWELLINGS GROWTH IN REGIONAL VICTORIA (2016-2046)

Source: SGS Economics and Planning, 2018

TABLE 8: BASE CASE POPULATION AND EMPLOYMENT GROWTH IN REGIONAL VICTORIA

Source: SGS Economics and Planning, 2018

	POPULATION			EMPLOYMENT		
SA3	2016	2046	GROWTH	2016	2046	GROWTH
Ballarat	107,000	181,000	69.4%	56,000	84,000	51.5%
Barwon- West	19,000	31,000	65.2%	6,000	8,000	35.3%
Baw Baw	49,000	97,000	100.2%	22,000	31,000	42.2%
Bendigo	95,000	156,000	64.8%	48,000	73,000	53.1%
Campaspe	37,000	43,000	16.4%	18,000	26,000	40.3%
Creswick- Daylesford- Ballan	28,000	39,000	37.1%	10,000	14,000	39.8%
Geelong	186,000	275,000	48.1%	104,000	155,000	48.8%
Gippsland- East	45,000	60,000	34.3%	21,000	31,000	45.1%
Gippsland- South West	62,000	99,000	59.2%	31,000	44,000	42.0%
Glenelg- Southern Grampians	35,000	36,000	1.8%	20,000	28,000	40.7%
Grampians	59,000	64,000	9.4%	34,000	47,000	40.8%
Heathcote- Castlemaine- Kyneton	46,000	63,000	36.2%	20,000	28,000	43.0%
Latrobe Valley	73,000	93,000	26.1%	34,000	52,000	50.0%
Loddon- Elmore	12,000	15,000	28.5%	7,000	9,000	28.1%
Maryborough- Pyrenees	25,000	30,000	23.1%	9,000	13,000	40.2%
Mildura	54,000	72,000	33.7%	26,000	39,000	45.6%
Moira	29,000	35,000	19.5%	13,000	19,000	38.6%
Murray River- Swan Hill	36,000	39,000	6.7%	19,000	26,000	36.7%
Shepparton	65,000	92,000	42.6%	35,000	51,000	47.8%
Surf Coast- Bellarine Peninsula	73,000	130,000	79.8%	23,000	34,000	49.2%
Upper Goulburn Valley	51,000	66,000	29.4%	25,000	36,000	42.6%
Wangaratta- Benalla	45,000	51,000	13.3%	27,000	38,000	44.0%
Warrnambool- Otway Ranges	87,000	110,000	25.9%	51,000	72,000	42.0%
Wellington	42,000	53,000	25.6%	20,000	28,000	42.2%
Wodonga- Alpine	70,000	101,000	44.8%	35,000	51,000	44.7%

TABLE 9: BASE CASE REGIONAL EMPLOYMENT BY INDUSTRY GROUP

Source: SGS Economics & Planning, 2018

	2016		2046	
INDUSTRY GROUP	PERSONS	SHARE OF REGION	PERSONS	SHARE OF REGION
Knowledge Intensive	112,000	15.7%	169,000	16.3%
Health and Education	146,000	20.5%	284,000	27.4%
Population Serving	243,000	34.1%	337,000	32.6%
Industrial	211,000	29.6%	245,000	23.7%

08
Land use scenarios

> "All scenarios broadly show the dispersion of dwellings and employment across Melbourne but there are some key differences in how the scenarios impact land use."

SGS assessed the impact of six project case scenarios with different possible outcomes for automated and zero emissions vehicle adoption. The scenarios were designed to test the impact of different ownership and take up mixes on land use distribution. The results of the analysis show a clear pattern of dispersion of housing and employment under all scenarios.

8.1 Interpreting the results

The scenarios were developed by Infrastructure Victoria and incorporate various mixes of ownership and use behaviour. They are as follows:

— **Slow Lane** – there is a 50/50 mix between private and shared ownership and between automated and zero emission and internal combustion vehicles. Marginal utility of travel time is high in all cases and cars empty run if part of a shared fleet.

— **Private Drive** – all cars are privately owned, zero emission and automated. The marginal utility of travel is high and cars do not empty run when not in use.

— **Private Drive low MUTT** – like above but the marginal utility of travel time is low

— **Private Drive empty running** – like Private Drive but cars can empty run between trips (if more affordable than parking).

— **Fleet Street** – all cars are zero emission and autonomous but are owned by a company or companies that rent them out, like Uber does now. The marginal utility of travel time is high and cars empty run when they are not in use.

— **Fleet Street low MUTT** – like above but the marginal utility of travel is low.

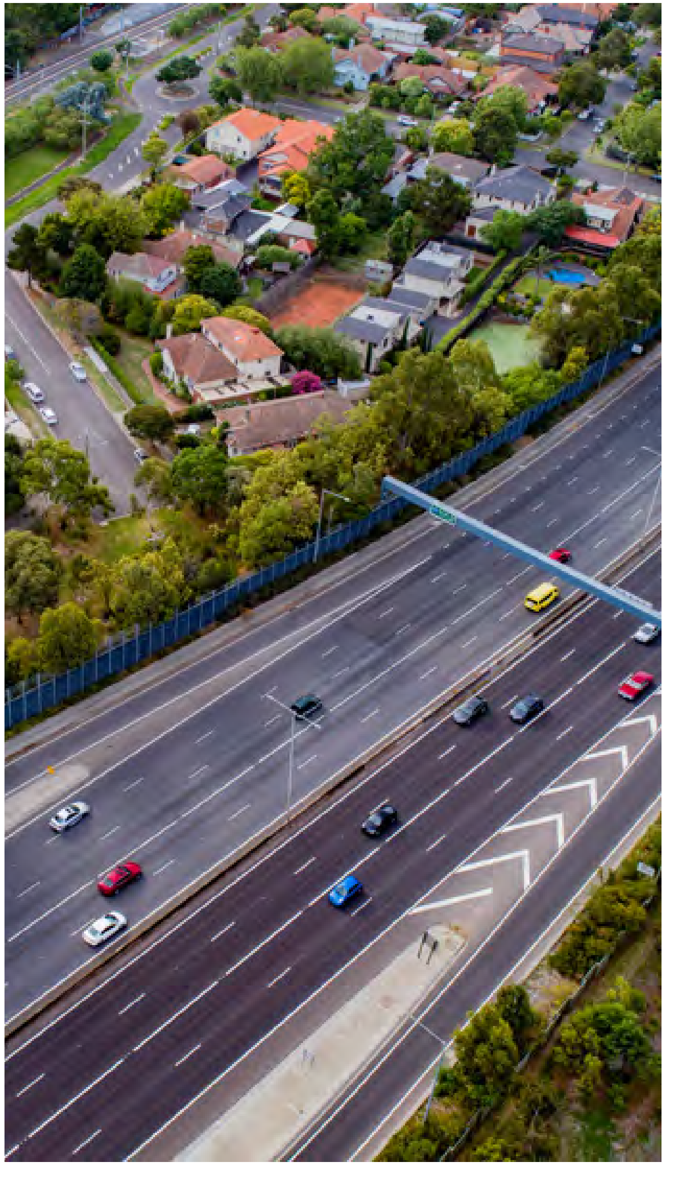
The results of the scenarios are presented as relative changes to the base case. There is no net change in the number of dwellings and jobs in Victoria. Rather the new scenarios represent a new distribution of dwellings and jobs in Victoria. Some areas (which have had an increase in relative EJD) have a net increase in dwellings and jobs and other areas (which have had a decrease in relative EJD) have a decline.

This is not to be interpreted as a movement of individual households. In a real-world situation, many households will move across Melbourne and Regional Victoria to optimise their travel options and dwelling choice. The scenarios represent a new distribution of dwellings and jobs given a new level of accessibility.

It should also be noted that housing and commercial markets will take time to adjust to the changes in transport accessibility. It may not be until 2030[29] that any significant changes in the distribution of land use patterns would be expected to be seen.

This is based on the analysis of the relationship between historical land use patterns and car ownership rates presented in Section 2 and the understanding of housing commercial feasibility presented in Section 6.

It is important to remember the land use estimates are developed to support a strategic view of Victoria and are calibrated with that macro view in mind. Therefore, caution is advised when focusing solely on individual small areas as this is not the intention of the data.



[29]Based on the assumptions for this project there would be a 50 per cent uptake of automated vehicles in the early 2030s, reaching 100 per cent in 2046.

8.2 Greater Melbourne results overview

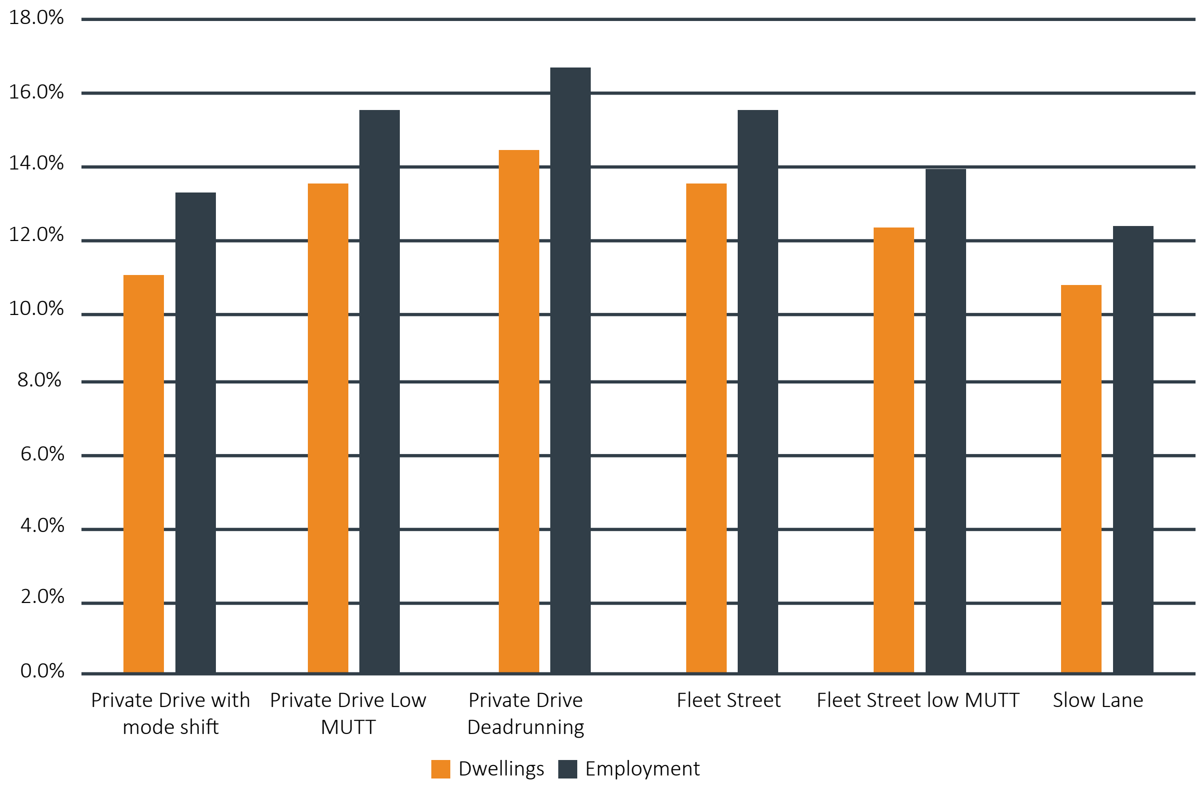
The impact of each scenario relative to the 2046 base case is presented below. These are the results from the TIM[30]. A decrease in population or employment under a scenario indicates less growth is expected between 2016-46 under this scenario than under the base case, and vice versa. Changes do not reflect overall increases or decreases in an area's population or employment over the period from 2016 to 2046.

All the scenarios show the uptake of automated and zero emissions vehicles causing significant shifts in where new jobs and households locate. The degree to which the shifts happen varies with ownership models, how travellers value their time, and rate of take up of the new type of vehicle, however, all the scenarios show a consistent overall pattern of dispersing urban development across Greater Melbourne.

The scenario results are in line with development patterns seen following the take up of private internal combustion engine vehicles during the 20th century. Between the late 1960s and the early 1990s car ownership doubled from around one per household to two. This proliferation of car travel was accompanied by the dispersion of population and employment growth across Melbourne and mass suburbanisation. The analysis suggests automated and zero emission vehicles will have a similar effect.

The results indicate that between 10.8 and 14.5 per cent of dwellings, and between 12.3 and 16.6 per cent of jobs in shifting location[31] (see Figure 26). In comparison, previous studies have shown major transport projects have only shifted 1 to 5 per cent of additional dwellings. This is because they have impacted on a single corridor within a city, while the automated and zero emissions vehicles are influencing accessibility across the whole city.

FIGURE 26: REDISTRIBUTION OF EMPLOYMENT AND HOUSEHOLD GROWTH UNDER DIFFERENT SCENARIOS



Source: SGS Economics and Planning, 2018

The overall shift is largest under the private drive with empty running scenario, likely because this model of uptake shares the least similarities with the base case. Slow Lane shows the smallest overall shift from the base case, reflecting the continuing role of traditional internal combustion engine cars and ownership model.

The considerable shift in employment and households will likely dramatically change the structure of the city and have significant impacts on how its population lives. Broadly, the scenario results indicate increasing reliance on major roads and public transport infrastructure, particularly that which connects outer and middle ring suburbs.

[30]MABM transport outputs were provided at the SA2 level. The TIM modelling was also undertaken at this level and the results were then aggregated to SA3s (on average an SA3 is made up of eight SA2s). This aggregation to SA3s allowed a clearer understanding of the impacts on the land use patterns under the various scenarios.
[31]These are dwellings or jobs that shifted location at the SA2 level.

They also show the increased importance of urban employment centres outside the CBD. These centres, particularly in Melbourne's east, emerge across scenarios as being major attractors of employment and dwellings, and contribute to a shift toward a suburbanisation of jobs, with agglomeration in Melbourne's suburban centres. The results of each scenario, detailed in the next section, will help in understanding the causes of these shifts and, ideally, inform better planning.

There are some locations which have higher levels of jobs and dwellings increase across several scenarios. These are shown in Table 10 and Table 11 with the SA3s that appear most commonly in the top five largest shifts for dwellings and employment, respectively.

The greenfield SA3 of Casey – North appears in the top five SA3s in all 6 scenarios for both dwellings and employment movements. On average, Casey – North has an additional 4,400 dwellings in 2046 and 6,800 jobs compared to the base case. Similarly, Whittlesea – Wallan is a greenfield SA3 which appears in the top five in three scenarios.

Given Casey – North and Whittlesea – Wallan are greenfield areas, it is appropriate to examine possible pressure on the urban growth boundary. However, housing density in these areas does not change dramatically with the extra dwellings. The automated and zero emission vehicles improve transport accessibility and therefore housing demand across a wide area. The market responds by providing additional medium density dwellings, but the dispersed nature of the demand means there is only a modest increase in housing densities to accommodate the increased population. Therefore, there would be no need to expand the existing urban growth boundary under these scenarios.

TABLE 10: MOST COMMON SA3 APPEARING IN TOP FIVE INCREASE FOR DWELLINGS

SA3	NUMBER OF TIMES SA3 APPEARS IN TOP FIVE	AVERAGE INCREASE IN DWELLINGS
Casey- North	6	4,400
Whittlesea- Wallan	3	3,900
Brimbank	3	1,800
Banyule	3	1,700
Knox	3	3,100

Source: SGS Economics and Planning, 2018

TABLE 11: MOST COMMON SA3 APPEARING IN TOP FIVE INCREASE FOR EMPLOYMENT

SA3	NUMBER OF TIMES SA3 APPEARS IN TOP FIVE	AVERAGE INCREASE IN DWELLINGS
Casey- North	6	6,800
Whittlesea- Wallan	3	5,900
Brimbank	3	2,700
Knox	3	4,800

Source: SGS Economics and Planning, 2018

The remaining three SA3s which appear in the top five are Brimbank, Banyule and Knox. All SA3s are in more established areas with very good freeway access. The same list of SA3s, except for Banyule, also appear in the list of SA3 with consistently high job increases.

Overall, the land use impact from the scenarios bears many similarities to the development patterns (as shown in Section 2) which were observed when car ownership became commonplace during the 1950s, 1960s and 1970s.

The following sub-sections present the dwelling and employment results of the change in each scenario, relative to the base case. The results are presented as an absolute number and a percentage change. The scenario densities for dwellings and employment are also presented to understand changes to the urban form across Melbourne under each scenario. To help understand the built form outcomes which could be expected, a series of example dwelling densities are also presented.

8.3 Slow Lane

The Slow Lane scenario shows a future where automated and zero emissions vehicles have only partially been taken up. Under it there is a 50/50 mix between automated and zero emission and traditional internal combustion engine vehicles and between private and shared ownership. Due to the mixed take up, some of the potential benefits of autonomous vehicles such as platooning, reduced noise, emissions and accidents and increased speeds are limited.

The effects of mixed technological take up and the shared/private ownership model will be the key drivers shaping how land use patterns change under the scenario. It is expected that the total number of car trips will decline relative to the base case, while public transport and walk trips will increase (see Figure 27).

This primarily reflects increasing trip times due to congestion stemming from the empty running of fleet owned vehicles, and the increased cost of shared car trips relative to other transport options. Public transport trips are expected to increase the most in the north, the north east and the south east. As a result, increases in employment and population should be seen around public transport hubs and major connecting roads in outer areas while the inner city declines.

SLOW LANE: THE LIVED EXPERIENCE

Doggett Professional Services moved to Keilor in 2040. Previously, the firm was in North Melbourne where it was best placed to access the best talent in its industry. The firm moved outward as zero emissions and autonomous vehicles became more common. The new cars brought about significant changes to the city, despite only being used by half of its residents. The cars, which drove and navigated autonomously, made driving a lot more enjoyable and productive than in traditional cars and this improvement led to people taking longer trips and using their cars more frequently.

Now, instead of the majority of people travelling to work by non-automated cars and mass public transport, a growing number commuted using theirs or a fleet owned automated vehicle. The inner city became clogged with cars, many of them empty, and general amenity decreased significantly. In deciding where to move, Doggett considered areas that would be best placed to benefit from automated and zero emission vehicle transport. The new headquarters in Melbourne's north-west is very well connected to the urban fringe through the Western Ring Road as well as to the CBD through Citylink. Doggett's employees, who can mostly afford autonomous vehicles, are happy to avoid the heavily congested inner city and to swap their public transport commute for a trip in an AV, during which time they can work.

The rent the firm saves by not being in the inner city is reinvested in the company and paid out in higher wages and the new location, close to the airport, allows interstate workers to come and go easily.

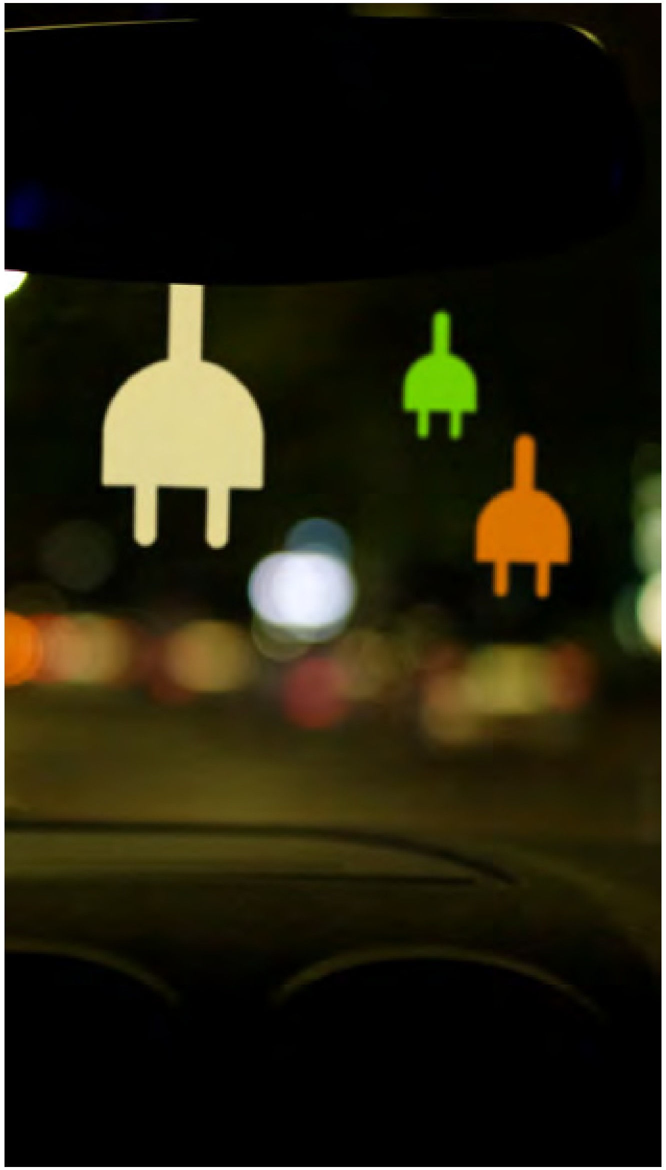
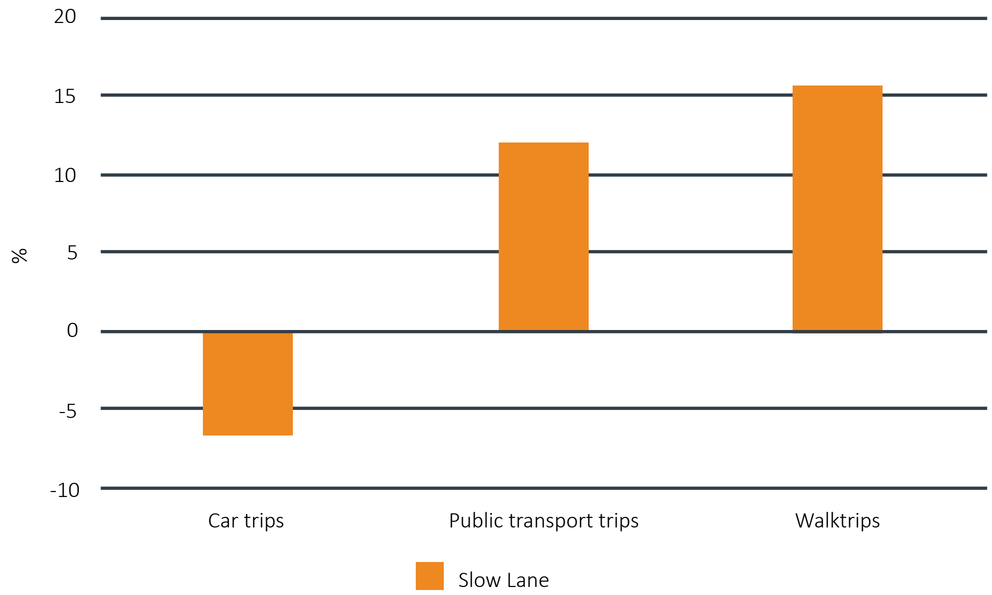


FIGURE 27: PERCENTAGE CHANGE IN TRIPS COMPARED TO 2046 BASE CASE- SLOW LANE



Source: SGS Economics and Planning based on KPMG modelling, 2018

TABLE 12: TOP FIVE SA3S BY FOR CHANGE FROM BASE CASE – SLOW LANE

SA3	INCREASE	% INCREASE
	EMPLOYMENT	
Casey – North	7,200	10.4
Brimbank	6,100	5.8
Knox	5,900	5.9
Casey – South	5,100	10.6
Cardinia	4,600	10.5
	DWELLINGS	
Casey – North	4,700	7.6
Brimbank	4,100	4.5
Knox	3,900	4.6
Casey – South	3,400	2.7
Cardinia	3,000	3.9

Source: SGS Economics and Planning, 2018

The effects of mixed take up and ownership are reflected in the results of the Slow Lane scenario which sees the lowest overall shift in employment and households but arguably the most marked decline in jobs and households from the inner city. The largest increases are seen in the greenfield areas of Casey – North, Brimbank, Casey – South and Cardinia in the outer west and east and in Knox in the east (see Table 12).

The pattern primarily reflects increasing accessibility provided by road corridors. The impact of the Eastlink, and improved motorway access to it through the North East Link and the E6 (the eastern-most section of the Outer Metropolitan Ring Road), can be seen in strong dwelling growth in Melbourne's east, including in Knox, Casey – North and Casey – South. In the west it can be seen in the increase at Brimbank, which contains the junction of the Western Ring Road, Western Freeway and Calder Freeway (see Figure 28). The freeway corridors in outer areas are where automated and zero emissions were expected to provide increases in accessibility.

Proportionally, the increase is largest in outer surburbs (see Figure 29). This reflects their relatively low density under the base case. The impact across the inner city varies. Melbourne City SA3 has a reduction of 1.2 per cent (11,100) in the number of jobs in 2046. While SA3s such as Brunswick – Coburg (7.3 per cent) and Port Phillip (7.2 per cent) have a much greater percentage decline.

The reduction in job growth in the inner city mostly come from the Health and Education, Population Serving and Industrial industries, with Knowledge Intensive industries seeing the smallest declines (see Table 13). This reflects the limited effect Slow Lane has on accessibility. Knowledge Based jobs typically require locations with the highest level of accessibility – usually this is the inner city – and the Slow Lane scenario does not widen accessibility enough to induce firms to move from the inner city.

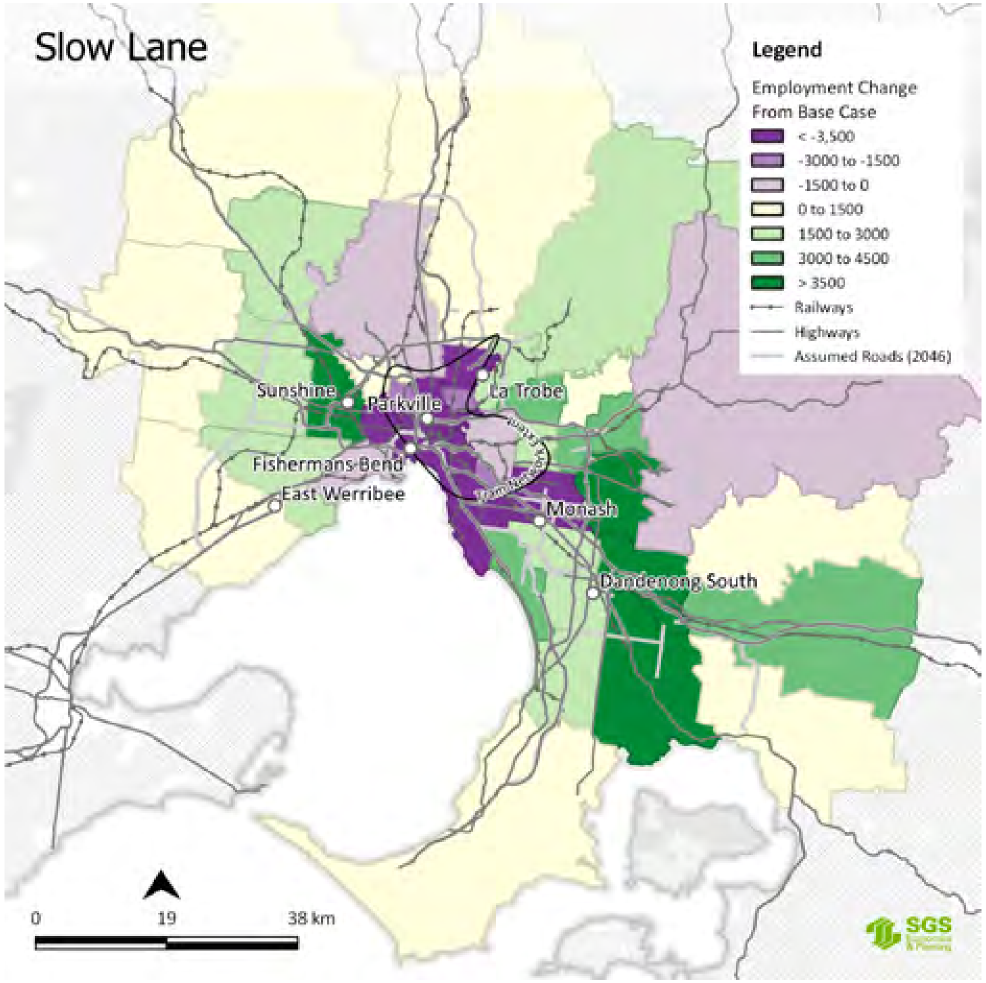
The pattern reflects increasing inner city congestion, likely resulting from empty running automated vehicles and the continued reliance on private ICE vehicles and public transport for much of the population.

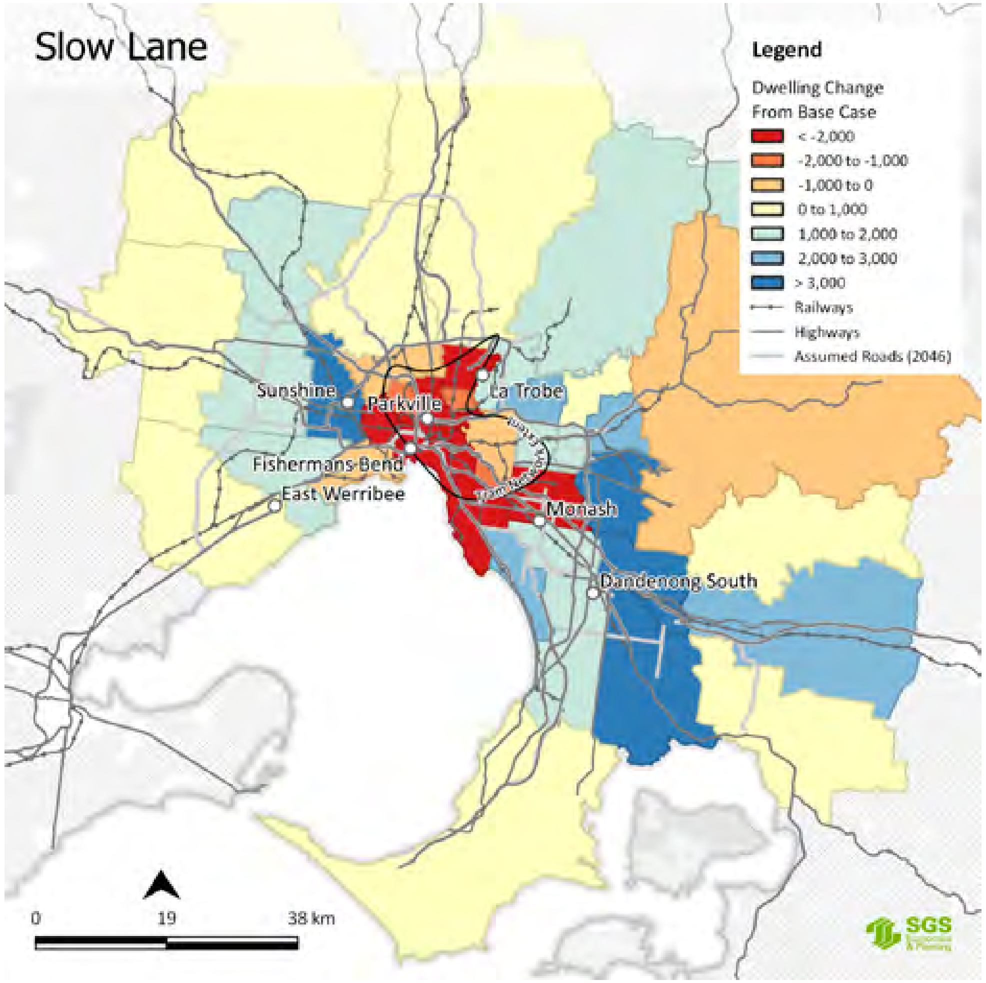
TABLE 13: EMPLOYMENT BY INDUSTRY GROUP AND REGION, BASE CASE AND SLOW LANE

SUBREGION	BASE CASE	SLOW LANE	CHANGE	% CHANGE
Inner Total	1,228,000	1,200,000	-28,000	-2.3%
Knowledge Intensive	616,000	607,000	-9,000	-1.5%
Health and Education	203,000	195,000	-8,000	-3.9%
Population Serving	292,000	284,000	-8,000	-2.7%
Industrial	118,000	113,000	-5,000	-4.2%
Inner South East Total	345,000	330,000	-15,000	-4.3%
Knowledge Intensive	91,000	88,000	-3,000	-3.3%
Health and Education	127,000	122,000	-5,000	-3.9%
Population Serving	106,000	101,000	-5,000	-4.7%
Industrial	21,000	19,000	-2,000	-9.5%
Western Total	473,000	475,000	2,000	0.4%
Knowledge Intensive	68,000	69,000	1,000	1.5%
Health and Education	132,000	133,000	1,000	0.8%
Population Serving	164,000	165,000	1,000	0.6%
Industrial	108,000	108,000	0	0.0%
Northern Total	533,000	532,000	-1,000	-0.2%
Knowledge Intensive	84,000	84,000	0	0.0%
Health and Education	175,000	175,000	0	0.0%
Population Serving	162,000	162,000	0	0.0%
Industrial	112,000	111,000	-1,000	-0.9%
Eastern Total	651,000	666,000	15,000	2.3%
Knowledge Intensive	107,000	111,000	4,000	3.7%
Health and Education	229,000	234,000	5,000	2.2%
Population Serving	198,000	202,000	4,000	2.0%
Industrial	117,000	119,000	2,000	1.7%
Southern Total	642,000	668,000	26,000	4.0%
Knowledge Intensive	79,000	86,000	7,000	8.9%
Health and Education	184,000	191,000	7,000	3.8%
Population Serving	223,000	231,000	8,000	3.6%
Industrial	156,000	160,000	4,000	2.6%

Source: SGS Economics & Planning, 2018

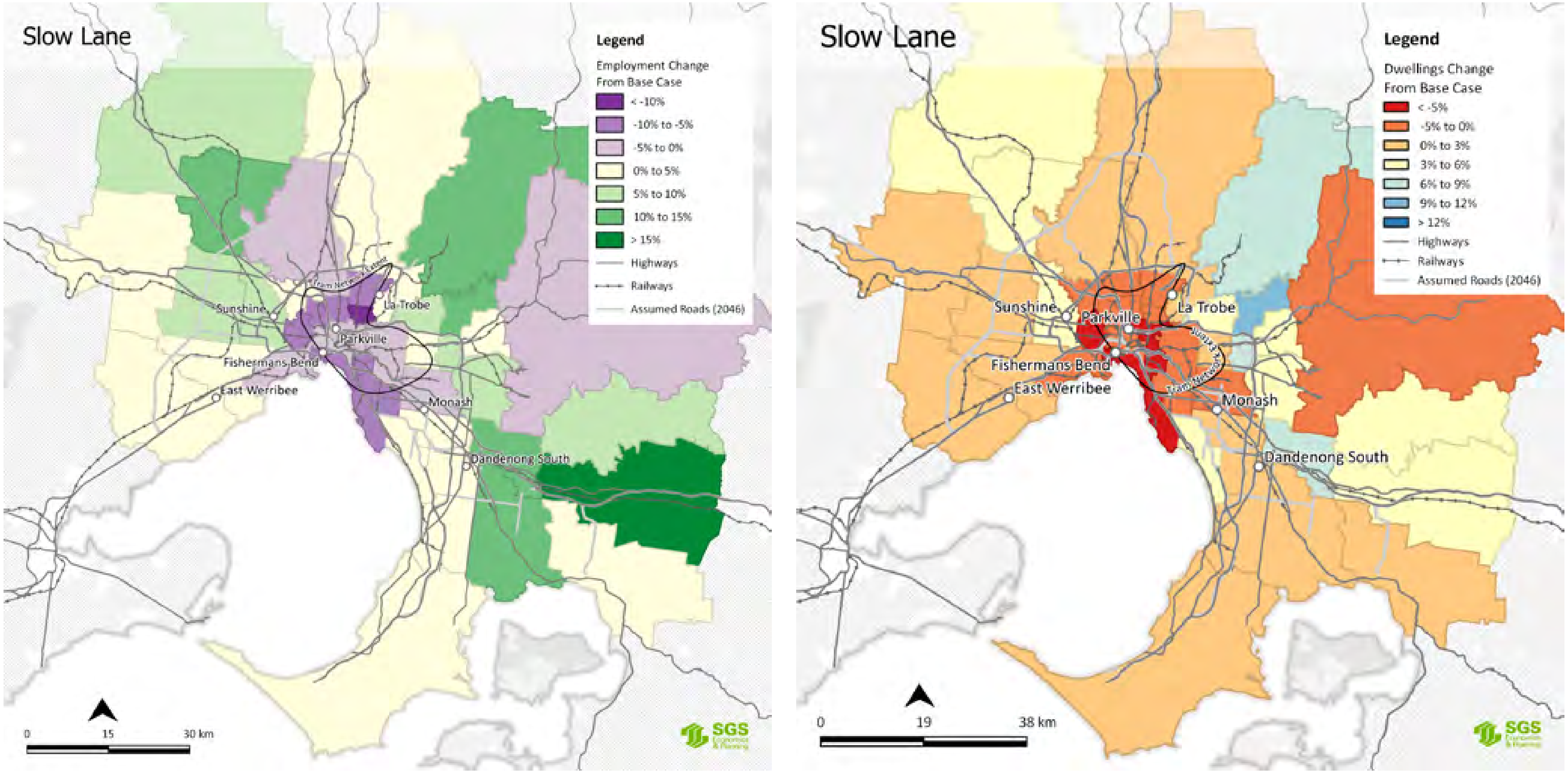
FIGURE 28: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- SLOW LANE





Source: SGS Economics and Planning, 2018

FIGURE 29: SA3 EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE- SLOW LANE



Source: SGS Economics and Planning, 2018

8.4 Private Drive scenarios

In the Private Drive scenario, all cars are privately owned, are zero emission and take you anywhere you want to go within the city or the country. You just tell it your destination, then sit back and relax. The car knows the best route to take because it is continuously updated with current traffic patterns and road maintenance data. Your car communicates with other road users and transport infrastructure, so the drive is smooth, and accidents are very rare.

PRIVATE DRIVE: THE LIVED EXPERIENCE

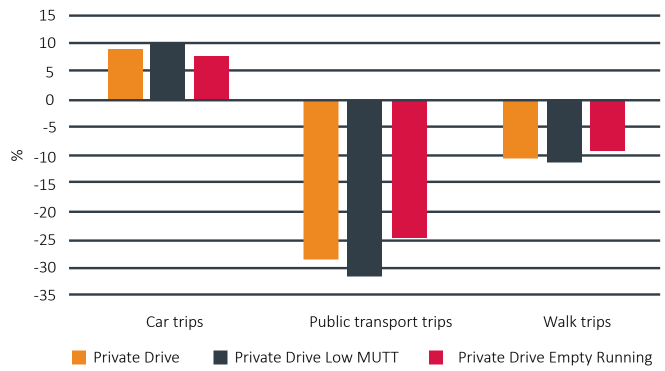
Patricia loves where she lives in Wallan, north of Melbourne. The suburb was rural until a few years ago but Melbourne's booming residential population, now more than 7 million people, and the advent of zero emissions and autonomous vehicles drew people and jobs outwards and saw Wallan go from rolling green plains to low density housing developments. The suburb is an hour and half outside the city centre and still doesn't have much public transport, but it doesn't matter to Patricia, who travels by electric autonomous vehicle to her job at a dental clinic in Melbourne's north east. Because she travels by electric autonomous Patricia's commute, which can take 30 minutes more than it did when traditional cars were in use, is cheap and is spent preparing for her day and playing with her children, who she drops to school on the way. The electric autonomous vehicle was expensive, but she saves on fuel and transport costs and can live in an area with a lot of space.

Under the Private Drive scenario, the effects of private ownership and full technological take up will drive the location of employment and population. Under this scenario, it is expected that the total number of car trips will increase while the total public transport and walk trips will decline. The results in Figure 30 below show the expected change in car, public transport and walk trips under different sensitivities of the private drive scenario.

The shift towards car trips is largest under the low MUTT scenario and smallest under empty running. These differences reflect the changing marginal costs of car travel under the different iterations as well as the effects of changing travel patterns on congestion. Under the low MUTT scenario, travellers perceive trips as being shorter than they are and so are happy to take longer ones and to tolerate more congestion. The effect of the low MUTT will be particularly important in outer areas where accessibility is low and travel times are generally high. This effect is apparent when looking closer at shifts in public transport use, which show the largest declines happening in middle and outer areas.

The smaller shift towards car travel under the empty running scenario shows the impact that increases in congestion will have on the marginal cost of car trips. Under this scenario, the practice of empty running means that there are more cars on the road than the other private drive scenarios which exacerbates congestion. While it is not enough to deter a lot of travellers, it is enough to induce some to continue using other modes of transport. Middle south eastern, outer eastern and southern areas show the largest sensitivity to this, with these areas seeing the largest decreases in public transport trips.

FIGURE 30: PERCENTAGE CHANGE IN TRIPS COMPARED TO 2046 BASE CASE – PRIVATE DRIVE



Source: SGS Economics and Planning, 2018 based on KPMG modelling, 2018

Private Drive

The results of the TIM analysis show a broad pattern of movement of jobs from inner to outer Melbourne, particularly in areas from the outer north to outer south east, under private drive. The general shift towards car travel under the scenario has made access to major roads especially important for businesses and households. Evidence of this relationship can be seen in the ranking of the areas that have seen the highest increase (see Table 14).

Casey – North had the highest increase and this area covers the intersection of the M1 and Princes Highway. The eastern areas of Frankston, Kingston and the Mornington Peninsula were among the top five areas with the five highest increases in dwellings and employment. These areas sit along a road corridor including the Peninsula Link, the planned Mordialloc Freeway and the Westall Road Extension (see Figure 31). Similarly, the entire east of Melbourne will benefit from the East Link, the Metro Ring Road and the planned North East Link in the east and north east.

TABLE 14: TOP FIVE AREAS FOR CHANGE FROM BASE CASE-PRIVATE DRIVE

SA3	INCREASE	% INCREASE
EMPLOYMENT		
Casey – North	7200	10.4
Frankston	5900	6.4
Nillumbik – Kinglake	5600	20.5
Kingston	5000	4.4
Mornington Peninsula	4700	5.6
DWELLINGS		
Casey – North	4400	7.2
Frankston	3800	4.9
Kingston	3700	5.2
Nillumbik – Kinglake	3300	10.5
Mornington Peninsula	2900	3.0

Source: SGS Economics and Planning, 2018

Proportional increases in employment and dwellings are the highest in the outer north west and the outer north east and east, highlighting the importance of growth fronts in the Private Drive scenario (see Figure 32). Percentage drops in the inner city are generally higher than under Slow Lane. For jobs, the impact across the inner city varies. For example, Melbourne City SA3 has a reduction of 1.3 per cent (12,200) in the number of jobs in 2046. And Brunswick – Coburg (7.6 per cent) has a slightly larger reduction in employment under the Private Drive scenario compared to the Slow Lane scenario.

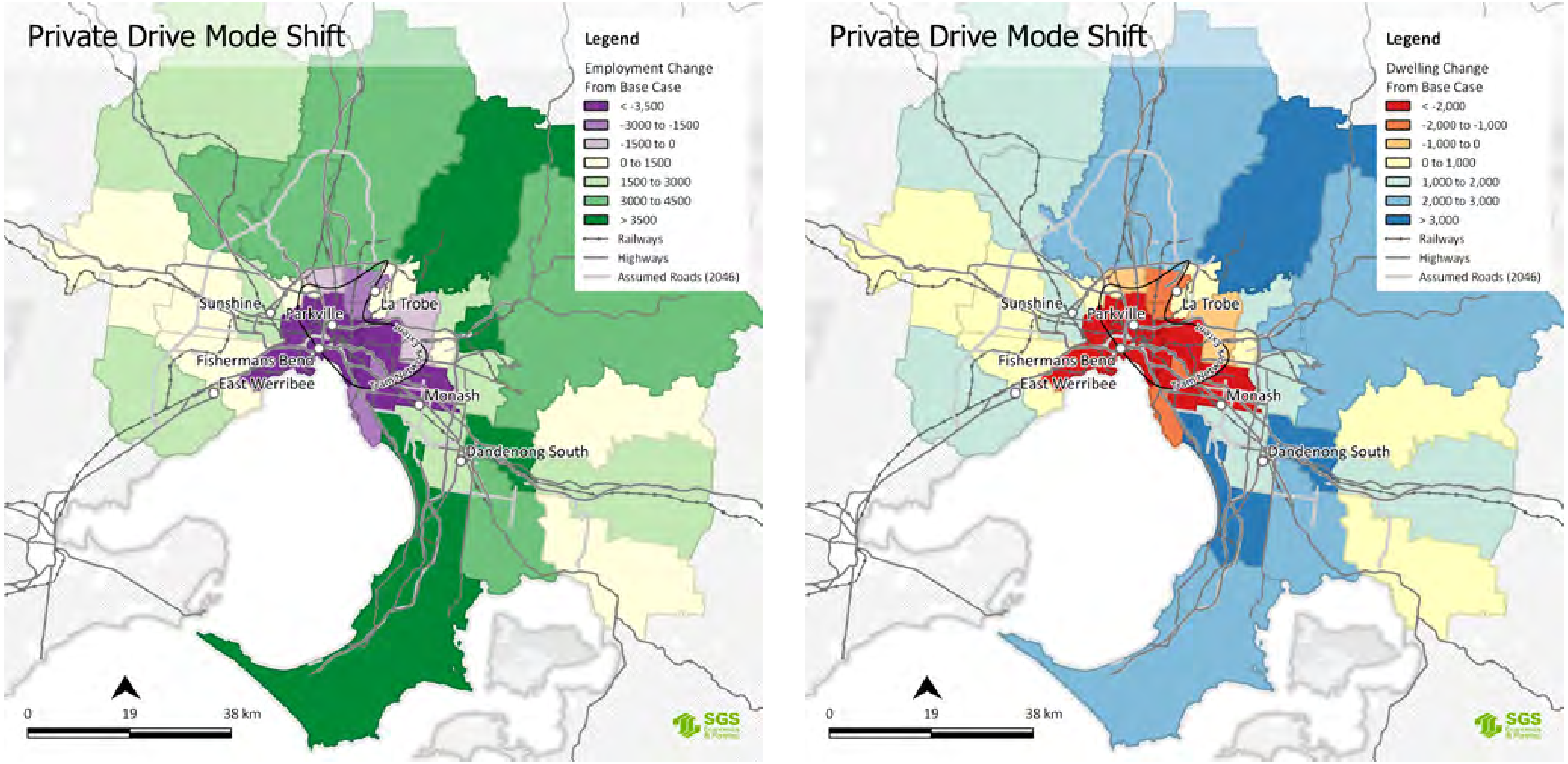
The largest shift in employment in an industry is seen in the Southern region, which sees employment in Knowledge Intensive industries increase by 11%. The Southern and Northern regions also see an uptick in knowledge intensive employment, while in the inner city it falls (see Table 15). The Inner South East sees the largest fall in growth in Industrial employment (9.5%).

TABLE 15: EMPLOYMENT BY INDUSTRY GROUP AND REGION, BASE CASE AND PRIVATE DRIVE

SUBREGION	BASE CASE	PRIVATE DRIVE	CHANGE	% CHANGE
Inner Total	1,228,000	1,197,000	-31,000	-2.5%
Knowledge Intensive	616,000	606,000	-10,000	-1.6%
Health and Education	203,000	195,000	-8,000	-3.9%
Population Serving	292,000	284,000	-8,000	-2.7%
Industrial	118,000	113,000	-5,000	-4.2%
Inner South East Total	345,000	328,000	-17,000	-4.9%
Knowledge Intensive	91,000	87,000	-4,000	-4.4%
Health and Education	127,000	122,000	-5,000	-3.9%
Population Serving	106,000	101,000	-5,000	-4.7%
Industrial	21,000	19,000	-2,000	-9.5%
Western Total	473,000	469,000	-4,000	-0.8%
Knowledge Intensive	68,000	68,000	0	0.0%
Health and Education	132,000	131,000	-1,000	-0.8%
Population Serving	164,000	163,000	-1,000	-0.6%
Industrial	108,000	107,000	-1,000	-0.9%
Northern Total	533,000	542,000	9,000	1.7%
Knowledge Intensive	84,000	87,000	3,000	3.6%
Health and Education	175,000	178,000	3,000	1.7%
Population Serving	162,000	165,000	3,000	1.9%
Industrial	112,000	113,000	1,000	0.9%
Eastern Total	651,000	657,000	6,000	0.9%
Knowledge Intensive	107,000	109,000	2,000	1.9%
Health and Education	229,000	231,000	2,000	0.9%
Population Serving	198,000	200,000	2,000	1.0%
Industrial	117,000	118,000	1,000	0.9%
Southern Total	642,000	675,000	33,000	5.1%
Knowledge Intensive	79,000	88,000	9,000	11.4%
Health and Education	184,000	193,000	9,000	4.9%
Population Serving	223,000	232,000	9,000	4.0%
Industrial	156,000	161,000	5,000	3.2%

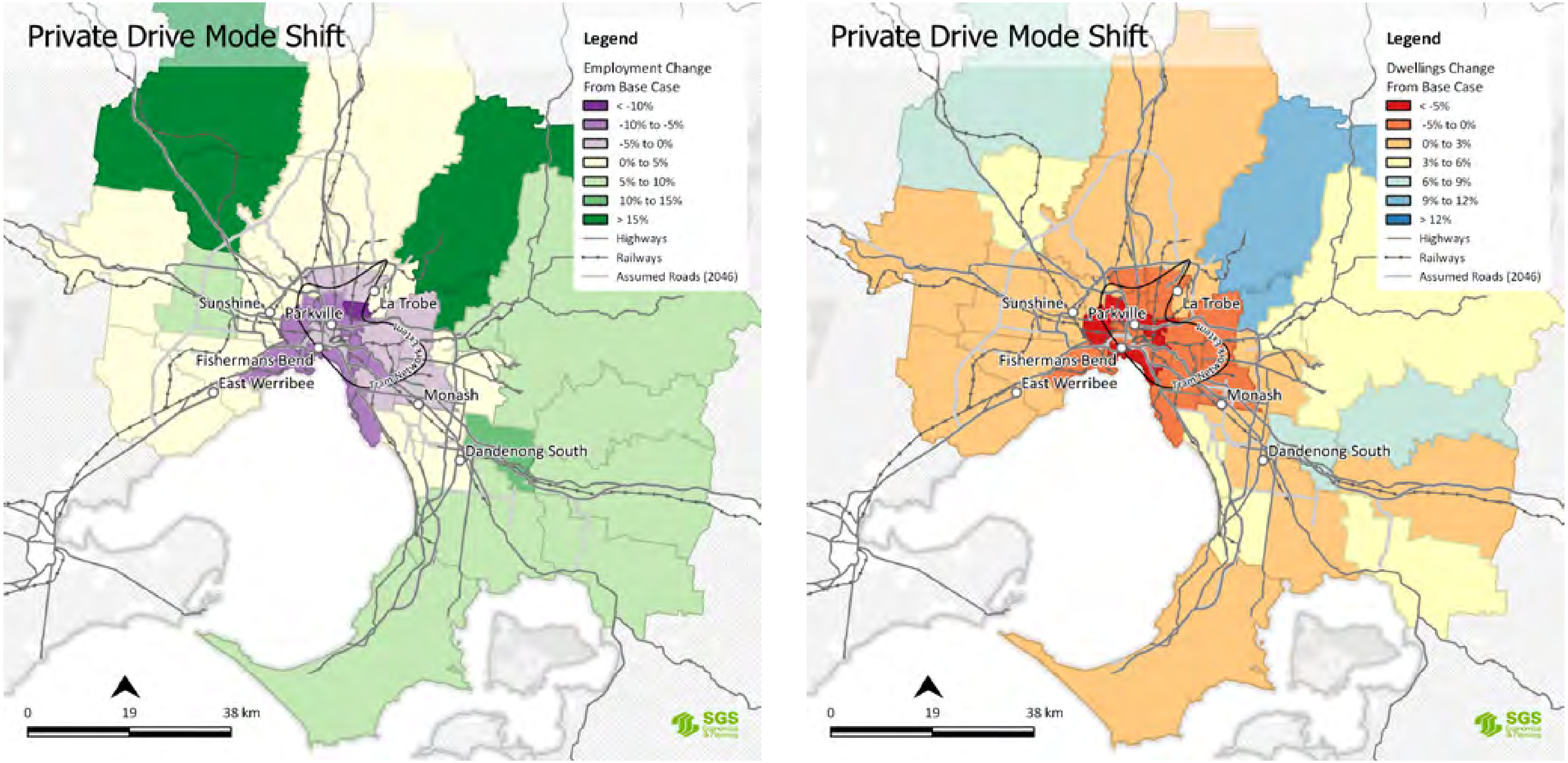
Source: SGS Economics & Planning, 2018

FIGURE 31: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- PRIVATE DRIVE



Source: SGS Economics and Planning, 2018

FIGURE 32: SA3 EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE- PRIVATE DRIVE



Source: SGS Economics and Planning, 2018

Private Drive low MUTT

A similar pattern emerges across the different Private Drive sensitivities but with some notable deviations. Under the low MUTT scenario concentrated development extends further south and north east in areas that are not well serviced by public transport (see Figure 33). This increased dispersion reflects the lower marginal travel costs and the more pronounced shift from public to private car transport.

The impact of Peninsula Link, Eastlink and the North East Link can be seen in the large increases in SA3s in Melbourne's east (see Table 16). Frankston and Kingston are particularly well placed to benefit from the Peninsula Link and nearby planned road developments, while Casey (Princes Highway and EastLink), Knox (EastLink) and Maroondah (EastLink and North East Link) have good access to the major freeways and motorways.

As well as the large increase along the north east to south east, the results shown in Figure 35 illustrate significant growth across the outer areas, particularly Whittlesea – Wallan (5,700 additional dwellings), Casey – North (3,800 dwellings) and Casey – South (2,100 dwellings). Proportionally, there is a larger percentage growth in the outer west and north (see Figure 34).

TABLE 16: TOP FIVE SA3S FOR CHANGE FROM BASE CASE-PRIVATE DRIVE LOW MUTT

SA3	INCREASE	% INCREASE
	EMPLOYMENT	
Frankston	6,900	7.5
Kingston	6,200	5.4
Casey – North	5,900	8.5
Knox	5,800	5.7
Maroondah	5,300	6.2
	DWELLINGS	
Frankston	4,500	7.2
Kingston	4,300	4.9
Casey – North	3,800	5.2
Knox	3,800	10.5
Maroondah	3,500	3.0

Source: SGS Economics and Planning, 2018

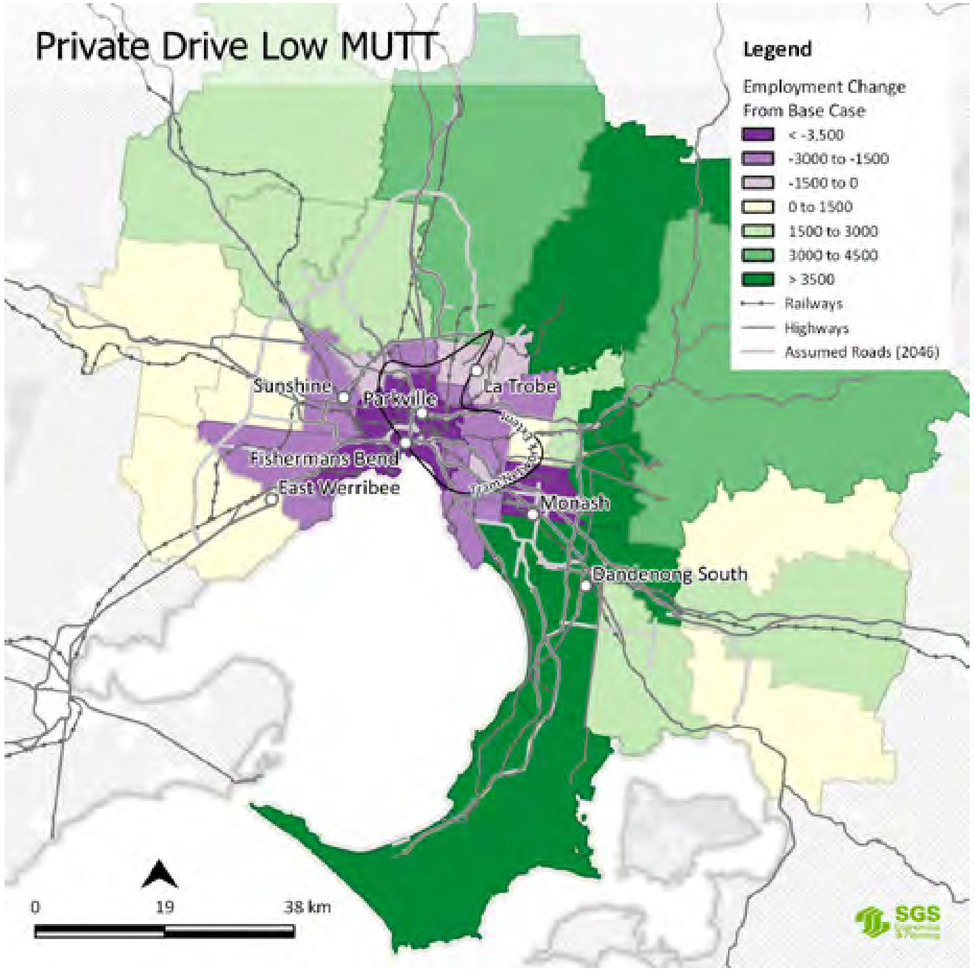
Industry shifts mirror those that occur under the standard MUTT Private Drive scenario, with the largest increases seen in the South and East, where the increase is highest in general (see Table 17).

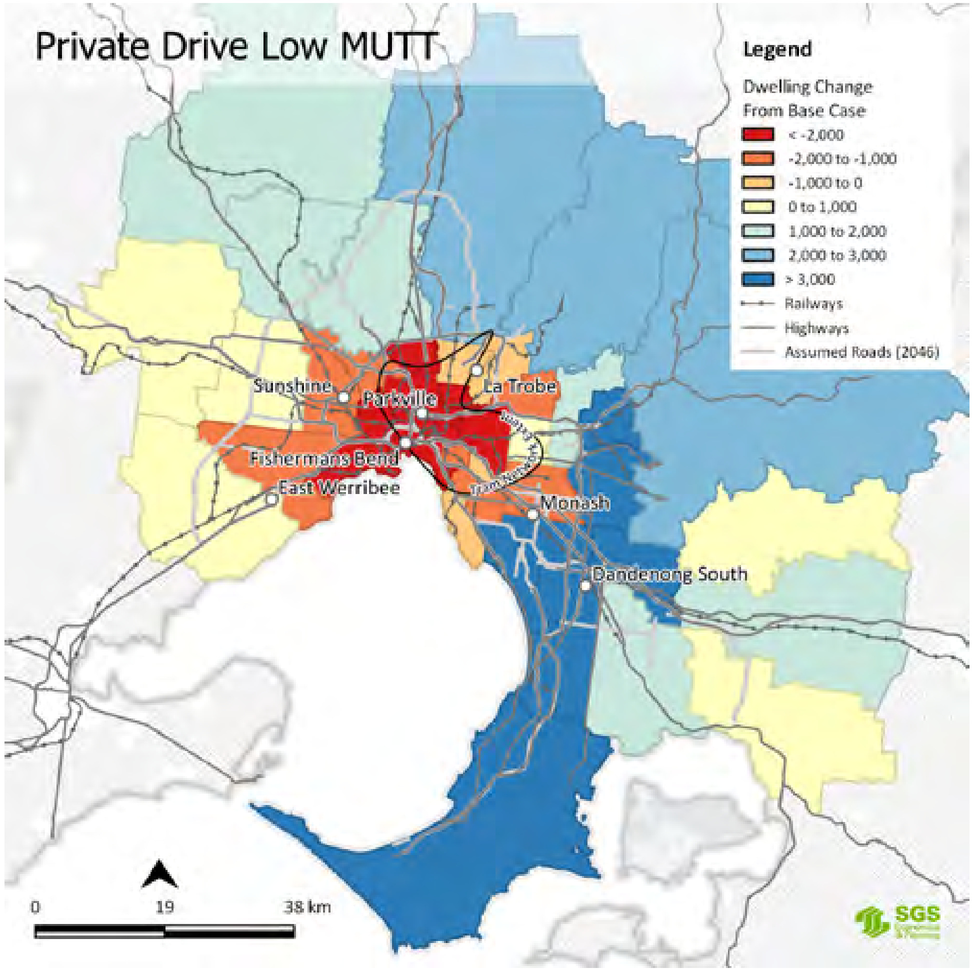
TABLE 17: EMPLOYMENT BY INDUSTRY GROUP, BASE CASE AND PRIVATE DRIVE LOW MUTT (2046)

SUBREGION	BASE CASE	PRIVATE DRIVE LOW MUTT	CHANGE	% CHANGE
Inner Total	1,228,000	1,208,000	-20,000	-1.6%
Knowledge Intensive	616,000	609,000	-7,000	-1.1%
Health and Education	203,000	198,000	-5,000	-2.5%
Population Serving	292,000	287,000	-5,000	-1.7%
Industrial	118,000	114,000	-4,000	-3.4%
Inner South East Total	345,000	334,000	-11,000	-3.2%
Knowledge Intensive	91,000	88,000	-3,000	-3.3%
Health and Education	127,000	123,000	-4,000	-3.1%
Population Serving	106,000	103,000	-3,000	-2.8%
Industrial	21,000	20,000	-1,000	-4.8%
Western Total	473,000	454,000	-19,000	-4.0%
Knowledge Intensive	68,000	64,000	-4,000	-5.9%
Health and Education	132,000	127,000	-5,000	-3.8%
Population Serving	164,000	158,000	-6,000	-3.7%
Industrial	108,000	104,000	-4,000	-3.7%
Northern Total	533,000	531,000	-2,000	-0.4%
Knowledge Intensive	84,000	84,000	0	0.0%
Health and Education	175,000	174,000	-1,000	-0.6%
Population Serving	162,000	162,000	0	0.0%
Industrial	112,000	111,000	-1,000	-0.9%
Eastern Total	651,000	665,000	14,000	2.2%
Knowledge Intensive	107,000	110,000	3,000	2.8%
Health and Education	229,000	233,000	4,000	1.7%
Population Serving	198,000	202,000	4,000	2.0%
Industrial	117,000	119,000	2,000	1.7%
Southern Total	642,000	677,000	35,000	5.5%
Knowledge Intensive	79,000	88,000	9,000	11.4%
Health and Education	184,000	194,000	10,000	5.4%
Population Serving	223,000	233,000	10,000	4.5%
Industrial	156,000	162,000	6,000	3.8%

Source: SGS Economics & Planning, 2018

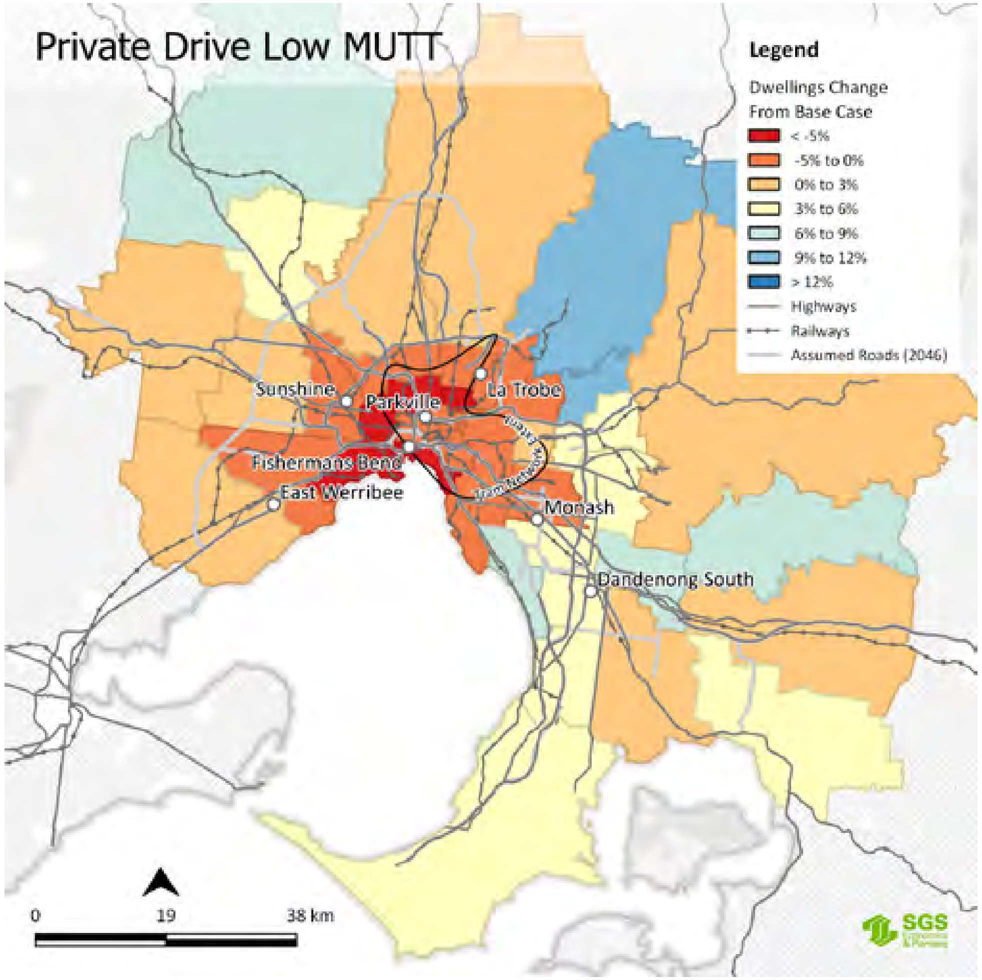
FIGURE 33: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- PRIVATE DRIVE LOW MUTT

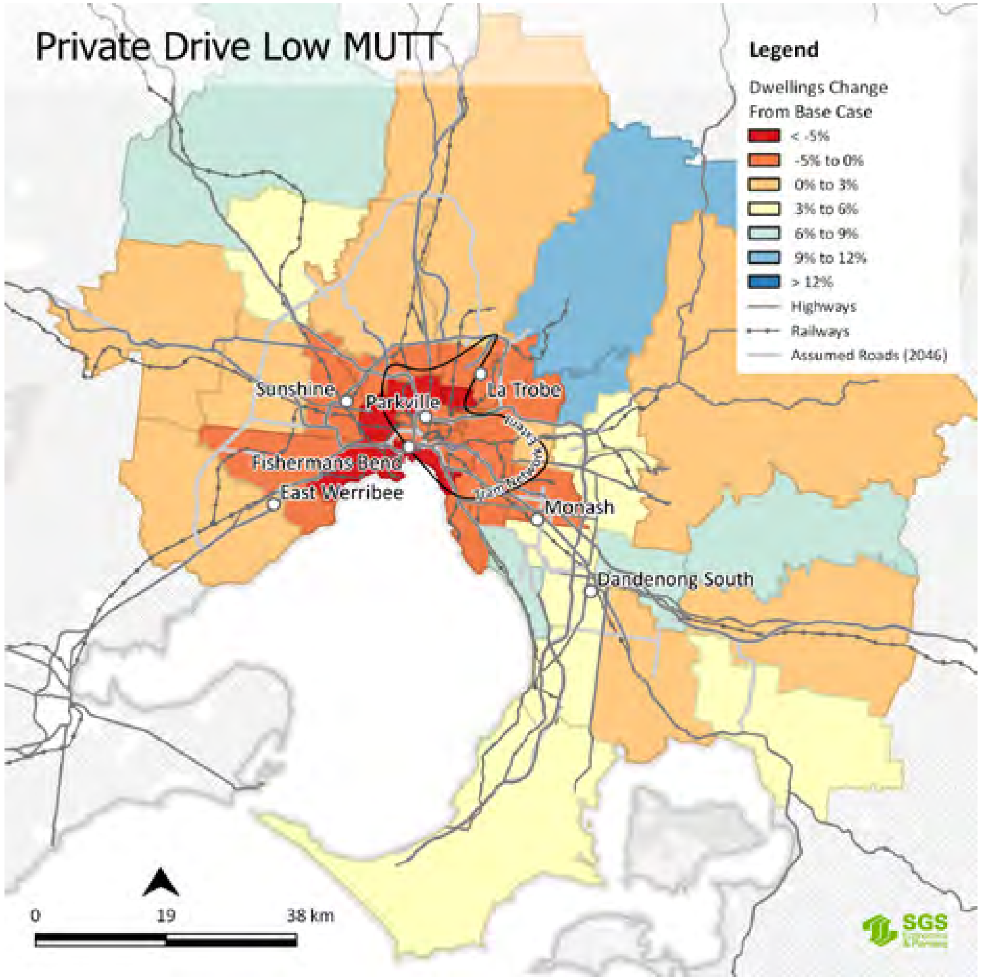




Source: SGS Economics and Planning, 2018

FIGURE 34: SA3 EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE- PRIVATE DRIVE LOW MUTT





Source: SGS Economics and Planning, 2018

Private Drive empty running

Under the empty running scenario, there is a sharper decline in employment and households from the inner city and a higher increase in the outer north and outer east compared to the central private drive scenario.

The greatest increase is seen in Knox, Maroondah and Whitehorse – West in the north east and east, in Whittlesea – Wallan in the outer north and in Casey – North in the south east (see Table 18).

The outward shift in development is broadly concentrated around public transport in the east. For example, Whitehorse – West has an 8.6 per cent increase (5,000 additional dwellings) and Whitehorse – East a 12.3 per cent increase. Frankston (4,600) is another SA3 which sees a strong increase in dwellings. Greenfield growth areas of Casey and Cardinia also see an additional 11,600 dwellings in 2046 and Whittlesea – Wallan in the north sees an additional 6,300 additional dwellings.

The shifts follow interconnected highways and train lines, reflecting increased inner city congestion and greater reliance on public transport than the other Private Drive scenarios. As seen in Figure 35, this is particularly evident in outer areas. The impact of Eastlink, the North East Link and planned new connections at Mordialloc and Westall Road can be seen with strong dwelling growth along a north east to south east corridor in Knox, Maroondah and Nillumbik – Kinglake (3,200 dwellings).

TABLE 18: TOP FIVE SA3S FOR CHANGE FROM BASE CASE- PRIVATE DRIVE EMPTY RUNNING

SA3	INCREASE	% INCREASE
EMPLOYMENT		
Knox	12,500	12.4
Whittlesea – Wallan	9,700	8.3
Casey – North	8,100	11.6
Maroondah	7,800	9.2
Whitehorse – West	7,700	8.2
DWELLINGS		
Knox	8,100	9.7
Whittlesea – Wallan	6,300	3.6
Casey – North	5,300	8.6
Maroondah	5,000	7.8
Whitehorse – West	5,000	8.6

Source: SGS Economics and Planning, 2018

Proportional increases are the largest in the outer east suburbs, showing the impact of greenfield development in growth fronts that will occur under the scenario (see Figure 36).

For employment, the impact across the inner city varies. For example, the number of jobs in Melbourne City SA3 drops by 2.4 per cent (22,400) compared to the base case, while SA3s such as Brunswick – Coburg (12.2 per cent) and Stonnington West (11.1 per cent) have a much greater percentage decline. This reflects the high demand for knowledge jobs located in the Melbourne City SA3 and the superior public transport in the CBD relative to Brunswick – Coburg and Stonnington West.

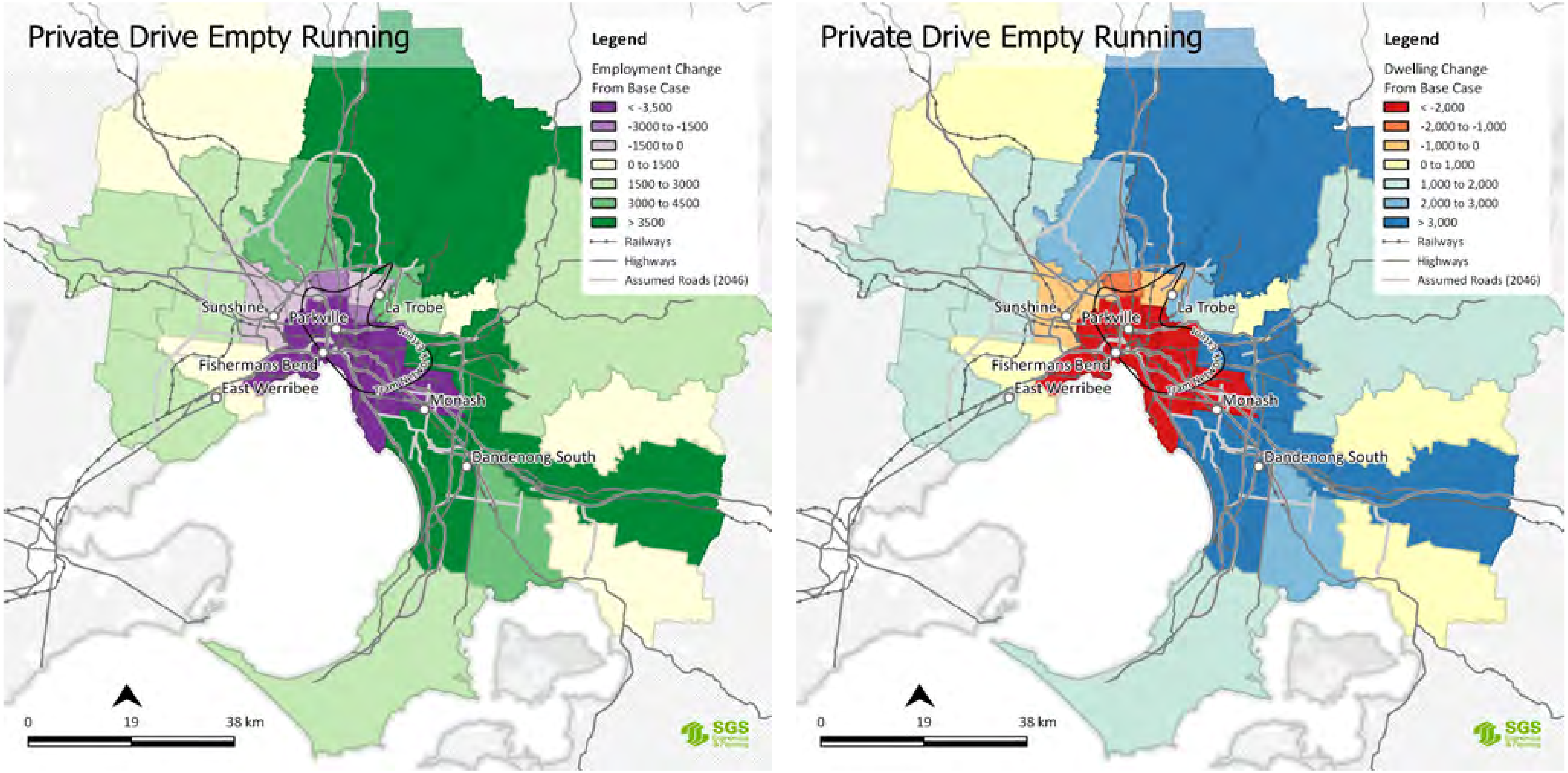
The dispersion of industries under empty running is similar to but more extreme than under the other Private Drive scenarios. Knowledge Intensive employment increases by more than 12% in the south and by more than 8% in the east and drops by more around 2% and 8% in the inner and inner south east regions (see Table 19).

TABLE 19: EMPLOYMENT BY INDUSTRY GROUP, BASE CASE AND PRIVATE DRIVE EMPTY RUNNING

SUBREGION	BASE CASE	PRIVATE DRIVE EMPTY RUNNING	CHANGE	% CHANGE
Inner Total	1,228,000	1,180,000	-48,000	-3.9%
Knowledge Intensive	616,000	601,000	-15,000	-2.4%
Health and Education	203,000	190,000	-13,000	-6.4%
Population Serving	292,000	279,000	-13,000	-4.5%
Industrial	118,000	110,000	-8,000	-6.8%
Inner South East Total	345,000	317,000	-28,000	-8.1%
Knowledge Intensive	91,000	84,000	-7,000	-7.7%
Health and Education	127,000	118,000	-9,000	-7.1%
Population Serving	106,000	97,000	-9,000	-8.5%
Industrial	21,000	17,000	-4,000	-19.0%
Western Total	473,000	461,000	-12,000	-2.5%
Knowledge Intensive	68,000	66,000	-2,000	-2.9%
Health and Education	132,000	129,000	-3,000	-2.3%
Population Serving	164,000	160,000	-4,000	-2.4%
Industrial	108,000	105,000	-3,000	-2.8%
Northern Total	533,000	544,000	11,000	2.1%
Knowledge Intensive	84,000	87,000	3,000	3.6%
Health and Education	175,000	178,000	3,000	1.7%
Population Serving	162,000	165,000	3,000	1.9%
Industrial	112,000	113,000	1,000	0.9%
Eastern Total	651,000	686,000	35,000	5.4%
Knowledge Intensive	107,000	116,000	9,000	8.4%
Health and Education	229,000	239,000	10,000	4.4%
Population Serving	198,000	208,000	10,000	5.1%
Industrial	117,000	122,000	5,000	4.3%
Southern Total	642,000	681,000	39,000	6.1%
Knowledge Intensive	79,000	89,000	10,000	12.7%
Health and Education	184,000	195,000	11,000	6.0%
Population Serving	223,000	234,000	11,000	4.9%
Industrial	156,000	162,000	6,000	3.8%

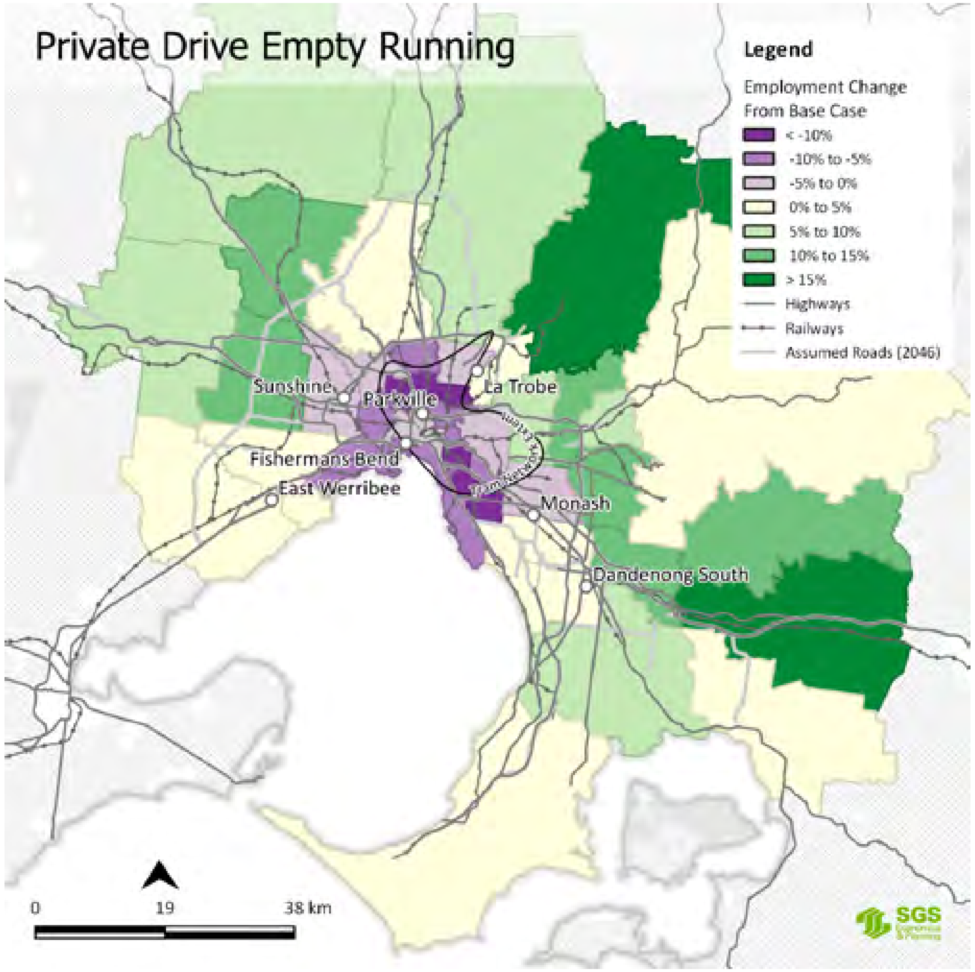
Source: SGS Economics & Planning, 2018

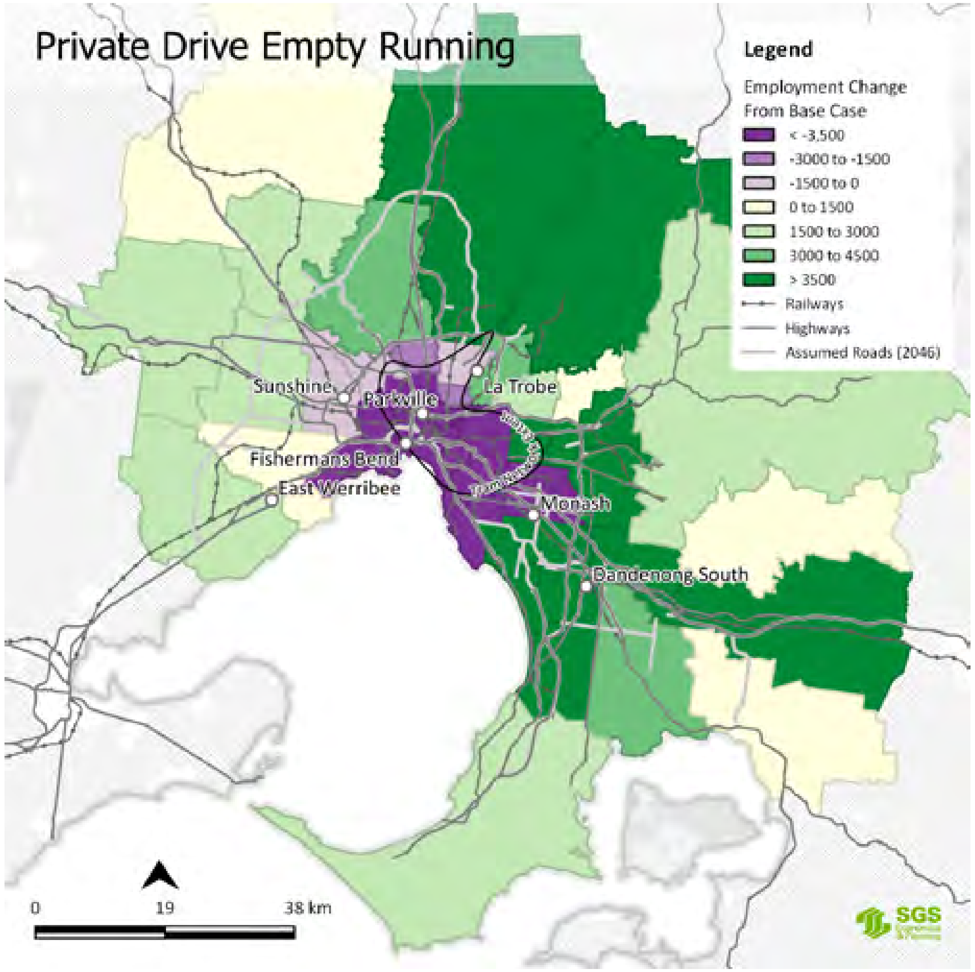
FIGURE 35: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- PRIVATE DRIVE EMPTY RUNNING



Source: SGS Economics and Planning, 2018

FIGURE 36: SA3 EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE – PRIVATE DRIVE EMPTY RUNNING





Source: SGS Economics and Planning, 2018

8.5 Fleet Street scenarios

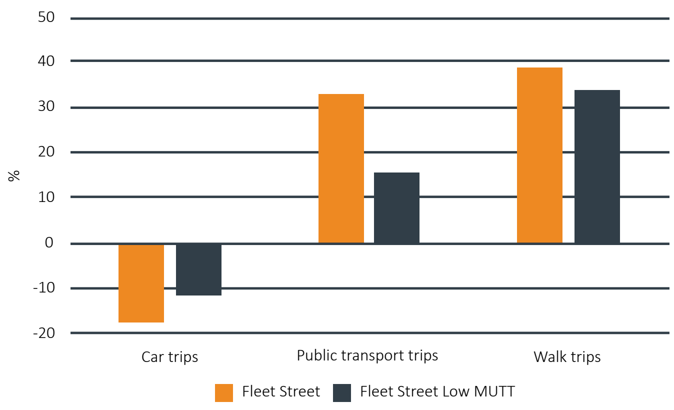
FLEET STREET: THE LIVED EXPERIENCE

Margaret has lived in Melbourne's north west for many years. She and her husband moved there to start a family forty years ago. Margaret is now long retired, and her adult children have moved to other areas of Melbourne. She is quite frail and moving around is getting harder, especially because her eyesight is bad. Fortunately, she is still able to visit her children and grandchildren in different parts of Melbourne using an electric autonomous vehicle service, which she can order to her house through her home assistant. Autonomous vehicles also bring groceries and other necessities to her house, as she now finds it difficult to get them herself. The convenience and relatively low cost of shared electronic autonomous vehicles have allowed Margaret to stay comfortably in her home for much longer.

In the Fleet Street scenario, all vehicles are automated and zero emission and are owned by a company or companies that rent them out as Robotaxis. There is no private ownership. Cars empty run when they are not in use and the marginal utility of travel time varies from standard under Fleet Street to low under Fleet Street Low MUTT. The effects of the shared ownership model, the full take up of automated and zero emission technology and variations in the marginal utility of travel time will drive travel decisions and land use changes under different sensitivities of the scenario.

Overall, car trips are expected to decline and public transport and walk trips to increase under the scenario. This trend is most pronounced under the base Fleet Street scenario with high MUTT, particularly in the case of public transport trips, which increase by around double that of the low MUTT scenario (see Figure 37).

FIGURE 37: PERCENTAGE CHANGE IN TRIPS COMPARED TO BASE CASE – FLEET STREET



Source: SGS Economics and Planning, 2018 based on KPMG modelling, 2018

The changes in trip modes reflect the effects of marginal travel costs and marginal utility of travel time. The cost of a trip in a Robotaxi is higher than the marginal cost if a car is privately owned and compared to public transport. This pushes people towards other forms of transport, particularly in outer areas where trips by Robotaxis are most expensive due to distances travelled. Congestion is also an important factor in this scenario. The shift to public transport and the overall decline in car trips due to the high costs of Robotaxis reduces congestion, however, the practice of empty running increases it, particularly in the inner city. These counteracting forces result in large increases in public transport use in the outer north east, south and west. The low MUTT scenario sees perceived travel times fall, increasing the length of trips that travellers are willing to take. It lessens the deterrent effect of congestion and increases demand for car travel, especially over long distances. The large difference between the number of public transport and walk trips under the low and high MUTT scenarios illustrates this point. Walk trips change only slightly under the two scenarios because they are usually short distances and so the effect of the change in the value of travel time is small. On the other hand, public transport is typically used to travel longer distances and so the effect of change in the value of travel time is more significant.

Fleet Street

These mixed effects are reflected in the results of the TIM analysis. Employment and households shift outwards under Fleet Street, like in the previous scenarios, but are less concentrated around major roads and more in growth areas in the outer north and outer south east, and in more established suburbs in the middle west

The SA3s that saw the most change under Fleet Street are in the outer west (Wyndham and Brimbank) and from the outer north (Whittlesea – Wallan) and east (Casey – North and Banyule) (see Table 20).

TABLE 20: TOP FIVE SA3S FOR CHANGE FROM BASE CASE- FLEET STREET

SA3	INCREASE	% INCREASE
EMPLOYMENT		
Whittlesea – Wallan	8,500	7.3
Casey – North	7,300	10.5
Banyule	6,400	7.6
Wyndham	6,100	5.5
Brimbank	6,100	5.8
DWELLINGS		
Whittlesea – Wallan	5,600	3.2
Casey – North	4,700	7.7
Banyule	4,100	6.0
Brimbank	4,100	4.5
Wyndham	4,000	2.2

Source: SGS Economics and Planning, 2018

The impact on the inner city is larger under Fleet Street than under Slow Lane and non empty running Private Drive scenarios, with Melbourne City SA3 seeing a 5.8 per cent drop in households under Fleet Street compared to 4.7 and 2.1 under Private Drive and Private Drive low MUTT. Brunswick – Coburg (7.6 per cent) has a slightly larger reduction in employment under the Private Drive scenario.

Road access still plays a role in this scenario. This can be seen around Sunshine (in the Brimbank SA3) in the north west, where very high employment and dwelling increases reflect the area's position at the intersection of the Western Freeway, Western Ring Road and Princes Freeway as well as several train lines. Banyule in the north east sees a similar set of conditions with the interaction of the Ring Road and North East Link. Under this scenario Banyule will see an additional 6,400 (7.6 per cent) jobs and 4,100 (6.0 per cent) additional dwellings (see Figure 38).

The largest proportional increase is seen in the middle north east as well as in outer suburbs, reflecting the consolidation of middle ring suburbs and limited sprawl under Fleet Street (see Figure 39).

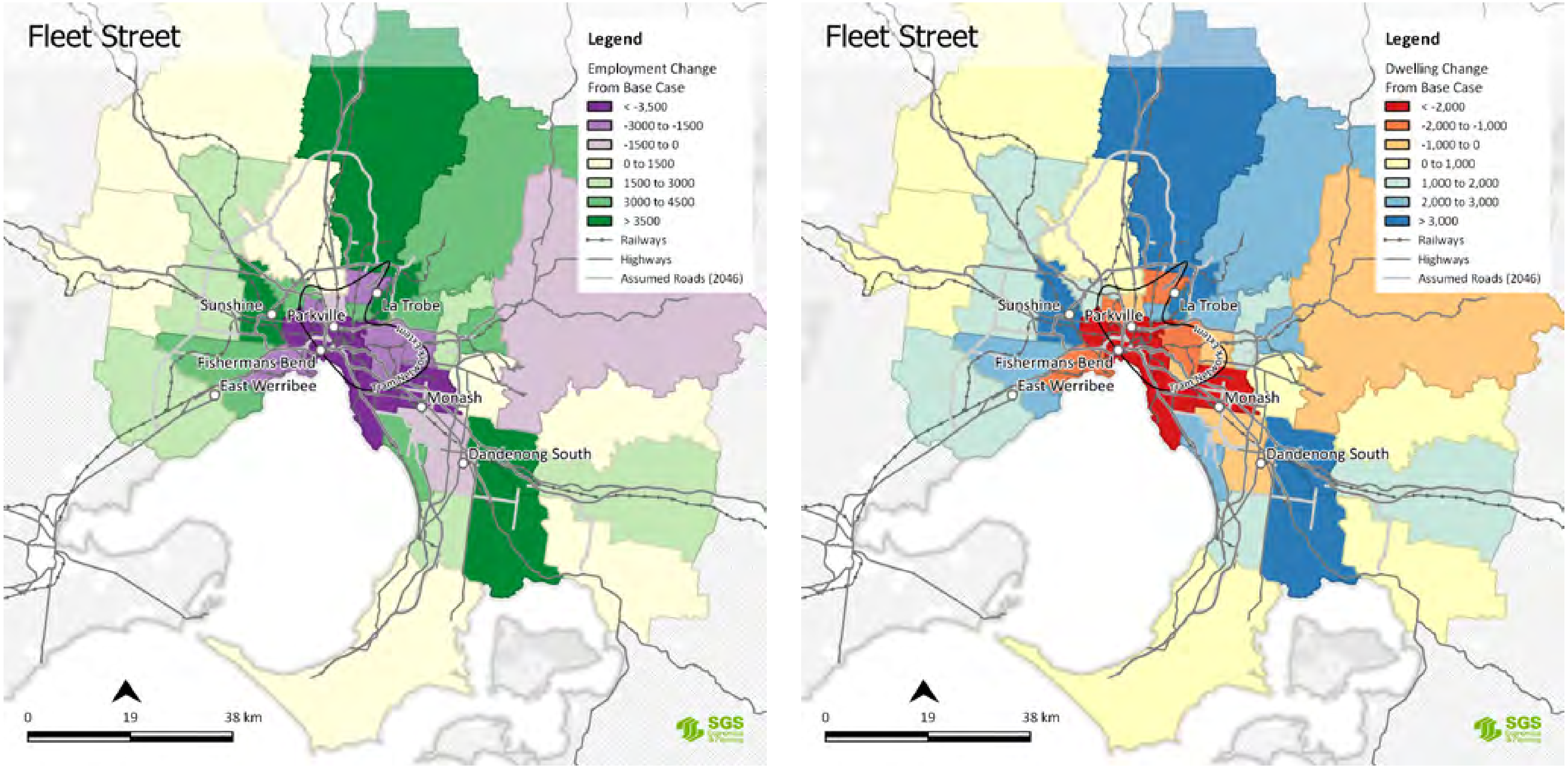
Changes in the distribution of industries across Melbourne are slightly more pronounced under Fleet Street than under the Private Drive (except empty running) and Slow Lane scenarios (see Table 21). The largest shifts are seen in the Inner South East (-6.4%), the Northern (4.5%) and Southern (3.3%) regions.

TABLE 21: EMPLOYMENT BY INDUSTRY GROUP, BASE CASE AND FLEET STREET

SUBREGION	BASE CASE	FLEET STREET	CHANGE	% CHANGE
Inner Total	1,228,000	1,193,000	-35,000	-2.9%
Knowledge Intensive	616,000	605,000	-11,000	-1.8%
Health and Education	203,000	194,000	-9,000	-4.4%
Population Serving	292,000	283,000	-9,000	-3.1%
Industrial	118,000	112,000	-6,000	-5.1%
Inner South East Total	345,000	323,000	-22,000	-6.4%
Knowledge Intensive	91,000	86,000	-5,000	-5.5%
Health and Education	127,000	120,000	-7,000	-5.5%
Population Serving	106,000	99,000	-7,000	-6.6%
Industrial	21,000	18,000	-3,000	-14.3%
Western Total	473,000	480,000	7,000	1.5%
Knowledge Intensive	68,000	71,000	3,000	4.4%
Health and Education	132,000	135,000	3,000	2.3%
Population Serving	164,000	166,000	2,000	1.2%
Industrial	108,000	109,000	1,000	0.9%
Northern Total	533,000	557,000	24,000	4.5%
Knowledge Intensive	84,000	90,000	6,000	7.1%
Health and Education	175,000	182,000	7,000	4.0%
Population Serving	162,000	169,000	7,000	4.3%
Industrial	112,000	116,000	4,000	3.6%
Eastern Total	651,000	654,000	3,000	0.5%
Knowledge Intensive	107,000	108,000	1,000	0.9%
Health and Education	229,000	230,000	1,000	0.4%
Population Serving	198,000	199,000	1,000	0.5%
Industrial	117,000	117,000	0	0.0%
Southern Total	642,000	663,000	21,000	3.3%
Knowledge Intensive	79,000	85,000	6,000	7.6%
Health and Education	184,000	190,000	6,000	3.3%
Population Serving	223,000	229,000	6,000	2.7%
Industrial	156,000	159,000	3,000	1.9%

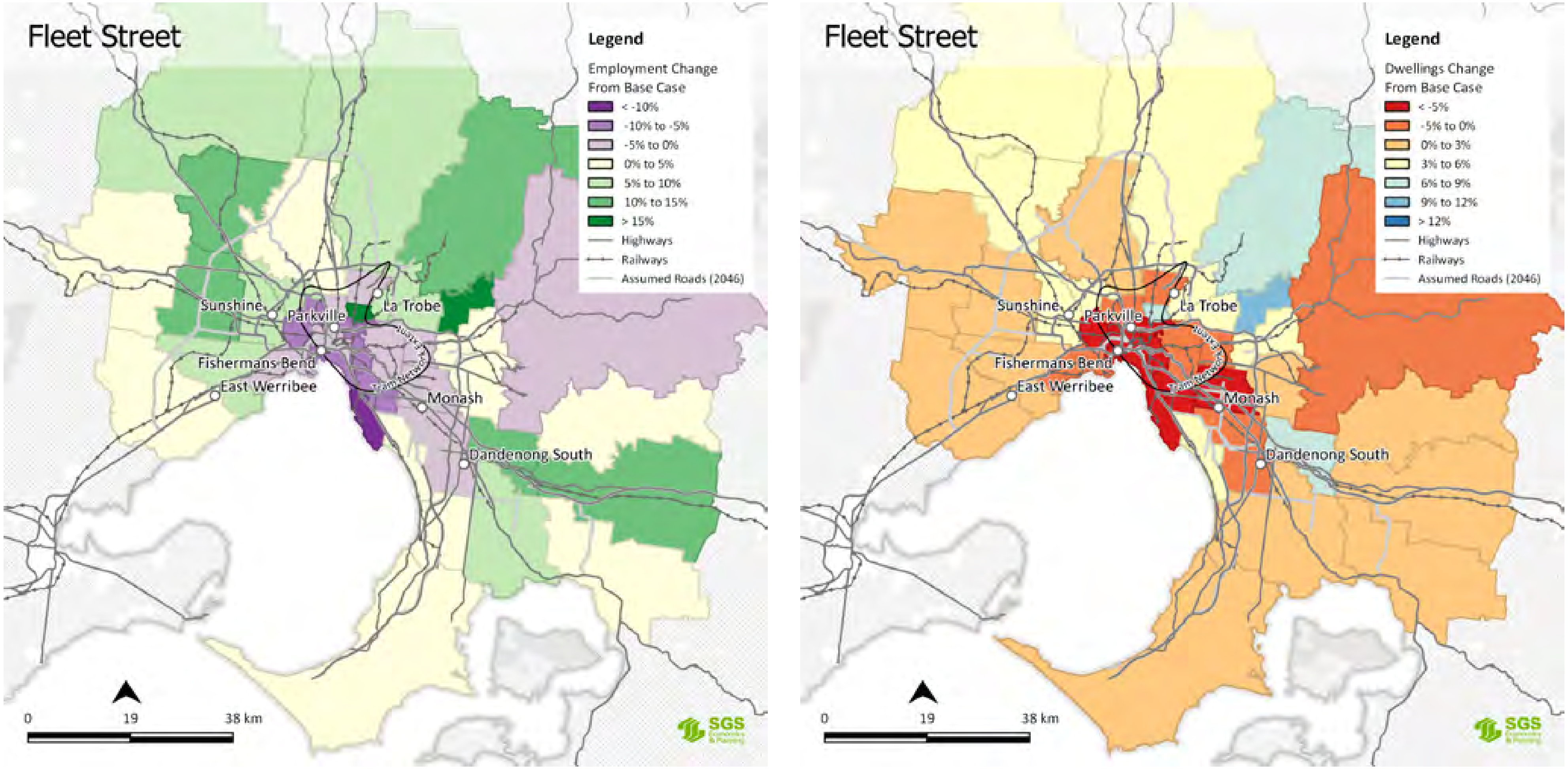
Source: SGS Economics & Planning, 2018

FIGURE 38: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- FLEET STREET



Source: SGS Economics and Planning, 2018

FIGURE 39: EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE- FLEET STREET



Source: SGS Economics and Planning, 2018

Fleet Street Low MUTT

The low MUTT Fleet Street scenario has similar results to the standard MUTT scenario. Employment and dwelling growth is highest in the middle west and north, and outer north and east. The largest difference between the two is in less pronounced southward sprawl and a smaller loss of employment and dwellings from inner west and inner east suburbs (see Figure 40).

Like under the standard MUTT scenario, the greenfield growth areas of Whittlesea – Wallan, Casey – North, and Casey – South see strong additional growth in 2046 (see Table 22). And the Brimbank SA3, centred on Sunshine and containing the intersection of the Western Freeway, Western Ring Road and Princes Freeway, see an additional 3,500 dwellings.

TABLE 22: TOP FIVE SA3S FOR CHANGE FROM BASE CASE-FLEET STREET LOW MUTT

SA3	INCREASE	% INCREASE
EMPLOYMENT		
Whittlesea – Wallan	5,700	3.3
Casey – North	3,500	5.8
Brimbank	3,500	3.8
Manningham – West	3,300	6.6
Banyule	3,200	4.6
DWELLINGS		
Whittlesea – Wallan	5,600	3.2
Casey – North	4,700	7.7
Brimbank	4,100	6.0
Manningham – West	4,100	4.5
Banyule	4,000	2.2

Source: SGS Economics and Planning, 2018

The inner city sees less extreme changes to employment and dwellings under Fleet Street low MUTT than under Fleet Street, although it does lose 23,200 dwellings compared to the base case. In Melbourne City SA3, dwellings fall by 5 per cent compared to 5.8 per cent under standard MUTT, Port Phillip falls by 6.9 per cent compared to 8 per cent, and Darebin – South grows by 3.6 per cent compared to 7 per cent.

The Bayside (3,800) and Glen Eira (5,300) SA3s in the inner south also have reduced levels of dwelling growth. While in the inner west, Hobsons Bay (2,200) and Maribyrnong (4,600) see reduced growth.

Within the 15km ring, Monash SA3 (3,800) has a significant fall in dwelling growth, unlike in previous scenarios. Monash SA3 has the highest employment densities outside of inner Melbourne.

These differences reflect the effect of changes in the marginal utility of travel time on transport mode preferences. The lower MUTT reduces the perceived cost of car trips and draws travellers away from public transport. However, the cost of car travel is still not low enough to attract dwelling and employment to outer suburbs that aren't very well connected to highways and public transport. The low MUTT also reduces the deterrent effect of congestion and is responsible for the comparatively limited losses from the inner city.

The greatest proportional changes to employment and dwellings is seen in the outer west and north (see Figure 41).

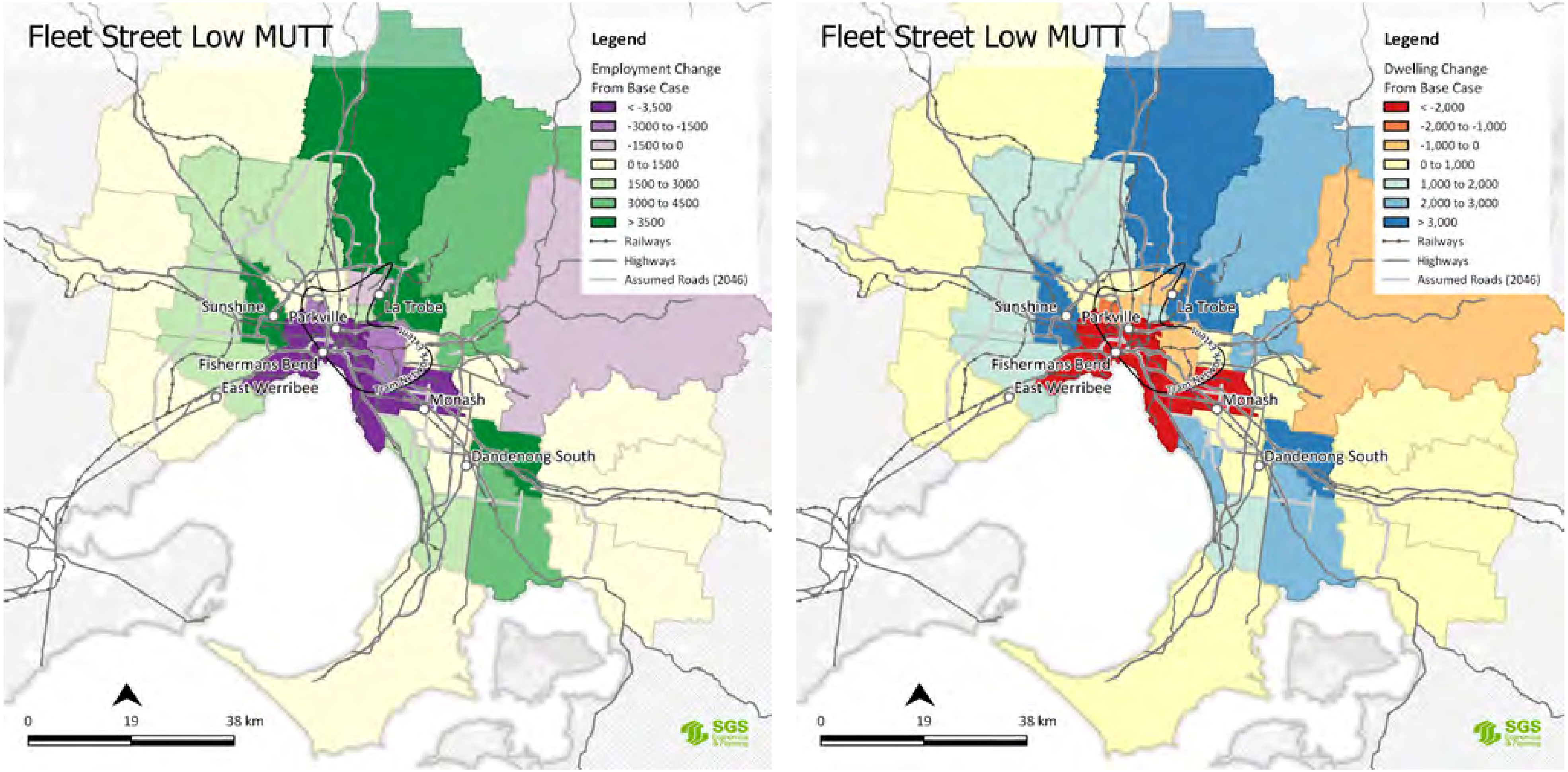
Shifts in the locations of types of jobs mirror those under Fleet Street. The north sees the largest increase in knowledge based jobs and the inner and inner east of the city see the largest drops (see Table 23).

TABLE 23: EMPLOYMENT BY INDUSTRY GROUP, BASE CASE AND FLEET STREET LOW MUTT

SUBREGION	BASE CASE	FLEET STREET LOW MUTT	CHANGE	% CHANGE
Inner Total	1,228,000	1,197,000	-31,000	-2.5%
Knowledge Intensive	616,000	606,000	-10,000	-1.6%
Health and Education	203,000	195,000	-8,000	-3.9%
Population Serving	292,000	284,000	-8,000	-2.7%
Industrial	118,000	113,000	-5,000	-4.2%
Inner South East Total	345,000	324,000	-21,000	-6.1%
Knowledge Intensive	91,000	86,000	-5,000	-5.5%
Health and Education	127,000	121,000	-6,000	-4.7%
Population Serving	106,000	99,000	-7,000	-6.6%
Industrial	21,000	18,000	-3,000	-14.3%
Western Total	473,000	474,000	1,000	0.2%
Knowledge Intensive	68,000	69,000	1,000	1.5%
Health and Education	132,000	133,000	1,000	0.8%
Population Serving	164,000	164,000	0	0.0%
Industrial	108,000	108,000	0	0.0%
Northern Total	533,000	557,000	24,000	4.5%
Knowledge Intensive	84,000	90,000	6,000	7.1%
Health and Education	175,000	182,000	7,000	4.0%
Population Serving	162,000	169,000	7,000	4.3%
Industrial	112,000	116,000	4,000	3.6%
Eastern Total	651,000	659,000	8,000	1.2%
Knowledge Intensive	107,000	109,000	2,000	1.9%
Health and Education	229,000	231,000	2,000	0.9%
Population Serving	198,000	200,000	2,000	1.0%
Industrial	117,000	118,000	1,000	0.9%
Southern Total	642,000.00	658,000.00	16,000.00	2.5%
Knowledge Intensive	79,000.00	84,000.00	5,000.00	6.3%
Health and Education	184,000.00	188,000.00	4,000.00	2.2%
Population Serving	223,000.00	228,000.00	5,000.00	2.2%
Industrial	156,000.00	159,000.00	3,000.00	1.9%

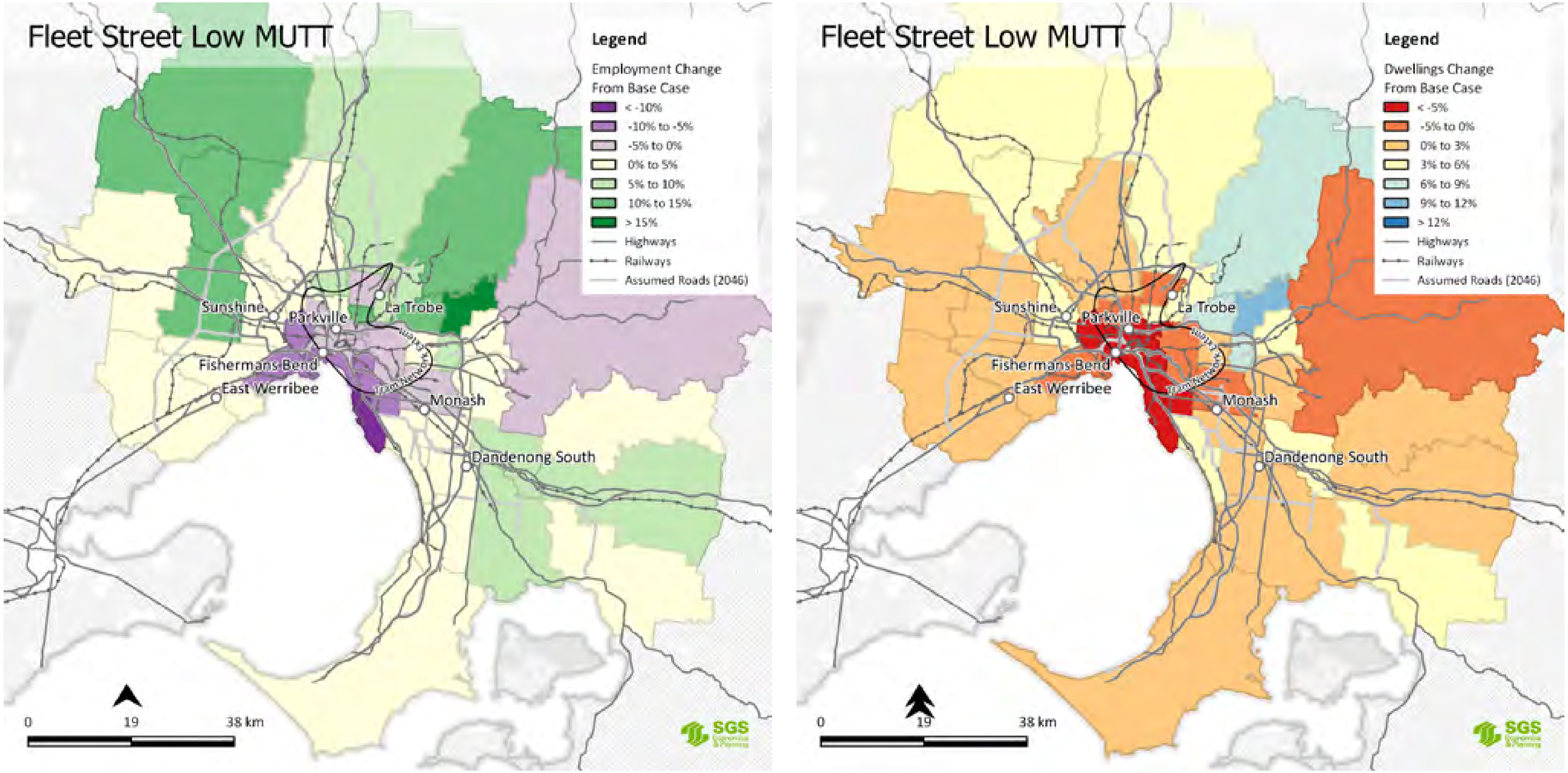
Source: SGS Economics & Planning, 2018

FIGURE 40: SA3 EMPLOYMENT & DWELLING CHANGE FROM BASE CASE- FLEET STREET LOW MUTT



Source: SGS Economics and Planning, 2018

FIGURE 41: EMPLOYMENT & DWELLING % CHANGE FROM BASE CASE- FLEET STREET LOW MUTT



Source: SGS Economics and Planning, 2018

8.6 Regional Victoria

Interpreting the regional results

The impact of automated and zero emissions vehicle technology on land use in regional Victoria was modelled separately to Melbourne Metro areas. The same modelling method was used for both areas with different travel time matrices that could not be combined. The trip matrices for the regional model covered all of Victoria, however, they did not have public transport trips. The trip matrices for the Melbourne Metro model covered only SA2s in greater Melbourne and included public transport trips. The trip times were also vastly different for some SA2s across both sets of matrices.

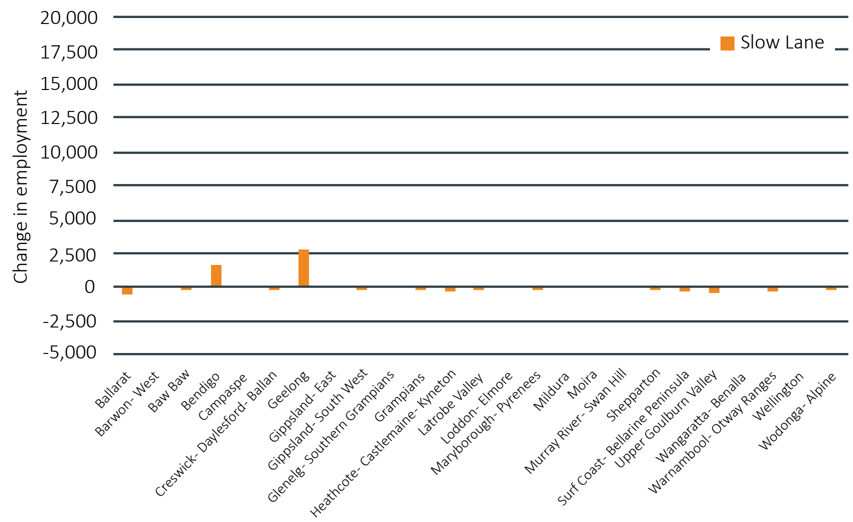
For these reasons, the regional and metro trip matrices were incompatible and the two models were run separately as 'closed systems'[33]. Each model allows dwellings, population and employment to shift across SA2s within Greater Melbourne or within regional Victoria but movements were not possible between the two areas. In reality, there would likely be some shifts across the boundary of greater Melbourne, however, these would be much smaller in scale than those presented in this report.

Slow Lane

As seen in Figure 42 and Figure 43, there is very little movement under the Slow Lane scenario when compared to the base case. This is likely due to the slower transition time which limits the effects seen in the other scenarios. The only noticeable shifts are towards Geelong and Bendigo. As will be seen in the subsequent scenarios, these are very small in scale when compared to the previous scenarios and reflect the later uptake in automated and zero emissions technology.

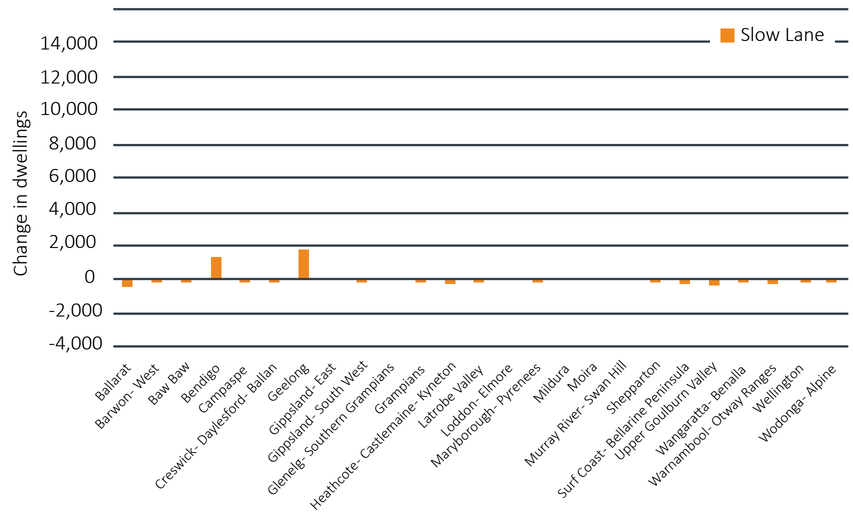
[33]Specifically, the Greater Melbourne EJDs were constrained in the regional Victoria model such that dwellings and employment levels remained equal to the base case across scenarios.

FIGURE 42: REGIONAL SA3 EMPLOYMENT CHANGE FROM BASE CASE- SLOW LANE



Source: SGS Economics & Planning, 2018

FIGURE 43: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE- SLOW LANE



Source: SGS Economics & Planning, 2018

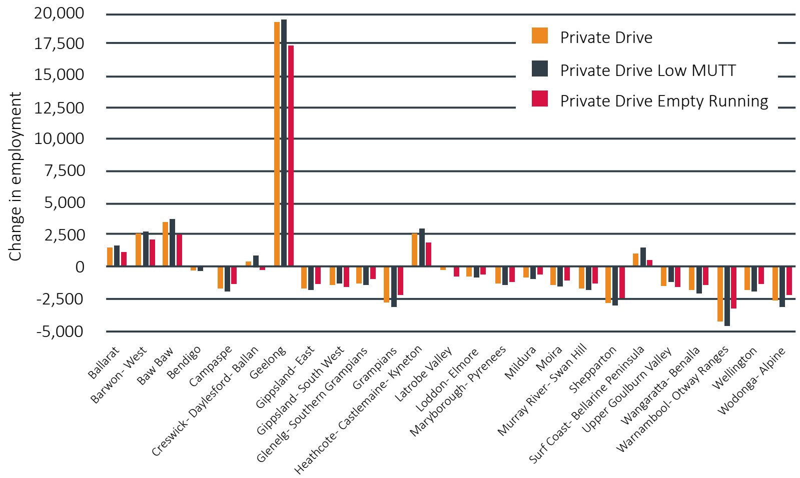
Private Drive

The results of the regional modelling of the Private Drive scenarios are shown in Figure 44 to Figure 47. The most striking trend to emerge from the Private Drive scenario is the attraction of dwellings and jobs into Geelong and the surrounding SA3s to the west: Barwon-West and Surf Coast. These results suggest small numbers from across the state are being attracted to big regional cities. The other major regional cities – Ballarat and Bendigo – see mixed results. There is a small increase in the former while the latter sees almost no change, however, Heathcote – Castlemaine – Kyneton to its south sees a considerable increase. This is likely due to an increase in accessibility for the area to jobs in both Melbourne and Bendigo.

Under Private Drive, peri-urban areas outside of greater Melbourne such as Baw Baw to the east and the Kyneton corridor between Melbourne and Bendigo, are more accessible. This effect is an extension of the sprawl exhibited in the Greater Melbourne modelling and reflects an increase in accessibility in those areas.

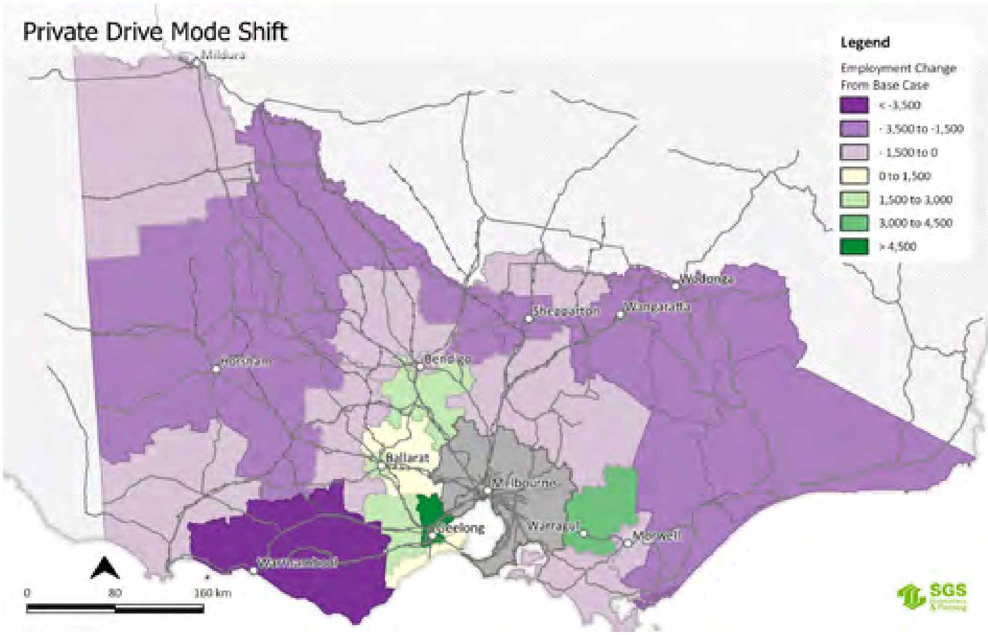
Like in the Greater Melbourne results, the low MUTT sensitivity exaggerates Private Drive effects and empty running limits them. The same effects would be driving these results, with low MUTT making outer regions of Geelong and Bendigo more accessible and therefore attractive and empty running increasing congestion and reducing accessibility.

FIGURE 44: REGIONAL SA3 EMPLOYMENT CHANGE FROM BASE CASE - ALL PRIVATE DRIVE SCENARIOS



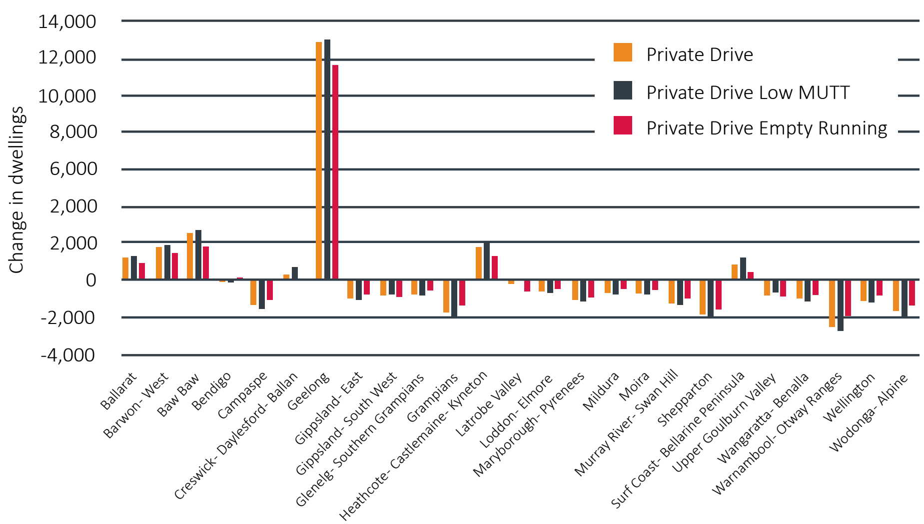
Source: SGS Economics & Planning, 2018

FIGURE 45: REGIONAL SA3 EMPLOYMENT CHANGE FROM BASE CASE- PRIVATE DRIVE



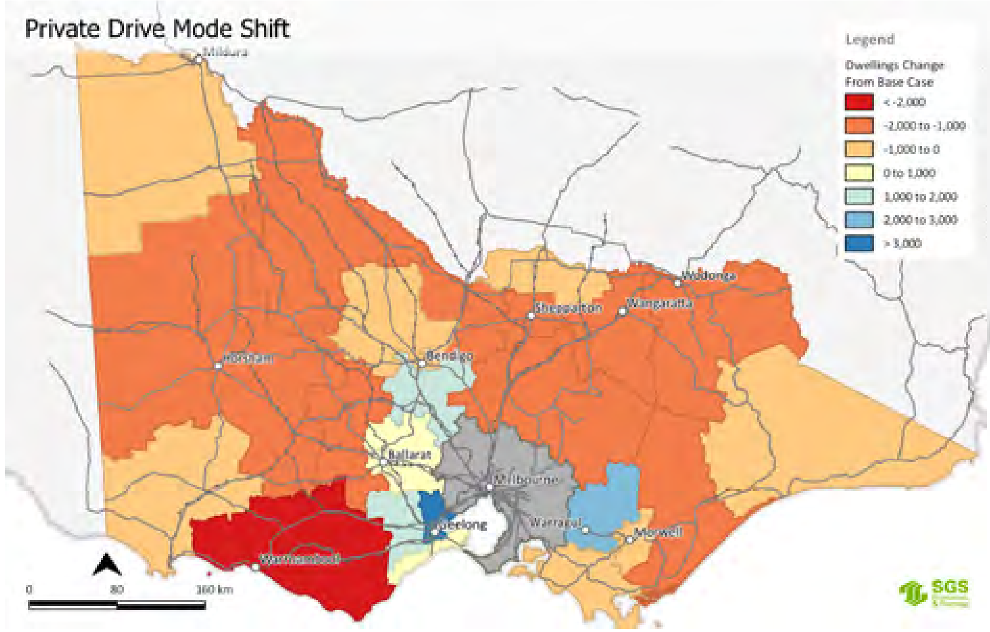
Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

FIGURE 46: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE - ALL PRIVATE DRIVE SCENARIOS



Source: SGS Economics & Planning, 2018

FIGURE 47: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE- PRIVATE DRIVE



Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

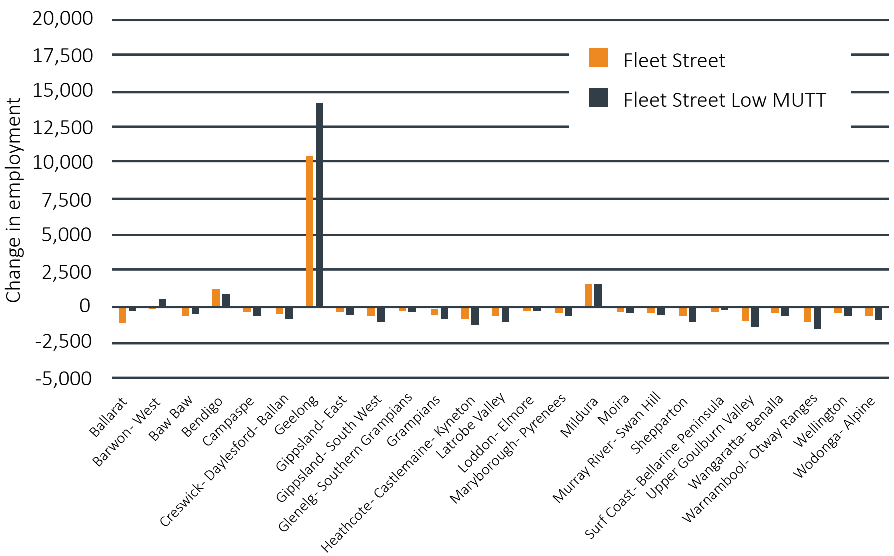
Fleet Street

Results for the Fleet Street scenarios can be seen below in Figure 48 to Figure 51. These scenarios produce similar results to Private Drive but with some important differences. Like in Private Drive, Geelong sees the most increase, however, there are drops in its surrounds in Barwon – West and Baw Baw, and overall shifts are less extreme. The Kyneton corridor, which saw a significant increase under Private Drive, is likely to see a reduction in dwelling and employment growth under Fleet Street. Bendigo increases slightly from the base case, and Mildura is the only other SA3 that sees an increase, but it saw a loss under Private Drive.

The regional results are a contrast to Greater Melbourne, where the largest shifts were seen in the Fleet Street scenarios. This difference is potentially due to the long wait times for Robotaxis and reduced opportunities for carpooling efficiency savings in isolated regional areas. This would result in more cars on the road, in addition to the empty running Robotaxis that are moving between pickups. Additionally, there could be a significantly higher perceived cost of travel in regional areas where trip fares are likely to be much larger than Greater Melbourne areas.

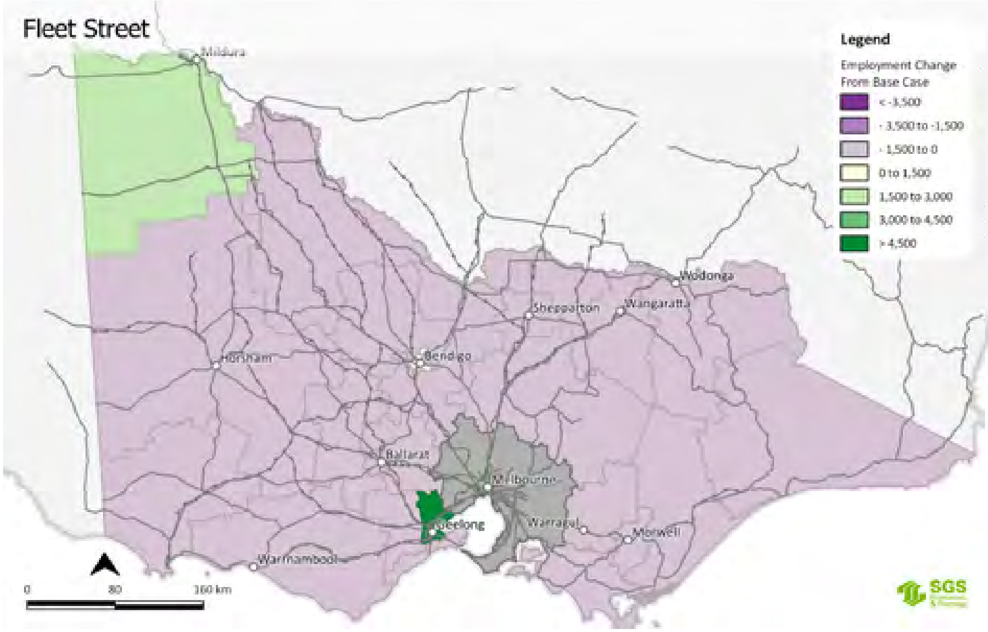
The low MUTT Fleet Street scenario, as with Private Drive, has a larger set of movements than under standard MUTT. Again, this is likely due to more people being happy to travel longer distances by car. This can be seen in the Barwon- West SA3 which sits outside of Geelong and turns from negative to positive growth (against the base line scenario).

FIGURE 48: REGIONAL SA3 EMPLOYMENT CHANGE FROM BASE CASE - ALL FLEET STREET SCENARIOS



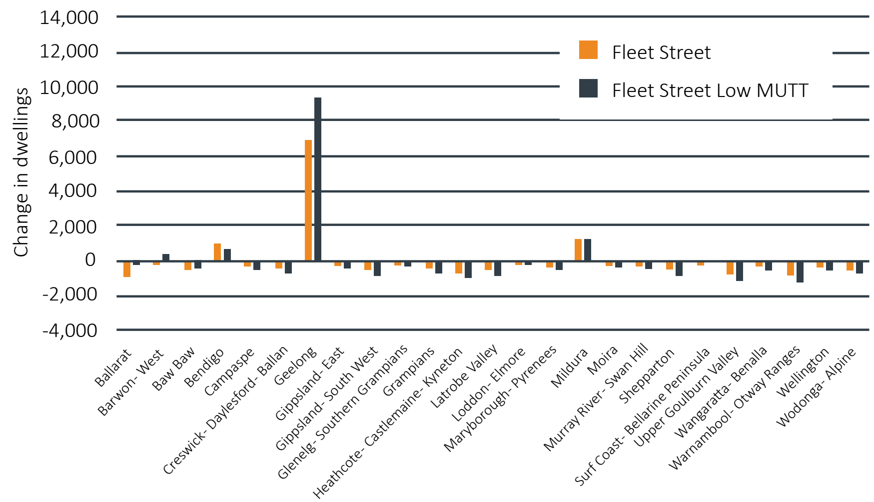
Source: SGS Economics & Planning, 2018

FIGURE 49: REGINAL SA3 EMPLOYMENT CHANGE FROM BASE CASE- FLEET STREET



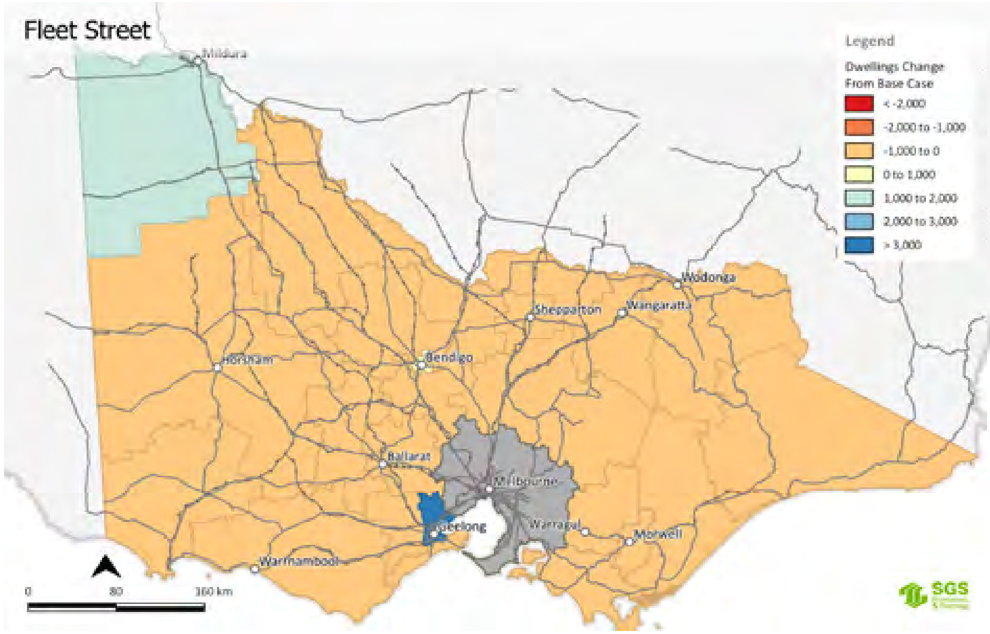
Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

FIGURE 50: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE - ALL FLEET STREET SCENARIOS



Source: SGS Economics & Planning, 2018

FIGURE 51: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE- FLEET STREET



Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

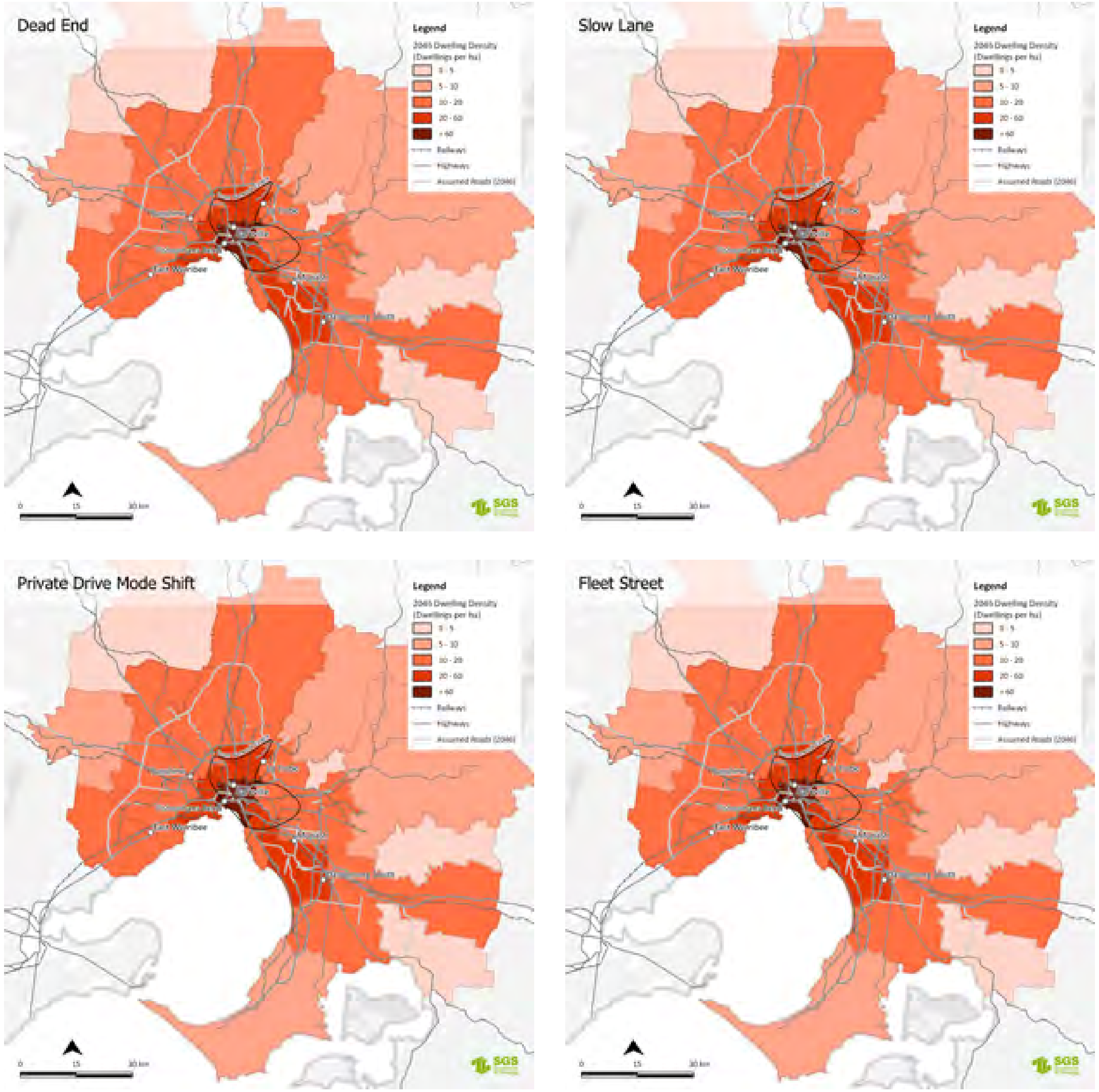
8.7 Density impacts

SGS examined density impacts as a robustness check for the modelled scenarios. This was to ensure that unrealistically high dwelling or employment densities do not arise due to increased accessibility of any given areas.

While the density analysis was conducted at an SA2 level, the overarching SA3 results of the analysis are mapped below in Figure 52 for dwellings and Figure 53 for employment. For reference, illustrative examples of real life dwelling densities of 20, 100 and 250 dwellings per hectare are shown in Figure 54.

In all cases, both dwelling and employment densities remain higher towards the centre of Melbourne and do the scenario results not change significantly when compared to the base case.

FIGURE 52: DWELLING DENSITIES FOR KEY SCENARIOS, BY SA3 (2046)



Source: SGS Economics and Planning, 2018

FIGURE 53: EMPLOYMENT DENSITIES FOR KEY SCENARIOS, BY SA3 (2046)

Source: SGS Economics and Planning, 2018

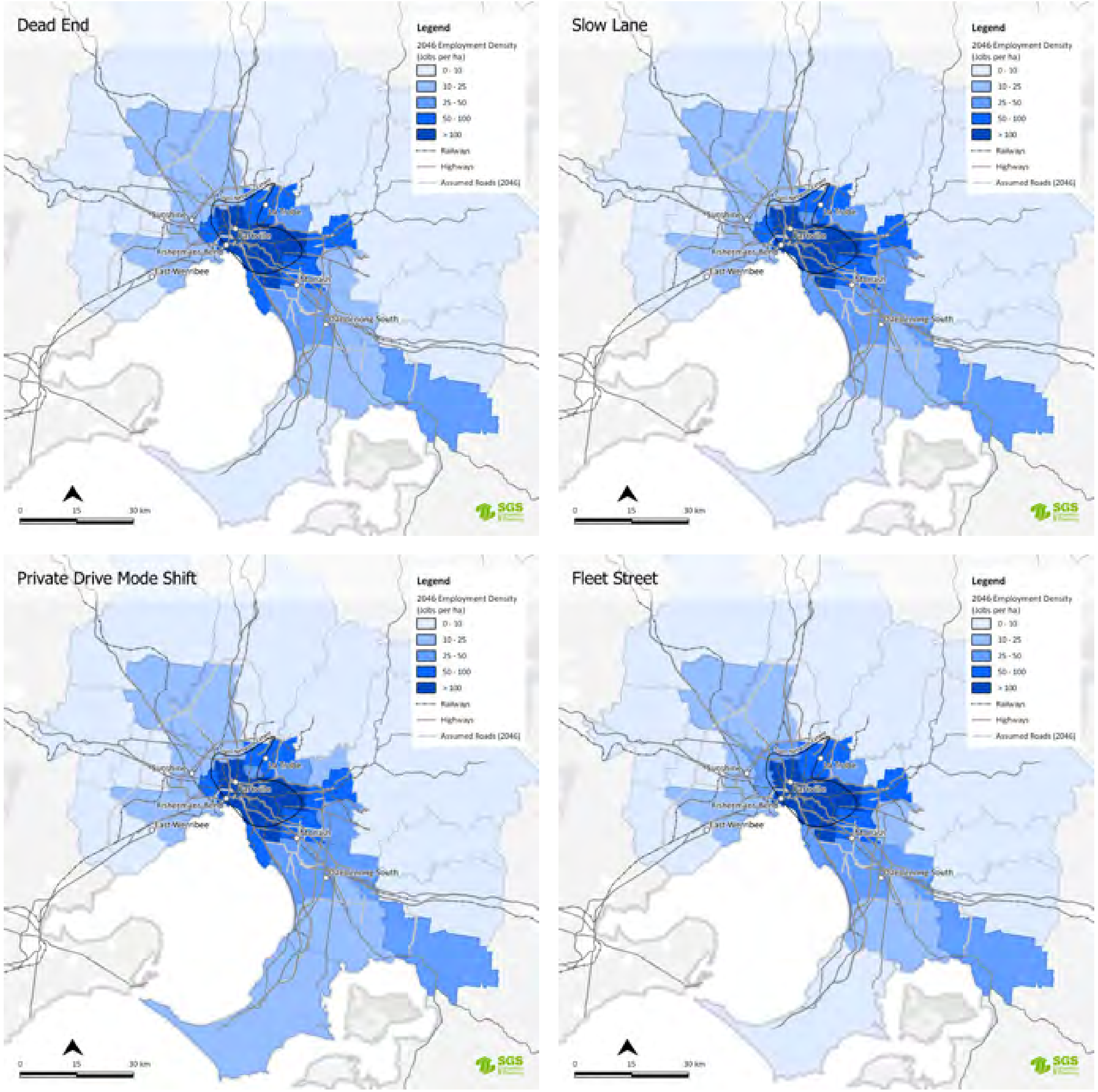


FIGURE 54: EXAMPLE DEVELOPMENTS OF VARIOUS SITE DENSITIES

20 DWELLINGS PER HECTARE

100 DWELLINGS PER HECTARE

250 DWELLINGS PER HECTARE

Source: SGS Economics and Planning, 2018

09 Conclusions and implications

> "Automated and zero emission vehicles have the potential to significantly change the way people travel and shape the pattern of urban development."

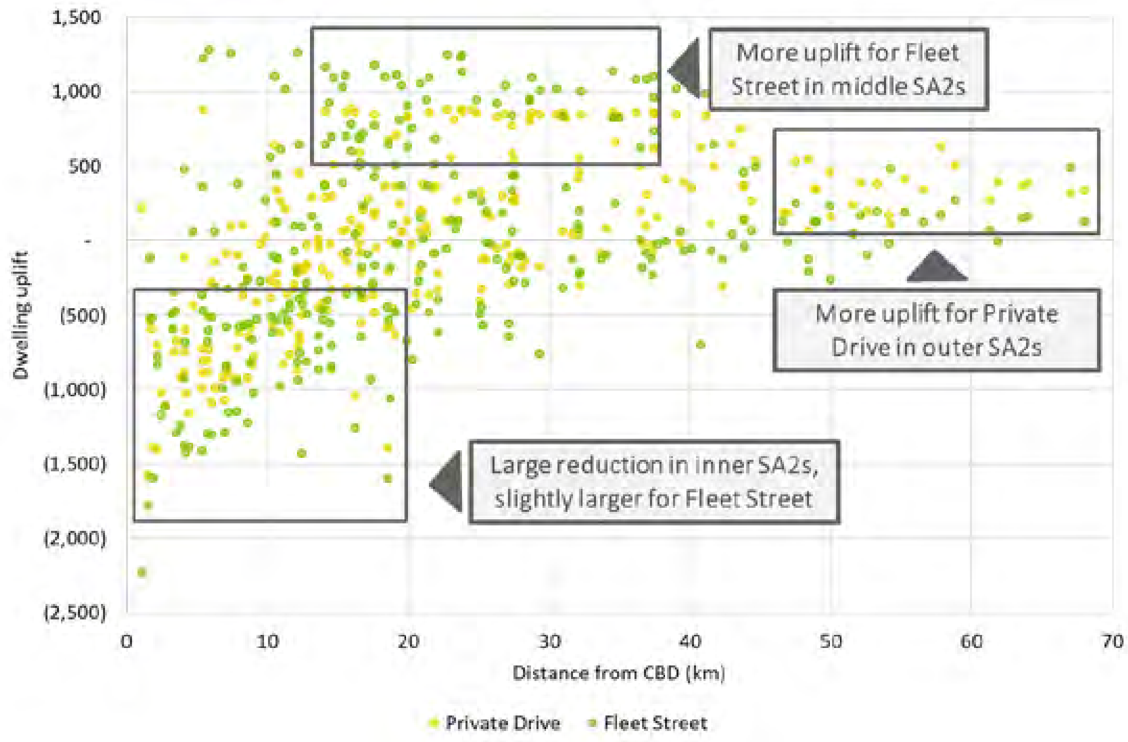
Automated and zero emission vehicles have the potential to significantly change the way people travel and shape the pattern of urban development. Planning for their eventual use will be crucial for maximising their benefits.

9.1 Summary of results

All scenarios broadly show the dispersion of dwellings and employment across Melbourne but there are some key differences in how the scenarios impact land use. The Private Drive and Private Drive low MUTT scenarios generally result in greater sprawl than the equivalent Fleet Street scenarios.

Figure 55 shows the dwelling change of each Melbourne SA2 under the Private Drive and Fleet Street scenarios compared to its distance from the CBD. Evidence of increased sprawl under Private Drive can be seen in the higher levels of change beyond approximately 45km from the CBD. On the other hand, Fleet Street results show a higher change in suburbs between around 15km to nearly 40km from the city and larger losses in SA2s between 0km and 20km. This rearranging may be due to differences in accessibility in middle ring suburbs. Results of a correlation analysis show change is more positively correlated with distance from the CBD under Private Drive (0.57) than under Fleet Street (0.35).

FIGURE 55: SA2 DWELLING CHANGE VS DISTANCE FROM CBD FOR PRIVATE DRIVE AND FLEET STREET



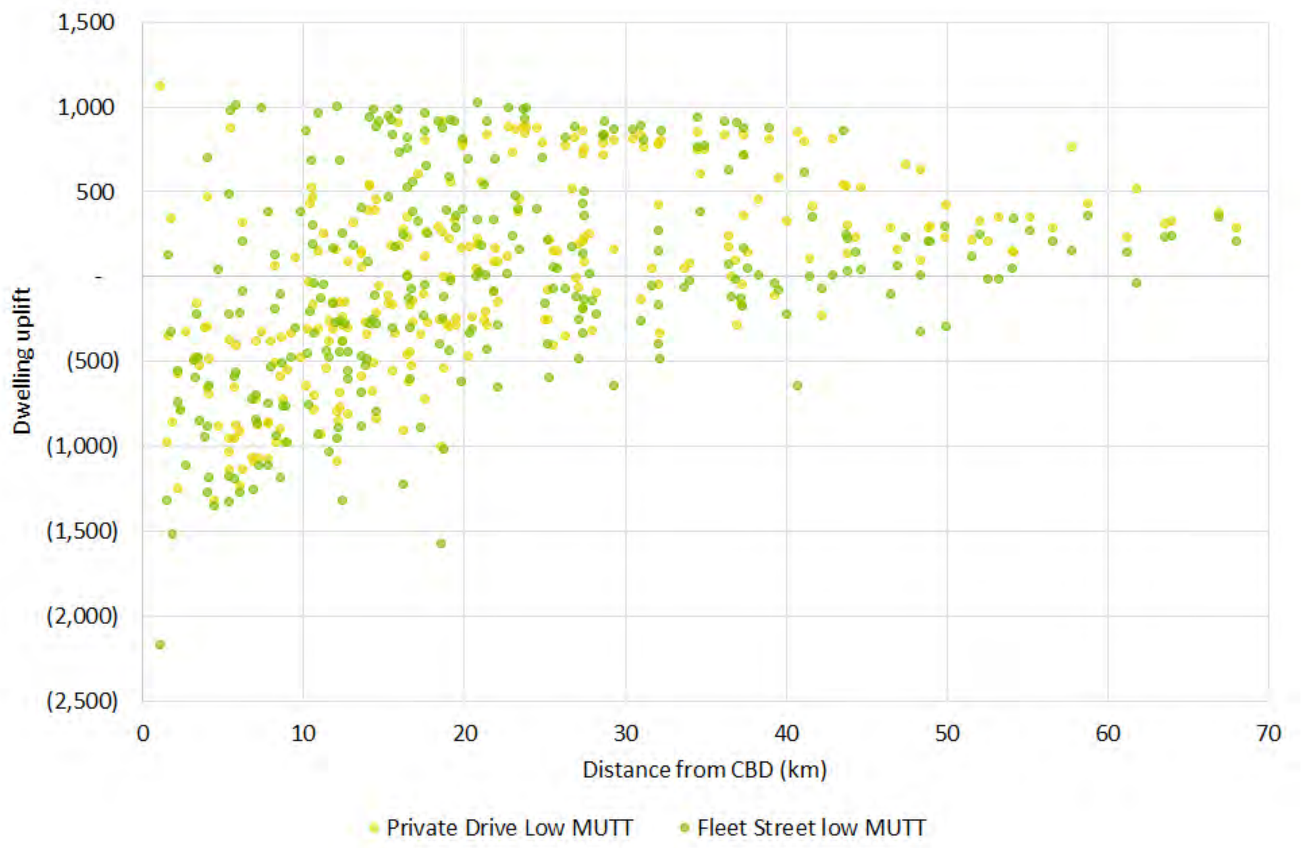
Source: SGS Economics and Planning, 2018

The pattern is similar but less pronounced under the low MUTT sensitivities of these scenarios (see Figure 56). Fleet Street redistributions are more extreme closer to the CBD, with both larger positive and negative shifts than Private Drive. The change under the Private Drive scenario is slightly higher further out from the centre of Melbourne. Correlations are around the same (approximately 0.3) under both the low MUTT scenarios.

The results suggest shifts away from inner, and consolidation of middle ring and outer suburbs under Fleet Street scenarios and a similar pattern under Private Drive but with increased sprawl. They reflect increased inner-city congestion under Fleet Street as empty running takes place, the low trip cost under Private Drive that induces longer trips, and that low MUTT has a mitigating effect on these two influences. This same pattern can be seen in the maps below which contrast the spatial effects of standard and low MUTT scenarios (see Figure 57 and Figure 58).

The difference in development patterns is particularly noticeable in the increase in the Mornington Peninsula under Private Drive, in Sunshine in the west, and in the northern middle to outer suburbs under Fleet Street. These differences show how sprawl under Fleet Street is only possible in areas that are very accessible by public transport and roads, while under Private Drive, outer areas that are not as well connected see more increase and outer areas that are very well connected to roads see the most.

FIGURE 56: SA2 DWELLING CHANGE VS DISTANCE FROM CBD FOR LOW MUTT SCENARIOS



Source: SGS Economics and Planning, 2018

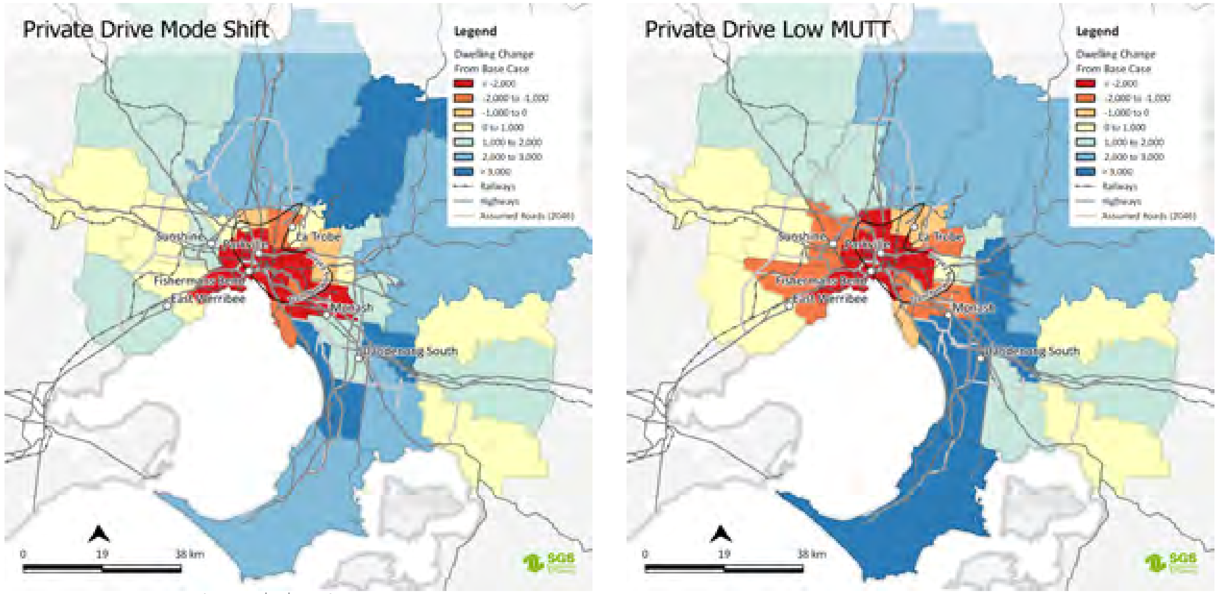
Turning to the regional results, there was a general consolidation of dwellings and employment in Geelong, some other regional cities and some peri-urban areas of Melbourne. This can be seen in the maps in Figure 59 and Figure 60 below, with large swathes of orange across rural areas of the state that indicate a reduction in dwellings compared to the base case.

At first glance, the regional Victoria results appear to contrast with the sprawling impacts of automated and zero emissions vehicles in the Greater Melbourne. The pattern occurs because roads in rural areas are already relatively uncongested in the base case and there are lower travel time improvements from automated vehicles. Regional cities do experience some congestion, particularly for commuters coming from their surrounding outer areas, such as from the Surf Coast to Geelong. Automated vehicles can reduce this congestion and improve accessibility for regional cities.

There were larger effects in the Private Drive scenarios than Fleet Street. This difference is likely due to the long wait times for Robotaxis and reduced opportunities for carpooling efficiency savings in isolated regional areas. The Slow Lane scenario had very small impacts due to the later uptake of the automated and zero emissions technologies.

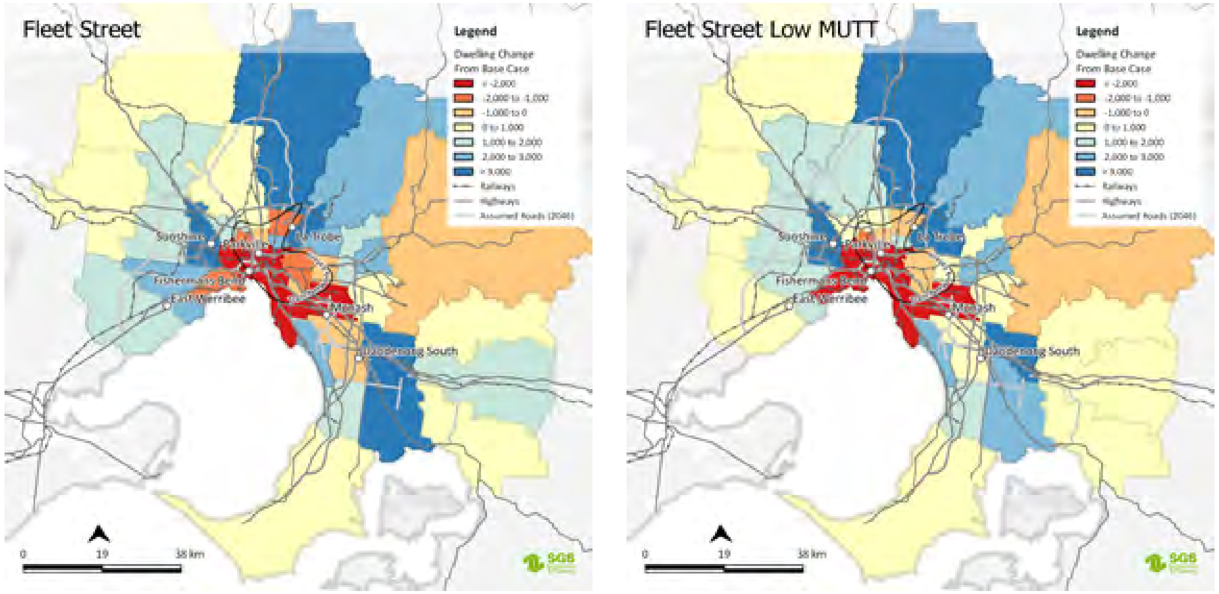
Low MUTT scenarios had a larger impact than those with a standard marginal utility of travel time. As with the Greater Melbourne results, this is likely due to more people being happy to travel longer distances by car. This makes peri-urban areas of Melbourne (such as the Baw Baw SA3) and the areas around regional cities (such as the Barwon – West SA3 outside Geelong) particularly attractive due to accessibility improvements.

FIGURE 57: PRIVATE DRIVE DWELLINGS CHANGE FROM BASE CASE – STANDARD AND LOW MUTT SCENARIOS



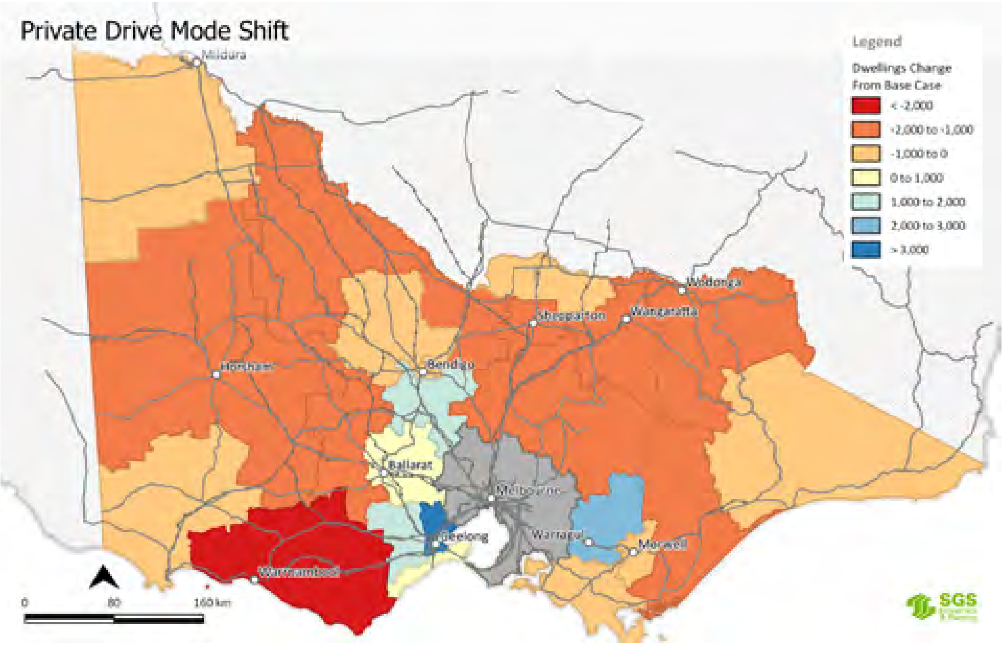
Source: SGS Economics and Planning, 2018

FIGURE 58: FLEET STREET DWELLINGS CHANGE FROM BASE CASE – STANDARD AND LOW MUTT SCENARIOS



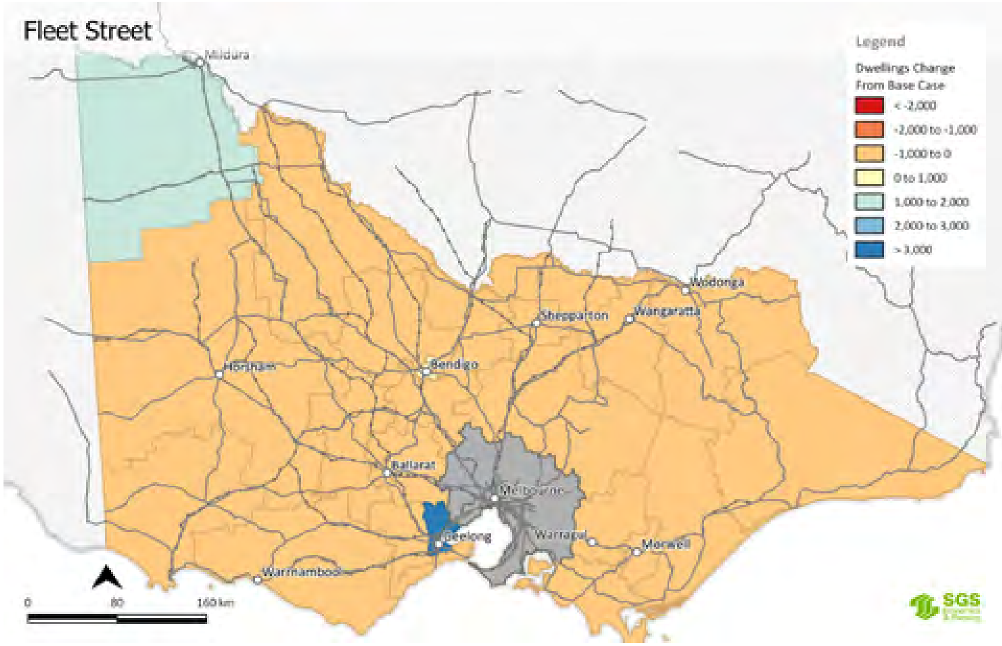
Source: SGS Economics and Planning, 2018

FIGURE 59: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE- PRIVATE DRIVE



Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

FIGURE 60: REGIONAL SA3 DWELLING CHANGE FROM BASE CASE- FLEET STREET



Note: Metro Melbourne is shown in grey because it was not included in the regional modelling.
Source: SGS Economics & Planning, 2018

9.2 Infrastructure implications

The results of land use scenarios suggest that automated and zero emissions vehicles will create additional residential growth fronts across urban Melbourne. Under these scenarios, automated vehicles could increase pressure on the infrastructure needs in established middle and outer ring suburbs, where there will be a surge in urban development. There is a question if there is capacity in the infrastructure network (in terms of school, health care facilities and similar services) to deal with the additional demand.

The middle ring suburbs which will see additional growth which should be able to absorb addition housing, without the need for significant additional infrastructure. Additional growth in greenfield areas would only add to the infrastructure challenge on Melbourne's urban fringe. This will place additional demand on infrastructure provision in areas that will already see the fastest and largest scale growth in Melbourne.

While there is a shift away from the inner city compared to the base case, there will continue to be significant rates of growth in inner areas when compared to today. Given the high level of baseline growth anticipated in the inner city locations, the decrease in additional population growth would have little impact on the need to provide additional infrastructure (e.g. schools, open space, health services) in this part of Victoria.

The impacts in regional areas may create some trigger points and threshold issues for the provision of some services and infrastructure. Trigger points are events or outcomes that require a change to infrastructure to ensure the healthy and safe functioning of its uses, they often relate to reaching the population threshold where existing infrastructure reaches capacity. This will be particularly pertinent in Geelong which experienced an increase in dwellings and employment over and above the base case in all scenarios. This may result in the need for extra services (e.g. retail and health) and infrastructure (e.g. schools).

The need for additional infrastructure on other regional areas will depend on how automated and zero emissions vehicles are adopted in the future. For example, the results indicate that private ownership will have a larger impact than shared ownership. Some peri-urban areas of Melbourne become relatively more accessible with private ownership but relatively less accessible when passengers depend on Robotaxis.

Impacts on urban growth boundaries in regional Victoria are likely to be small. Any additional growth in dwellings that occurs in Geelong and (to a lesser extent) Ballarat, Bendigo and Melbourne's peri-urban areas, can be accommodated via infill development and small increases in densities, such as through medium-density housing developments. There would not be a need to expand urban growth boundaries or encroach on other land uses.

At a more detailed level, there is a question about the amount of carparking currently being provided in the inner city of Melbourne. As noted earlier, there is already a significant underutilisation of car parking spaces which, when combined with the ongoing trend of parking added to newly built apartments, may result in large amounts of redundant land. This is especially true under Fleet Street scenarios where people no longer own their own cars.

It would be difficult for this internal space to be converted to another use (e.g. residential or commercial use). This is due to lower ceiling heights and a lack of access to utilities (e.g. water and sewage) and the cost to retrofit these services.

As mentioned earlier, automated and zero emissions vehicles have the potential to improve amenity along roads. Higher amenity is likely to result in increased dwelling densities along busy road corridors. However, with the MABM transport outputs provided at the SA2 level and the TIM results aggregated at the SA3 level, it has not been possible to isolate any clear housing density improvements stemming from amenity improvements in this modelling.

It is important to note that these conclusions for future infrastructure provision have not been able to consider the very local infrastructure and service provision thresholds, which would have to be reviewed in the face of changes to population growth.

Appendix A: Glossary

TERM	DEFINITION	ABBREVIATION
Australian and New Zealand Standard Industry Classifications	The standard framework under which business units carrying out similar productive activities can be grouped together, with each resultant group referred to as an industry.	ANZSIC (2006)
Australian Statistical Geography Standard	The Australian Statistical Geography Standard is the Australian Bureau of Statistics' new geographical framework and it is effective from July 2011, replacing the ASGC. The vast majority of ABS spatial data will be based on the ASGS by 2014.	ASGS
Estimated Resident Population	The total number of people that live within a defined area. This includes both people residing in private and non-private dwellings (i.e. dormitories, jails, nursing homes).	ERP
Health and Education Employee	Employee working in one of the following ANZSIC Industry Divisions: Education and Training; Health Care and Social Assistance.	
Household size	The ratio of *persons in occupied private dwellings to occupied private dwellings.* This means on average there are 1.91 persons in each occupied private dwelling).	
Industrial Employee	Employee working in one of the following ANZSIC Industry Divisions: Agriculture, Forestry and Fishing; Mining; Manufacturing; Electricity, Gas, Water and Waste Services; Wholesale Trade; Transport, Postal and Warehousing.	
Iterative Proportional Fitting	Statistical method which aligns known totals to an estimated distribution.	IPF
Knowledge Intensive Employee	Employee working in one of the following ANZSIC Industry Divisions: Information Media and Telecommunications; Financial and Insurance Services; Rental, Hiring and Real Estate Services; Professional, Scientific and Technical Services; Administrative and Support Services; Public Administration and Safety.	
Non-Private Dwelling	Communal accommodation provided by institutions such as hospitals or prisons and transitory accommodation such as hotels and motels.	NPD
Occupied Private Dwellings	A private dwelling that is occupied on Census night. Also represents households.	OPD
Occupancy Rate	The ratio of occupied to unoccupied private dwellings	OR
People in Occupied Private Dwellings	Estimated resident population who reside in private dwellings	POPD
People in Non-Private Dwellings	This includes persons in communal or transitory type accommodation (i.e. prisons, boarding school, hospital, defence establishments).	PNPD
Place of Institution	Refers to variables which are based on education locations (e.g. the number of people attending a tertiary institution within a particular zone)	PoI
Place of Usual Residence	Refers to variables which are based on the home location of population (e.g. the number of people who live in a particular zone)	PUR
Place of Work	Refers to variables which are based on employment locations (e.g. the number of ‘Retail Trade’ industry jobs within a particular zone)	PoW
Population Serving Industry Employee	Employee working in one of the following ANZSIC Industry Divisions: Construction; Retail Trade; Accommodation and Food Services; Arts and Recreation Services; Other Services.	
Structural Private Dwelling	A privately-owned building or structure that people live in. This may include a house, an apartment, or it may be a mobile dwelling such as a caravan.	SPD
Travel Zone	Travel Zones (TZs) are the smallest standard geography used for a number of transport datasets in Victoria. They represent geographical areas that are used in origin-destination transport modelling.	TZ
Trip Attractors	Variables relate to destinations. These destinations range from places of work and education to destinations such as shopping centres.	
Trip Generators	Variables relate to the origin location of travel (i.e. place of residence)	

Appendix B: Transport Impact Model

Historical relationship analysis

Over the past 20 years, several major road infrastructure projects have had a significant impact on the accessibility of certain locations across Greater Melbourne, such as:

- 1996 to 2001 – Western Ring Road
- 2001 to 2006 – Citylink
- 2006 to 2011 – Eastlink and major improvements to the Monash Freeway and the West Gate Bridge
- 2011 to 2016 –Regional Rail Link

These projects help to provide an evidence base for understanding the degree to which firms and households change their locational preferences due to shifts in the metropolitan accessibility contours.

Furthermore, over this period, detailed information regarding the distribution and accessibility changes of Melbourne has been made available from the ABS Census and the DOT (Victorian Integrated Transport Model). This data has all been aggregated to the SA2 level for five time periods for this analysis (1996, 2001, 2006, 2011, 2016).

Using the changes in accessibility that were driven by the major infrastructure projects, a detailed statistical regression analysis was undertaken using this historical data to test and quantify the following theory:

- All else being equal, a SA's share of Greater Melbourne's total employment by industry sector is based on two broad factors:
- Share of population/dwellings[34]
- Accessibility.[35]
- In addition, if all else was equal, a SAs share of Greater Melbourne's total housing stock is based on two key factors:

  - The urban land supply[36]
  - Accessibility.

This theory suggests that the strong growth within a greenfield area is a result of increased land supply, while the recent strong growth within the inner city is a result of increased accessibility. Furthermore, if a location's accessibility is improved it will increase the level of demand and, in turn, the growth rate (similar to releasing land within a greenfield area). The strength of this relationship varies from industry to industry, depending on its requirements and willingness/capacity to pay for more accessible locations.

For this analysis, these two factors have been identified as the key considerations in the distribution of households and employment. However, in reality, the exact spatial distribution of households and employment is far more complex, particularly at a local level. Issues at the local level include historical factors and development trends that also determine the locational choices of firms and people. We assumed that these additional localised issues are indeed inherent and therefore captured within the base case projections. Consequently, any changes observed in the Project Case scenario are over and above these other local contextual issues.

To undertake this statistical analysis, three key data variables were synthesised by SGS for each SA across Greater Melbourne from 1996 to 2016:

- SAs share of total employment by industry sector and households
- SAs share of total urban land
- SA housing capacity indicators
- SAs relative accessibility.

[34]The share of population/housing has been included to capture the distributional changes of the underlying population serving employment.
[35]Where, accessibility is defined in its broadest sense. That is, a locations access to activity centres, skilled workers, employment opportunities, services, education, transport infrastructure, restaurants, etc.
[36]The amount of urban land has been included to capture the varying geographic sizes of SLAs. That is, if SLA X is 10 times larger than SLA Y, all else being equal, it should have 10 times the amount of dwellings.

Population and industry employment

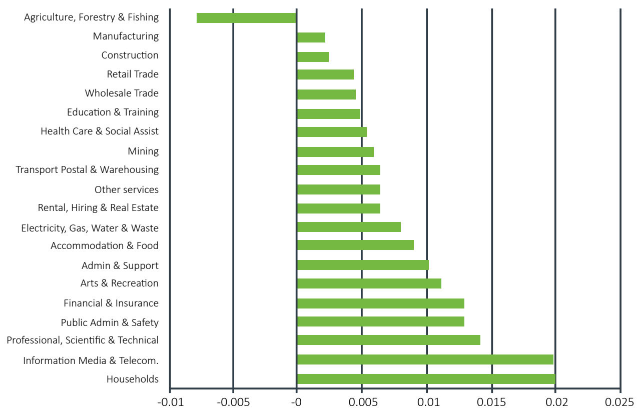
Historical employment and housing data for 1996, 2001, 2006, 2011 and 2016 by SA has been collated from a range of ABS data sets including the past Censuses, the ABS labour force survey data[37] and ABS estimated resident population[38].

Total employment by industry sector and households for each SA is converted to a share of overall metropolitan Melbourne levels. The share of Greater Melbourne was used as it was assumed that there is a wide range of other external factors such as international and interstate migration and economic trends that influence the total amount of population and employment in a city. Furthermore, it is assumed that a project such as this will only have an influence in the reorganisation (or locational decisions) of people/firms within Melbourne and will not be able to influence a person from Sydney. In other words, it was assumed that a project of this scale is unlikely to affect the overall employment outcomes for Greater Melbourne with only the reorganisation of employment within the metropolitan economy envisaged.

Over the past 15 years, much of Melbourne's housing growth has been focused on two broad regions: fringe growth areas (about half) and inner city Melbourne (about one fifth). Greenfield growth is predominately a result of large amounts of land supply from significant areas of land being rezoned as urban residential. By comparison, strong growth within the inner city can be attributed to a preference to be close to jobs, services and the city's core (i.e. accessibility). As a result, households have been estimated to have a strong propensity to relocate due to changes in accessibility.

In relation to a firm's locational preference, the service sector and higher value-added industries exhibit a higher preference for more accessible locations. This is shown in Figure 61, with the regression coefficients for relative Effective Job Density (EJD). Information media & telecommunications, Professional, scientific & technical services and Finance & insurance are some of the most susceptible industries to changes in accessibility. The Agriculture industry experiences the only negative coefficient with relative EJD. Agriculture uses typically require large and relatively cheap land parcels away from major centres. Furthermore, particularly within the fringe growth areas, farm land within the MSD has been rezoned and changed uses to housing or other employment.

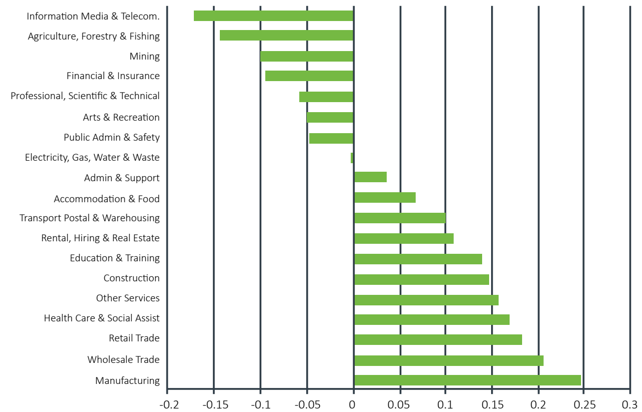
FIGURE 61: RELATIVE EJD REGRESSION COEFFICIENTS



Source: SGS Economics & Planning, 2018

For employment, there is a secondary effect resulting from the estimated shifts in households. That is, many industries depend on a local population as either customers or skilled workers. Therefore, an increase in population in an area often results in a further increase in population-servicing employment. This is employment in industries such as such retail trade, health care, education & training and accommodation & food services. The coefficients related to a change in household share for each of the employment industry sectors. As expected, industries that thrive on proximity to population relationship with an induced change in households.

FIGURE 62: HOUSEHOLD SHARE REGRESSION COEFFICIENTS

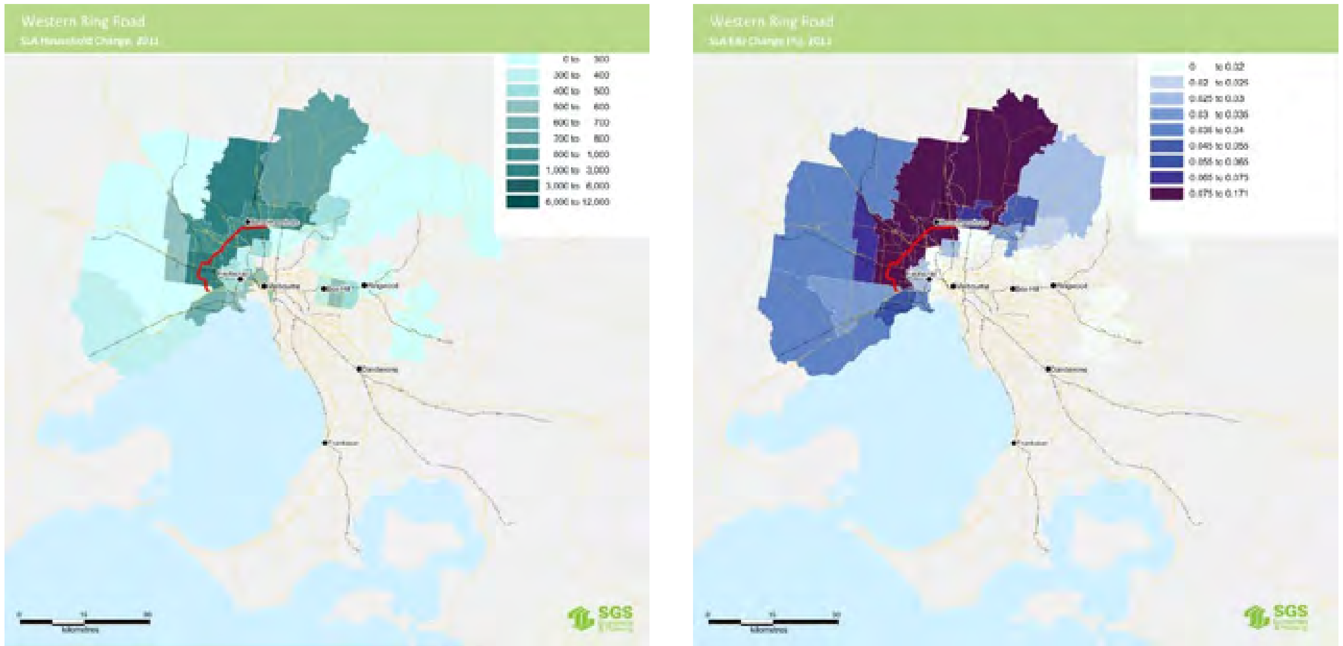


Source: SGS Economics & Planning, 2018

[37] ABS Cat. No. 6202.0
[38] ABS Cat. No 3201.0

The effect of changes to accessibility is the cornerstone of the analysis of impacts for the four projects. The varying ages of the projects and subsequent issues in data availability and the stream of benefits over time mean that different approaches are required to understand how they have shaped Melbourne's population, and household and employment formation and distribution. For example, the left panel of Figure 63 shows the geographical distribution of the change in EJD brought about by the Western Ring Road and the right panel shows the change in household numbers.

FIGURE 63: IMPACT OF WESTERN RING ROAD



Source: SGS Economics & Planning, 2018

Urban land

There is a range of data sources that could be used (such as the Victorian Planning Provisions) to calculate the amount of total urban land that a SA has as a proportion of Greater Melbourne. However, many of these datasets are difficult to source consistently across a 15-year historical time period (1996-2011). Therefore, a geographic unit referred to as Urban Centre Locality (UCL) was used as a broad estimate of the amount of urban land. The UCL measures the broad extent of urbanisation for a city/town and is published by the ABS for the 1996, 2001 and 2006 Censuses. An estimate of the Melbourne UCL for 2011 was made by adding in all future 2010 Urban Development Program (UDP) broad hectare sites to the 2006 UCL. This provided a consistent measure across all time periods.

As the UCL grows for an area (i.e. due to green-field land being released) the proportion of total Melbourne UCL for other established locations was found to decrease. This statistic isolates dwelling growth related to changes in accessibility that come from increased development opportunities.

Accessibility

SGS has developed a measure of accessibility within a specified geographical region and the ability to access overall economic activity across the wider MSD, known as relative EJD. Quantifying changes to relative accessibility was performed through translating the absolute EJD's across the four years of analysis into a 0 to 1 index, i.e. a relative EJD index. The index is created using the SA that has the highest EJD. This was consistently found to be Melbourne (C) – Inner across all years of analysis, which provides a ceiling for the index (a score of 1). To provide a floor to the index the converse is performed. Consistently Yarra Ranges (C) – Central was found to have the lowest EJD and is thus given a score of 0.

The equation used to calculate the relative EJD ranking is shown below.

$$Relative\ EJD_i = \frac{EJD_i - Min\ EJD}{Max\ EJD - Min\ EJD}$$

Where:

EJD_i = Effective Job Density for SA i

$Min\ EJD_{SLA}$ = the SA found to have the lowest EJD amongst all MSD SAs

$Max\ EJD_{SLA}$ = the SA found to have the highest EJD amongst all MSD SAs

Appendix C: SAM Dwellings and Population

The following section details the approach, data inputs, and assumptions used to create the small area dwelling and population projections by Place of Usual Residence.

Overview

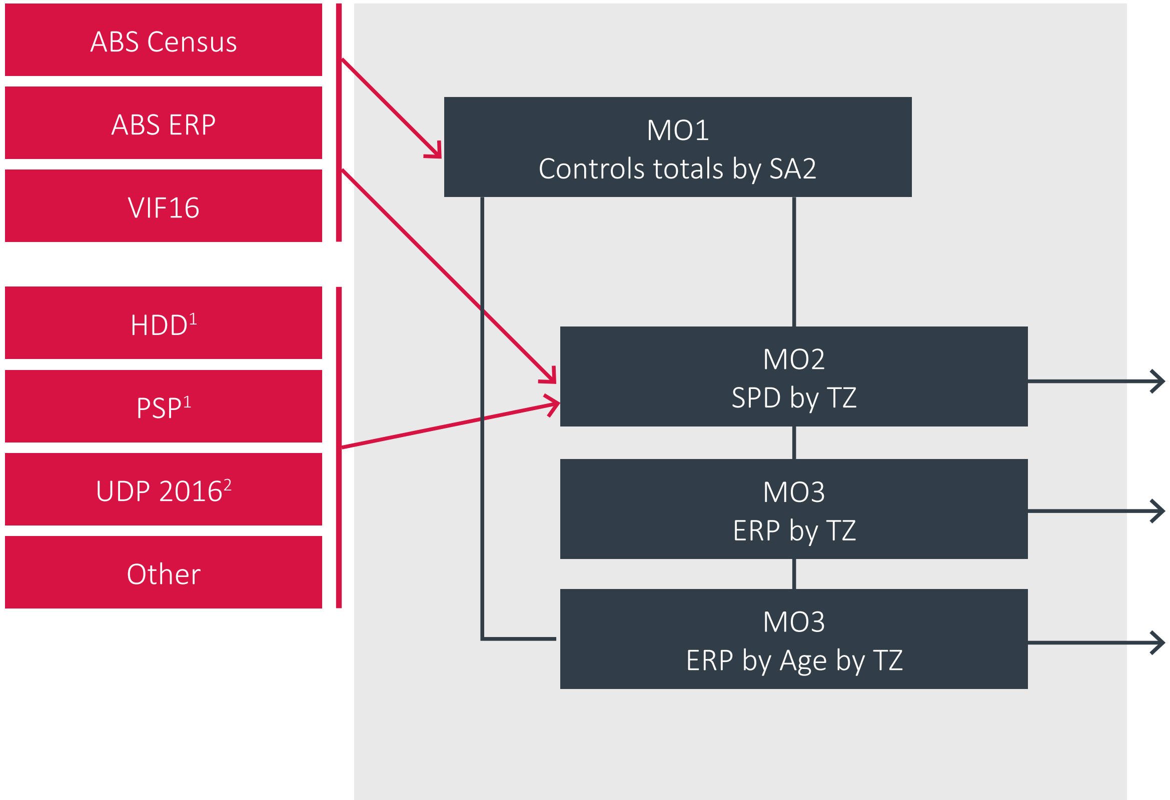
Figure 64 presents an overview of the key data inputs and analysis modules.

First control totals by SA2 are established – Module 1 (M01). This is largely based on VIF15 data, while some other datasets are used to create historical trends and additional demographic breakdowns used in other modelling stages.

Dwellings (i.e. occupied and unoccupied dwellings) is the first variable estimated at a travel zone level- Module 2 (M02).

Dwellings are then systematically disaggregated to occupied private dwellings, population, and age groups. People in non-private dwellings (i.e. nursing homes, jails, hotels, etc) are also estimated and incorporated into the population and population by age projections.

FIGURE 64: STAGE 1 - DWELLING AND POPULATION APPROACH OVERVIEW



[1] HDD 2014 and PSP data is relevant to Greater Melbourne only.
[2] Urban Development Program 2016 data is available for Greater Melbourne only. 2012 UDP data is used for the rest of Victoria

Detailed approach description

MODULE 1 – SA2 CONTROL TOTALS

Conceptual approach
This module collates SA2 control totals for all dwelling and population variables, ranging from SPD to ERP by age. For the years 2011 and 2016 to 2051 (5-year intervals), the control totals were provided by VIF16 projections. For the years 1996-2006 (5-year intervals), 2014 and 2015, the ABS' RegionaMol Population Growth dataset and Census data were aligned to create control totals for each of the dwelling and population variables.

Key assumptions

- Household sizes and occupancy rates held consistent over the course of 1996-2011.

Key data sources

- Victoria in Future (VIF) 2015
- ABS Catalogue 3218.0 – Regional Population Growth
- ABS Census 1996, 2001, 2006, 2011

MODULE 2 – STRUCTURAL PRIVATE DWELLINGS BY TRAVEL ZONE

Conceptual approach
This module estimates SPD at a travel zone level. Module 1 historical and projected SA2 control totals are distributed down to a travel zone level using a staged approach.

A historical travel zone level SPD dataset is created for the years 1996-2011. This is developed using Housing Development Data for Greater Melbourne and Mesh Block and Collection District Census data for the rest of Victoria.

Housing Development Data for Greater Melbourne is used to updated SPDs by travel zone to 2014. For Regional Victoria, the 2011 distribution along with SA2 trends from VIF15 are used to create a 2014 estimate.

Forecast SPDs are then estimated using a sequenced allocation approach.

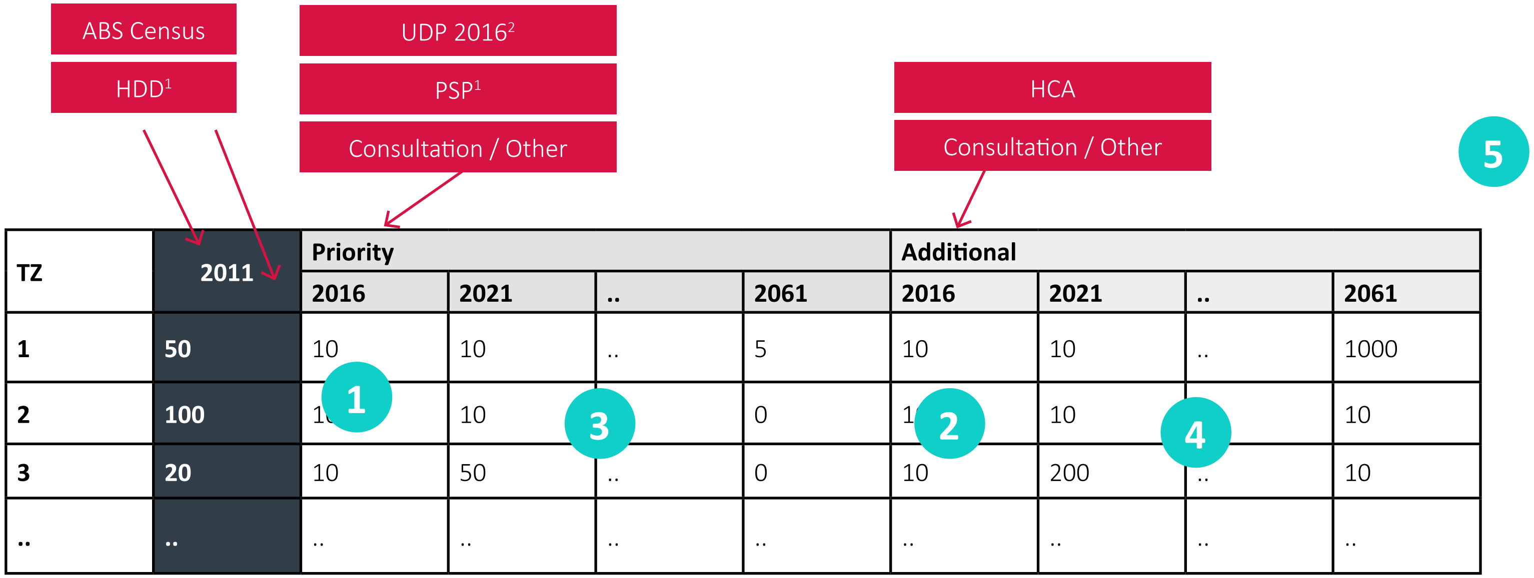
A wide range of local level development datasets (such as the Urban Development Program and Precinct Structure Plans (PSP) information) are consolidated into a new development database. This also includes density/growth by location type assumptions to manage long term growth where information is missing/unclear.

Using these sources, a 'priority' and 'additional' capacity was created for each travel zone across Victoria, as well as a timing associated with each of these capacity measures.

- Priority capacity (5-year intervals): Includes certain and localised development information including the 2016 Urban Development Program and approved Precinct Structure Plans (as of June 2017) and previous consultation.
- Additional capacity (5-year intervals): Includes all other capacity information, some of which have timing components. Sources include incremental infill data from HCA, previous consultation, and broad density limit assumptions.

These capacity measures are then used to distribute the growth in periods at an SA2-level (see Figure 65 below). Priority capacity in its relevant timing is first used to allocate SA2-level growth down to a travel zone level. If there are any remaining SPDs to be allocated at an SA2 level, additional capacity for the relevant period is used to allocate the remaining SPDs to a travel zone level. Following this, if there are remaining SPDs to be allocated at an SA2 level, future priority capacity (up to 15 years) is used followed by future additional capacity, and if necessary, the dwelling stock within each travel zone at the given time period as a 'fail-safe' to ensure forecasts always align to VIF15 control totals. Within each of these classes, dwellings are allocated to capacity within a SA2 on a pro-rata basis, that is location with more capacity capture more of the growth.

FIGURE 65: MODULE 2 - SPD ALLOCATION METHOD SPD



TZ	2011	Priority				Additional			
		2016	2021	..	2061	2016	2021	..	2061
1	50	10	10	..	5	10	10	..	1000
2	100	1	10		0	1	10		10
3	20	10	50	..	0	10	200	..	10
..	..	..	..	..	..	..	..	..	..

1. VIF15 dwellings are first allocated to *priority capacity* in that period
2. Remaining VIF15 dwellings are then allocated to *additional capacity* in that period
3. Remaining VIF15 dwellings are then allocated to *priority capacity* in future periods
4. Remaining VIF15 dwellings are then allocated to *additional capacity* in future periods
5. Remaining VIF15 dwellings are then allocated across stock at that period

This process is repeated for all SA2s up until 2051 to derive an estimate of SPDs at a travel zone level up until 2051.

In the situation where priority or additional capacity is not realised in a particular year, this remaining capacity is added to the next time period's priority/additional capacity. As such, the development inputs (i.e. sources used to create priority and additional capacity) are treated as development opportunities that are only realised if there is sufficient demand within the SA2: each development input is either pushed out or brought forward to ensure alignment with the control totals.

Detailed checks are then completed. This includes both automated validation checks (i.e. no negatives, density limits) and common-sense checks using summary tables and maps.

Key assumptions

— Underlying dwelling development capacity and timing from input datasets.

Key data sources

— ABS Census 1996, 2001, 2006 and 2011
— Housing Development Data 2011-2014
— Urban Development Program 2015-16 (Broadhectare and Major Residential)
— Urban Development Program 2012 (Regional Victoria)
— Precinct Structure Plans (VPA)
— Housing Capacity Assessment 2008 (SGS Economics & Planning)
— Consultation and other local level data and policy information

MODULE 3 – ESTIMATED RESIDENT POPULATION BY TRAVEL ZONE

Conceptual approach
Upon synthesising SPD for each travel zone in Victoria, SGS applied a housing unit method to estimate the number of occupied private dwellings, persons in occupied private dwellings, persons in non-private dwellings and estimated resident population by TZ. This is a similar approach as used by VIF to forecast SA2 population and dwelling components.

This stepped approach results in robust results which capture a range of issues while still being closely aligned with estimated development patterns. Some issues captured by this approach include:

— Holiday locations which tend to have lower occupancy rates
— Growth areas which tend to have larger household sizes, and
— Inner city areas which tend to have smaller household sizes but are seeing a transition to more family household types.

Table 24 highlights the key steps and assumptions in the approach.

During each step results are aligned to VIF2015 control totals and individual TZ trends are reviewed to ensure realistic results (i.e. if there is population there must be dwellings).

Key data sources
— Results from Module 1 and 2
— ABS Census 1996, 2001, 2006 and 2011

TABLE 24: MODULE 3: KEY ASSUMPTIONS

HOUSING UNIT COMPONENT	DESCRIPTION
Occupied Private Dwelling (OPD) = SPD * Occupancy Rate	A historical occupancy rate for each TZ is derived from 1996, 2001, 2006 and 2011 Census data. This is trended forward based on SA2 occupancy rates sourced from VIF2015. Trend rates for individual TZs within an SA2 are varied based on their life cycle and relationship with other TZs. For example, very new growth area zones with low occupancy rates will be trended back to the SA2 average quickly to reflect new families moving in, while other TZs will remain stable.
People in OPD (POPD) = OPD * Household Size	A historical household size for each TZ is derived from 1996, 2001, 2006 and 2011 Census data. This is trended forward based on SA2 household size rates sourced from VIF2015. Trend rates for individual TZs within an SA2 are varied based on their life cycle and relationship with other TZs. TZs with apartments and very low household size ratios will not continue to drop below 'unrealistic' rates.
People in Non-Private Dwellings (PNPD)	This includes persons in communal or transitory type accommodation (i.e. prisons, boarding school, hospital, defence establishments). The current distribution of PNPD for each TZ has been derived from the ABS Census. Given this is a small component of the total population, and minimal data on how it may change is available, SA2 control totals have simply been allocated down based on the current distribution pattern on a pro-rata basis. Which implies no new facilities will be created and any growth in this population segment will go to existing facility locations.
Estimated Resident Population (ERP) = PNPD + POPD	Total Estimated Resident population simply equals the combination of POPD and PNPD.

MODULE 4 – ESTIMATED RESIDENT POPULATION BY AGE BREAKDOWN BY TRAVEL ZONE

Conceptual approach
Total population is further disaggregated to age groups using the Residual Allocation System (RAS) (also referred to as Iterative Proportional Fitting (IPF)).

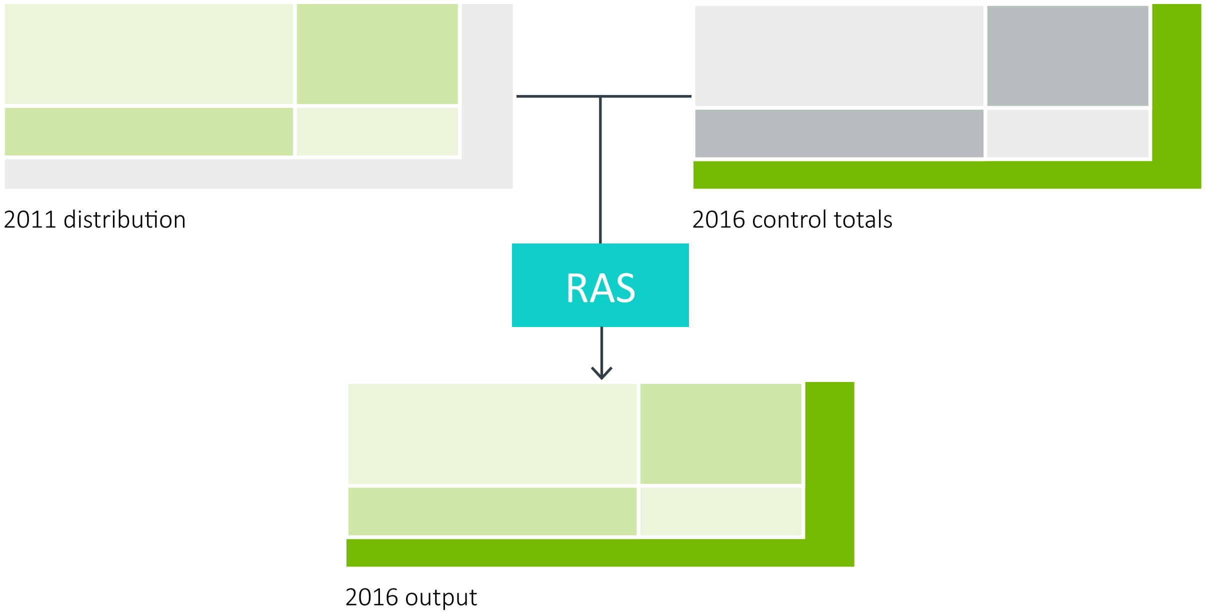
This involves aligning the previous period age structure with the future total population by TZ (from module 3) and the population by age SA2 control totals (from module 1). For the first year, the distribution is based on ABS Census data aligned to TZs. Adjustments are made to the distribution table to account for new development areas (i.e. locations which currently don't have population but will in the future).

The RAS approach is illustrated in Figure 66. The approach essentially involves a number of iterations (in the 100s) where the distribution is aligned to row control total and then column control totals and then back again.

The result is a detailed breakdown of population by age by TZ which equals the SA2 control totals and reflects the historical distribution of the area as much as possible.

Key data sources
- Results from Module 1 and 3
- ABS Census 1996, 2001, 2006 and 2011

FIGURE 66: RAS METHOD TO DEVELOP POPULATION BY AGE BY TRAVEL ZONE



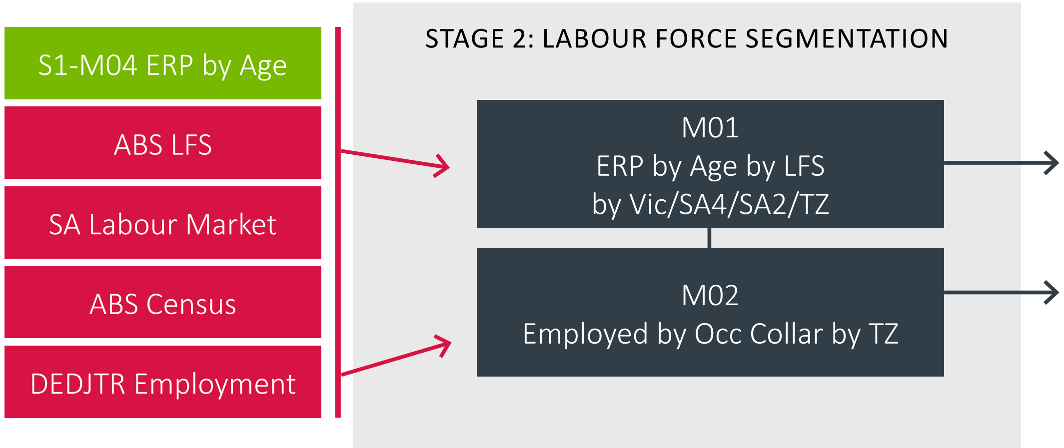
Overview SAM labour force segmentation

The following section details the approach, data inputs and assumptions used to further segment population into key labour force components.

Figure 67 provides an overview of the approach used. Population by age is further segmented into labour force status and employment occupation collar for resident workers. These are also cross checked with employment (Stage 3).

Detailed approach description

FIGURE 67: STAGE 1 - LABOUR FORCE SEGMENTATION APPROACH OVERVIEW



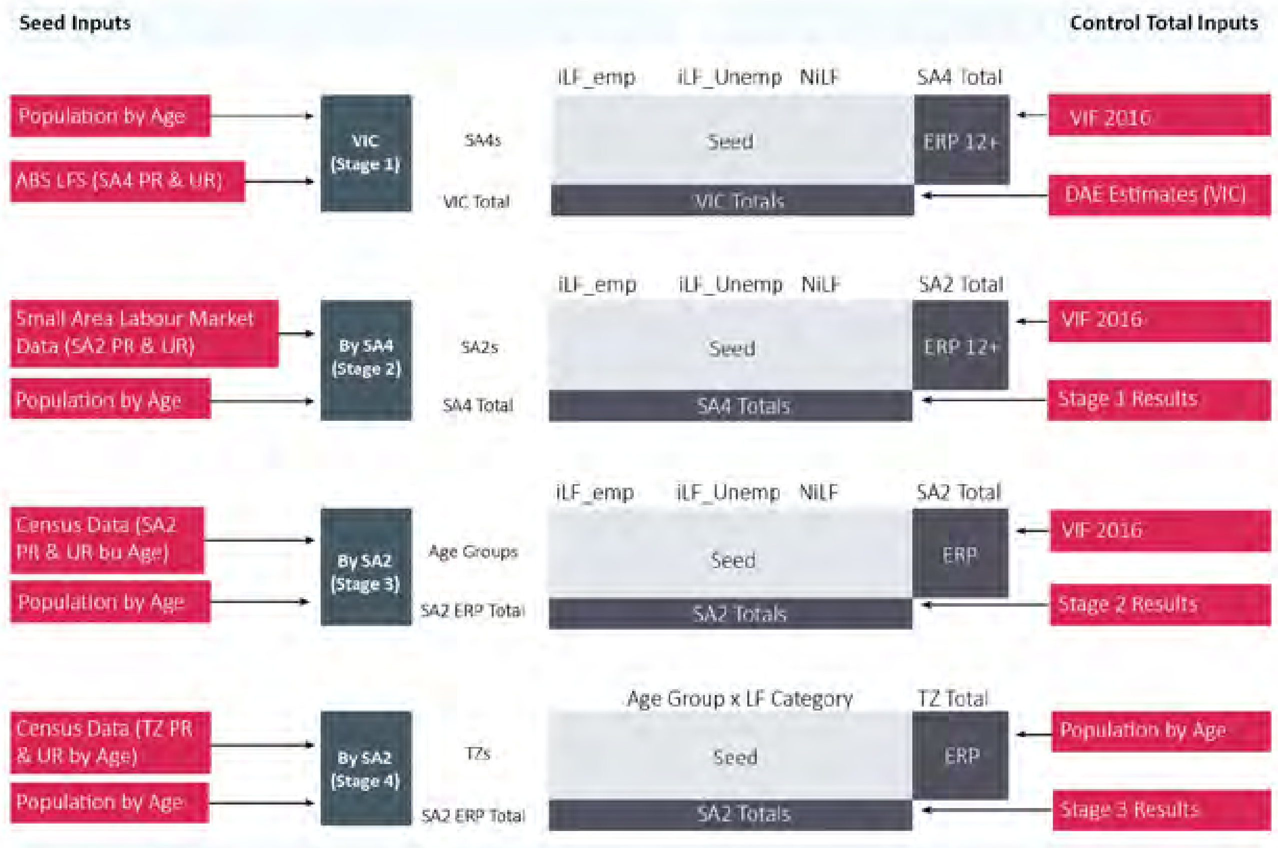
MODULE 1 – ERP BY AGE BY LABOUR FORCE STATUS

Conceptual approach

Population by age is segmented into labour force categories in four stages (see Figure 68), each of which use the RAS algorithm (as described in Stage 1- Module 4).

- Labour Force Survey (LFS) age-specific participation rates (PR) and unemployment rates (UR) are used in conjunction with VIF16 population by age forecasts to disaggregate Victorian control totals by SA4. Using LFS data captures spatial variation in labour force characteristics with a high degree of accuracy.
- The SA4 control totals are disaggregated to the SA2 level while maintaining consistency with VIF2016 ERP totals by SA2. Seed values for each SA2 are computed using population by age forecasts along with PR and UR from Small Area Labour Market (SALM) data. Using SALM to perform this intermediate step provides a finer level of spatial disaggregation that LFS data while also being more recent that Census data.
- For each SA2, the labour force categories estimated in the previous stage are then disaggregated by age group. PR and UR by age group are sourced from Census data and combined with VIF2016 population by age forecasts to derive seed values.
- The final stage disaggregates the outputs of stage 3 (labour force category by age group by SA2) across Travel Zones (TZ). This also maintains consistency with TZ level population forecasts. Seed values for the final stage are computed using population by age forecasts by TZ in conjunction with PR and UR by age group sourced from Census data.

FIGURE 68: LABOUR FORCE SEGMENTATION BY AGE



Key data sources

- Results from Stage 1 (Dwellings and Population) and Stage 3 (Employment)
- ABS Census 2011
- ABS Labour Force Survey: Participation rates and unemployment rates by SA4
- Department of Employment: Small Area Labour Market by SA2

MODULE 2 – EMPLOYED PERSONS BY COLLAR

Conceptual approach
This module uses a single RAS algorithm, as shown in Figure 69. Employed persons by Travel Zone, which is an intermediate output of module 1, are segmented into three collar categories (white collar – high skill, white collar – low skill, blue collar). TZ level collar type seed values are based on 2011 Census data.

Key assumptions

— Areas for which base data does not exist (e.g. future greenfield sites) are attributed with the occupation propensities of the broader region.

Key data sources

— Results from Stage 1 (Dwellings and Population) and Stage 3 (Employment)
— Results from Module 1
— ABS Census 2011

FIGURE 69: LABOUR FORCE SEGMENTATION BY COLLAR

Overview SAM employment

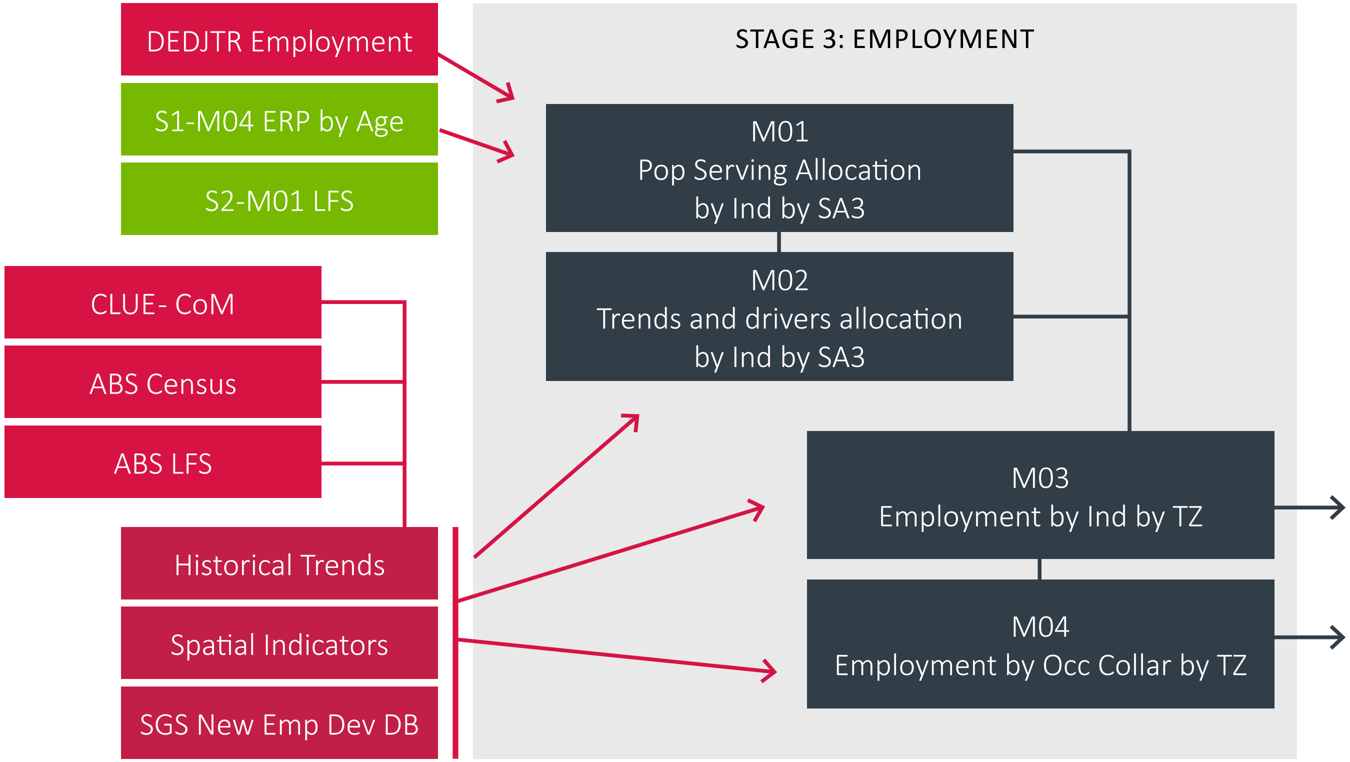
This section details the process used to forecast employment by industry and employment by collar at a travel zone level.

Figure 70 presents an overview of the approach used to forecast employment by industry.

Official DEDJTR/DAE Victorian employment by one digit ANZSIC industry forecasts are disaggregated to travel zones. Employment is first estimated at an SA3 level and then further disaggregated to travel zones. Every job is assigned to a location, with no undefined location or industry categories. Employment by industry is then further disaggregated into three occupation collar types.

Several input datasets are created to support this process. This includes; historical employment by industry, a series of spatial indicator series and a new employment developments database which consolidates local level employment intelligence.

FIGURE 70: EMPLOYMENT BY INDUSTRY OVERVIEW



Key input data synthesis

The following outlines the key input datasets which were created for this stage of SALUP17.

HISTORICAL EMPLOYMENT BY INDUSTRY BY TRAVEL ZONE

Conceptual approach
Estimation of historical employment by industry follows the following key steps:

- Sourcing census data for years 1996 – 2011 by destination zones.
- Systematically reallocate unallocated/undefined categories.
- Allocate respective Census year destination zone employment data to 2011 Mesh Block (MB) geographies based on land use category and spatial overlap (e.g. If a destination zone is comprised of two MB, one with a commercial land use and one with an industrial land use, then professional services jobs are largely allocated to the first MB, while manufacturing jobs are primarily allocated to the second).
- Recalibrate City of Melbourne using CLUE Block data for employment by industry.
- Align intermediate estimate with Victorian employment by industry control totals.
- Aggregate MB employment data to SALUP17 travel zone.

Key data sources
- DEDJTR/DAE Employment forecasts
- ABS Census 1996, 2001, 2006 and 2011
- ABS Labour Force Survey
- City of Melbourne: Clue Block employment data

SGS NEW EMPLOYMENT DEVELOPMENTS DATABASE

Conceptual approach
Various information on future employment trends at a micro (i.e. zone or lot level) were consolidated into a new employment development database. This includes information on the scale of development, type (i.e. industry), timing and likelihood.

This information was not taken as given in the analysis process, rather it was used to allocated future regional level demand and account for new local level supply opportunities. This is further discussed in the module descriptions.

Key data sources
- Urban Development Program 2016
- Data extracted from precinct structure plans for greenfield regions
- Data on urban renewal sites (e.g. Docklands, Fisherman's Bend, Arden, etc.)
- Consultation data (e.g. proposed hospital locations)
- Fisherman's Bend – Moderate Intervention Scenario

Detailed approach description

MODULE 1 AND 2 – SA3 EMPLOYMENT BY INDUSTRY FORECAST

Conceptual approach
Forecasts of employment by industry at an SA3 level are computed using a four-step approach. This segments the forecasting process into components which can synthesise the different types of information available.

Each industry is first allocated based on population growth, this varies based on the industries 'population serving' role (i.e. more growth allocated for retail less for manufacturing). The extent of this allocation was determined using historical (2001 – 2011) patterns of growth (i.e. additional jobs per new resident) and review of relevant research/literature.

Each industry is allocated based on the SGS New Employment Development Database which consolidates a wide range of small area development supply and policy data. These inputs represent changes to historical employment trends that cannot be forecast by a data-driven methodology. It captures future capacity opportunities for growth within an SA3, expected changes to infrastructure, and the spatial policy considerations of government.

Employment is then allocated base on a range of spatial drivers. The effect of each spatial driver is varied by industry. The three core spatial drivers used are:

- **Effective Job Density**, which measures how concentrated employment activity is in a location. This is a key driver for knowledge intensive sectors which gain benefits from diverse, well connected economic hubs;
- **Industrial land supply (existing and planned)**, which heavily influences the distribution of industrial sectors (e.g. manufacturing, wholesale trade). Agricultural land is also considered as part of this spatial indicator series; and
- **Existing employment** levels, distribution and historical trends (2001 – 2011).

Finally, the resulting forecasts were reviewed against several measures, and refined if required. Factors considered as part of this review included:

- Level growth by industry (as well as total employment) assessed against SA3 size (i.e. density thresholds);
- Industry growth rates assessed against historical trends and comparator regions,
- SA3 share of industry employment assessed against historical trend and comparator regions;
- Employment self-containment (i.e. ratio of employment to workforce) to ensure reasonable inter-regional flows; and
- Results were also mapped and a range of summaries produced to enable broader 'reasonableness' checks and

an understanding of the overall employment narrative.

Key assumptions

- Jobs per new resident is defined by historical rates observed from 2001 to 2011. For each industry, the ratio is chosen to be between the 50th and 70th.
- Various capacity thresholds were applied via the New Employment Developments Database and during the final review process.

Key data sources

- DEDJTR/DAE Employment forecasts (VIC)
- Historical employment dataset
- SGS: New Employment Development Database
- Results from Stage 1 and Stage 2

MODULE 3 – TRAVEL ZONE EMPLOYMENT BY INDUSTRY FORECAST

Conceptual approach

SA3 employment by industry is then further disaggregated to travel zone. The distribution is largely informed by the SGS New Employment Developments Database.

The 2011 distribution of employment by industry was also used to allocate SA3 employment to TZ. This represents a proportional intensification of existing employment centres consistent with recent trends where employment consolidates around existing nodes.

Finally, a detailed review of employment by industry was undertaken at both a district and travel zone level. This considers several measures, which include:

- Employment density
- Share of SA3 (or for TZ – Share of district)
- Growth rates assessed against comparator districts and zones
- Assessment against known background conditions (e.g. known infrastructure developments).

Adjustments based on this review process are then incorporated into the forecasts as necessary.

Key data sources

- Results from Module 1 and 2
- Historical employment dataset
- SGS: New Employment Development Database

MODULE 4 – TRAVEL ZONE EMPLOYMENT BY COLLAR FORECAST

Conceptual approach

Travel zone level employment is also disaggregated by occupation collar (i.e. white collar – low skill, white collar – high skill, blue collar). This is based on DEDJTR/DAE Victorian totals, seed values from the 2011 ABS Census and an IPF or RAS approach.

Key assumptions

- The relationship between industry and occupation remains largely static

Key data sources

- Results from Module 3

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