CITY OF MELBOURNE

Transport Strategy Refresh

Transport, Greenhouse Gas Emissions and Air Quality

Prepared by the Institute for Sensible Transport

April 2018

Executive Summary

The purpose of this report is to describe current trends in transport emissions, offer a critique of existing methods of calculating transport emissions and make suggestions for how transport outcomes can be aligned with the City of Melbourne's reduction targets.

The evidence reviewed for this report show that current transport emissions exceed the levels required to meet Australia's obligations under the Paris Climate Agreement. These emissions are forecast to increase under the existing policy context. *Sustained* and *unprecedented* action will be required to arrest and then reverse this trend.

The Australian Government has set the target of reducing emissions by 26 – 28% below 2005 levels by 2030. In reality, this will require per capita reductions of around 50%, given population projections.

At the City of Melbourne level, mode shift towards more sustainable transport has not reflected the City of Melbourne's carbon reduction ambition, and a continuation of current trends will result in the City of Melbourne not meeting its commitment to addressing climate change. Despite this, many of the City of Melbourne's policies and plans related to transport have the right strategic direction, but this has not yet been reflected in on-the-ground implementation of initiatives that reduce the use of carbon intensive transport.

The privately owned motor vehicle fleet has shown only modest fuel efficiency improvements over the last 40 years, from around 12 litres per 100km to around 10 litres per 100km. Whilst electric vehicles have made considerable improvement in recent years, a combination of factors, including low petrol price, limited government incentives, a lack of charging infrastructure and high purchase price have meant little uptake within the Australian vehicle fleet.

This report has also found that due to the carbon intensity of the Victorian electricity grid, in operational terms a Tesla Model S powered by Victorian electricity is estimated to be *dirtier* than many of the most popular petrol cars. This underlined a key finding of this report; greening the electricity grid will need to be a priority if the City of Melbourne (and Victoria) is to meet its emission reduction targets. Moreover, if households were to replace all fossil fuel powered cars with an electric vehicle, it is estimated this would increase electricity consumption by 84%, which may increase the lifespan of fossil fuel plants in order to the increase in energy demand.

The previous approach to the calculation of transport related GHG emissions was developed prior to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) standards and needs to be updated to align with this international standard. A number of suggested changes will help ensure future approaches are compliant and are more reflective of actual GHG emissions associated with the City of Melbourne. This report has provided an estimate of the vehicle kilometres travelled (VKT) and CO_2 emissions associated with different forms of land transport and compared our suggested approach with the previous method, as shown in the table below. The GHG accounting for transport emissions is described in more detail in Section 3.5.

Vehicle type	MELBOURNE LGA TRANSPORT GHG MODEL		Our estimate (GPC compliant)	
	VKT	CO_2 (Tonnes)	VKT	CO_2 (Tonnes)
Car	945,344,510	240,915		
Motorcycle	11,631,800	1,913		
LCV	121,392,955	36,949		
Sub-total	**1,078,369,265**	**279,777**	**1,287,590,836**	**313,914**
Light Rigid	36,129,017	21,550		
Heavy Rigid	9,365,867	7,161		
Articulated	105,557,861	159,714		
Buses	16,501,773	18,672		
Sub-total	**167,554,518**	**207,097**	**107,398,624**	**110,610**
Total	**1,245,923,783**	**486,874**	**1,394,989,460**	**424,524**

Comparing the previous and new approach to estimating on road transport GHG emissions

The material reviewed as part of this project reveal a disparity between climate change ambitions and transport emissions performance and trajectories. Whilst there has been a slight trend away from motor vehicle usage as a method of travel to and from the City of Melbourne, strong population growth has meant no substantial reductions in GHG emissions have been achieved. In fact, the Victorian trend is for *increased* car ownership (both in absolute and per capita terms), meaning that as Melbourne grows, so too will its private vehicle fleet. Although cars are driven slightly less per annum than in previous decades, there will still be a marked increase in vehicle kilometres travelled (VKT) across the metro Melbourne area as a result of these new vehicles and their subsequent use. Nationally, there has been a stagnation of total car related emissions for approximately the last decade. This is a result of changed driving behaviour and improved fuel efficiencies. Current trends in transport emissions mean Australia’s relatively modest emission reduction targets will not be met.

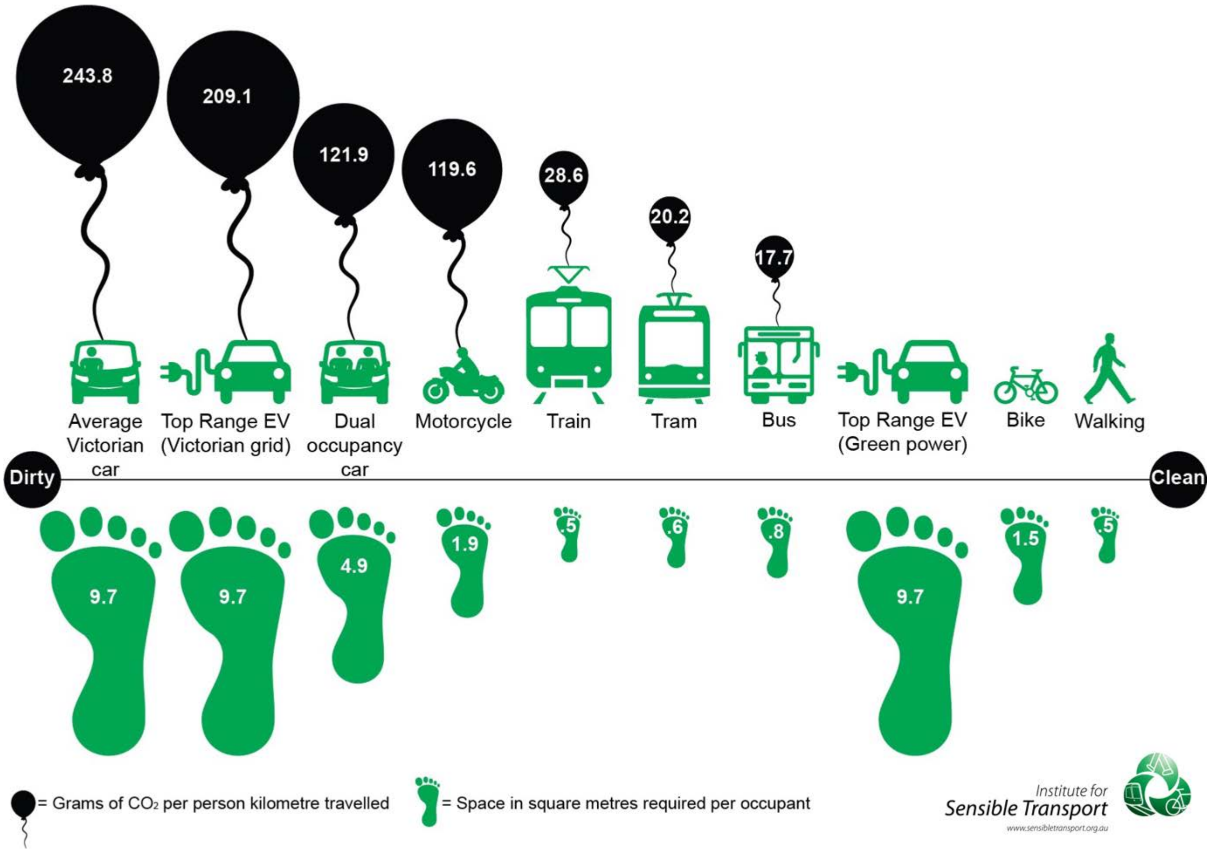
Major new road projects, such as the West Gate Tunnel and North-East Link, and a possible East-West Link, have the potential to radically increase VKT through the City of Melbourne. The behavioural consequences of these projects will be two-fold: firstly, they will add to the road carrying capacity, allowing tens of thousands more people to drive into and through Melbourne’s core; secondly, by causing reductions in travel time, even if marginal and temporary, they will further affect the urban landscape, encouraging and permitting a continuation of urban sprawl that Melbourne has been experiencing since the post-war period.

The challenge of reducing emissions in line with the Paris Agreement is exacerbated by projected population growth. *Plan Melbourne 2017-2050* envisions Melbourne growing to 7.9 million residents by 2050, and this will in turn increase visitors and workers into the City of Melbourne. Without improvements to the coverage and carrying capacity of the public transport network, many of these new visitors may be left with little option other than to travel by car.

Rapid advances in transport technologies open up new possibilities for shared mobility, reduced car use, and conversion to electric, autonomous vehicles. These developments, without changes to the policy, energy and transport landscape will exacerbate current problems (e.g. congestion and emissions). A new set of policy signals (e.g. network based road user pricing) will be required before these technologies will be able to achieve their potential in terms of emissions reduction and wider transport efficiency gains.

This report has detailed a number of case studies from three cities: San Francisco, Amsterdam and London. The overarching theme from these case studies is the effectiveness of road space reallocation decisions that re-orientate streets towards moving people using space and energy efficient means. The development of electric vehicle charging infrastructure was also a consistent feature, and Amsterdam demonstrated the importance on focusing on the vehicles that do the most driving (e.g. taxis) when rolling out charging programs for electric vehicles.

The evidence reviewed in this report reveal a disparity between current transport trends/emissions and the ambition of the City of Melbourne to reduce its contribution to climate change. The challenge of restructuring the transport system to bring about the reduction in emissions that will be necessary to meet current commitments cannot be overstated. This is a challenge for all three levels of government. As the cultural, economic and transport hub of Victoria, the City of Melbourne is in a uniquely powerful position to take a leadership role in achieving the deep cuts to transport emissions that are necessary. The figure below illustrates the stark contrast between *dirty* and *clean* transport modes and the *space* each mode consumes. This report has found that the dirtiest, and least space efficient modes of transport continue to receive the largest allocation of road space. The City of Melbourne's street network continues to reflect priorities from earlier generations. The City of Melbourne's strategic ambition to become a *connected, creative eco-city* will depend partly on the degree to which it can create the conditions in which walking, cycling and public transport thrive.



Emissions and space intensity, various modes

The street network within the City of Melbourne needs to reflect its ambition for a low emission future. Whilst recognition of the negative consequences of automobile dependence is well established, positive change has been slow, uneven, and at times, a reversal of past gains has occurred.

Strategic opportunities

There are four main areas of action necessary to successfully arrest and then reverse the growth in transport emissions, as shown below. Additionally, Appendix 1 provides an itemised list and rank of each action based on six criteria that broadly align with the City of Melbourne's strategic objectives.

Strategic policy directions to reduce transport emissions

1. *Road space reallocation* will involve a widening of footpaths and expanding and enhancing the cycling network and on-road public transport priority. It is inevitable that this will at times come at the expense of space previously allocated to private motor vehicles (either as a moving traffic lane or car parking). This report has identified several specific instances in which the City of Melbourne can evolve their street network to better support its strategic ambitions, including its emission reduction targets (e.g. see Section 6.3.2).
2. *Intersection priority for sustainable modes* includes recommendations to change intersections to better reflect the priorities of the City of Melbourne. A disproportionate number of crashes involving vulnerable (and sustainable) road users occur at intersections, and it is unlikely the City of Melbourne's safety or emissions targets will be met without substantial changes to intersection treatments, that favour pedestrians, cyclists and public transport users.
3. It is inevitable that the *way we pay for motor vehicle use* will need to change if we are to meet our emission targets, and maintain the productivity of a growing city. Moving towards a network based road user charge will provide the pricing signals necessary to help make smarter transport choices. This report has recommended the City of Melbourne take a leadership position on this issue, so that when the state government does introduce such a charge, the City of Melbourne is more likely to have their strategic priorities supported by its implementation. Moreover, this report has also recommended significant changes to car parking fees in the City of Melbourne (see Section 6.5.1).
4. *Low-emission vehicles* is something the City of Melbourne has limited capacity to change, but is still an essential element of a low carbon transport future. Lowering the emissions intensity of the Victorian electricity grid will be essential for electric vehicles to have their desired impact. The City of Melbourne's parking policy represents an area in which local government can have an influence on the uptake of

electric vehicles and the report makes a number of specific actions the City of Melbourne can take to boost electric vehicle uptake. Section 6.6 describes measures that can be taken to lower the emissions intensity of motorised vehicles, including public transport.

Future transport scenarios

To assist the City of Melbourne align its transport outcomes with their climate change ambition, three scenarios have been modelled. The scenarios are:

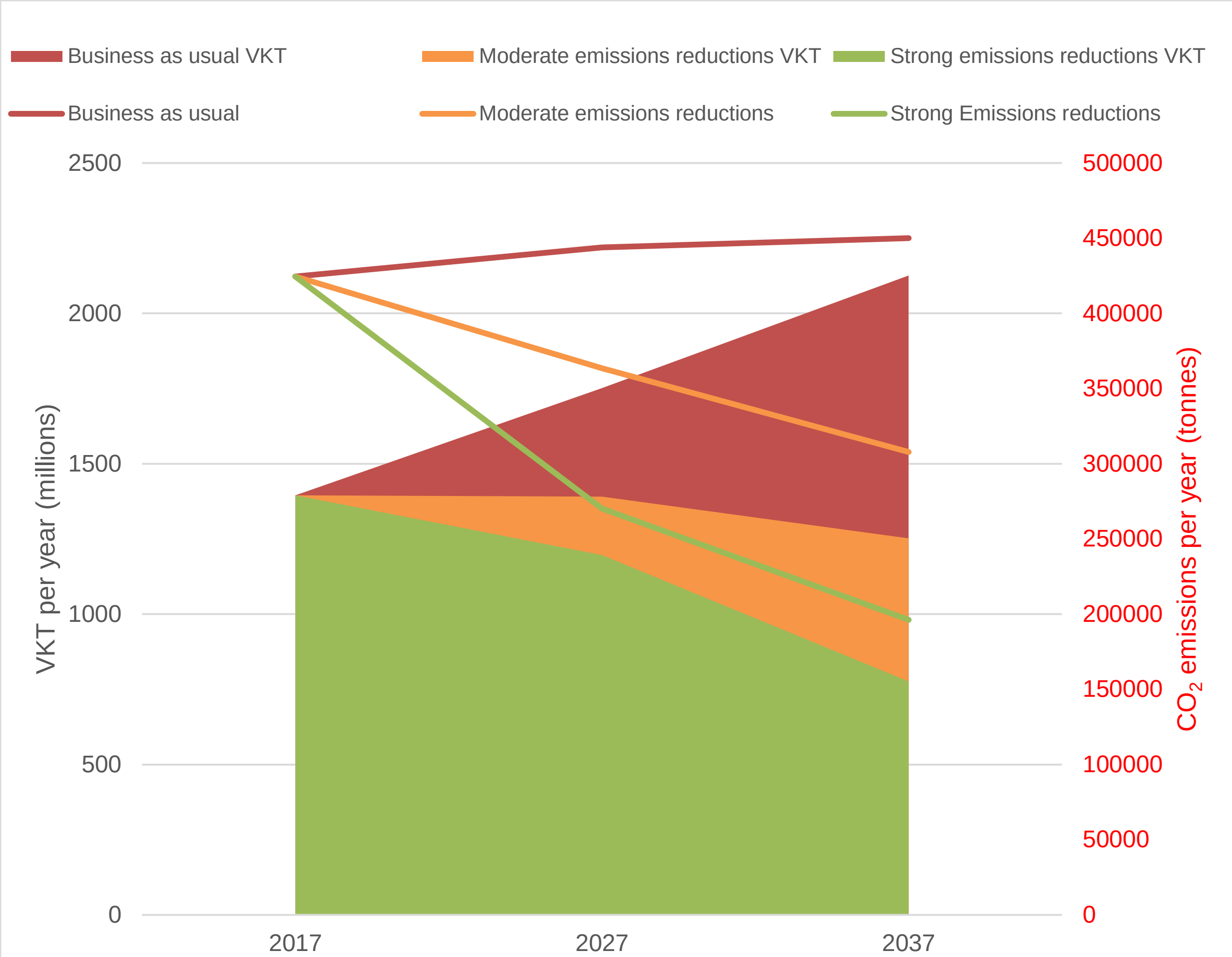
1. *Business as usual*, forecasting a continuation of current trends;
2. *Moderate emissions reduction*, forecasting a medium level of electric vehicle uptake and greater shifts away from private vehicles;
3. *Strong emissions reduction*, forecasts the City of Melbourne's existing mode shift targets being met and a higher uptake of electric vehicles.

All three assumptions have estimated Vehicle Kilometres Travelled (VKT) and GHG emissions for 2017, 2027 and 2037 for all on-road transport. The key assumptions underpinning the three modelled scenarios are shown in the table below and described in more detail in Section 7.1.

	Business as usual	Moderate emissions reduction	Strong emissions reduction
Electric vehicles fleet percentage in 2027	1.9%	5.3%	10.7%
Electric vehicles fleet percentage in 2037	5.6%	10.2%	24.7%
Electric vehicle energy source	Victorian electric grid average	Certified renewable power	Certified renewable power
Mode share	Continuation of mode shift trend observed in VISTA data	City of Melbourne target met in 2037	City of Melbourne target met in 2030 and trend continues to 2037
Private car mode share in 2027	32.4%	28%	23.7%
Private car mode share in 2037	28.7%	20%	11.2%
Fuel consumption of internal combustion engine (ICE) vehicle decrease	10% every ten years	20% every ten years	30% every ten years

Comparison of scenario assumptions

The figure below provides a comparison of the different scenarios, in terms of VKT per year (on the left hand side vertical axis) and CO_2 emissions per year (on the right hand side vertical axis). The implication of this modelling exercise for the City of Melbourne is that **only the *strong emissions reduction* scenario provides the level of CO_2 emission reduction necessary to meet its commitment to the Paris Agreement.**



Comparison of projected per capita GHG emissions and transport mode share in 2037

The *strong emissions reduction* scenario has a powerful impact on the per capita intensity of transport. Indeed, the reduction is 49% by 2027, consistent with the 50% by 2030 required to meet Australia's per capita reductions within the Paris Climate Accord.

The three scenarios can also be expressed in terms of per person emissions and mode share, as shown in the figure below.

Comparison of projected per capita GHG emissions and transport mode share in 2037

To achieve the outcomes modelled in the *strong emissions reduction* scenario, substantial changes in road space allocation, towards more space and emissions efficient modes are necessary. The mode shift changes that are required in this scenario require a transformation in road space allocation, to provide the priority for walking, cycling and public transport to encourage a substantial increase in the use of these modes. As identified by the IPCC at the beginning of this report, it is clear that *'aggressive and sustained'* mitigation options will be required for the City of Melbourne to have a reasonable chance of meeting its emission reduction targets.

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1. Background

The City of Melbourne is currently in the process of refreshing its *Transport Strategy* and *Zero Net Emissions Strategy*. These are major initiatives identified in the 2017-18 City of Melbourne *Annual Plan*. The refreshed strategies support the City of Melbourne's long-term vision for a *"sustainable, inventive and inclusive city that is vibrant and flourishing"* as defined in Future Melbourne 2026. The overall purpose of this report is to identify the long-term strategic opportunities to bring transport related greenhouse gas emissions in the City of Melbourne to within their reduction targets.

The next 10 – 30 years is widely acknowledged to be a period of profound disruption in the transport sector. Creating the right set of policy tools to ensure these technological changes serve to reduce our emissions and respond to climate change, whilst accommodating growth as a city will be the key challenge. It is difficult to overstate the magnitude of this task. Meeting this challenge will require bold innovations, unconstrained by conventional traffic engineering practices alone.

This research project is focused on offering options to enable the City of Melbourne to grow sustainability, to meet its emission targets, and strengthen its position as the economic hub of Melbourne.

2. Transport and Emissions: Strategic policy context

2.1. International

2.1.1. Intergovernmental Panel on Climate Change (IPCC)

2.1.1.1. Understanding the scale of the challenge

The Intergovernmental Panel on Climate Change (IPCC) notes in its 2014 report that:

> '*Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gas emissions are the highest in history. Recent climate changes have had widespread impacts on human and natural systems'* (Intergovernmental Panel on Climate Change, 2014).

The Panel found that the last 30 years have become successively hotter, in terms of the Earth's surface temperature than any decade since 1850. Indeed, it is probable that, in the Northern Hemisphere, the period between 1983 and 2012 was the hottest 30-year period in the last 1,400 years. Combined land and ocean temperatures have also shown a warming trend (Intergovernmental Panel on Climate Change, 2014).

Human caused greenhouse gas (GHG) emissions have risen by around 10GtCO_2e in the ten years from 2000. Transport was responsible for 11% of this increase (Intergovernmental Panel on Climate Change, 2014). As of 2010, 14% of global GHG emissions was attributable to the transport sector. The challenge, identified by the IPCC, will be to limit CO_2e concentrations to around 450ppm, in order to make it likely that warming might be limited to 2^oC above pre-industrial levels.

The IPCC report notes that mitigation options are most effective when adopting an integrated approach that combines reductions in each of; energy use, GHG intensity, and lowering of carbon based energy sources. This is closely aligned with the City of Melbourne's policy positions, which will be described in later sections of this report.

2.1.1.2. IPCC Transport Chapter

The IPCC discussion on the transport aspects of climate change are dealt with in a dedicated IPCC chapter (see Sims et al., 2014). The key points of relevance for this report are captured in the following points:

- Continued growth in passenger and freight transport could make reducing emissions difficult, even with the implementation of mitigation measures. De-coupling the trend in use of transport from Gross Domestic Product (GDP) growth will be necessary to meet emission reduction targets for transport.
- Transport was responsible for 23% of total *energy-related* CO_2 emissions (6.7GtCO_2).
- Despite improvements in vehicle fuel efficiency, transport emissions continue to increase.
- It is forecast that without the implementation of *aggressive* and *sustained* mitigation policies, transport emissions may rise faster than other sectors, reaching around 12 GtCO_2 by 2015.
- Pricing and other stringent measures are necessary to arrest the forecast growth in transport emissions.
- Reducing the number of vehicle trips, and mode shifts away from car use towards sustainable travel (e.g. walking, cycling and public transport), in combination with vehicle fuel efficiency gains are highlighted as offering high mitigation potential.

The magnitude of the growth in transport related emissions contained in the IPCC report is shown in Figure 1. Road transport now accounts for 72% of all transport emissions (as of 2010) and has risen substantially since 1970, in both absolute and proportional terms. This is highly significant for the City of Melbourne, which arguably has more influence over road transport than it does other areas of transport (e.g. aviation, shipping, rail).

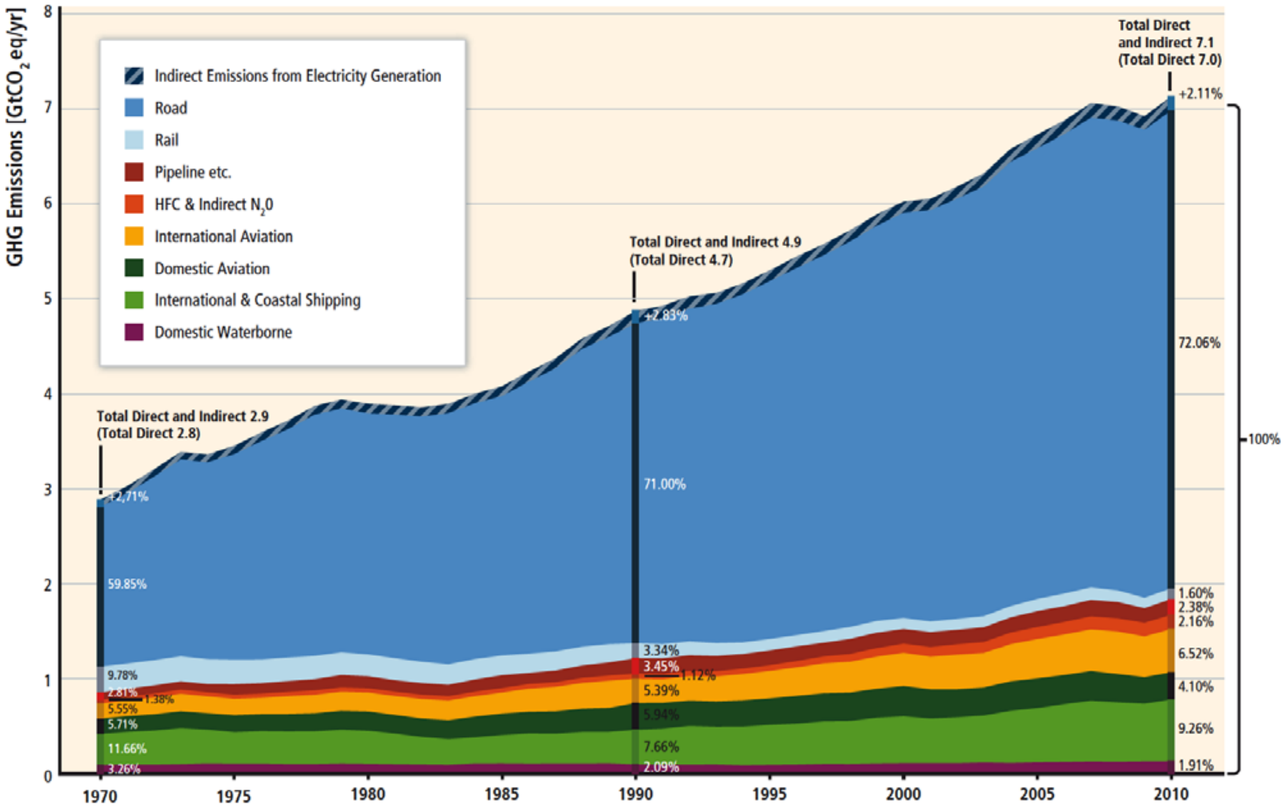

Figure 1 Global direct GHG emissions of the transport sector
Source: IPCC (Sims et al., 2014, p. 606, Figure 8.1)

2.1.1.1. Transport and global equity

The disparity in transport emissions between countries based on their wealth is highlighted by the IPCC (Sims et al., 2014). In particular, it notes that some 10% of the global population contributes to 80% of total motorised passenger kilometres. This is especially relevant to Greater Melbourne, which is both wealthy (in global terms) and has high rates of car use, *and* relatively high average trip distances. From a carbon budget perspective, Melburnians' transport related carbon emissions are substantially higher than the global average. It may also mean that as low-income countries are likely to see a rise in their annual emissions over coming years, a sharp decline in the per person transport emissions from developed countries (including Australia) will need to occur if the emission targets set out in the Paris Agreement (see below) be achieved.

Policy options for reducing transport related GHG emissions included within the IPCC's report (Sims et al., 2014, p. 603) are:

- *avoiding journeys where possible* — by, for example, densifying urban landscapes, sourcing localised products, internet shopping as a replacement for car journeys, restructuring freight logistics systems, and utilising advanced information and communication technologies (ICT);
- *modal shift to lower-carbon transport systems* — encouraged by increasing investment in public transport, walking and cycling infrastructure, and modifying roads, airports, ports, and railways to become more attractive for users and minimise travel time and distance;
- *lowering energy intensity* (MJ / passenger km or MJ / tonne km) — by enhancing vehicle and engine performance, using lightweight materials, increasing freight load factors and passenger occupancy rates, deploying new technologies such as electric 3-wheelers;
- *reducing carbon intensity of fuels* (CO_2e / MJ) — by substituting oil based products with natural gas, bio-methane, or biofuels, electricity or hydrogen produced from low GHG sources.

In the medium to long term (up to 2030), to long term (to 2050) it is suggested by Sims et al. (2014) that GHG intensity could be reduced by 20 – 50% (from 2010 baseline levels) through:

- integrating transport and land use planning, to densify urban development along new or existing sustainable mobility corridors
- creating an urban form that supports enhanced opportunities for walking and cycling
- widespread construction of high speed rail to curb the growth in aircraft travel.

The barriers to reducing transport emissions are said to include a combination of financial, institutional, cultural and legal issues. One barrier identified was the lack of an effective price on carbon. For city and national governments, the IPCC suggests barriers to climate friendly transport can be overcome by incentivising alternatives to emissions intensive transport modes, which are noted as having co-benefits related to health and accessibility. The IPCC identified that a road user price and airport usage charges may provide the necessary pricing signals to reduce transport emissions.

The IPCC report argues that *'decarbonising the transport sector is likely to be more challenging than for other sectors, given the continuing growth in global demand, the rapid increase in demand for faster transport modes in developing and emerging economies, and the lack of progress to date slowing growth of global transport emissions in many OECD countries'* (Sims et al., 2014, p. 604). Consistent with the general thrust threaded throughout the transport related policies of the City of Melbourne, the IPCC note that many of the non-climate policies associated with transport objectives (reduce congestion, improve liveability, and road safety) also have climate co-benefits, and can therefore be efficiently pursued together.

The challenges for reducing freight emissions are no less significant than for passenger transport. The IPCC report identifies that it is inevitable that demand will increase and, due to the slow turnover of the vehicle fleet, progress will be slow. The implementation of stringent policies and new technologies will be required to assist in bringing freight emissions down from their current levels.

2.1.1. Paris Agreement (2015)

Strengthening the global response to the threat of climate change is the key objective of the Paris Agreement. It aims to keep the global temperature rise this century to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius (United Nations, 2015). Australia is a signatory to the Paris Agreement and this commits Australia to set mitigation targets from 2020, scheduled to be reviewed every five years. The Australian Government has set the target of reducing emissions by 26 – 28% below 2005 levels by 2030.

2.2. Australian

2.2.1. National emission standards and trends

Australia has had national vehicle emission standards in place over the last four decades and wherever possible, the intention is to align these standards with those developed by the United Nations (Department of Infrastructure and Regional Development, 2017). Minimum standards are:

- New light vehicles in Australia: ADR 79/04 (based on the Euro 5 standards), adopted in November 2016
- New heavy vehicles: ADR 80/03 (based on the Euro V standards).

The emission standards are primarily focused on air quality, rather than climate change (Mortimore, 2015)

In the EU, the Euro 5 standard came into effect in 2001 and from mid-2015, all new vehicles sold within the EU must meet Euro 6 standard (Mortimore, 2015). At the time of writing, a *Ministerial Forum on Vehicle Emissions* is reviewing whether Australia should update its standards to Euro 6 for light vehicles and Euro VI for heavy vehicles.

2.3. Victorian

2.3.1. Transport Integration Act (2010)

The *Transport Integration Act* is the primary transport statute for Victoria. Its purpose is to create a new framework for the provision of an integrated and sustainable transport system.

The Act forms an overarching legislative framework for transport related state planning policies and has been integrated within the Victoria Planning Provisions (VPP). Under the Act, Council is defined as an 'interface body', and the Local Government Act has been updated accordingly to ensure that Council considers the Act in all decisions that may impact on transport and land use planning.

The Transport Integration Act includes specific consideration of sustainability and transport emissions. One *objective*, titled *Environmental sustainability*, details that (Victorian Government, 2010):

The transport system should actively contribute to environmental sustainability by:

4. *protecting, conserving and improving the natural environment;*
5. *avoiding, minimising and offsetting harm to the local and global environment, including through transport-related emissions and pollutants and the loss of biodiversity;*
6. *promoting forms of transport and the use of forms of energy and transport technologies which have the least impact on the natural environment and reduce the overall contribution of transport-related greenhouse gas emissions;*
7. *improving the environmental performance of all forms of transport and the forms of energy used in transport;*
8. *preparing for and adapting to the challenges presented by climate change.*

2.3.2. Climate change legislation

The *Climate Change Act (2010)* has a number of purposes, but the overarching one is to combat climate change by reducing greenhouse gas emissions. While there is little in the way of direct implications for transport, given that transport accounts for a significant proportion of Victoria's emissions, reforms in the transport sector will be necessary in order to meet the objectives of the Act.

2.3.3. Climate change policies

2.3.3.1. Vehicle emission standards

The Environment Protection (Vehicle Emissions) Regulations were updated in 2013 and aim to minimise the negative impact from motor vehicles. These regulations cover noise and air emissions. One of the points that differentiate the new 2013 regulations from the 2003 regulations relates to the inclusion of so-called 'smoky vehicles'. By including a hydrocarbon emissions standard, the 2013 regulation is better able to address the issue of heavily polluting vehicles (Environment Protection Authority, 2016).

The EPA does not currently regard climate change as a central component of its work and therefore greenhouse gas mitigation strategies from transport is not a focus of the EPA's work at this time.

2.4. City of Melbourne

2.4.1. Transport Strategy 2012

The City of Melbourne's 2012 *Transport Strategy* outlines a set of directions broadly supportive of the ambition to reduce transport related emissions. The six key directions are (City of Melbourne, 2012a):

- Integrate transport and land use planning.
- Go anywhere, anytime public transport for inner Melbourne.
- Support public transport, walking and cycling as the dominant modes of transport in inner Melbourne.
- Develop high-mobility pedestrian and public transport streets in the central city.
- Make Melbourne a cycling city.
- Foster innovative, low-impact freight and delivery in central Melbourne.

Although emissions reduction is not explicit in the above directions, the above directions provide a very clear indication that the City of Melbourne is prepared to make the necessary changes to create a city that prioritises low emission forms of transport. Figure 2 illustrates the mode split target set out in the 2012 Transport Strategy. The share of private car trips is targeted to drop from 39% (833,729 people) in 2009, to only 20% in 2030 (667,844 people). This represents a very significant challenge, but one that will need to be met in order to meet the City of Melbourne's current commitment to become carbon neutral.

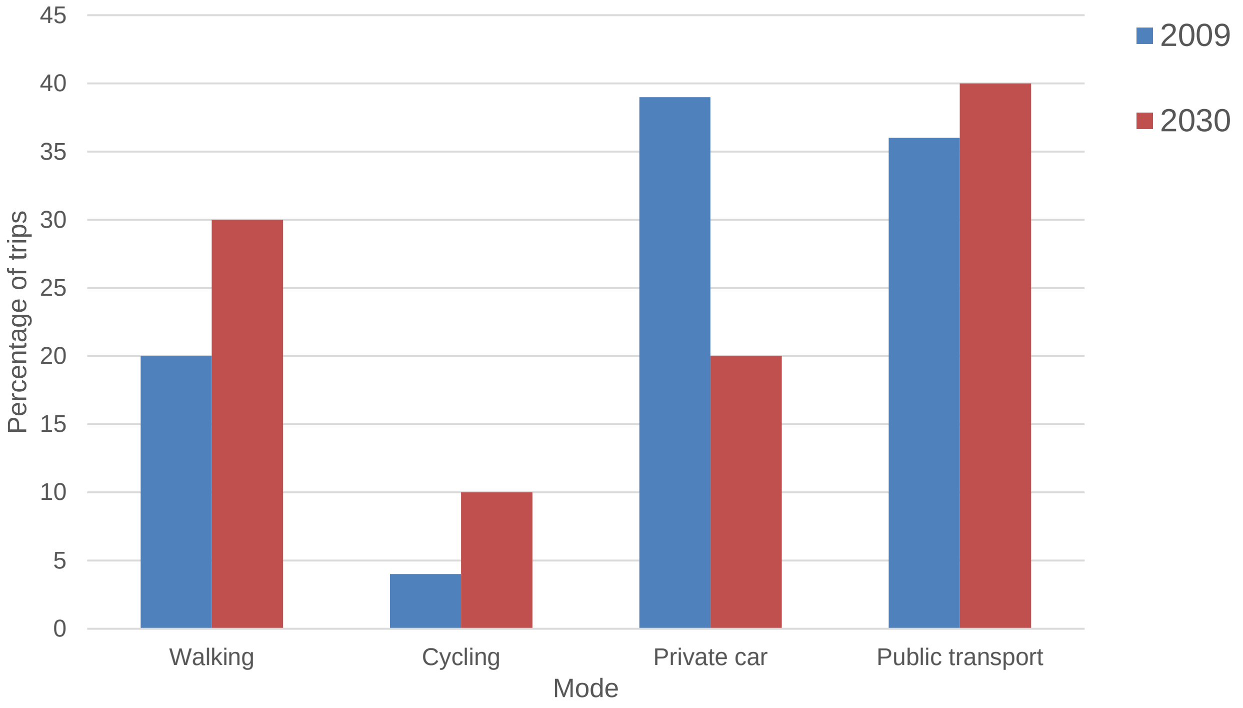

Figure 2 Percentage of trips by mode, weekday 2009 and 2030
NB: The figures shown in Figure 2 include those *to*, *within* and *from* the City of Melbourne.
Source: Taken from Figure 1.3 of the City of Melbourne's Transport Strategy (2012a)

A small selection of the policy targets set out in the 2012 Transport Strategy of relevance to the lowering of transport emissions include:

- Increasing the provision of off-street bicycle parking, creating 30 on-street bicycle parking corrals and creating two separated north/south and east/west routes in the Hoddle Grid.
- Pedestrian priority at traffic signals for all key intersections in the Central City and reduce pedestrian fatalities and major trauma by 25%.
- Create a minimum of 300 on-street car share spaces and reduce speeds to 40km/h in central Melbourne.
- Expanding the public transport network through the Melbourne Metro and Regional Rail Link. Peak hour frequency of train services is increased by 50% (from 115 services during 2012).
- Average tram speeds increased by 20% and frequency minimums of 10 minutes across the network.

- Bus travel times are reduced by 30% through improvements in Queen Street and Lonsdale Street.

The key directions of the Transport Strategy are broadly consistent with a reduction in transport emissions, as illustrated by the policy targets offered above. A section of the Strategy outlines the relationship between transport and environmental sustainability. This includes direct discussion of *transport emissions* and *greenhouse gas emissions*. The Strategy references the *Victorian Transport Integration Act (2010),* indicating the Act's requirement that the '*transport system actively contribute to environmental sustainability by protecting the natural environment, minimising harm to the broader environmental, promoting more sustainable modes of transport and improving the environmental performance of all modes of transport'* (City of Melbourne, 2012a, p. 25). The following directions, also from the 2012 Transport Strategy, offer opportunities for reducing transport emissions:

- Reducing travel distances
- Increasing the use of environmentally sustainable transport
- Ensuring all forms of transport are more resource efficient and environmental friendly.

The need to bring transport emissions in line with the City of Melbourne's commitment to *Zero Net Emissions by 2020* is identified in the Transport Strategy, including the fact that 20% of total GHG emissions (in 2005-06) are from transport. This is expected to rise to 61% by 2020. Private cars are the major contributor to these emissions (50% of all transport emissions). In terms of what is within the control of the City of Melbourne, the Transport Strategy specifically recognises that *'policies and action to facilitate a mode shift away from cars to public transport, cycling and pedestrian options'* present opportunities to reduce emissions (City of Melbourne, 2012a, p. 25).

A brief discussion of a carbon price and transport was included in the Transport Strategy, though since 2012, the federal government has moved away from pricing carbon. Petrol was excluded from the *Clean Energy Future Plan* in any case. The role of electric vehicles is also detailed within the Transport Strategy. It was predicted (correctly) that electric vehicles will become more common over the 20 years to 2032, which is supported by a recent report on the electric vehicle market in Australia (ClimateWorks Australia, 2017). While there has indeed been a trend towards electric vehicles, Australia has not adopted electric vehicles at the same rate as many other OECD countries. This will be discussed in Sections 4, 6 and 7. On a cautionary note, the Transport Strategy makes the important point that whilst electric vehicles do hold benefits in terms of local air and noise pollution, they do not change many of the underlying negative impacts of car use (e.g. congestion, road safety). Moreover, as long as the Victorian electricity supply remains reliant on burning brown coal, the climate change reduction potential of electric vehicles is contested.

The impact of air quality on human health is also identified within the Transport Strategy. Motor vehicles, it is pointed out, are the major source of particulates, nitrogen oxides and volatile organic compounds (VOC).

2.4.2. Last Kilometre Freight Plan

The *Last Kilometre Freight Plan* (City of Melbourne, 2016b) was developed to improve the efficiency of the freight task, in order to improve the productivity, liveability and sustainability of Melbourne. The Plan identifies that there are more than 10,300 delivery vehicles entering the central city on an average weekday and that the number of workers and businesses in the central city area has grown rapidly in the last decade to 2015.

A selection of key directions within the Freight Plan are shown below (City of Melbourne, 2016b):

- Establishing current and future freight needs in local area plans.
- Considering the impact of public transport infrastructure and network changes on the function of freight.
- Encouraging freight innovations amongst local businesses and delivery industry.
- Supporting and adapting to new innovations, sharing information and maintaining clear lines of communication with our stakeholders.

- Regulating building and street design to support efficient servicing and delivery.

The role of cargo bikes is highlighted as an opportunity to boost the environmental performance of the last kilometre freight task. They are considered particularly suitable to dense inner-city environments as they require less space and are easier to park than a larger vehicle (e.g. truck). Improvements to e-bike technology has meant that heavier loads can be carried by cargo bike and so they have become a practical alternative to trucks for a wider range of freight tasks. The Plan identifies that a number of pilot projects will be funded by the City of Melbourne in order to foster freight innovation. Another Action within the Last Kilometre Freight Plan (City of Melbourne, 2016b) of relevance to emissions reduction is the investigation of enhancing cycling infrastructure to encourage more freight tasks to be undertaken by cargo bike. Finally, using the Queen Victoria Market redevelopment as an opportunity to create a low impact vehicle freight hub might also assist in reducing the use of greenhouse emitting vehicles to deliver last kilometre freight.

2.4.1. C40

The City of Melbourne is part of the C40 network of 85 global cities that have come together in an effort to tackle climate change. The C40 cities share knowledge and constructive competition towards the goal of reducing GHG emissions, at a faster rate and lower cost than would be possible if they were working independently.

2.4.2. Zero Net Emissions by 2020

Zero Net Emissions by 2020 was updated in 2014 and is the City of Melbourne's strategy to become carbon neutral. One of the focus areas of this Strategy is *transport and freight* and includes a target to *'increase the percentage of all trips using low emissions transport from 51% in 2009 to 60% in 2018'* (City of Melbourne, 2014b, p. 4).

Transport emissions are included in Table 1, and show a significant growth in 2012/13, compared to previous years.

Table 1 Measuring progress

Municipality of Melbourne's Greenhouse gas emissions profile					
Carbon footprint (kt CO_2-e) Carbon dioxide equivalent	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**2012/13**
Water (residential)	11	11	11	10	11
Water (non-residential)	33	35	32	31	35
Electricity (residential)	316	521	448	262	292
Electricity (non-residential)	3,202	2,144	1,908	3,462	4,153
Gas (residential)	73	69	78	78**	78**
Gas (non-residential)	251	241	262	262**	262**
Residential waste	26	27	30	30	31
Industrial waste	107*	107*	107*	107*	107*
Transport	923*	923*	923*	923*	1,025
Total	**4,943**	**4,079**	**3,799**	**5,164**	**5,994**

* Once-off audit to obtain average annual estimate
** 2010/11 data used as updated data was not available at time of printing

Source: Taken from City of Melbourne (2014b, p. 12)

The cost and abatement potential of different categories are outlined in the *Zero Net Emissions 2014 Update* and show that *'shifting to more efficient vehicles'* is among the most cost-effective measure to reduce emissions (on a $/t$CO_2$-e basis). Train fleet efficiency improvements are also listed, but no other transport initiatives are identified. It is unclear whether *'shifting to more efficient vehicles'* includes transfers from car to bicycle, but the symbol of a car included in the graphic suggests it does not.

In terms of the City of Melbourne's corporate GHG inventory, transport emissions account for only 3% of overall emissions. In an effort to reduce this, the Zero Net Emissions Strategy provides some measures that can be taken at the corporate travel level to lower emissions. These options include (City of Melbourne, 2014b, p. 16):

- Investigate procuring vehicles run on new and emerging sustainable technologies.
- Work with the Victorian Government on its electric vehicle trial by using electric vehicles in Council's fleet and assessing their performance.
- Investigate opportunities to install renewable energy technologies for recharging Council's electric vehicles.
- Encourage greater take-up of electric and low emission transport through staff engagement and education.

A section of the Zero Net Emissions Strategy is dedicated to *Transport and Freight* and its overarching goal is to reduce the number of car trips and increase the role of walking, cycling and public transport for inner urban travel. This section highlights the current level of emissions by different modes of motorised transport, as shown in Figure 3. Whilst the data source and method of collection is not stated, it would appear to include emissions produced *to, from and within* the municipality itself for motor vehicles. However, for train and tram it appears to include all emissions produced by the entire metro wide Metro Trains Melbourne and Yarra Trams networks. This would explain why *train* is relatively high (48% of total emissions), compared to 30% for cars. This issue is explored further in Section 3. It would also be interesting to express this data as *per person* emissions from different modes of transport.

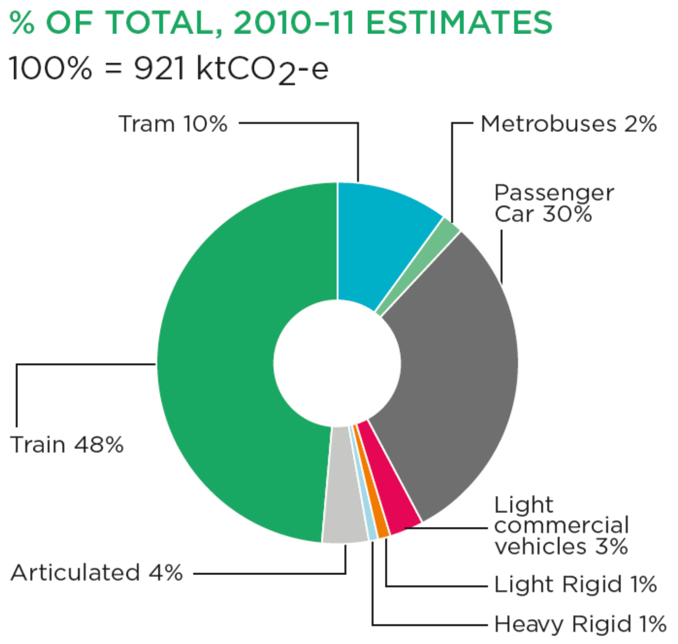

Figure 3 Breakdown of emissions by mode
NB: 100% = 921 ktCO_2-e

The Strategy's proposed approach to reduce emissions are summarised in the following points:

- Use 'green asphalt' and investigate additional options for reducing the greenhouse impact of infrastructure development.

- Prioritise pedestrians across the central city.
- Implement the *Bike Plan 2012 – 2016* by continuing to enhance the bicycle infrastructure network, including fully separated routes.
- Prepare a Walking Plan (this has now been completed).
- Increase the efficiency of freight.
- Implement behaviour change programs to assist people in making more efficient transport decisions, including shared vehicle initiatives.
- Conduct research to better quantify and understand transport emissions and develop an evidence base of effective measures to reduce these emissions.
- Lead by example, by enhancing the environmental performance of the corporate vehicle fleet.

2.5. Conclusions

The set of City of Melbourne Plans and Strategies provide a clear, consistent policy direction; there is an overwhelming recognition of the need to reduce car use and increase the role walking, cycling and public transport play in central Melbourne. When motor vehicle use is necessary, the adoption of low emission technology will become increasingly important. Each of the City of Melbourne policy documents reviewed here have highlighted the productivity, liveability and sustainability benefits of a substantial shift towards a city that prioritises people walking, cycling and using public transport.

3. Transport and Climate Change: Defining the problem

3.1. Introduction

Transport emissions have been rising steadily over the past 40 years in Australia, including in Melbourne. While there has been a growth in the number of people using sustainable transport in the last 15 years, use of private motorised transport has also continued to grow, and only minor efficiency gains have been realised in the vehicle fleet. These trends have led to an overall growth in emissions from transport, including car, freight and aviation. This section describes transport's contribution to emissions, travel behaviour and vehicle fuel efficiency, using a range of national and Victorian data. This section also provides a critique of the current approach to calculating transport related GHG emissions and our suggested approach to produce a realistic picture of transport emissions in the City of Melbourne.

3.2. BITRE Yearbook

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) Yearbook 2016 (Department of Infrastructure and Regional Development, 2016) provides detailed statistics on Australian transport trends. These include passenger and freight movements, car fleet trends, fuel usage and GHG emissions. A summary of these statistics is provided in Figure 4.

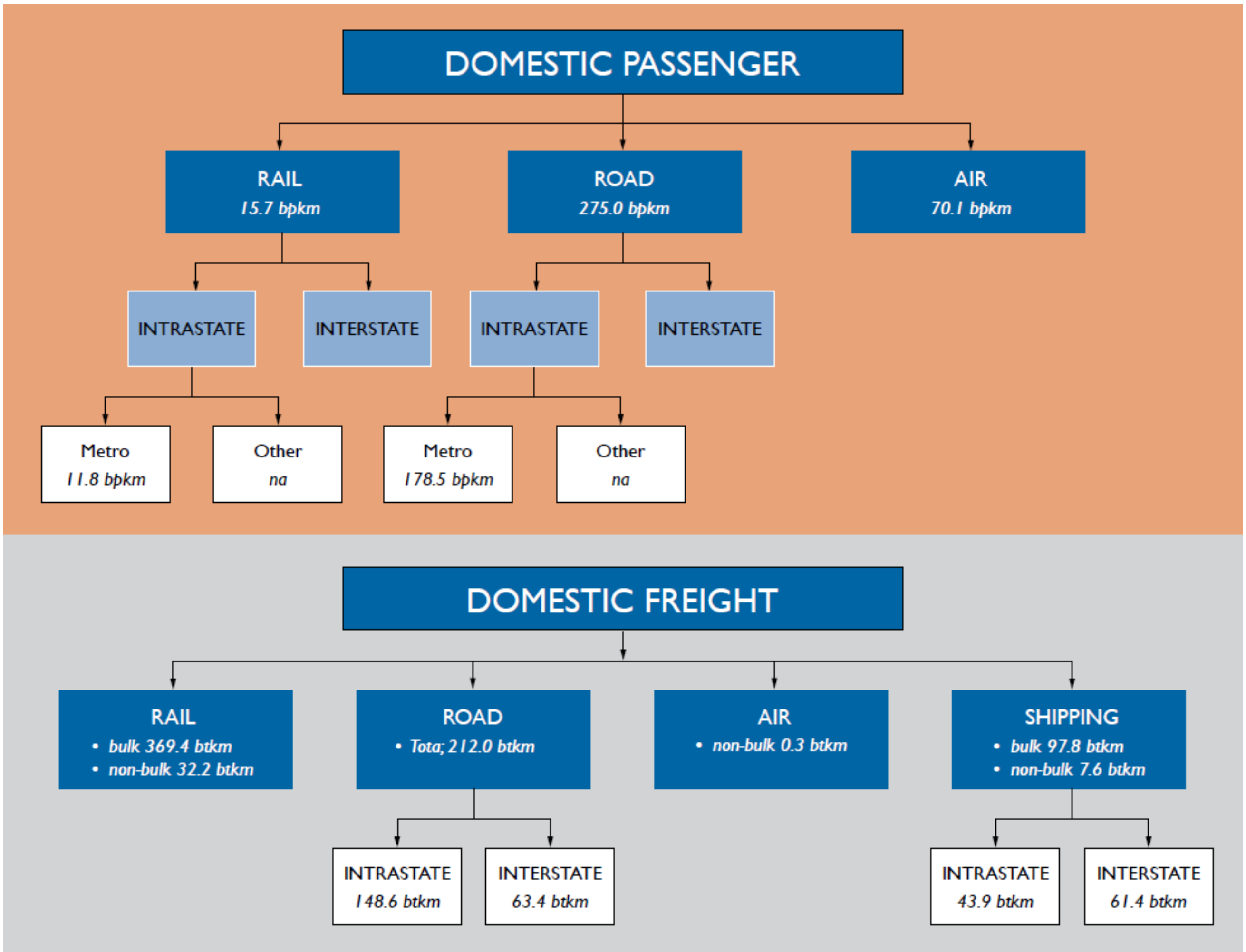

Figure 4 BITRE Yearbook, 2016
Source: Department of Infrastructure and Regional Development (2016)

The BITRE Yearbook data makes it clear that the overwhelming majority of passenger kilometres in the 2014-15 year were by road, as illustrated in Figure 5. Well over three quarters of passenger kilometres were by road. Of relevance to the City of Melbourne, the BITRE Yearbook notes that the overwhelming majority of both rail and road passenger kilometres were in metropolitan areas. Most domestic freight, by weight, is carried by rail, however, the Yearbook notes that a large increase in rail freight traffic in recent years is largely due to the mining boom, and that coastal freight (shipping) has been decreasing since 2006-07 (Department of Infrastructure and Regional Development, 2016).

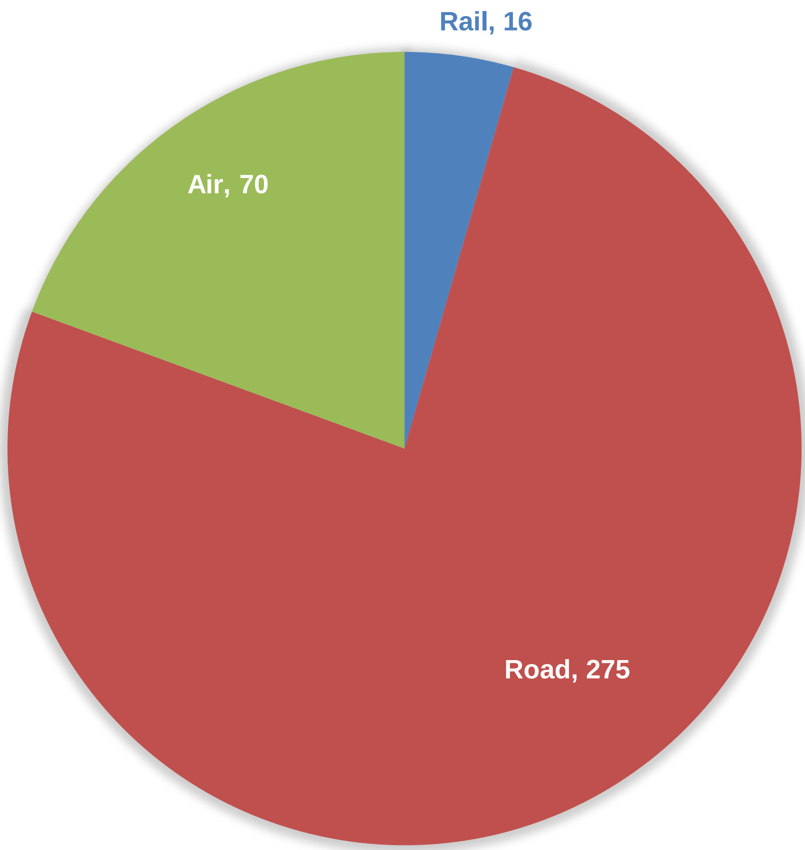

Figure 5 Billion passenger kilometres by mode, Australia
Source: Department of Infrastructure and Regional Development (2016)

The Yearbook catalogues transport infrastructure investment from 1986-87 to 2015-16. Over that period, $53.5 billion has been invested in railways, while $236.5 billion has been invested into roads. Mobility in Australia is highly dependent on road based motorised transport and this dependence has been created, in large part, by the funding imbalance that has seen roads receive over four times the investment that rail has over the last 30 years. Notwithstanding this imbalance, there has been a marked increase in investment in rail infrastructure since 1999.

Victoria has 36,417km of urban roads and 109,320km of non-urban roads. A breakdown of Victorian road-related expenditure, by government level, is shown in Figure 6. Local governments are major contributors towards road expenditure in Victoria, accounting for approximately one third of total expenditure.

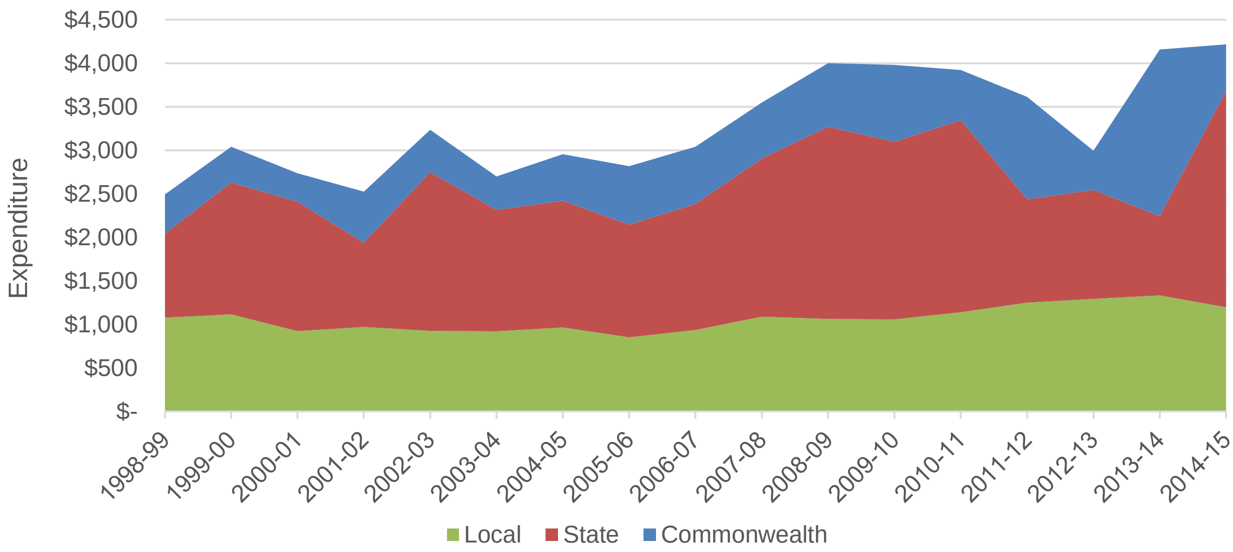

Figure 6 Victorian road-related expenditure by government level
Source: Department of Infrastructure and Regional Development (2016)

Fuel consumption has direct implications for transport emissions. Fuel excise payments can be used as a measure of fuel consumption. Fuel excise payments to the Commonwealth peaked in 2012-13 at $17.6b for petrol and have been declining slightly since. The revenue to the Commonwealth is not inconsiderable and may act as an incentive to continue road spending investment. The continued shift towards more efficient vehicles, and in the future, electric vehicles, will further reduce this revenue stream.

3.2.1.1. Freight

Since 1972-73 there has been a large increase in interstate freight movements in Victoria (measured as tonne–kilometres). Figure 7 shows this trend, segmented by mode. Much of this increase has been road based transport, with both rail and shipping being reasonably flat over the period. A notable exception is a large increase in rail freight traffic post 2006. While BITRE offer no explanation, increased fuel prices may be a contributing factor. Intrastate freight in Victoria has also increased, however, this is almost entirely road based, with there being virtually no intrastate rail or shipping freight tonne kilometres.

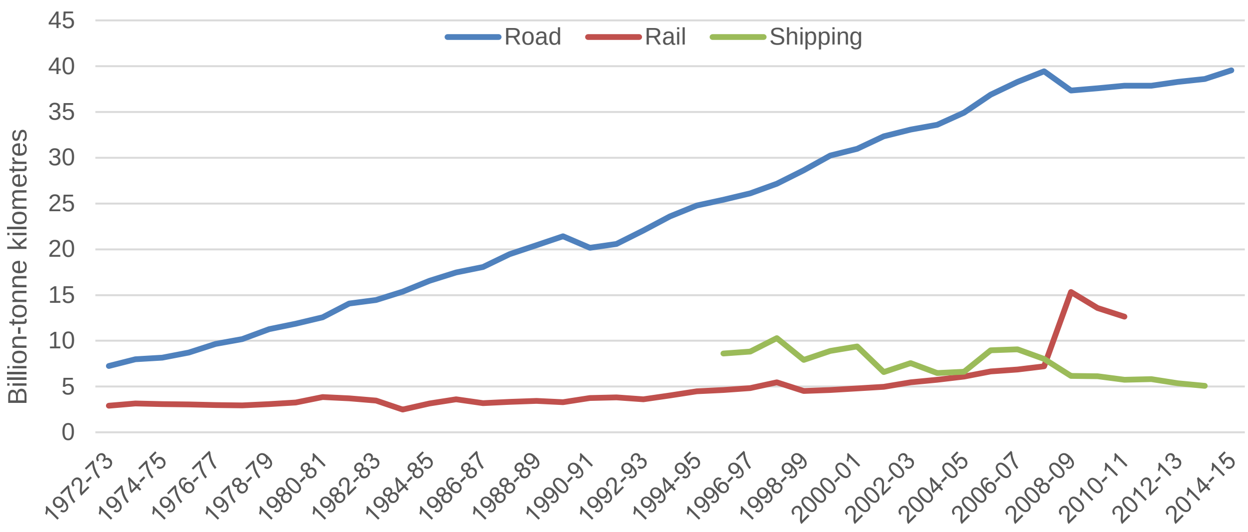

Figure 7 Domestic freight in Victoria (billion tonne kilometres)
Source: Department of Infrastructure and Regional Development (2016)

3.2.1.2. Passenger travel in Greater Melbourne

Total passenger kilometres travelled in Melbourne has almost doubled in the period from 1976-77 to 2014-15. Figure 8 shows this change, segmented by mode type.

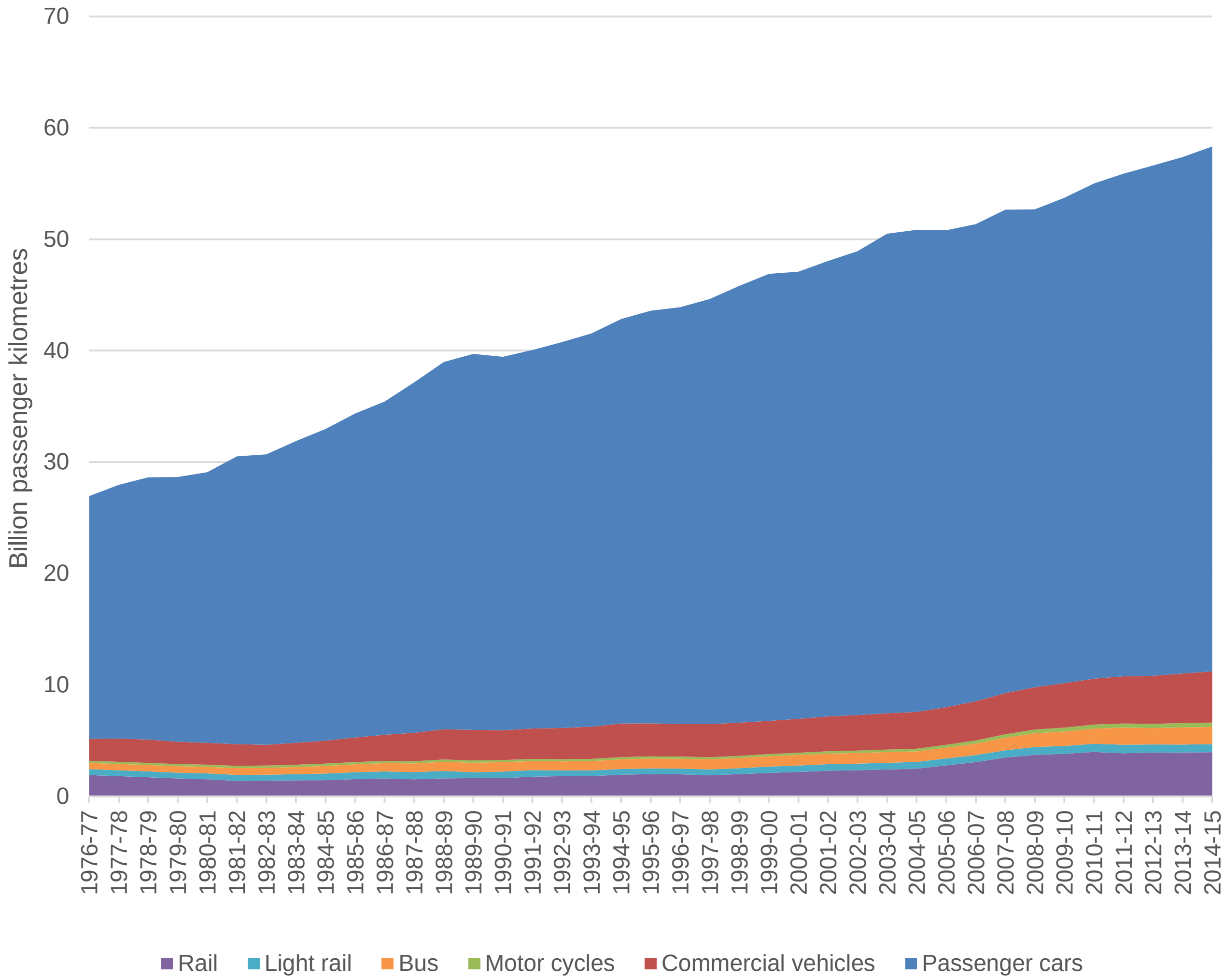

Figure 8 Total passenger kilometres travelled in Melbourne
Source: Department of Infrastructure and Regional Development (2016)

While there has been a large increase in travel on most of the modes shown in Figure 8, the *proportion* of kilometres by car declined marginally since 2005 (see Figure 9). Public transport usage declined from 1976 until the mid-1990s, but has seen growth in recent years, with billion person kilometres almost doubling and mode share increasing from 7.4% to 10.7% from 1997-98 to 2014-15. Increasing fuel costs, congestion and rising CBD based employment are likely factors in this shift from private to public transport.

Figure 9 offers a stark reminder of the scale of the transport emissions challenge identified in the IPCC reports. It shows that cars (almost all of which are powered by fossil fuels) carry out the vast major of the transport task.

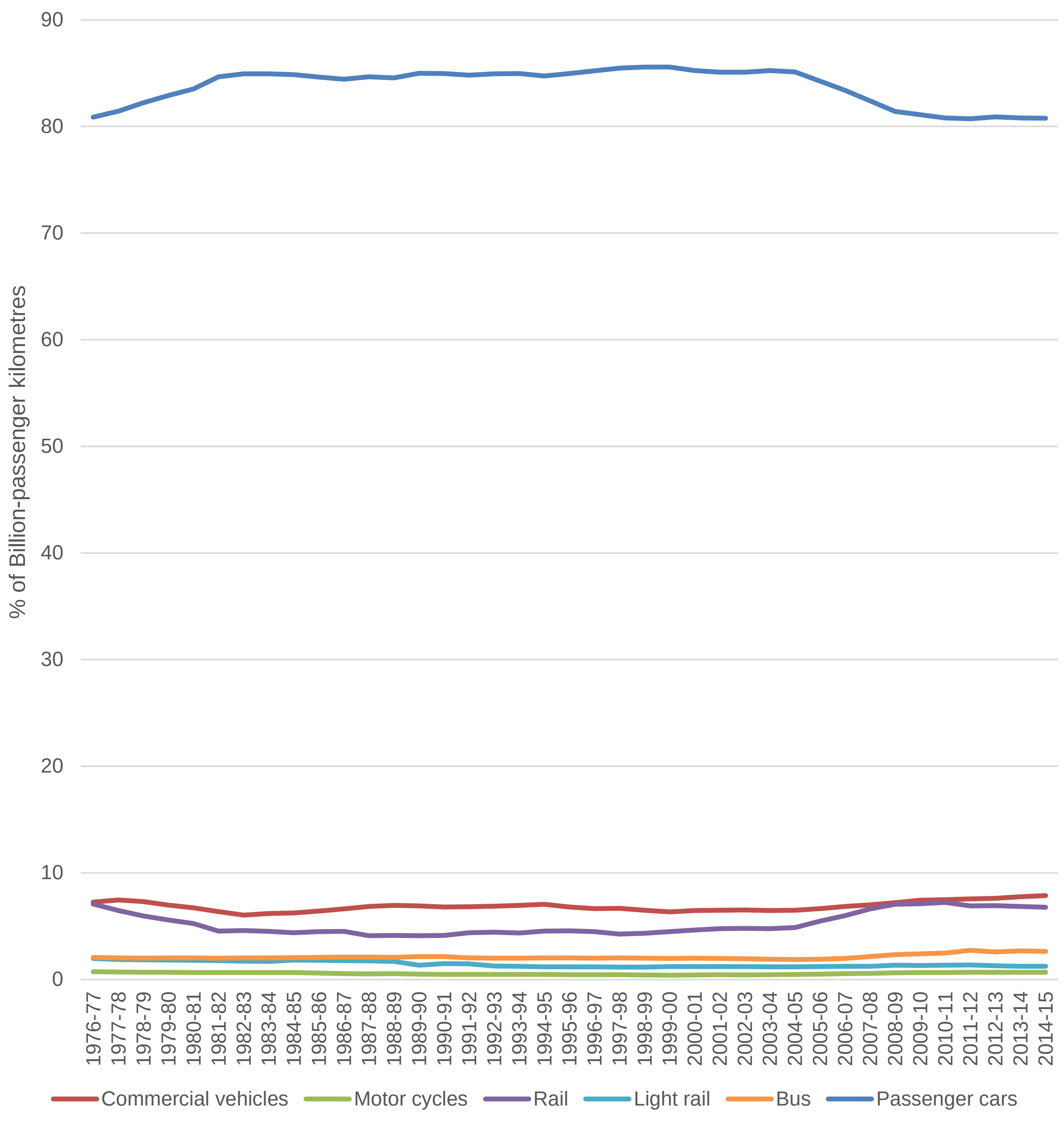

Figure 9 Percentage of person km travelled in Greater Melbourne by mode
Source: Department of Infrastructure and Regional Development (2016)

3.2.1.3. Rail

Victoria has 4,221km of railway lines, of which 375km are electrified. The Melbourne heavy rail passenger network is 403km, with 373km electrified. Electrification is contained to the Melbourne metropolitan area. There are an additional 59km of freight-only lines in metropolitan Melbourne, with 171km of railway shared between passengers and freight.

There has been an increase in passengers and freight on Victorian railways in recent years. Figure 10 shows that heavy rail and tram/light rail patronage in Melbourne was stagnant during the 1980s, increased mildly during the 1990s, and (especially in the case of heavy rail) increased markedly in the 2000s. BITRE offer no explanation for fluctuations in tram/light rail patronage, however, the 1990 tram strike and chronic overcrowding in recent years are often listed as factors.

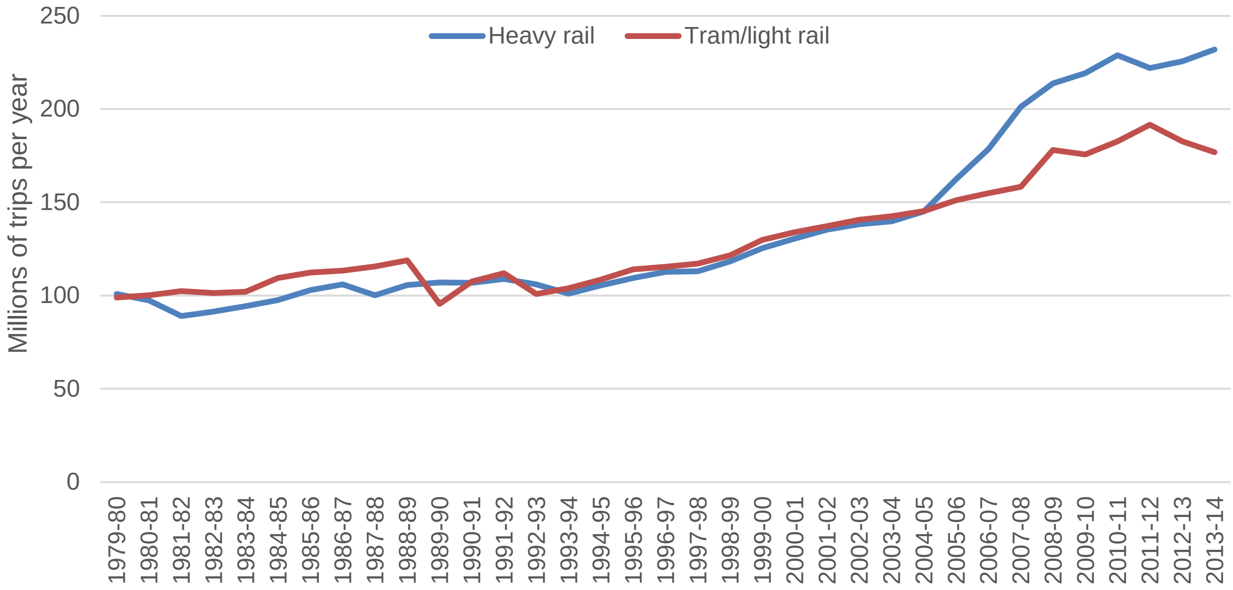

Figure 10 Millions of trips per year, Greater Melbourne passenger rail
Source: Department of Infrastructure and Regional Development (2016)

3.2.1.4. Aviation

Nationally, there has been an substantial increase in air travel from 1977-78 to 2015-16. Total movements have increased by almost 70%. There are two troughs – 1989-90 and 2001-02 – the first can be explained by the 1989 pilots' strike; and the second as a combination of factors including the collapse of Ansett Airlines and decreased aviation activity following the September 11 2001 terrorist attacks in the US. It should also be noted that although flights may have gone up by 70%, passenger numbers have risen even faster (from 11 million in 1977-78 to 58 million in 2015-16), which is likely due to larger aircraft which carry more people (but also consume more fuel in absolute terms). This has had a significant impact on emissions.

Melbourne Airport has seen a large increase in aircraft movements, from 86,391 in 1985-86 to 234,789 in 2015-16, as shown in Figure 11. There has also been a large increase in passengers, from 6.5 million in 1985-86 to 33.7 million in 2015-16. Although Melbourne Airport is outside of the City of Melbourne, it is still important from a GHG emission perspective. Most visitors to Greater Melbourne will visit the City of Melbourne, and the commercial activities within the City of Melbourne are a large attractor for business trips and tourism. There is significant potential to decrease aircraft movements along the eastern seaboard by building a high-speed rail link, which could be powered by renewable energy, reducing GHG emissions from domestic travel.

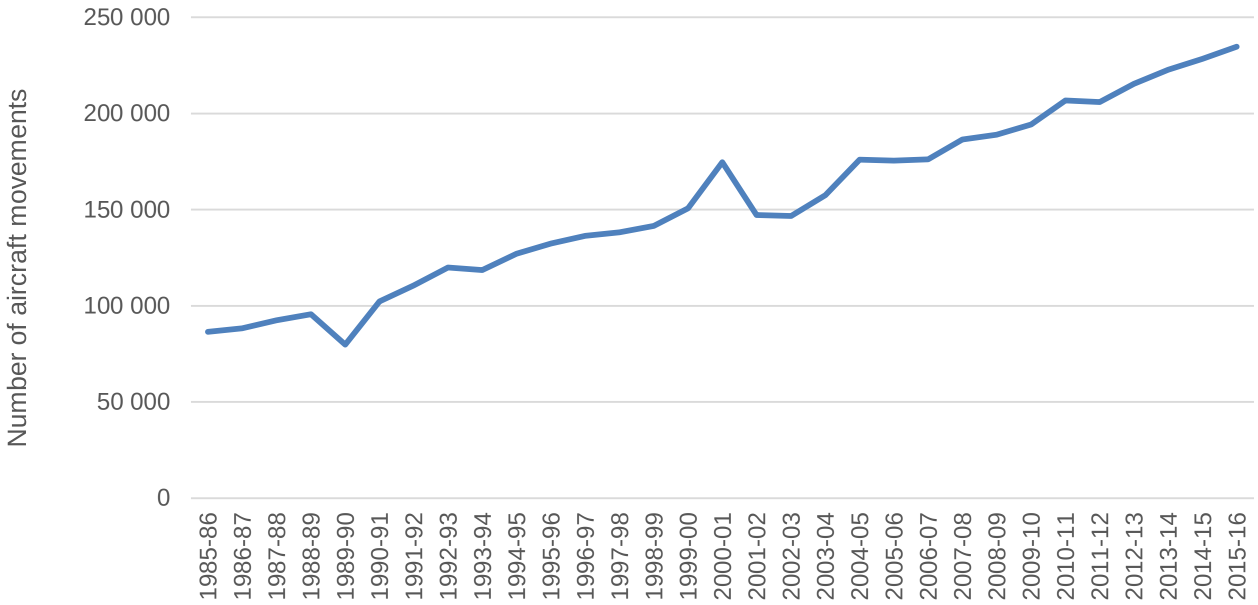

Figure 11 Aircraft movements at Melbourne Airport
Source: Department of Infrastructure and Regional Development (2016)

3.2.1.5. Shipping

Approximately 4,000 port calls are made by ships to Victorian ports annually. This number has been reasonably stable over the last 15 years (see Figure 12). The Port of Melbourne takes most of the port calls. There has been a rapid expansion in container exchange at the Port of Melbourne over the last 20 years (Department of Infrastructure and Regional Development, 2016). This has no doubt contributed to an increase in rail freight, but also a growth in truck movements to and from the Port of Melbourne.

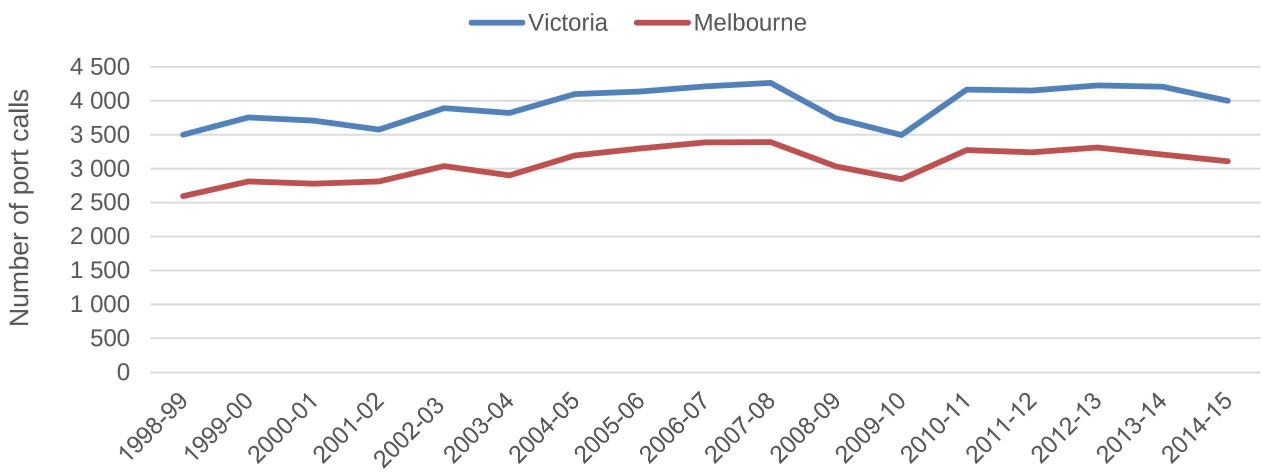

Figure 12 Number of port calls made by ships involved in coastal or international voyages
Source: Department of Infrastructure and Regional Development (2016)

3.2.1. Energy and the Environment

Australian GHG emissions from road, rail (excluding electric traction), domestic maritime, and domestic aviation are shown in Figure 13. Total GHG emissions have more than doubled from 1974-75 to 2015-16. Over 85% of this increase is due to increased motor vehicle usage. Challenges to reducing transport emissions are not restricted to road based transport. Domestic aviation GHG emissions have more than quadrupled over the 40-year period to 2015-16. This rise correlates with the rise in air traffic and passenger movements, facilitated by larger jet aircraft. The GHG emissions from rail have also increased, but still represent a very small segment of overall transport emissions. The increase is likely due to a growth in freight movements associated with the mining boom, counteracting overall increases in fleet efficiency. It should be noted that rail excludes electric traction, meaning that most commuter rail services (heavy rail and light rail) are not included. Domestic maritime GHG emissions have reduced significantly over the time period. It is hard to ascertain if this is due to a decrease in domestic shipping, increases in fuel efficiency and carrying capacity of vessels, or a combination of both.

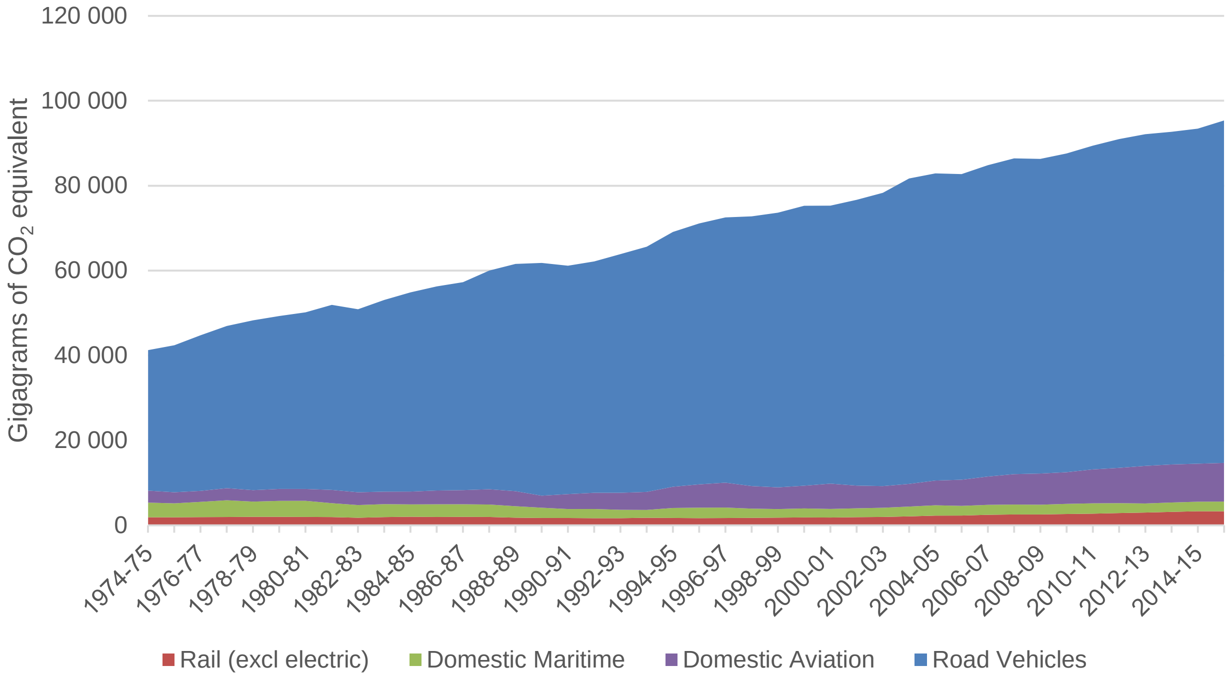

Figure 13 Direct transport GHG emissions (gigagrams of CO_2 equivalent)
Source: Department of Infrastructure and Regional Development (2016)
NB: Whilst BITRE use gigagrams, these are equivalent to kilotons.

Figure 14 shows the full fuel cycle GHG emissions of transport in Australia, from 1974-75 to 2014-15. Unlike Figure 13, this *does* show emissions from electric traction railways. There has been a slight increase in GHG emissions from rail traffic, however, it can be deduced that much of this is from electricity used to provide motive traction, and could therefore be relatively easily be converted to renewable energy sources.

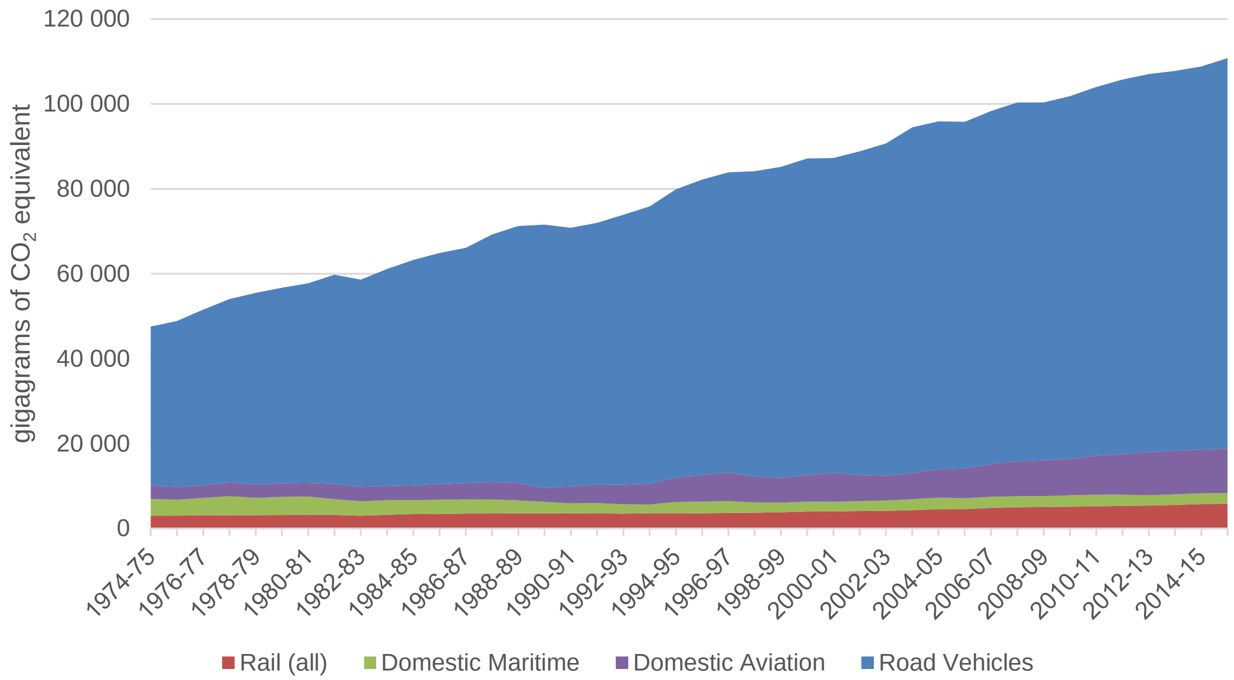

Figure 14 Transport full fuel cycle GHG emissions (gigagrams of CO_2 equivalent)
Source: Department of Infrastructure and Regional Development (2016)
NB: Whilst BITRE use gigagrams, these are equivalent to kilotons.

Figure 15 shows the GHG emissions from different road transport vehicles from 1989-90 to 2015-16. Most GHG emissions are produced by cars, however, a significant (and growing) amount is produced by commercial vehicles and trucks.

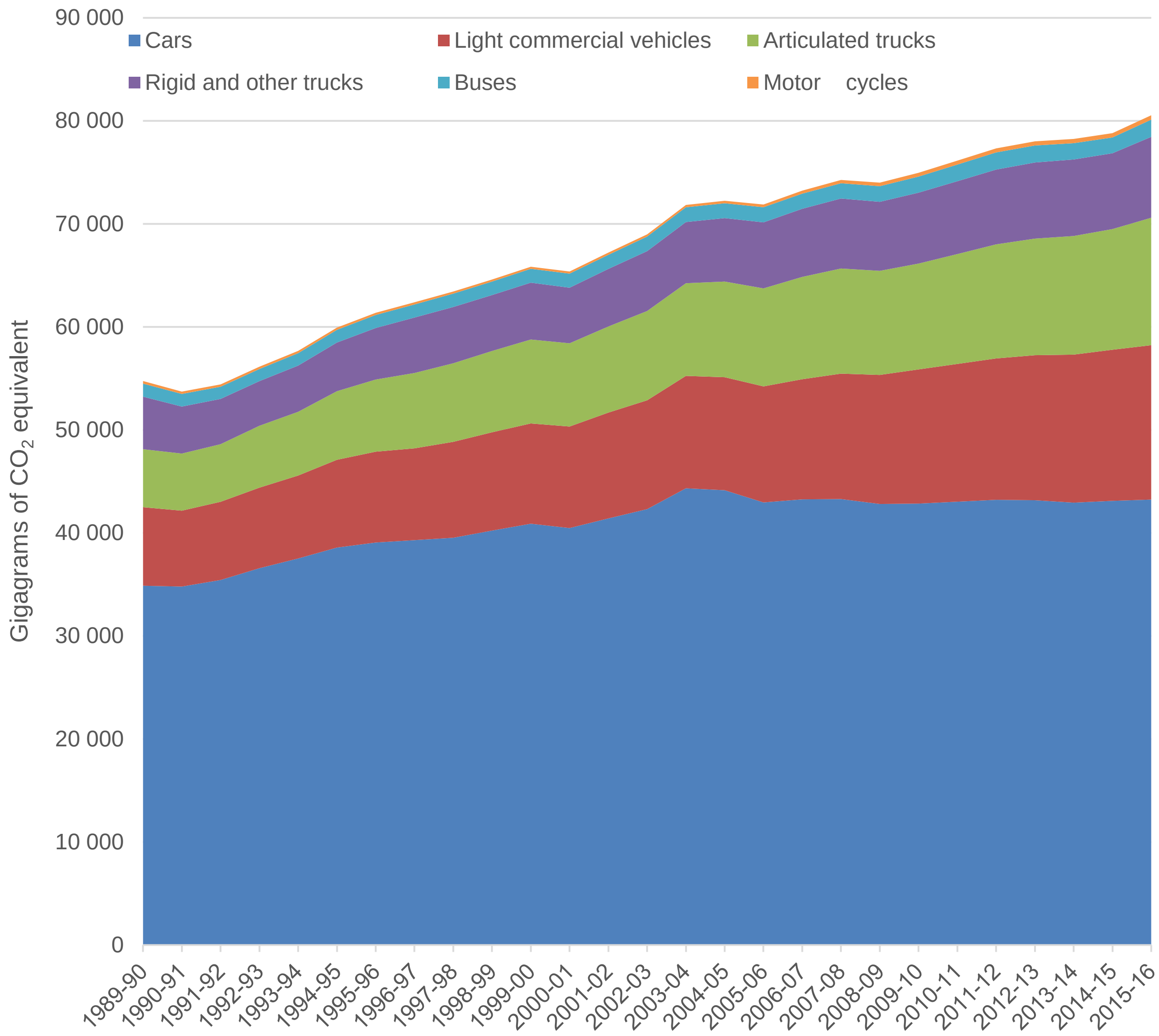

Figure 15 Australian road transport direct GHG emissions by vehicle type (gigagrams of CO_2 equivalent)

Source: Department of Infrastructure and Regional Development (2016)

NB: Whilst BITRE use gigagrams, these are equivalent to kilotons.

3.3. ABS Motor Vehicle Survey and Emissions

The Australian Bureau of Statistics (ABS) gathers information on motor vehicle ownership and trends (Australian Bureau of Statistics, 2017b). Figure 16 shows the growth of Victorian motor vehicle ownership since 1982. It shows that the Victorian vehicle fleet has more than doubled, to 4.6 million vehicles.

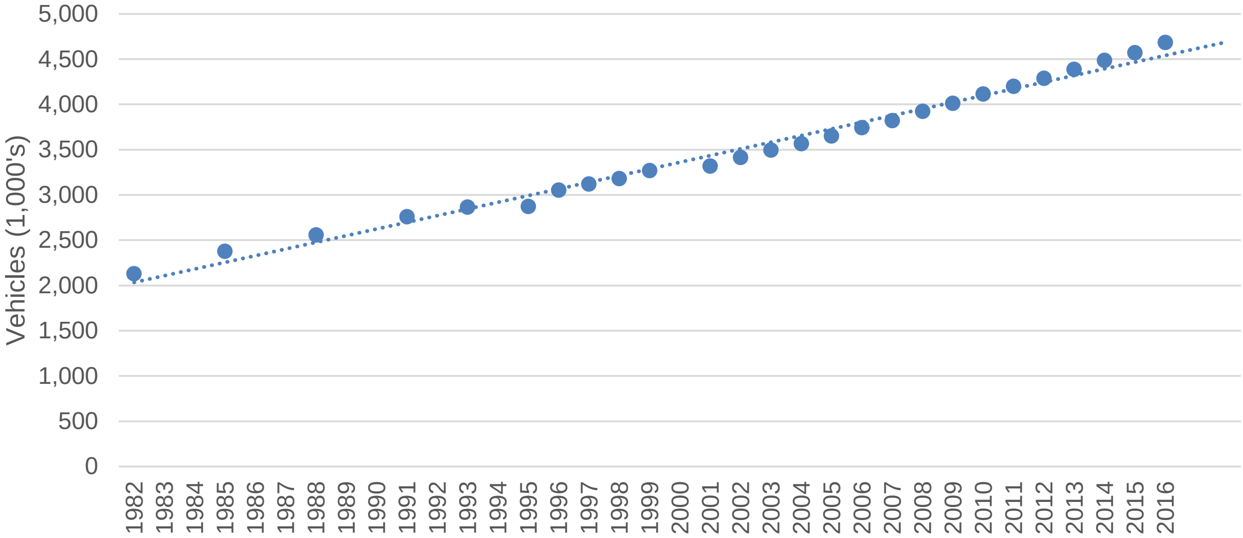

Figure 16 Growth in registered motor vehicles in Victoria (1000's)
Source: Historical ABS Surveys on motor vehicle ownership

The *use* rather than *ownership* is of most direct importance to transport emissions. Figure 17 shows the total kilometres travelled by each vehicle class. Passenger vehicles account for 49.9 billion kilometres, or approximately 75%, of all kilometres travelled in Victoria for the 12 months to June 2016. Light commercial vehicles, rigid trucks, and articulated trucks account for a larger share of kilometres travelled than their ratio of the fleet, but this is to be expected given the role they play in distributing freight and performing commercial activities.

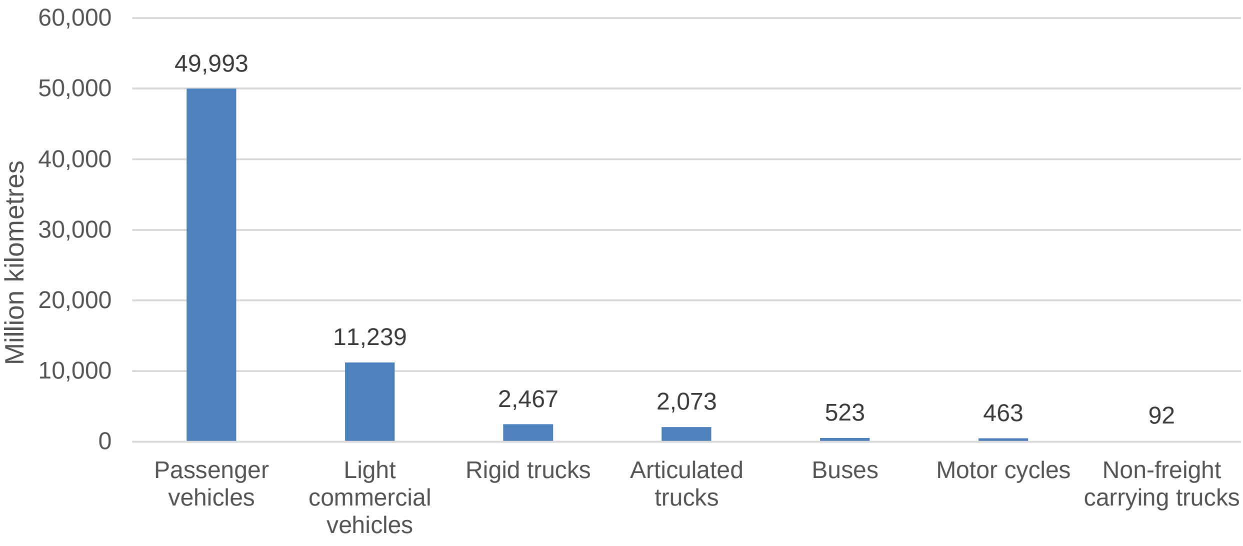

Figure 17 Total kilometres travelled in Victoria, by Vehicle type (expressed in Millions)
Source: Australian Bureau of Statistics (2017b)

Figure 18 shows the average fuel consumption of petrol and diesel vehicles in Victoria. The average consumption of a passenger vehicle in Victoria is 10.6L per 100km for petrol and 9.7L per 100 km for diesel. Trucks and buses have substantially higher fuel consumption, but make up less of the fleet.

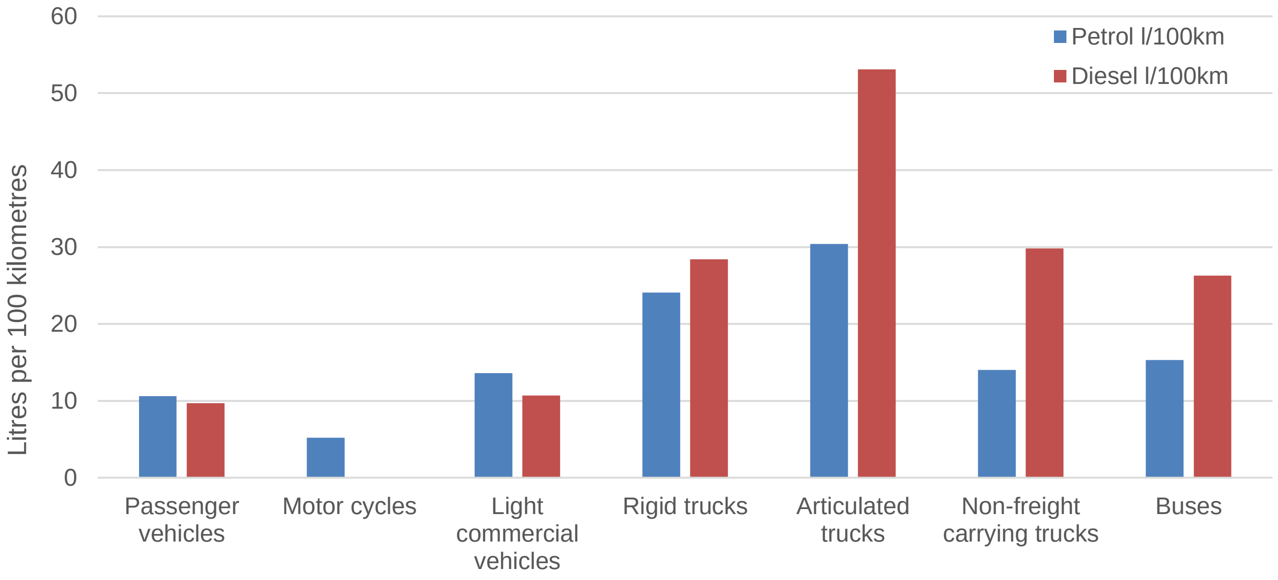

Figure 18 Victorian vehicle fleet, fuel consumption (averages)
Source: Australian Bureau of Statistics (2017b)

Historically, fuel consumption among the Australian vehicle fleet can be measured using multiple year surveys undertaken by the ABS. This shows that in the last 40 years there has been a very modest reduction in fuel consumption per 100km travelled. Should this trend continue, it is unlikely transport emissions will be reduced in line with the abatement targets necessary to meet Australia's Paris Agreement commitment or the IPCC's transport reduction goals identified in Section 2.

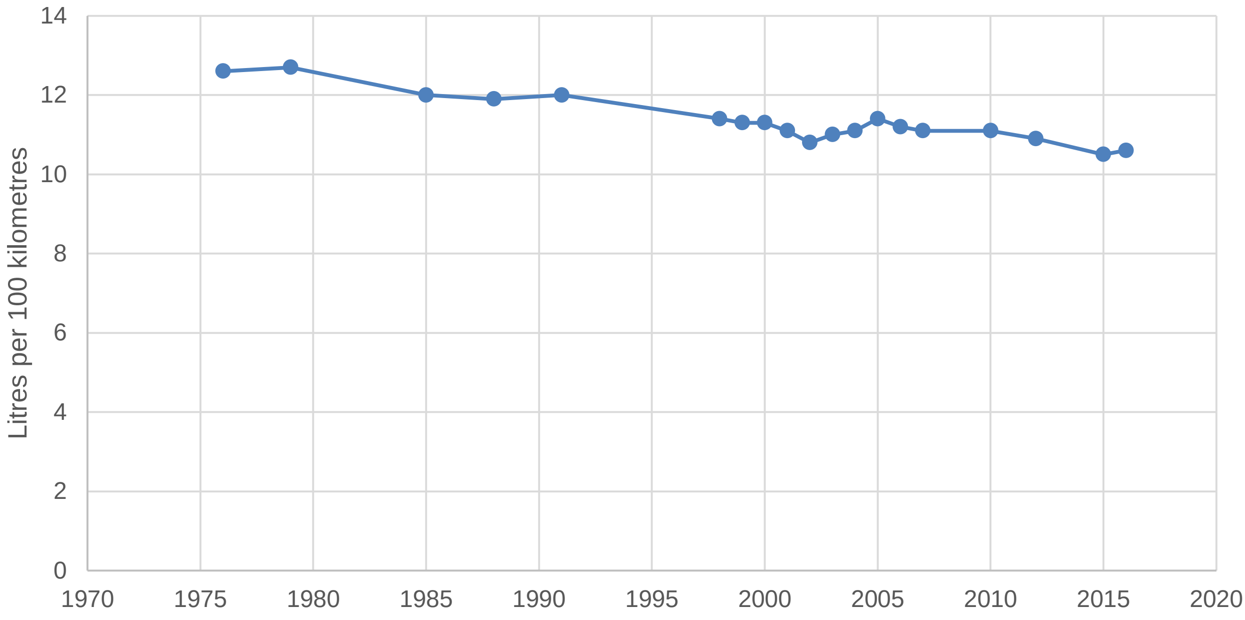

Figure 19 Historical changes to passenger car fuel consumption (litres/100km)
Source: Multiple years of ABS vehicle surveys

Grams of CO_2 emitted per kilometres travelled, by vehicle type is shown in Figure 20. Passenger vehicles in Victoria are estimated to emit an average of 243.8 grams of CO_2 per km for petrol, and 261.9 grams of CO_2 per km for diesel. Trucks and buses have substantially higher emissions per km travelled. In all cases these are tail pipe emissions released into the area in which the vehicle is operating. These emissions can therefore adversely impact on air quality. Air quality can be substantially compromised as a result of a large amount of diesel vehicles, although newer diesel vehicles have better filtration systems to reduce the release of particulates.

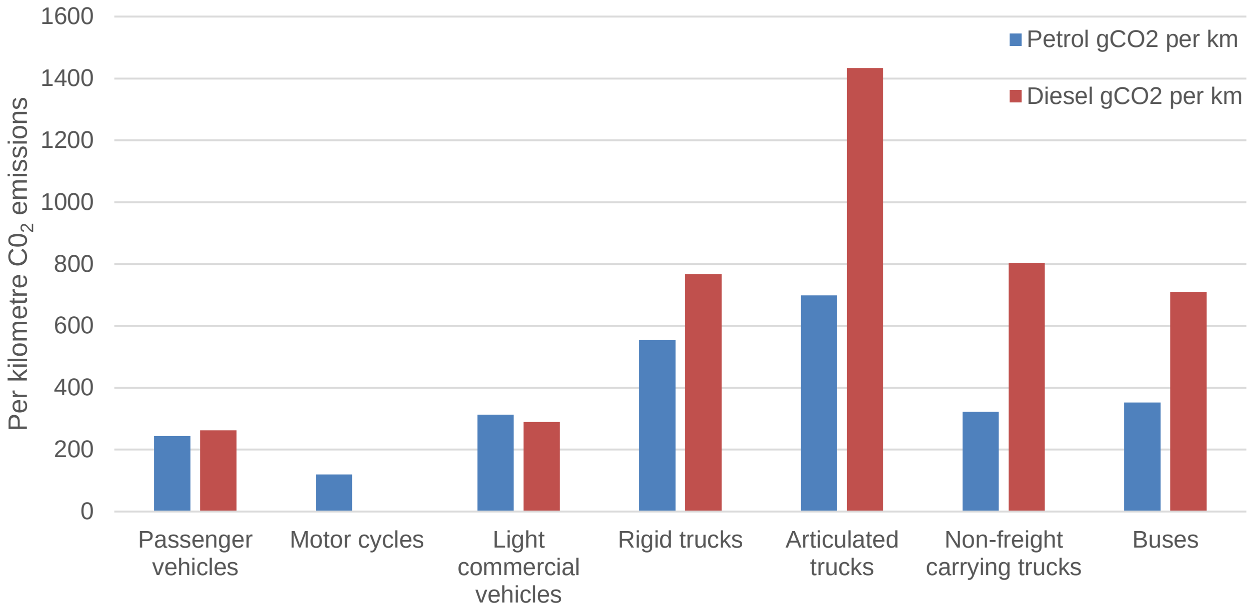

Figure 20 Victorian vehicle fleet estimated per kilometre CO_2 emissions
Source: Institute for Sensible Transport estimate based on Australian Bureau of Statistics (2017b) data

In 2017 Victoria's passenger vehicle fleet grew 2.3% to 3,750,484. Passenger vehicle ownership per person also rose, from 607 per 1,000 people in 2012 to 615 per 1,000 people in 2017. The average age of a passenger vehicle in Victoria is 9.7 years, slightly lower than 10.1 years in 2012.

3.3.1. Vehicle emission intensity: Counter-intuitive impacts of electric vehicles in Melbourne

The *GreenVehicleGuide* is an initiative of the Australian Government intended to better inform consumers about the environmental performance of vehicles (GreenVehicleGuide, 2017). Every month a list of the top performers (in terms of low emissions) and a list of top sellers are released on the GreenVehicleGuide website. The GreenVehicleGuide only considers tail pipe emissions, therefore the electricity consumption of plug-in electric and plug-hybrid vehicles is not considered by the guide. However, this is likely to radically understate potential emissions from an electric vehicle fleet, especially in Victoria where electricity production is carbon intensive.

The top ten performers and top ten sellers, as listed in the GreenVehicleGuide in November 2017 are shown in Figure 21. The figure has included CO_2 emissions from fuel, as listed by the GreenVehicleGuide and CO_2 emissions from electricity, estimated by the average CO_2 emissions per kWh of electricity in Victoria (Department of the Environment, 2015). Charging plug-in electric or plug-in hybrid vehicles from the standard Victorian electricity grid is, in some cases, *more CO_2 intensive* than other options, such as petrol-electric hybrid of diesel vehicles. **Of critical relevance to this project, the five worst performing vehicles, if using Victorian grid electricity, are all plug-in electric or plug-in hybrid vehicles.**

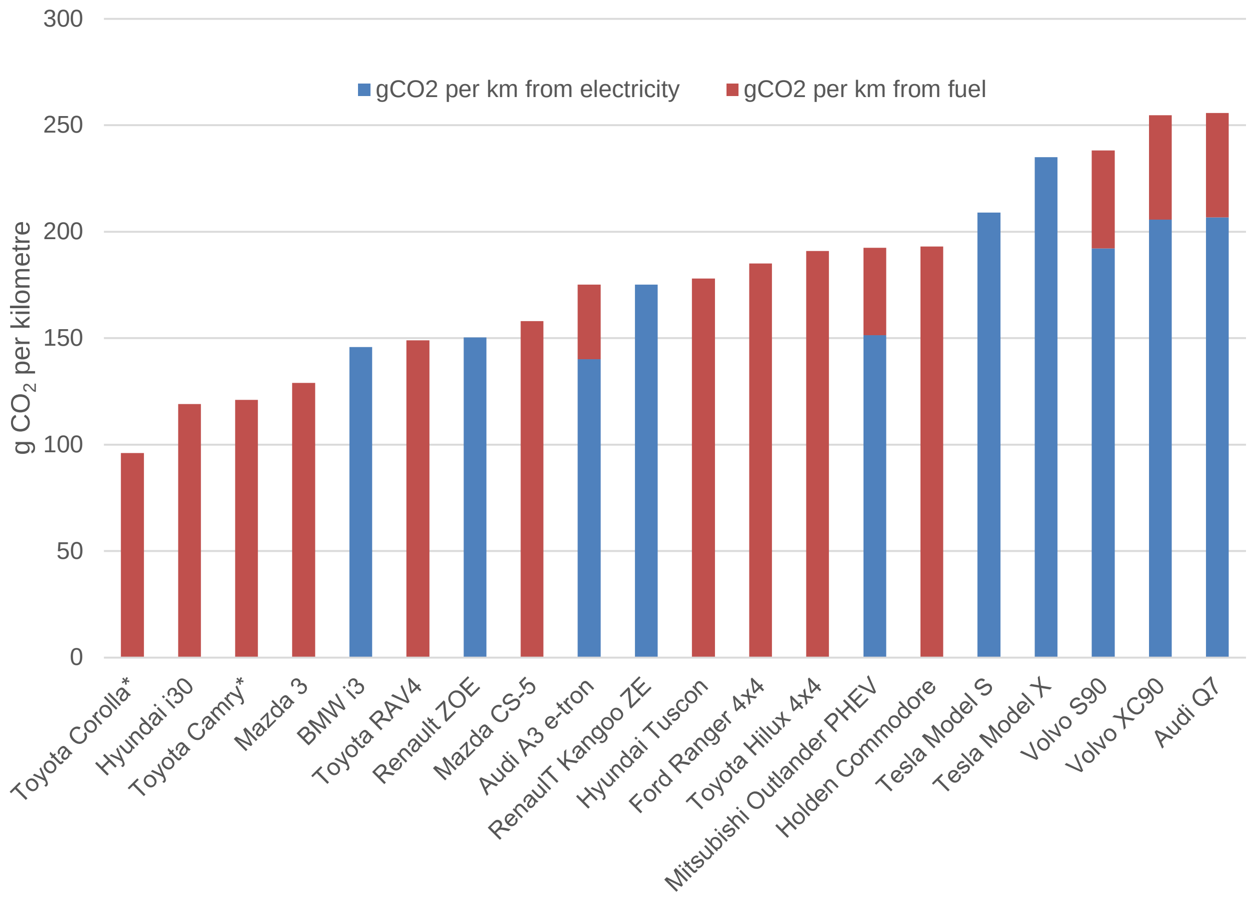

Figure 21 Top 10 selling vehicles and Top 10 most efficient vehicles
Source: GreenVehicleGuide (2017)
NB: * denotes a hybrid vehicle, vehicles with electric and liquid fuel are plug in hybrids, all cars except the Toyota Corolla, Camry, Hyundai Tuscon and Holden Commodore are Diesel. We use the assumption of 1.13 grams of CO_2 per watt/hour of electricity, which is based Australian Government data (see Department of the Environment, 2015).

If powered by emissions intensive Victorian electricity, an electric vehicle travelling in the City of Melbourne will benefit *local* air quality, compared to the driving of an internal combustion engine vehicle. This impact is accentuated if the electric vehicle is replacing a particulate intensive diesel-powered vehicle. However, for electric vehicles to make substantial cuts to GHG emissions, they must be powered by renewable energy sources. Failure to ensure that they are charged on renewable energy will simply move, rather than eliminate, GHG emissions.

The mean estimated electricity consumption of the top five performing plug-in electric vehicles, if travelling the Victorian average of 13,800km per annum, is 2,235.6kWh. If Victoria's entire passenger vehicle fleet were converted to plug-in electric, this would greatly increase the demand on the power system. For example, in 2012 mean household electricity consumption in Victoria was 4,793kWh, while in the 2016 Census the mean number of vehicles per household was 1.8. **If each household had 1.8 electric vehicles, based on current passenger vehicle usage and average efficiency, this could increase household electricity consumption by approximately 4,024kWh per year. This equates to an 84% increase in residential electricity consumption.** An enormous increase in investment in renewable energy will be required to meet such demand. If this demand is not met, electric vehicles have the potential to *increase* the lifespan of fossil fuel power plants, as polluting power generation will be required to meet basic energy demands.

See Section 3.6 for more information on the impact of a 100% fleet conversion to electric vehicles and this impact this may have on transport emissions.

3.4. Current travel behaviour in the City of Melbourne

3.4.1. Victorian Integrated Survey of Travel and Activity (VISTA)

The *Victorian Integrated Survey of Travel and Activity* (VISTA) is a survey of Victorians' travel activity. Residents of Greater Melbourne, Geelong, and some regional centres are randomly selected and asked to complete a travel diary for a specific day. Data is collected over a one-year period to ensure a seasonally representative view of travel activity. VISTA differs from the ABS Census travel data in that it collects travel activity across *all trip purposes,* while the ABS Census only collects journey to work data for those who travelled to work on Census day.

There was an average of 635,610 weekday trips *into* the City of Melbourne in 2015-16, up from 571,670 in 2009-10 (increase of 11.2%). The largest mode shares were train and motor vehicles. Train saw the largest growth, from 195,580 to 230,790, however, walking saw the largest growth in percentage terms, almost doubling from 15,950 to 30,190 (see Figure 22). Cycling trips increased by almost 20%, from 24,040 to 28,670. There was a slight increase in motor vehicle trips, both as a driver and as a passenger, by approximately 4%. Trams were the only mode to see a decrease in usage, of approximately 8%. This may be partly explained by overcrowding, or by land-use changes that place more residents within walking distance of the central business district. The statistics for weekday trips from the City of Melbourne are largely the same.

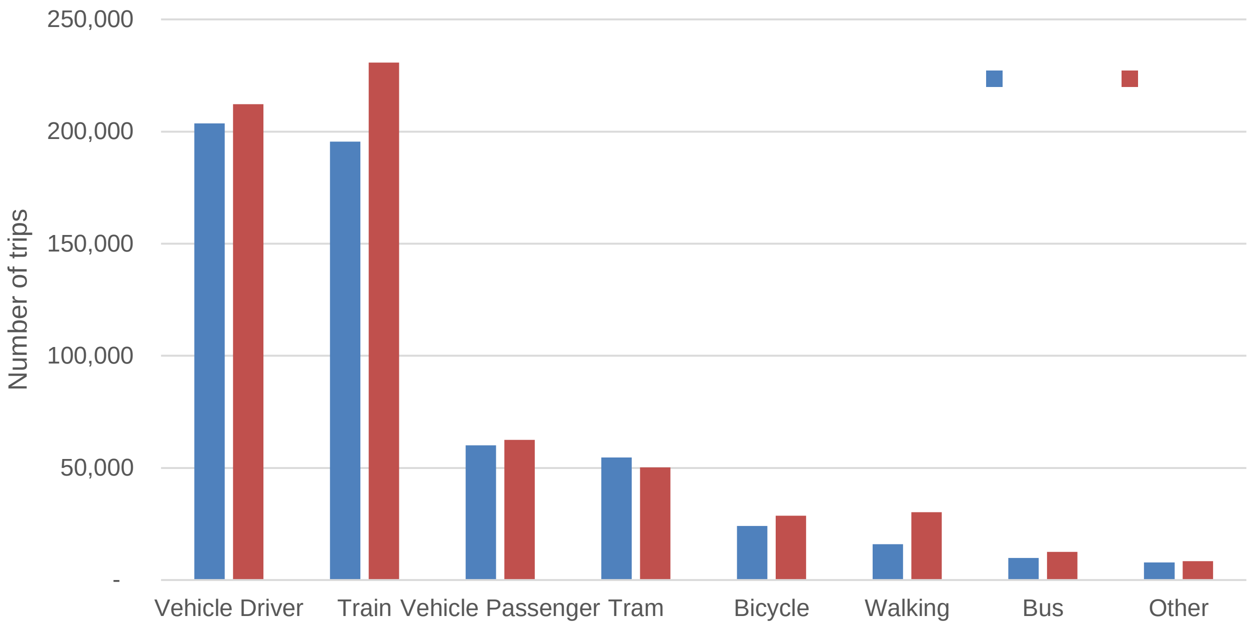

Figure 22 Weekday trips to the City of Melbourne
Source: Sift Research (2017)

There was an average of 491,947 weekday trips *within* the City of Melbourne in 2015-16, up from 442,556 in 2009-10 (increase of 11.1%). Figure 23 shows mode share for trips *within* the City of Melbourne, and indicates that walking is the dominant mode (65.9% of all trips). Although vehicle driver and vehicle passenger had a small mode share, at 12.3% and 4.9% respectively, both saw large increases in total numbers. A majority of these internal private vehicle trips are undertaken by local residents. Tram and cycling have both seen relative decreases in usage, of 24% and 12.2% respectively (see Figure 23). In the case of tram this is an oddity as the Free Tram Zone is widely acknowledged as increasing short distance tram usage in the CBD. There are serious implications to this, as **overall mode share of private vehicles has risen by 18.2%, and this will lead to increases in congestion and GHG emissions**.

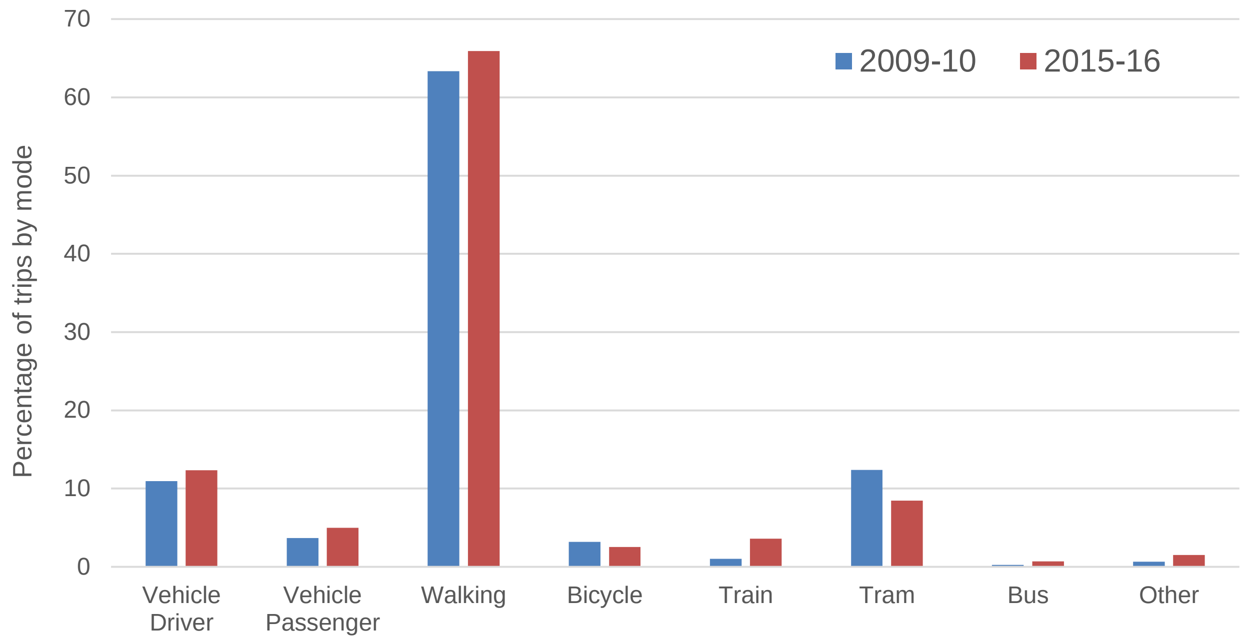

Figure 23 Mode share for trips within the City of Melbourne (weekday)
Source: Sift Research (2017)

The VISTA data shows that there are some gains in active and public transport mode share for journeys *to, from*, and *within* the City of Melbourne. However, there are still increases in private motor vehicle travel, and this will continue to increase transport related GHG emissions within the City of Melbourne. Indeed, much of the increase in public transport and cycling can be attributed to the general increase in population and journeys being made. In this regard, the performance of the transport system is insufficient in supporting the City of Melbourne's climate ambitions and is failing to generate the significant cuts in GHG emissions attributed to transport that are required.

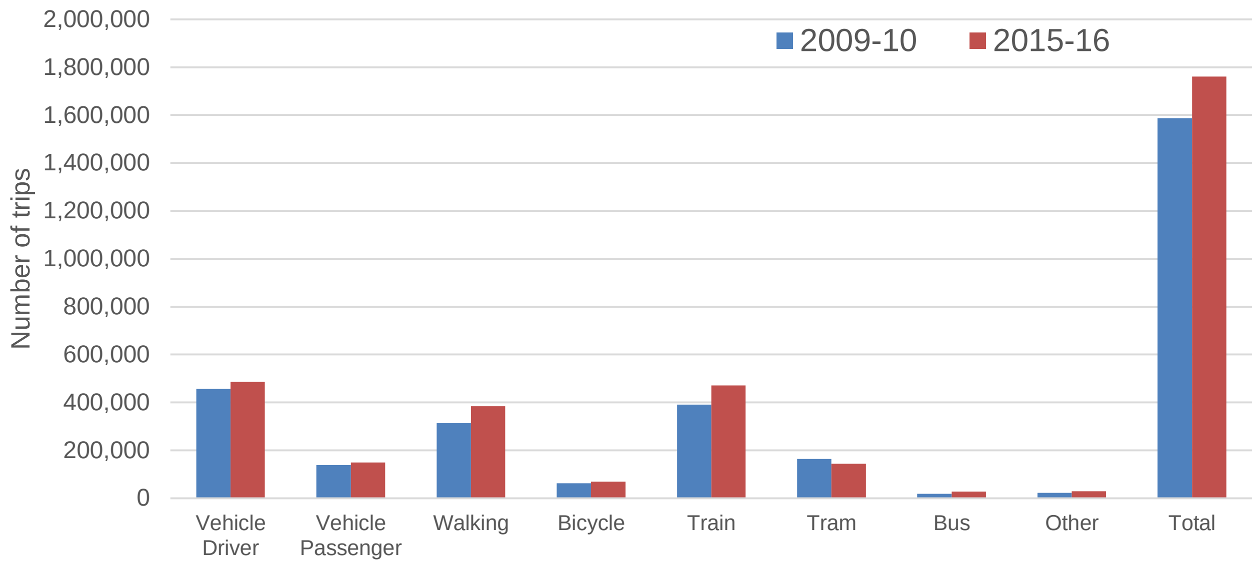

Figure 24 Total trips TO, FROM, and WITHIN City of Melbourne
Source: Sift Research (2017)

3.4.1.1. Trip purposes

The average number of weekday trips into or in the City of Melbourne in 2015-16 was 1.1 million. Of these, work related trips account for over 50%. The average weekend saw 790,000 trips, with only 10% being work related. The survey also revealed that many visitors to the City of Melbourne will have multiple purposes, with an average of 160-170 trips being undertaken for every 100 visitors to the City of Melbourne (Sift Research, 2017). It should be noted that the survey does not include tourists; people living outside of the Melbourne or Geelong metropolitan areas; professional drivers; and through-travel, and so will underrepresent the real number of trips to and through Melbourne.

During weekdays shopping is the third most popular trip purpose in the City of Melbourne, accounting for 8% of all trips. On weekends shopping rises to the second most popular trip purpose, accounting for 19% of all trips. However, as many visitors will undertake multiple trips, 14% of weekday visitors and 30% of weekend visitors will buy something within the City of Melbourne. As these data exclude tourists, the real number of trips may be higher. Figure 25 provides total numbers for different trip purposes on an average weekday.

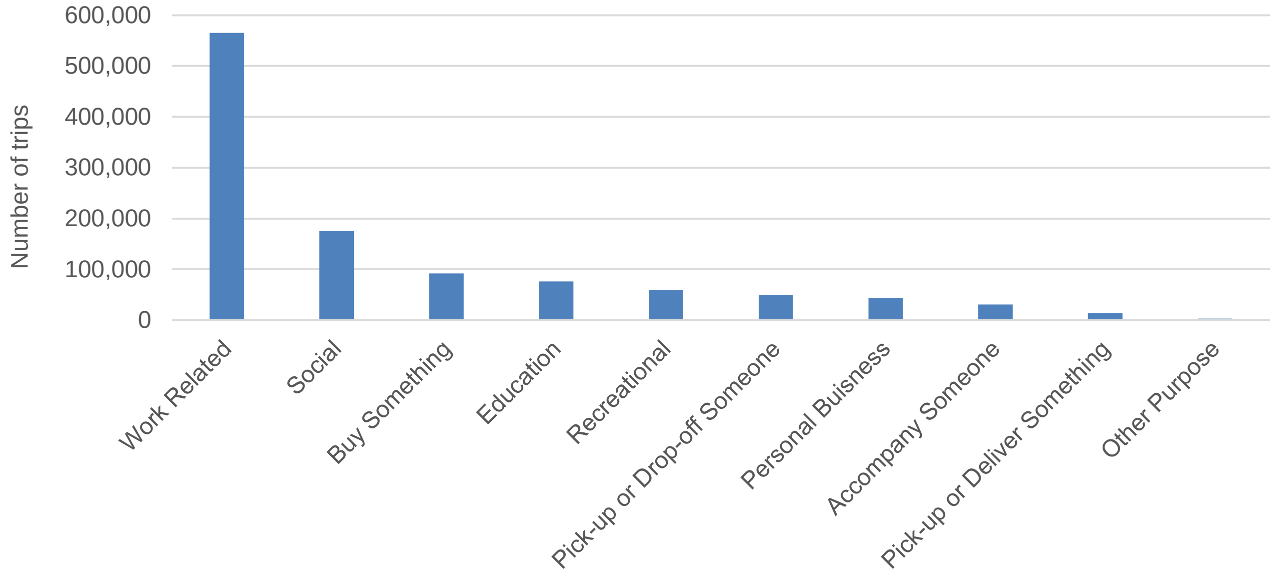

Figure 25 Purpose of travel to the City of Melbourne (weekday)
Source: Sift Research (2017)

Socialising is a major trip generator on weekdays and weekends, accounting for 15% and 54% of trips respectively. Some 27% of weekday visitors and 72% of weekend visitors will make trips to socialise. As these data exclude tourists, the real number of trips is likely to be higher.

3.4.2. Census Land Use and Employment (CLUE)

The City of Melbourne *Census of Land Use and Employment* (CLUE) provides information on land use, employment, and economic activity in the City of Melbourne. In 2016 there were 16,000 business providing 455,800 jobs in the City of Melbourne, with business services, finance and insurance, and health care and social assistance being the largest employment sectors. Many of these jobs are in offices, which are central to the City of Melbourne's economy. The City of Melbourne contains 71,000 dwellings, with 86% being residential or student apartments, and the remaining 14% houses or townhouses.

From 2014 to 2016 there was a 2% increase in employment (an increase of 9,600 jobs). This increase is despite a loss of 4,000 jobs due to the relocation of the Melbourne Market to Epping. This will have reduced the number of truck movements and private vehicle trips made into West Melbourne associated with the distribution of fresh food and commutes of market workers.

The City of Melbourne has 32.9 million m^2 of floor space. Residential accounts for 6.7 million m^2, office space for 5.4 million m^2, and car parking 4.1 million m^2. Between 2014 and 2016 there was an increase in floor space of 2.7 million m^2, or 9%. Much of this growth is associated with residential and office space, with some reductions in warehousing, which can be seen as part of the general shift towards a service economy. The increase in floor space has also seen an increase in car parking spaces. Residential car parking spaces have increased by 12%, to 49,500, in the two years from 2014 to 2016. This increase in car parking is likely to increase vehicle movements (Carse, Goodman, Mackett, Panter, & Ogilvie, 2013) within the City of Melbourne, and therefore increase GHG emissions.

3.4.3. Australian Census (2016) data analysis

The Australian Census is conducted every five years and contains a question on people's journey to work. While the journey to work (commute) only constitutes around 15 – 20% of all trip purposes, it is the only one consistently asked in the Census.

Figure 26 shows the residential locations of those who indicated they work in the City of Melbourne. The map uses ABS Statistical Areas level 2 (SA2) areas, which loosely align with suburbs. Many workers are concentrated within the City of Melbourne and inner-city suburbs, although people do come from all around Greater Melbourne (and beyond) to work in the CBD.

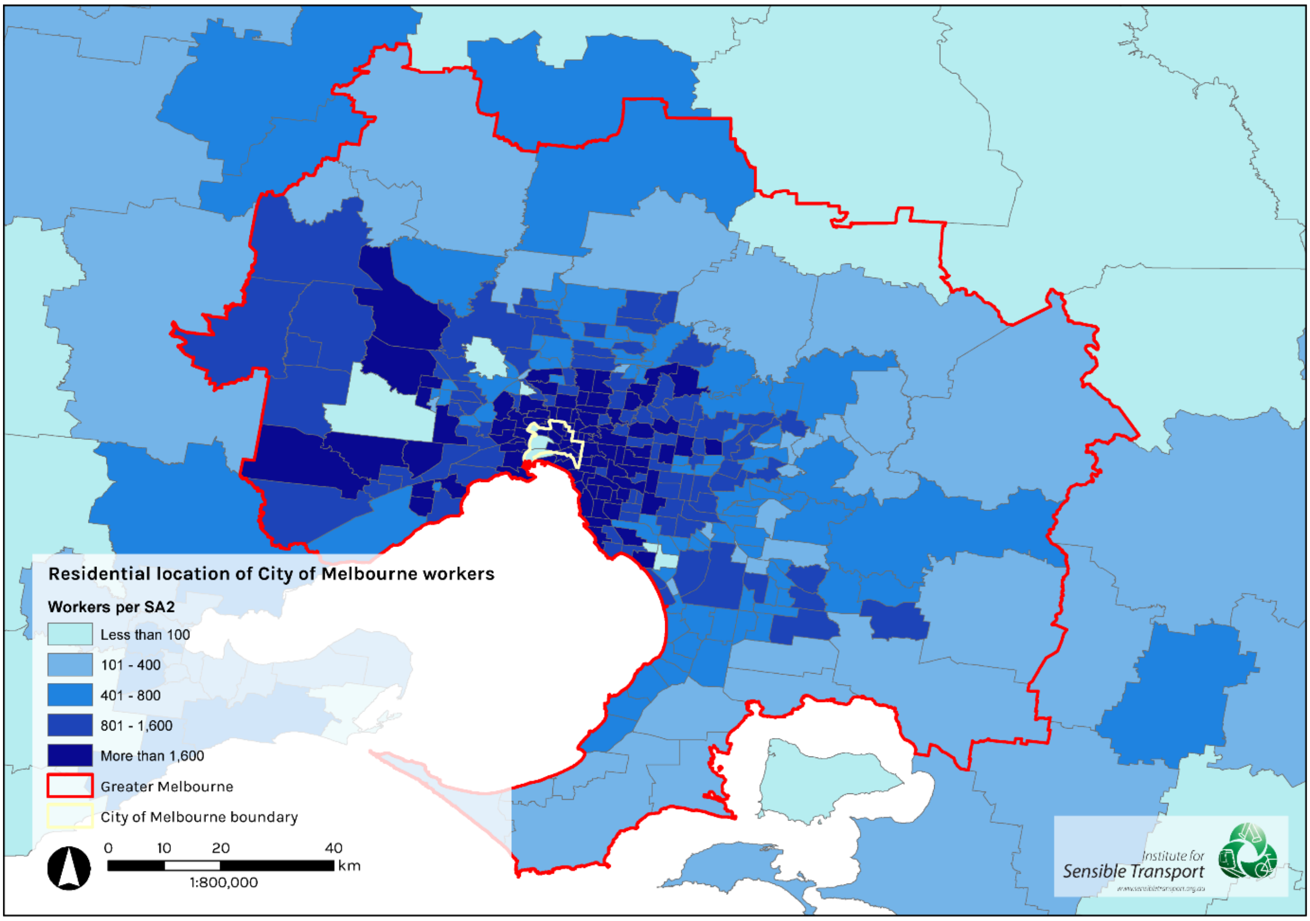

Figure 26 Residential locations of City of Melbourne Workers
Source: Australian Bureau of Statistics (2017a)

The predominant mode of travel into the City of Melbourne varies depending on the local context of the suburb or area from which the worker is commuting. As shown in Figure 27, walking is the prominent mode for people who both live and work in the City of Melbourne.

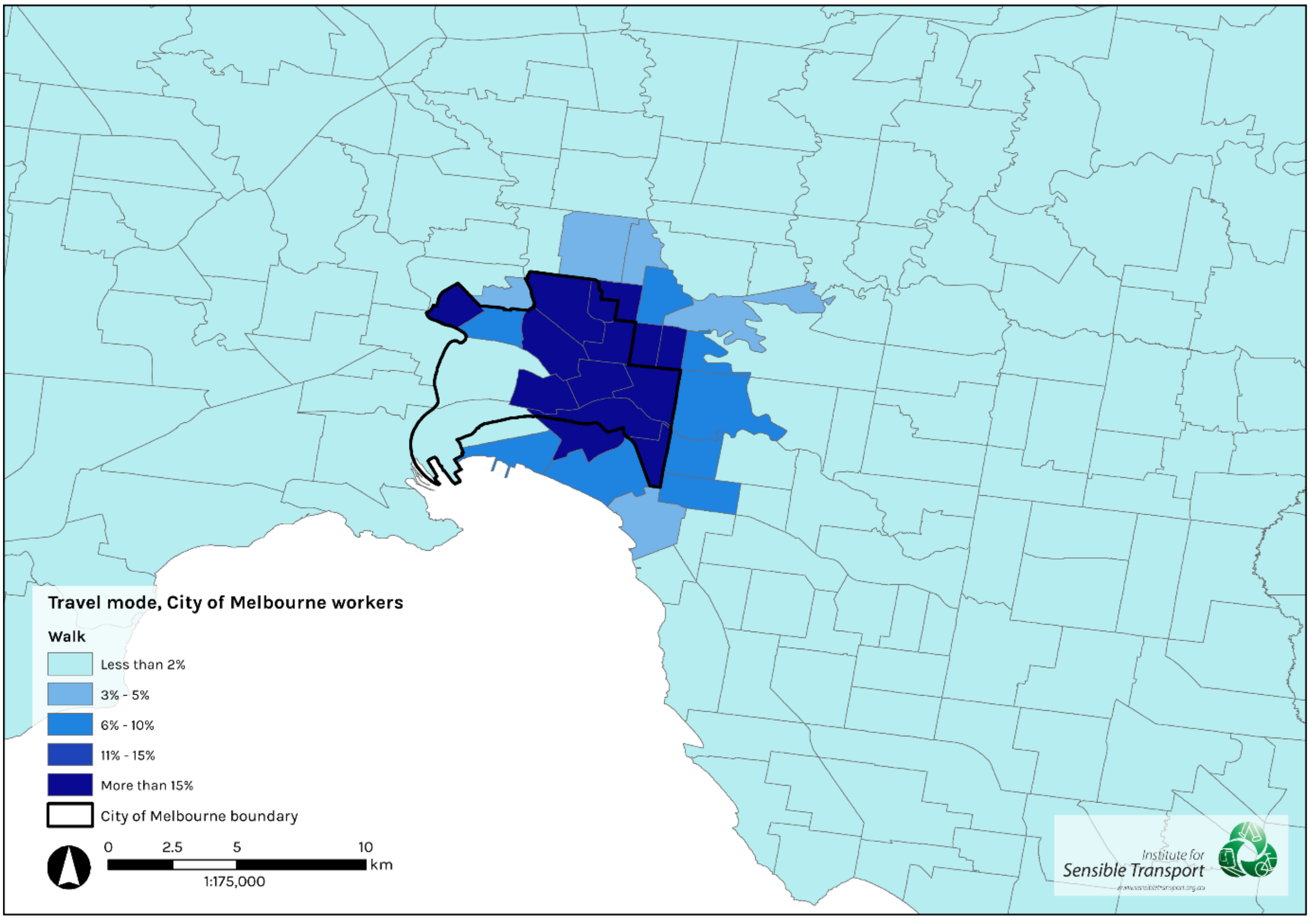

Figure 27 City of Melbourne workers who walked, by origin SA2
Source: Australian Bureau of Statistics (2017a)

Cycling is strongest in the areas directly surrounding the City of Melbourne, as shown in Figure 28. The inner northern suburbs have the largest percentage of work commutes by bicycle into the City of Melbourne. Many of these residents will be living within the 2km to 8km range of work where walking is too far, and cycling becomes a more appealing prospect. Further, as can be seen in Figure 28, the areas with a high incidence of cycling generally also have large sections of the Principal Bicycle Network. As such, it is likely that comparatively higher quality infrastructure, appealing distances, and other local area traffic management techniques have made cycling a more attractive prospect for those in the areas surrounding the City of Melbourne, particularly the north, and this has translated to high rates of cycling as a commute to the City of Melbourne. The lack of the Yarra river as a barrier for those accessing the CBD from the north my also increase the directness with which people can cycle into central Melbourne.

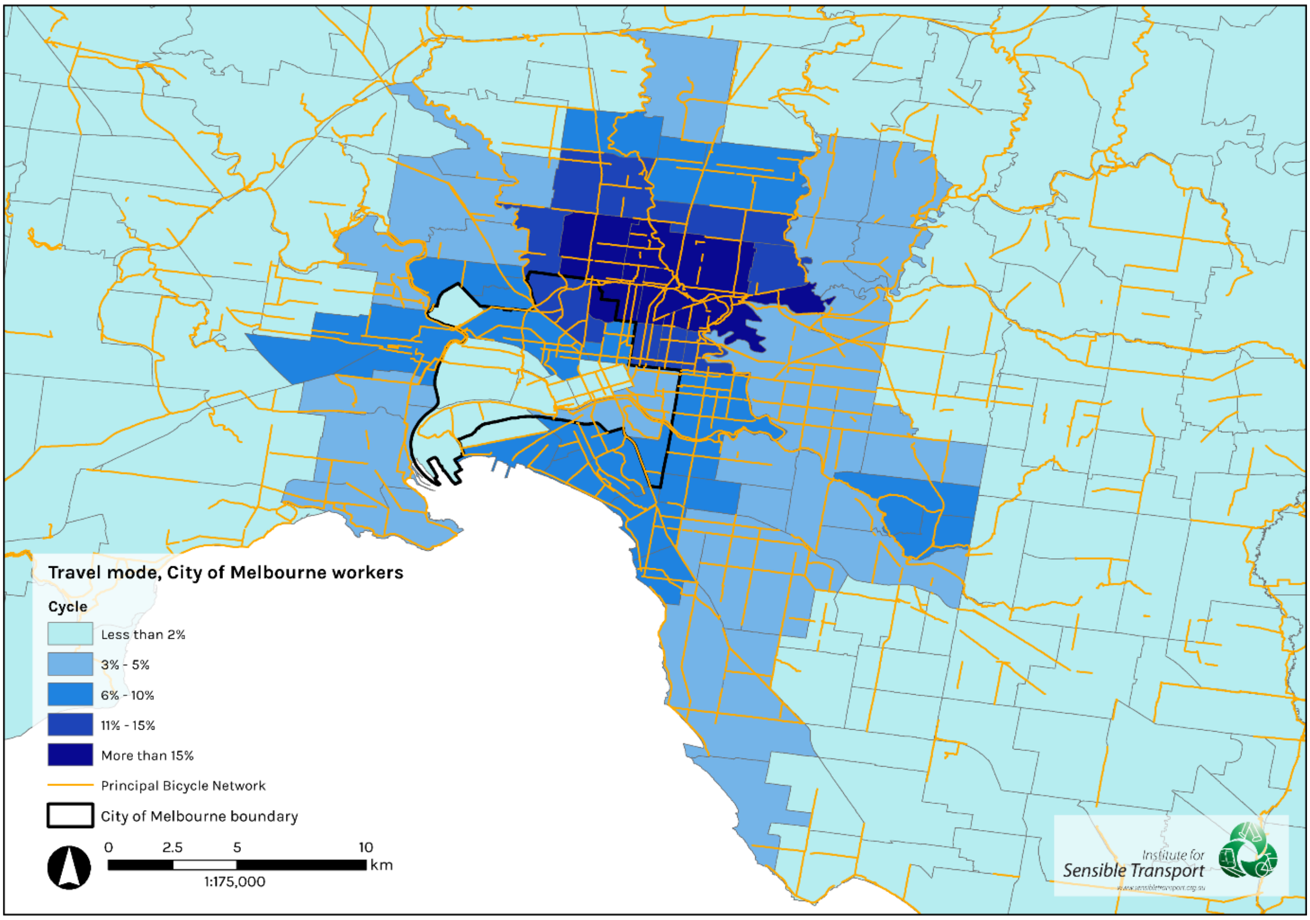

Figure 28 City of Melbourne workers who cycled, by origin SA2
Source: Australian Bureau of Statistics (2017a)

Journeys to work by public transport, for those working in the City of Melbourne is captured in Figure 29. This shows the strong correlation between public transport usage and availability. Public transport usage is strongest along rail corridors and this is especially true for areas east of the City of Melbourne. Much of the inner and middle areas are also serviced by Melbourne's extensive tram system. It can be inferred that due to constraints to car use within Melbourne's core, such as parking costs and congestion, many commuters are choosing public transport, when that option is available to them.

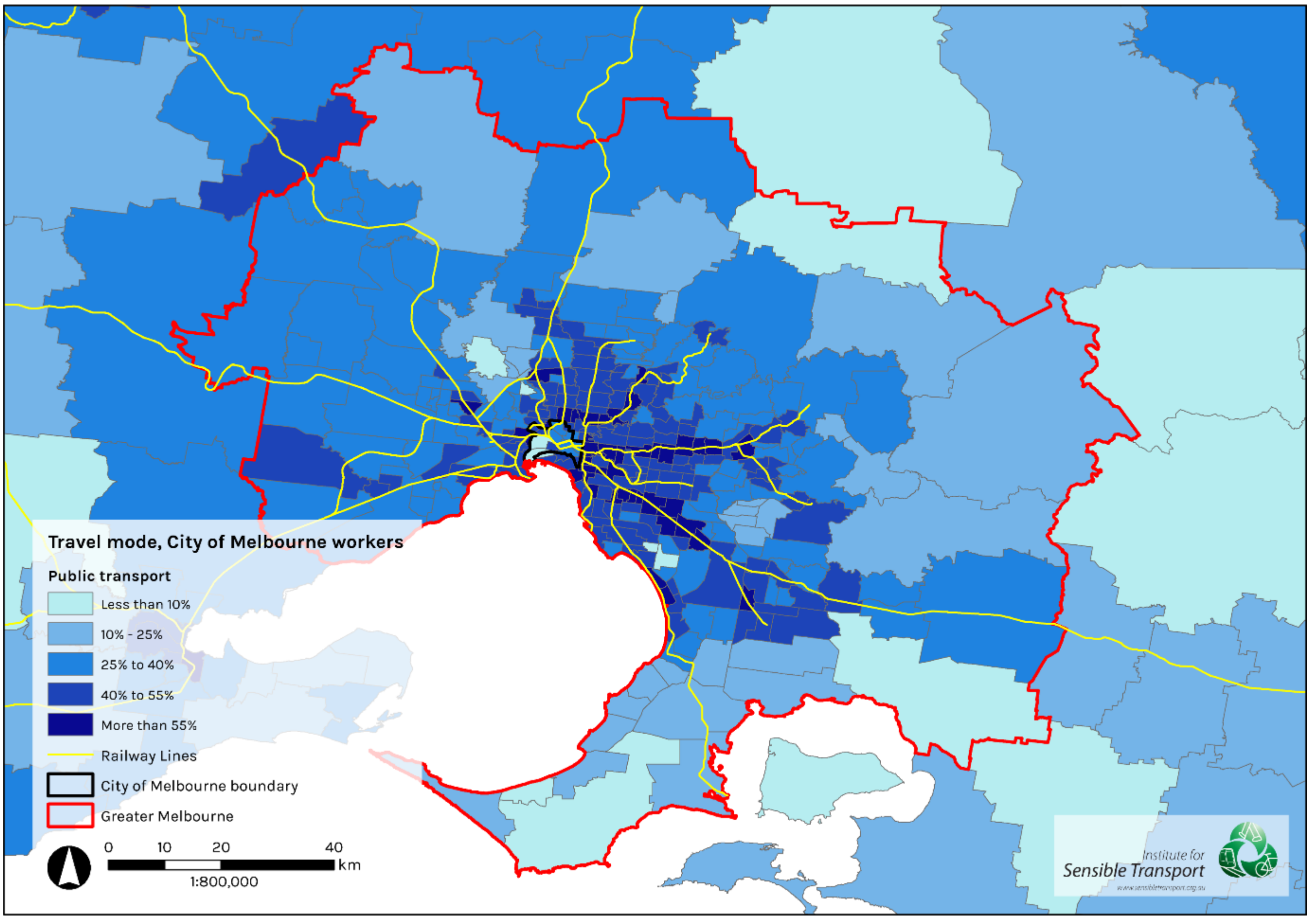

Figure 29 City of Melbourne workers who use public transport, by origin SA2
Source: Australian Bureau of Statistics (2017a)

Almost 25,000 train users commuting to the City of Melbourne arrive at the station by car. Figure 30 illustrates the spatial variation in the use of all mode public transport (mostly train) and car to work, for those working in the City of Melbourne. The areas with the highest proportion of workers doing so are largely on the periphery of Melbourne, where people are less likely to live within walking distance to high frequency public transport. This indicates latent demand for public transport which is not available to residents of these areas.

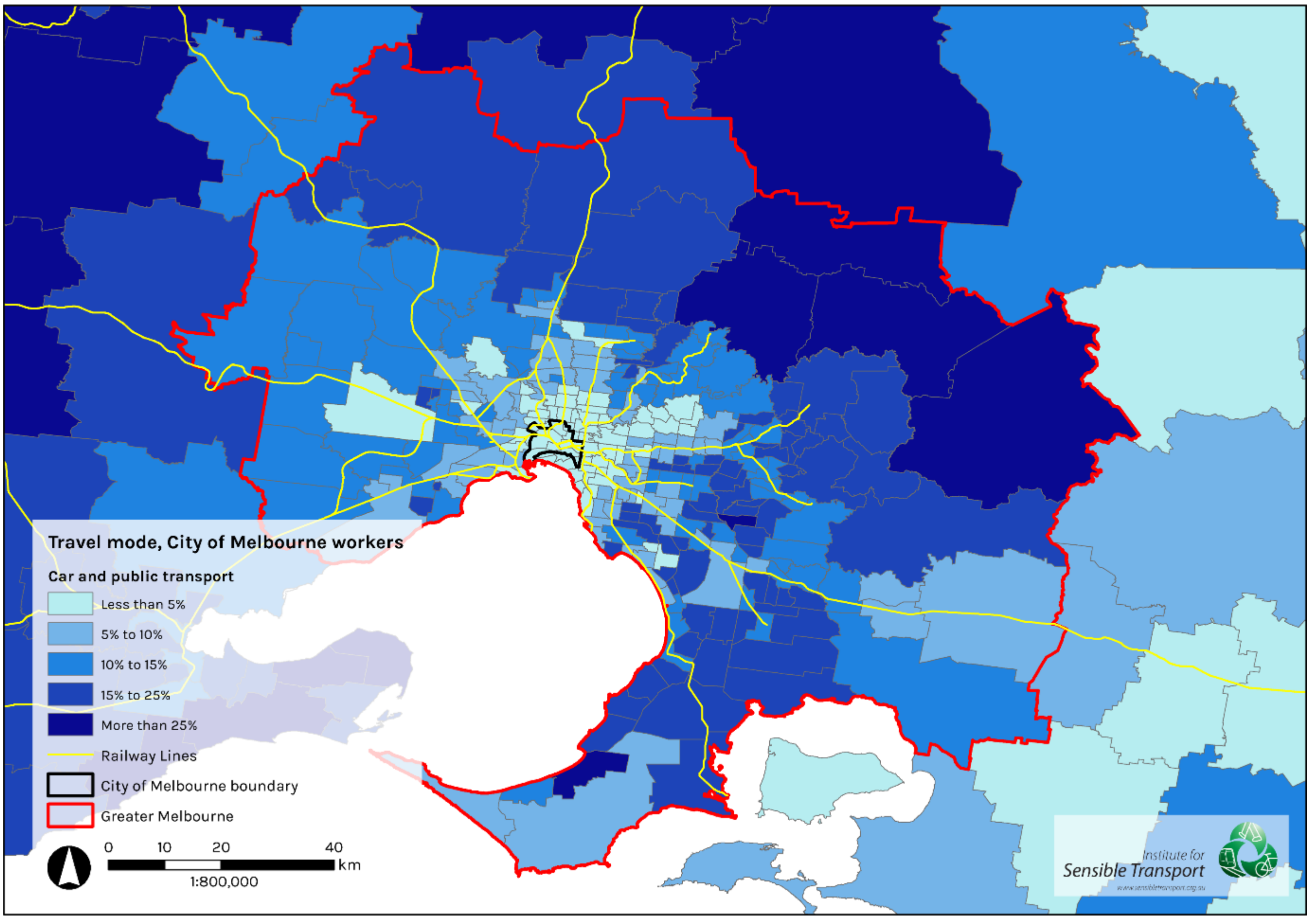

Figure 30 City of Melbourne workers who use car and public transport, by origin SA2
Source: Australian Bureau of Statistics (2017a)

A separate analysis of the same ABS Census data from 2016 shows the number of people travelling by car to train stations is shown in Figure 31. Of concern from a climate change perspective, the majority of trips by car to train stations are within a short distance from trip origin (less than 2.5km). These trips are especially polluting, as car emissions are higher per km at the very beginning of a trip. These short trips represent *'low hanging fruit'* in terms of their potential for conversion to active transport.

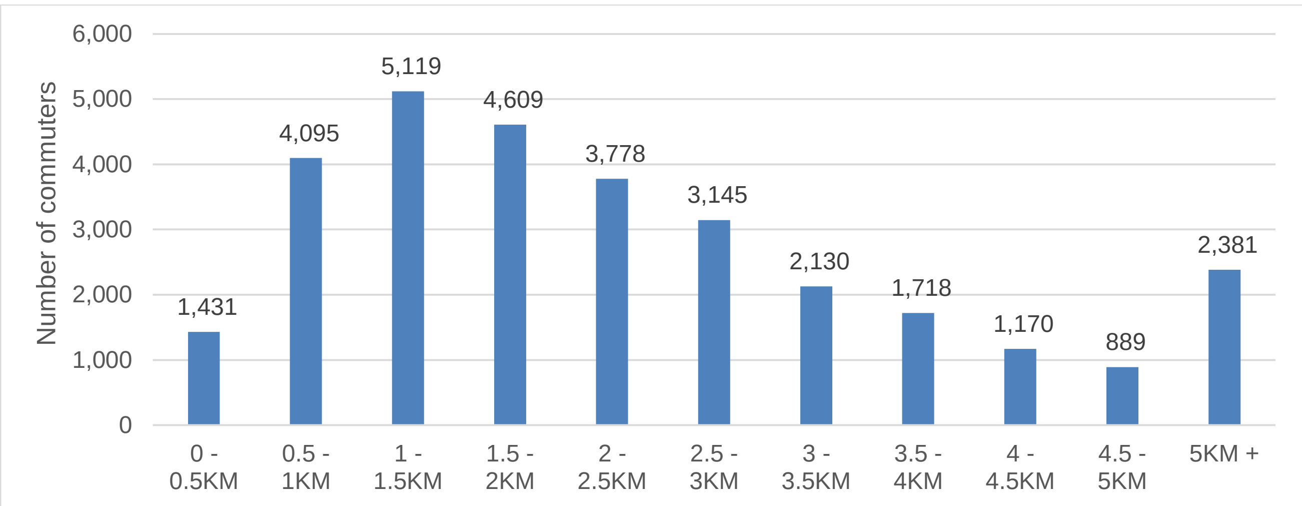

Figure 31 Journey to work, train and car by distance from train station (number of commuters)
Source: Charting Transport, using Australian Bureau of Statistics (2017a) data

The proportion of residents who work in the City of Melbourne and commute by car is shown in Figure 32. Motor vehicle usage (for Journey to Work) within the inner city, and particularly around rail corridors in the middle eastern suburbs are consistently below 20%. It is only further out, where public transport options become fewer that car mode share arises above 40%. One stark exception to this is the tract of land between the Hurstbridge and Ringwood lines (north east of the City of Melbourne), towards Doncaster. This corridor is connected to the City of Melbourne by the Eastern Freeway, which carries the DART (Doncaster Area Rapid Transit) bus network. Similarly, suburban areas just beyond the Metro Trains Melbourne operated rail system and Regional Rail Link have noticeably higher car mode share. It is inferred from this that when given a quality alternative to driving, those working in the City of Melbourne will opt for that alternative. For those living in areas outside close proximity to high frequency, direct public transport services are in essence *forced* to use the car (Currie, Stanley, & Stanley, 2007).

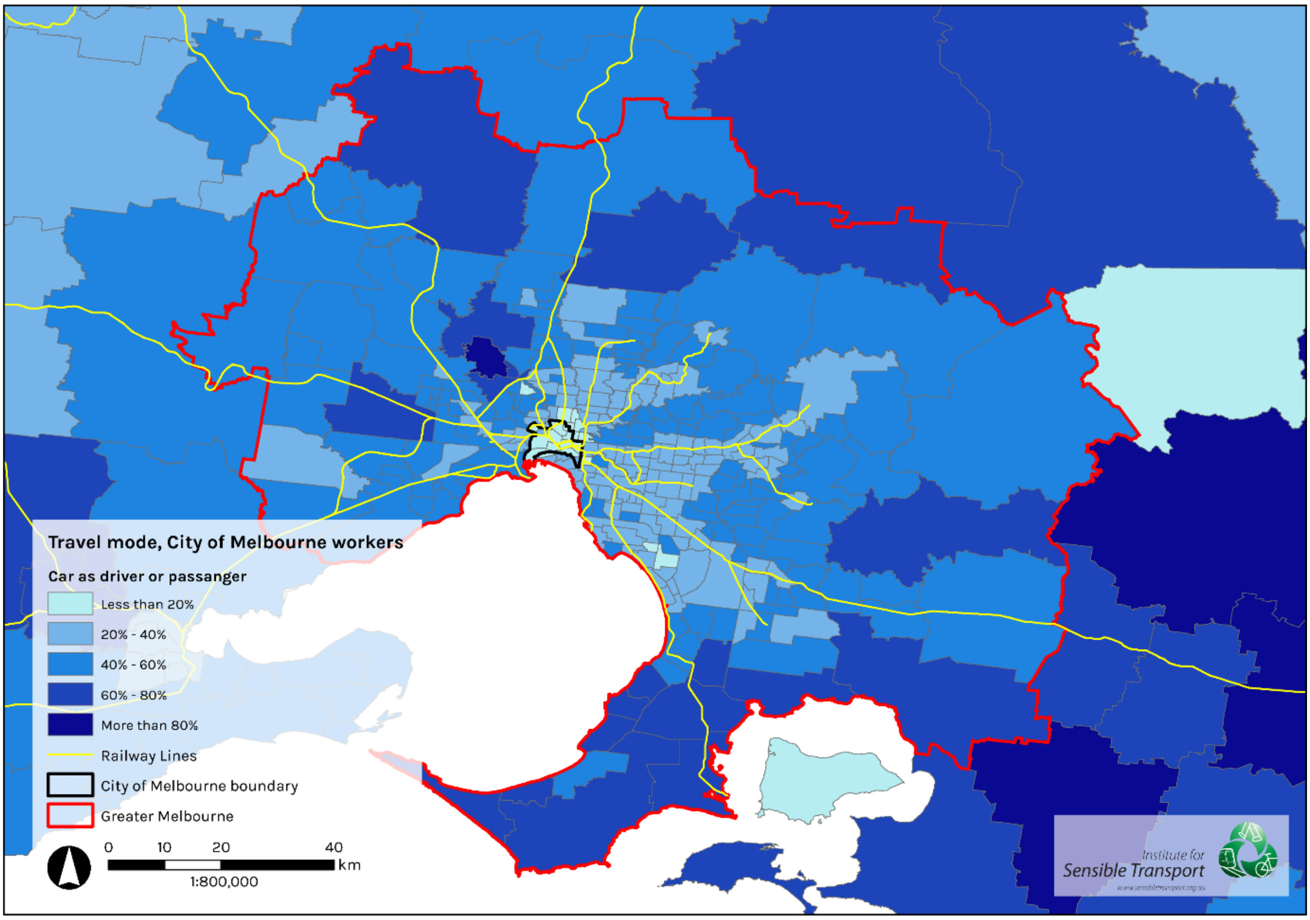

Figure 32 City of Melbourne workers who use a car, by origin SA2
Source: Australian Bureau of Statistics (2017a)

3.5. Calculating Transport Greenhouse Gas Emissions

3.5.1. Previous approach and critique

The City of Melbourne has been relying on the *Melbourne LGA Transport GHG Model*, developed in 2012, to account for GHG emissions attributable to transport within the City of Melbourne. While this tool has provided the City of Melbourne with a baseline of transport emissions, the tool is non-compliant with the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) standards (see World Resources Institute, 2014) and has radically overestimated some emissions (see Section 3.5.3 *Applying our approach to road vehicle emissions)*. It should be noted while reading the below critique that the *Melbourne LGA Transport GHG Model* was developed *before* the release of GPC standards.

Rather than calculate all transport GHG emissions, the tool only calculated GHG emissions from on-road transport and electrically powered rail services (Metro Trains Melbourne and Yarra Trams operations). As such it omits GHG emissions attributed to fossil fuel powered rail services; water-borne transport; aviation; and off-road transport (all defined in World Resources Institute, 2014).

The way the City of Melbourne tool calculates on-road transport GHG emissions is not compliant with GPC standards. The number of trips per vehicle type appears to be calculated through a combination of VISTA data and City of Melbourne traffic counts. This number of trips is then multiplied by the average trip distance of a motor vehicle in Victoria to generate an estimated Vehicle Kilometres Travelled (VKT). However, this methodology includes VKT undertaken inside, as well as *outside* the City of Melbourne boundaries. Although this method can be compliant with GCP standards, the failure to classify VKT and associated emissions as Scope 1 (GHG emissions occurring within the City of Melbourne) and Scope 3 (GHG emissions occurring outside the City of Melbourne) is non-compliant, and has the potential to exaggerate the estimated emissions attributable to on-road transportation within the City of Melbourne. Further, the tool lacks the ability to calculate Scope 2 emissions, rendering it unable to account for GHG emissions associated with plug-in electric vehicles.

Moreover, there appears to be two major faults with the way the tool calculates railway GHG emissions. Firstly, it only calculates emissions associated with electricity generation, and therefore fails to account for any diesel freight trains operating intra and inter-state (including those from the Port of Melbourne, Australia's busiest container port), interstate passenger trains (which are all diesel powered), or V/Line regional Victorian passenger trains (which are all diesel powered). Secondly, the tool appears to count all VKT of Metro Trains Melbourne and Yarra Trams operations across the entire Greater Melbourne area. As such, all GHG emissions associated with all electric rail services operating in the Greater Melbourne area are directly attributed to the City of Melbourne. This is a gross over-estimation of GHG emissions given that only a fraction of the rail or tram system actually operate with the City of Melbourne. The method of calculating the number of Passenger Kilometres Travelled (PKT) is unclear. Understating PKT would lead to an overestimation of GHG emissions per PKT, which would lead to distorted GHG intensity figures.

The *Melbourne LGA Transport GHG Model* has provided data that the City of Melbourne has relied upon since 2012 to estimate transport GHG emissions. This data has undoubtedly aided the City of Melbourne in understanding GHG emissions related to transport, and the challenges faced. However, continued reliance on the *Melbourne LGA Transport GHG Model* will provide distorted accounts of GHG emissions, and should be avoided where possible. A new accounting regime, based on the principles outlined immediately below should be implemented to provide a more comprehensive and accurate account of GHG emissions, which is compliant with GPC protocols.

3.5.2. Our suggested approach

An assessment of past transport GHG emission assessment tools and existing transport data have allowed for the development of a new approach to estimating transport emissions. This section does not intend to perform this calculation in full, but rather will describe the methodology that should be applied in order to arrive at a GPC compliant estimate. For conceptual and illustrative purposes, this section will conclude with an application of this suggested methodology, focused on road vehicle emissions.

The *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC) is a framework which aids in the calculation of GHG emissions (World Resources Institute, 2014). The framework is the product of a collaboration between World Resources Institute, C40 Cities Climate Leadership Group and ICLEI - Local Governments for Sustainability. It is designed to allow cities to track their emissions, allowing for the monitoring of GHG reduction strategies and helping cities compare GHG reduction progress. There are six sectors defined by the GPC for GHG emission calculation. Under the Transport sector, there are five sub-sectors (which are discussed below).

The purpose of this section is to outline a method for calculating GHG emissions that is compliant with the GPC framework. In calculating GHG emissions, the GPC requires cities to define an inventory boundary in which emissions will be calculated. This may be a region, single local government, or parish of a local government. The City of Melbourne is one of 32 Local Government Areas in Greater Melbourne, which covers the Central Business District of the metropolitan area. For the calculation of GHG emissions, the municipal boundary of the City of Melbourne shall be used. Compliant with the GPC framework, GHG emissions shall be calculated over the period of one year.

The GPC set out two methods of calculating GHG emissions attributable to transport BASIC and BASIC+. BASIC counts Scope 1 emissions, which are GHG emissions attributed to the consumption of carbon based fuels within the city area, and Scope 2 emissions, which are GHG emissions attributed to the drawing of electricity from the grid. BASIC+ expands on the GHG emissions counted and includes Scope 3 emissions, which are transport emissions which occur outside of the city area, but are part of a journey that encompasses a portion within the municipality.

The information provided to the authors regarding the City of Melbourne’s GHG accounting suggests an alignment with the BASIC framework (i.e. only including emissions that take place within the City of Melbourne’s boundaries). This will count all emissions attributed to the direct consumption of carbon based fuels within the City of Melbourne (e.g. internal combustion engines) while also counting emissions related to the consumption of electricity which is produced outside of the City of Melbourne (e.g. electrified rail and plug-in electric cars).

3.5.2.1. On-road transportation

The GPC categorises on-road transportation as ‘including electric and fuel-powered cars, taxis, buses, etc.’ Greater Melbourne has an extensive road network, with several freeways and arterial roads providing access to the Central Business District in the heart of the City of Melbourne.

Although the GPC does not stipulate a method for calculating on-road transport emissions, it does recommend one of the four following methods be used:

- **Fuel sales method** – which quantifies transport emissions based on the sales of fuel sold within the city boundary.
- **Induced activity method** – which quantifies transport emissions which are induced by the city including trips which begin, end, or are fully with the city boundaries, but usually discounts trips which pass through.
- **Geographic or territorial method** – which quantifies emissions for all transportation activity which occurs within the city boundaries.
- **Resident activity method** – which quantifies emissions from transport activities undertaken only by those who reside in the city boundaries.

The GPC compares the **Fuel sales method** to the other three (designated as VKT – Vehicle Kilometres Travelled), finding that any VKT model is better able to produce detailed data which has broader planning implications and integrates better with transport models. However, VKT methods are more expensive and time consuming than Fuel sales and due to variations in models used, can be hard to compare from city to city. VKT is also dependent on having traffic count data or modelling that estimates traffic counts.

The **Fuel sales method** is considered inappropriate for the City of Melbourne, as there are few petrol stations within the LGA boundaries, and many cars that travel into the central city area do so from outside the City of

Melbourne. The **Induced activity method** is similarly inappropriate for the City of Melbourne as it fails to account for substantial through traffic along the freeway and arterial road network. Due to the high employment compared to residential rates within City of Melbourne, the **Resident activity method** is also deemed inappropriate as it would not count the hundreds of thousands of trips made into the City of Melbourne each day by residents of other LGAs. Therefore, **Geographic or territorial method** is most appropriate as it will count all VKT within the City of Melbourne, by residents from any other LGA and account for the large amount of through traffic and freight traffic (including to and from the Port of Melbourne). Transport for Victoria, Public Transport Victoria and VicRoads have extensive traffic data available which provides the data required for a **Geographic or territorial method** approach to calculating VKT travelled within City of Melbourne and the associated emissions.

VicRoads provide traffic count data for all major and declared roads in Victoria. Within the City of Melbourne this means that many roads, especially those which carry large traffic volumes, have reliable actual or estimated traffic numbers. Notable exceptions in this data are the CityLink components (Bolte Bridge, and Domain and Burnley Tunnels). The data are provided as a GIS readable file (shapefile for use with ArcGIS products) and can therefore overlay a street or aerial map of Melbourne. This data can also be clipped so that only roads within the City of Melbourne are shown, and have geometry calculated, designating every length of street with and *ALLVEHS_AADT* (Yearly volume for all vehicles divided by 365), *TRUCKS_AADT* (Yearly volume for trucks divided by 365), and *Length* (in kilometres, to 3 decimal places). Non-truck VKT can therefore be calculated (in ArcGIS) as follows:

Non-truck VKT per year = ((ALLVEHS_AADT - TRUCKS_AADT) X Length) X 365

While truck VKT can be calculated (in ArcGIS) as follows:

Truck VKT per year = (TRUCKS_AADT X Length) X 365

All lengths can then be exported from ArcGIS to give total VKT for trucks and non-truck vehicles across all City of Melbourne roads which have reliable count data. However, it should be noted that data are currently not available for all streets: data are largely missing from quiet residential streets which are unlikely to carry large amounts of traffic. This missing data may slightly underestimate total VKT. For increased accuracy, the City of Melbourne should undertake traffic counts on all streets annually to determine traffic volumes. Doing so would give additional data to the transport teams, allowing for finer grain analysis of traffic movements and more comprehensive planning outcomes.

Non-Truck VKT per year can further be segmented by vehicle class using fleet data and mode data from BITRE's Yearbook and ABS Survey of Motor Vehicle Use (see Australian Bureau of Statistics, 2017b; Department of Infrastructure and Regional Development, 2016). This will give a detailed breakdown of how many kilometres are travelled per year on City of Melbourne streets, broken down by trucks, motorcycles, cars (fossil fuel), cars (hybrid), and cars (plug-in electric). Each of these shall then have an associated emissions factor, providing the total VKT and total GHG emissions each year from on-road transport.

All VKT and associated emissions from vehicles that run on fossil fuels shall be categorised as Scope 1. All VKT and associated emissions from vehicles that run from electricity sourced from charging stations shall have that electricity categorised as Scope 2. Also, it is important that electricity used for charging vehicles is not included in the **Stationary Energy** sector too, as this will lead to double counting.

Public transport buses

Although buses should already be included in the road network VKT, the City of Melbourne may wish to separately account for the GHG emissions, as a way of calculating per-traveller GHG emissions. The total route length of each bus route's portion which operates in City of Melbourne (in each direction) shall be calculated. Examination of timetable and discussion with operators will determine the number of services run on each route, in each direction. The number of services operated multiplied by the route distance will yield a VKT which can be multiplied by the GHG emissions factor of an average commuter bus. This will provide the total GHG emissions from buses. Passenger numbers can be determined through discussion with PTV, and extrapolated to determine average GHG emissions per passenger.

3.5.2.2. Railway

The GPC categorises railway as *'including trams, urban railway subway systems, regional (inter-city) commuter rail transport, national rail system, and international rail systems, etc.'*

Scope 1 emissions are produced by V/Line rail, XPT, the *Overland* and freight trains, as all services are non-electrified. The GPC requires emissions to be counted from these vehicles while they travel within the City of Melbourne boundaries. The total distance per service can be calculated from investigating the timetable, maps and/or discussions with operators. The distance travelled per service shall be multiplied by the number of services per period (e.g. weekly, monthly) to provide a periodical VKT. Multiplying VKT by emissions per kilometre, to be determined in discussion with operators, will yield total Scope 1 emissions. It should be noted that different services will have substantially different emissions per kilometre, and as such, separate calculations should be made for:

- V/Line DMU (Sprinter/V/Locity) for each consist type
- V/Line locomotive hauled trains
- XPT
- Overland
- Freight trains (this will require discussion with separate operators)

With regards to V/Line services, passenger numbers can be determined in discussion with PTV and V/Line. These numbers can be extrapolated to determine average GHG emissions per passenger.

All Metro Trains Melbourne (MTM) and Yarra Trams (YT) services that operate within the City of Melbourne operate on electricity and are counted as Scope 2 emissions. The GPC stipulates that *'grid-supplied electricity used to power rail-based transportation systems is accounted for at points of supply'*. A strict interpretation of this would lead to the accounting of all electricity passing through 1500VDC (MTM) and 600VDC (YT) substations within the City of Melbourne. This is a very simple method of accounting for GHG emissions as it simply requires the rail operators to report substation electricity use and electricity sources to the City of Melbourne. However, this could include electricity used to provide motive traction to rail vehicles outside of the City of Melbourne and could conversely exclude electricity provided by substations in neighbouring LGAs to rail vehicles inside the City of Melbourne. As such, this technique should be avoided.

The GPC also requires that *'electricity charged for railway vehicle travel within the city boundary shall be accounted for under scope 2 emissions'*. In order to meet this requirement, an alternative approach to GHG emission calculation should be undertaken. The total distance traversed by each electric rail service (in both directions, and in the case of the City Loop, in am and pm) shall be calculated in consultation with operators and rail line diagrams. Timetables will need to be examined to determine the number of services operating to, from, and through City of Melbourne each week, based on each permeation. Multiplying timetabled services by distance travelled will give a weekly VKT for MTM and YT rail vehicles. This would then be able to be multiplied by the emission factor per kilometre travelled, on average, per rail vehicle which would be discovered through discussion with MTM and YT. Passenger numbers can be determined in discussion with PTV, and extrapolated to determine average GHG emissions per passenger.

3.5.2.3. Water-borne transportation

The GPC categorises water-borne transportation as *'including sightseeing ferries, domestic inter-city vehicles, or international water–borne vehicles.'* The City of Melbourne contains the Port of Melbourne, Australia's busiest contain port. This generates a large amount of shipping traffic, and associated transport (both on-road and railway). Sightseeing vessels operate along the Yarra River. West of Webb Bridge there is a number of private moorings, predominantly occupied with private vessels.

All GHG emissions from water-borne travel within City of Melbourne boundaries are counted as Scope 1. Accounting for these GHG emissions is complicated by the fact that the boundary between the City of

Melbourne and City of Maribyrnong is in the centre of the Yarra River. Highly accurate estimates of GHG attributable to the City of Melbourne's shipping would require investigating the position of shipping channels in relation to the boundaries. Scope 1 emissions accounting will also require the inclusion of the fuel mix used by all vessels.

Methods of calculation

To determine an estimate for shipping emissions associated with Swanston Wharf, the distance travelled within the City of Melbourne component of the Yarra River must be estimated and this is then multiplied by the average consumption of ships (laden and unladen). Both these estimates need to be made in consultation with the maritime industry. This calculation shall be made based on the number of port movements, and the distance each port movement is assumed to make within the City of Melbourne. Fuel consumed while berthed must also be estimated. The GHG emissions while berthed need to be calculated in discussion with the Port of Melbourne and/or port operating (e.g. stevedoring) companies.

Ferries – GHG emissions shall be determined following discussion with operators regarding fuel consumption rates and analysis of timetables/routes to determine how many VKT are undertaken within the City of Melbourne and how many journeys are made each day.

Personal watercraft – GHG emissions shall be determined following discussion with marina operators regarding fuel consumption and boat usage. This is going to be very difficult to calculate due to the wide variety in size of personal watercraft and their fuel consumption. As such, these accounts are likely to have a wide margin of error. Another difficulty comes from power consumed on board personal watercraft while docked, as this may come from grid electricity, solar, or fossil fuels.

All electricity consumed by ships while berthed is counted at Scope 2 GHG emissions. Accounting for these emissions will require discussion with marina and port operators.

3.5.2.4. Aviation

The GPC categorises aviation as *'including helicopters, domestic inter-city flights, and international flights, etc.'* The City of Melbourne has no facilities for fixed wing aircraft to land or take off, but does have several helipads. The Royal Children's Hospital has two helipads while the Royal Melbourne Hospital and the Alfred Hospital both have one. There are also four commercial helipads. Additionally, our assessment found that a helicopter landing facility may exist at Government House, the Docklands, and Fishermans Bend.

To determine an estimate of the GHG emissions associated with the use of helicopters over the City of Melbourne, discussions with helipad operators regarding the kilometres travelled over the City of Melbourne will need to occur. In the case of hospital helipads, GHG emissions shall be calculated in collaboration with Ambulance Victoria and any other relevant emergency or lifesaving aviation bodies.

3.5.2.5. Off-road

The GPC categorises off-road as *'including airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles, etc*.'

As the City of Melbourne is a densely populated area without substantial agricultural or resource activities, off-road transport uses are limited largely to construction and warehousing activities. Emissions from vehicles, operating off-road, within these industries are best calculated as part of the industry they directly support. As such, it is recommended that off-road emissions not be included in the transport emissions, but rather as an emission of industry. For instance, emissions from bulldozers should be included in *construction* not *transport*.

3.5.3. Applying our approach to road vehicle emissions

Using the suggested method described earlier in this section, we have developed an estimate of VKT and CO_2 emissions within the City of Melbourne that is GPC compliant. As a comparison, we have included the

Melbourne LGA Transport GHG Model estimates, although it should be noted that this uses data taken around three years earlier. Our modelling looks solely at on-road VKT within the City of Melbourne. This is in contrast to previous modelling which counts all VKT for all journeys that are to or from the City of Melbourne, even for the parts of the journey outside the City of Melbourne. By contrast, our model will rely on VicRoads traffic count data, enabling the inclusion of through traffic, which may have been omitted under the previous modelling based on VISTA.

VicRoads traffic count data does not differentiate between different types of light vehicles. As such, all VKT from cars, motorcycles, and LCVs are treated as one, with an emissions profile of a passenger vehicle. VicRoads traffic count data also does not differentiate between different types of trucks. Therefore, an average emissions profile, based on the ratio of VKT travelled by each heavy vehicle type was calculated and then applied to the total VKT.

The results are provided in Table 2 and despite some differences in approach, arrive at a broadly comparable result. The previous approach estimated less VKT but higher CO_2. The reason for this discrepancy may relate to the fact that heavy vehicles (light rigid, heavy rigid, articulated and buses) VKT estimates are higher in previous modelling. This can be explained by a methodological change, with our modelling relying on VicRoads traffic count data rather than trip modelling. The previous trip modelling assumed 742,594 trips annually, with each trip being 142.15km. While this may be true of articulated truck trips, many of these kilometres will be travelled in areas which are not within the City of Melbourne.

Vehicle type	MELBOURNE LGA TRANSPORT GHG MODEL		Our estimate (GPC compliant)	
	VKT	CO_2 (Tonnes)	VKT	CO_2 (Tonnes)
Car	945,344,510	240,915		
Motorcycle	11,631,800	1,913		
LCV	121,392,955	36,949		
Sub-total	**1,078,369,265**	**279,777**	**1,287,590,836**	**313,914**
Light Rigid	36,129,017	21,550		
Heavy Rigid	9,365,867	7,161		
Articulated	105,557,861	159,714		
Buses	16,501,773	18,672		
Sub-total	**167,554,518**	**207,097**	**107,398,624**	**110,610**
Total	**1,245,923,783**	**486,874**	**1,394,989,460**	**424,524**

Table 2 Comparing the previous and new approach to estimating on road transport GHG emissions

In order to represent intensity of emissions, Figure 33 offers an illustration of estimated emissions across the road network monitored by VicRoads. Emissions are expressed in grams/linear metre of roadway, with the darker the line, the greater the emissions. CityLink is not included in Figure 33, as it is not monitored by VicRoads. The omission of CityLink leads to an undercounting of total road based emission in the City of Melbourne. If accurate count data were available, it would be simple to add CityLink and future toll roads into the data calculations.

Figure 33 Estimated emissions from the road network within the City of Melbourne

Based on our analysis, the roads that account for the highest emissions, from one to ten, within the City of Melbourne are:

1. Westgate Freeway
2. Kings Way
3. Punt road
4. Princes Street
5. Punt Rd/Hoddle Street
6. Mt Alexander Road
7. Wurundjeri Way
8. Montague street
9. College Cres
10. Victoria Street

3.6. A future contribution from electric vehicles: Exploring scenarios and impacts

Electric vehicles are often suggested as a policy approach to reducing transport emissions (e.g. see Sims et al., 2014). As an initial activity, we have conducted a high level exploratory assessment of a future scenario in which *all* passenger vehicles are plug-in electric. We have compared this to a separate scenario in which the passenger vehicle fleet is made up of the top 10 most commonly sold vehicles. As shown in Table 3 this illustrates a somewhat counter-intuitive finding; the *all-electric* scenario reduces emissions *less* than simply modernising the fleet with new internal combustion engine vehicles. This is of course due to the current level of reliance on brown coal in the Victorian electricity grid and assumes that the vehicles are charged on this power source, rather than renewable energy. This calculation also assumes no behavioural change in VKT, even though it is quite plausible that a move to plug in electric may be associated with an *increase* in VKT due to lower operating costs and potentially "guilt free driving", a modern day manifestation of the Jevons paradox. These findings are consistent with earlier analysis on vehicle emissions (e.g. see content surrounding Figure 21).

Fleet type	**VKT**	**Tonnes Emitted**	**CO_2 Reduction (Tonnes)**	**% Reduction**
All Electric (160 Wh/km - 180.8 gCO_2 per km)	1,287,590,836	232,796	81,118	26%
Modern popular cars (equally weighted average of 151.2 gCO_2 per km)	1,287,590,836	194,684	119,230	38%

Table 3 Scenario forecasts

4. Transport and Emissions: The Key Issues

4.1. Implications of travel behaviour for emissions

The material reviewed as part of this project reveal a disparity between climate change ambitions and transport emissions performance and trajectories. Whilst there has been a slight trend away from motor vehicle usage as a method of travel to and from the City of Melbourne, strong population growth has meant no substantial reductions in GHG emissions have been achieved. In fact, the Victorian trend is for increased car ownership (both in absolute and per capita terms), meaning that as Melbourne grows, so too will its private vehicle fleet. Although cars are driven slightly less per annum than in previous decades, there will still be a marked increase in vehicle kilometres travelled (VKT) across the metro Melbourne area as a result of these new vehicles and their subsequent use. Nationally, there has been a stagnation of total car related emissions for approximately the last decade. This is a result in changed driving behaviour and improved fuel efficiencies. Current trends in transport emissions mean Australia's relatively modest emission reduction targets will not be met.

Major new road projects, such as the West Gate Tunnel and North-East Link, and a possible East-West Link, have the potential to radically increase VKT through the City of Melbourne. The behavioural consequences of these projects will be two-fold: firstly, they will add to the road carrying capacity, allowing tens of thousands more people to drive into and through Melbourne's core; secondly, by causing reductions in travel time, even if marginal and temporary, they will further affect the urban landscape, encouraging and permitting a continuation of urban sprawl that Melbourne has been experiencing since the post-war period. The link between sprawl and increased transport emissions has been established for a number of decades (e.g. see Newman & Kenworthy, 1999) and has more recently been implicated in rising consumption generally and increased overall emissions (Owen, 2012).

4.1.1. Public transport

The ABS Journey to Work data (see Section 3.4.3) shows that people who work within the Melbourne municipality as well as those who live near quality public transport infrastructure (e.g. high-frequency railway lines), are most likely to use public transport. However, Melbourne has outgrown its high quality public transport infrastructure and residential development has expanded into green-field areas on the fringe, in which car use becomes the only viable option for many (Currie et al., 2007). ABS Journey to Work data shows that areas surrounding Regional Rail Link, the South Morang rail extension and Craigieburn now have public transport mode shares exceeding 40%. Large-scale public transport projects such as Melbourne Metro will further increase the appeal of public transport, distribute people throughout the inner-city, and increase the capacity of Melbourne's commuter rail system. Improvements in public transport have the greatest potential to replace the need for private motor vehicles, increase the economic reach of the City of Melbourne municipal area and achieve the City of Melbourne's climate change mitigation ambitions. Section 6.7 will describe strategic opportunities to optimise the role public transport plays in helping to maintain and enhance mobility whilst lowering emissions.

4.1.2. Freight

All data reviewed thus for in this report suggests freight will grow, in both proportional and absolute terms. The Internet has had a profound impact on our lives and changed the way we purchase goods. Australians are making more purchases via the Internet (Startrack, 2017), and this trend is expected to continue to grow with new market entrants such as Amazon. This shift is accompanied by increased commercial delivery vehicle trips. The number of containers entering the Port of Melbourne has been rising, and is expected to continue to increase in the future. The rise of containerisation will lead to more large trucks on Melbourne roads, while the growth of Internet shopping will lead to more delivery vehicles. Together, this has potential to increase GHG emissions across metro Melbourne and within the Melbourne municipality. As will be described in Section 6.6.3, there are numerous opportunities Melbourne could take to enhance the efficiency of land freight in order to lower emissions.

4.1.3. Aviation

There has been a dramatic increase in aviation activity and passengers carried since the 1970s, as discussed in Section 3.2.1.4. In recent years there has been an expansion of choice in the aviation sector, with more airlines providing access to a greater variety of destinations, and competition including the budget airline segment driving down prices. Air travel is now in many cases the most affordable and convenient mode for travelling from Melbourne to other capital cities. In the Melbourne context it is notable that, under certain metrics, Melbourne - Sydney is one of the busiest air routes in the world and there are no time and cost competitive alternatives, such as high-speed rail. While these emissions may not be directly attributable to the City of Melbourne municipal area, they are inexorably linked with the role of Melbourne's central city as a driver of economic prosperity and a major attractor of tourism. Without alternatives aviation will continue to dominate travel to and from Melbourne to other major cities, with increasing GHG emissions which are indirectly attributable to the central city.

4.1.4. Active travel

Active transport (walking and cycling) is the most inclusive and environmentally friendly form of transport. Participation is widely accessible; most journeys begin and end as a pedestrian. Walking is the predominant mode of travel *within* the City of Melbourne (66% of all trips). VISTA data has shown a large increase in walking as a mode of accessing the City of Melbourne. There are a number of built form and behavioural factors which may be influencing this trend. Increased density on the periphery of the City of Melbourne in municipalities such as the City of Yarra may have increased the population within a walkable distance of jobs and activities within the City of Melbourne. Overcrowding on the public transport network, particularly trams, may also be a factor, with some choosing to walk instead of waiting for overcrowded trams.

The role of cycling in the City of Melbourne's transport mix is small and increasing very slowly in percentage terms. ABS Journey to Work data shows that the majority of cycling journeys into the City of Melbourne are from suburbs to the north, largely in the City of Moreland, City of Yarra and City of Darebin. These LGAs are the ideal distance for a cycling commute, are well connected to the City of Melbourne through relatively high quality cycling links with favourable geography. These factors increase the value proposition of cycling and can help explain the higher levels of cycling from these areas. Given that the mode share of cycling is largely stagnant, it is unlikely that major increases in cycling participation can be achieved without a more concerted effort to significantly enhance cycling connections to/from Melbourne's CBD, providing safe, protected and convenient routes into the city.

Section 6.3.2 will describe some of the strategic opportunities that exist to help make Melbourne a cycling city, while improving pedestrian outcomes is described in numerous areas within Section 6.

4.1.5. Summary

If the prevailing transport trends and behaviours exhibited in Melbourne continue, it will not be possible to make the decreases in emissions required for the City of Melbourne to reach its climate change ambitions and contribute to Australia meeting its targets under the Paris Agreement. The car is still the dominant mode of transport in Melbourne, and as discussed in Section 3.6, even a shift to pure electric vehicles will not have the desired GHG emission outcomes, and will do little to enhance the liveability and vibrancy of the City of Melbourne. A more substantial shift away from car use as the predominant transport mode, towards sustainable transport options such as walking, cycling and public transport will be required. These modes have the potential to carry many more people than the private motor vehicle within the equivalent amount of space (United Nations, 2013). Further, these modes have much lower GHG emissions intensity than private motor vehicles and can much more easily be powered by renewable sources. There will always be a role for the motor vehicle in metropolitan Melbourne and the City of Melbourne, but current trends are unsustainable, and should Melbourne wish to meet its climate change targets, reprioritising the transport landscape to make it easier to not have to drive will be unavoidable.

4.2. Air quality implications of current travel behaviour

If current behavioural trends continue, the City of Melbourne is likely to see decreased air quality in the short to medium term, due to emissions from motor vehicles. The increase in car usage and truck movements will increase particulate matter and other air borne pollutants. The increased throughput of the Port of Melbourne and extra road capacity from projects like the West Gate Tunnel will cause more vehicles, including articulated trucks carrying containers, to drive through the City of Melbourne. Articulated trucks generally operate on diesel and as such, will increase particulate matter (Dora & Phillips, 2000), which will be particularly damaging to cardio-respiratory health because their size is small enough to pass through the protective structures of the respiratory tract (MacIntyre et al., 2014; Rojas-Rueda, de Nazelle, Tainio, & Nieuwenhuijsen, 2011). It should also be noted that the shift towards more diesel cars, with six of the top ten most popular cars in Australia now being diesel, may also exacerbate air quality problems. Diesel fuel creates more particulates per litre consumed than petrol and is a known carcinogen. This increase in diesel fuel consumption will decrease air quality and have public health consequences.

Electrically powered vehicles such as trains and trams, and plug-in electric cars avoid tail pipe emissions and can therefore lead to improved *local* air quality, regardless of the source of electricity. However, if electricity is produced from fossil fuels, there will be air quality degradation at the site of generation, in areas outside of the City of Melbourne, where the electricity is generated. The overall impact on human health may be reduced, as the population density is typically less, however cleaner solutions to meeting our transport needs are now available, and should be pursued in order to reduce total GHG emissions and improve air quality. See Section 6.6 for a description of opportunities designed to reduce pollution from motorised transport.

Maritime activity at the Port of Melbourne reduce air quality. A problematic form of fuel, known as bunker fuel, is sometimes used by shipping companies due to its low cost. Bunker fuel has a high sulphur content and generates a large amount of particulate matter which can negatively affect human health (Dora & Phillips, 2000) and is banned in many countries. If shipping companies berthing at the Port of Melbourne are to use bunker oil, and the number of port calls increases, this will decrease air quality in the City of Melbourne.

4.3. Contributing factors to transport related emissions: An overview

4.3.1. Private vehicles

The past 40 years has seen a gradual albeit small decrease in the emissions intensity of private vehicles. Fuel consumption of the Victorian passenger vehicle fleet is now at 10.6 litres per 100km, from 12.6 litres per 100km in 1976. Modern vehicles are achieving much higher efficiency, but substantial fuel efficiency benefits only arise when a significant proportion of the fleet utilise this technology (which is currently not the case). Hybrid vehicle technology and diesel engine performance has helped to lower vehicle emissions. It is unlikely that any major reductions in GHG emissions will be achieved simply from improvements to Internal Combustion Engine (ICE) efficiency and there is some evidence that improved efficiency can result in greater VKT (Owen, 2012). The largest potential for decreasing emissions intensity of the private vehicle fleet is likely to come from electric vehicles, but only if powered by renewable energy sources, as described in Section 3.6 and Section 6.6.2.

4.3.2. Freight

Increases in light commercial vehicle travel, which is widely expected, will increase GHG emissions in metropolitan Melbourne. Trucks have a much longer age than private vehicles, meaning that older, dirtier vehicles stay on the road for longer (Sims et al., 2014).

4.3.3. Public transport

Melbourne's public transport system will need to be modernised and expanded in order to create the shift away from private motor vehicle use that will be required to meet emission targets. The tram network now has its equivalent energy use met with renewable energy (Minister for Energy Environment and Climate Change, 2017). Internationally, some train networks (e.g. the Dutch train system) are now powered by 100% renewable energy and adopting a similar approach for the Melbourne train system would achieve a major reduction in public transport emissions across Metropolitan Melbourne.

4.3.3.1. Marginal 'cost' of emissions from higher vehicle occupancy

The most efficient way of increasing the number of people a transport system can carry is to increase vehicle occupancy. As long as no extra vehicles are required, increasing vehicle occupancy is not expected to alter GHG emissions to a meaningful degree, but will lower GHG emissions on a person km travelled basis. In the case of private cars, there is generally extra capacity, with VISTA data showing that passengers account for only around one fifth of those who access the City of Melbourne by car. As such, actions which have the potential to increase occupancy, such as network based road user charging (see Section 6.5.2), may reduce per capita GHG emissions. The amount of reduction will be dependent on the vehicle and its emissions profile, and the distance being travelled.

Determining the emissions implications from increased public transport occupancy is more complex. There is often ample capacity outside of peak times, and increasing occupancy levels during these periods will reduce the person km travelled GHG emission profile of the public transport vehicle. However, PTV load surveys of the tram and train system show that during peak periods many public transport vehicles entering the City of Melbourne are near or at capacity (Public Transport Victoria, 2017). As such, there is limited capacity to increase vehicle occupancy of these services. Alterations can be made to increase the capacity of carriages, increasing standing room and decreasing seating, however, this may reduce overall comfort levels and desirability of the public transport services. Further, train services to renewable energy, as suggested earlier, mitigates all GHG emissions from operating the vehicle. As such, there are effectively zero emissions and the marginal cost of adding passengers or services will be zero.

4.4. Energy sources for transport

4.4.1. Petrol

As referenced earlier, the efficiency of the Australian petrol car fleet has been marginally improving over the last 40 years, from 12.6 litres per 100km in 1976 to 10.6 litres per 100km in 2016. In recent years petrol-hybrid technology has become more commonplace and can result in lower fuel consumption – for example the GreenVehicleGuide's most popular car of November 2017 (the Toyota Corolla hybrid) at 4.1 litres per 100km compares favourably with other cars.

4.4.2. Diesel

Diesel cars have become increasingly popular in Australia in recent years. Modern technology and increased efficiency appears to have encouraged demand for diesel vehicles. Six of the ten most popular cars, as listed by GreenVehicleGuide in November 2017, are diesel, with consumption of a Hyundai i30 being 4.5 litres per 100km. As identified earlier, small particulate emissions are higher in diesel vehicles and this can have significant negative health implications (Dora & Phillips, 2000).

4.4.3. LPG

In terms of CO_2 emissions, LPG sits between diesel and petrol vehicles. LPG is cheaper than petrol as it attracts a lower excise. Despite this, it appears to be less attractive compared to alternatives such as petrol-hybrid or diesel powered cars. Taxis are emblematic of this change, with almost all taxis in Metropolitan Melbourne being LPG a decade ago, while modern taxis today are have predominantly petrol-hybrid engines.

4.4.4. Coal-fired electricity

The Victorian electricity grid is highly GHG emissions intensive when compared to other developed nations (Ang & Su, 2016). For every kWh produced on the Victorian grid, 1.13kg CO_2-e is released (Department of the Environment, 2015). This makes Victorian electricity about 25% more emissions-intensive than NSW, the next highest in Australia. A consequence of this GHG emissions intensity is that plug in electric vehicles (which have the potential for very low emission profiles) become exceedingly polluting, as discussed in Section 3.3.1. This is especially the case with electric cars, and to a lesser extent, electrified rail services. The passenger carrying capacity of electrified rail means that the per capita emissions are still lower than petrol vehicles.

While the Hazelwood power plant, then Australia's most emissions-intensive, was decommissioned in early 2017, Loy Yang A and B and Yallourn remain operational, providing a large amount of Victoria's power needs through the high-emitting process of burning lignite (brown coal). For the City of Melbourne and Victoria to achieve their GHG reduction targets, there must be a move away from carbon intensive brown coal power and towards low or no emission power sources.

4.4.5. Electricity from other sources

Adequate supplies of renewable energy are required to facilitate a shift away from fossil fuel transport, towards electrically powered transport in Melbourne. Plug-in electric cars have the potential, if used in the same way as ICE cars are today, to place an enormous extra strain on the electricity grid, as highlighted in Section 3.3.1.

A mixture of renewable energy sources will be required to power any increase in the number of electric cars in the Metropolitan Melbourne area. With appropriate regulatory and market mechanisms (see for example Section 5.3.3 on Amsterdam's electric vehicle policy), electric cars themselves have the potential to facilitate the shift towards renewable energy. An example of this is the Tesla Model S, which is fitted with a 100kWh battery, large enough to power the average Victorian home for a week. Having this standard of electric cars connected to the electricity grid would allow the batteries to absorb surplus electricity during times of abundant production and also discharge into the grid when production is low. This option has the potential to even out the energy production lows and could make an important contribution to moving baseload power away from fossil fuel sources.

4.5. The challenges of growing demand for transport

As Greater Melbourne's population grows, so too will the number of people living, working, and visiting the City of Melbourne. Between 2009-10 and 2015-16 the number of people visiting the City of Melbourne on an average weekday increased by 11.2%. *Plan Melbourne 2017-2050* envisions Melbourne growing to 7.9 million residents by 2050, and this will in turn increase visitors and workers into the City of Melbourne. Without improvements to the coverage and carrying capacity of the public transport network, many of these new visitors may be left with little option other than to travel by car.

As indicated earlier, the growth of Melbourne's population has not seen a proportional increase in the development of the sustainable transport network (Davison, 2004; Mees, 2010; Mees & Groenhart, 2012). A negative effect of which is that GHG emissions from car travel are expected to increase. Even with a rise in the number of electric vehicles, it is likely there will continue to be many ICE cars on the roads for decades to come and without a renewable power supply electric cars, as highlighted earlier, may not improve the environmental performance of motoring.

Even with substantial public transport investment, projects such as the West Gate Tunnel will worsen congestion across the City of Melbourne, lowering liveability and productivity. Increased motor vehicle traffic and the associated noise and safety reductions will reduce urban amenity of the City of Melbourne's streets. Increased congestion on the road network will further slow trams and buses, reducing the attractiveness of public transport and decreasing the overall efficiency of the network.

4.6. Future transport technologies

4.6.1. Introduction

Urban transport is currently experiencing substantial disruptive forces due to a confluence of inter-related factors. Major advances in mobile Internet and GPS have created fertile ground for app-based ride sourcing platforms (e.g. *Uber*) as well as new car share business models. Advances in mobile technology are also being used to allow smartphones to act as an *access-all-modes* travel tool to help plan multi-modal travel journeys. Combining many of these technologies with rapid advances in autonomous vehicle capabilities has the potential to make a useful contribution to transport related emission reductions. A 2016 report commissioned by the City of Melbourne (see Fishman, 2016) described some of the impacts and implications of disruptive transport technology on the City of Melbourne and should be referred to for more detail.

4.6.2. Mobility as a Service

The rapid advance of so called *Mobility as a Service (MaaS)* platforms has opened the prospect of people being able to *access* mobility, without the need for ownership. Given that the average car is often the second most expensive item households own yet sits stationary for 96% of the day, the transport sector is now seen my many technology and industrial behemoths as fertile ground for disruptive innovation. Under the MaaS model, people typically use their internet connected device to book/summon a transport service and this, to a varying degree, replaces vehicle ownership.

New MaaS platforms, focused on passenger vehicles (e.g. Uber) or small-scale transit are rapidly emerging in many cities, including Melbourne. For example, almost one in five Australians have used Uber in the last three months (Roy Morgan Research, 2017). MaaS has existed in the City of Melbourne for a number of years, in the form of by-the-hour car share, and since 2010, *Melbourne Bike Share* has offered the opportunity for short term bike use, without the need for ownership, which has resulted in a very modest reduction in transport emissions (Fishman, Washington, & Haworth, 2014).

On demand, pop up transit has had a somewhat volatile commercial history, with many ventures failing to be economical (Enoch, 2015). There are some small-scale pilots of on-demand bus service occurring in Australia (e.g. Sydney and NSW Central Coast) however it remains to be seen whether they are viable in the long term.

A number of cities (e.g. San Francisco, Seattle) share an ambition to have an *access-all-modes* Smartphone app, in which users are able to gain information, access and pay for a variety of transport services, all through a single App. This would include paying for public transport, taking an Uber, unlocking a bike share bike, or renting a car share vehicle. The implication of these developments for the City of Melbourne and its ambition to significantly reduce its contribution to climate change is that MaaS changes the car ownership paradigm that currently exists. Many of the inefficient transport behaviours that contributed to the rise in GHG emissions have been linked to the cost structure associated with vehicle ownership. Once the car is purchased, it makes more economic sense to use it for all (or most) trips, even those that are very short (compared to if paying for each trip individually). This skew towards *fixed* rather than *variable* costs has led to an overuse of the motor vehicle (Litman, 2015, 2016). There is a real opportunity offered by MaaS to de-link vehicle use from vehicle ownership. This promises the possibility of more economical use of the car and a dramatic reduction in the need for space dedicated to motor vehicle parking.

4.6.3. Autonomous vehicles

There are no fewer than 26 companies currently licenced to test autonomous vehicles on public roads in California alone. Locally, South Australia has introduced legislation allowing autonomous vehicle trials (Government of South Australia, 2016) and Infrastructure Victoria is actively investigating infrastructure requirements to facilitate the introduction of autonomous vehicles (Infrastructure Victoria, 2017). Apple, Google, Tesla, Volvo, GM and Daimler Chrysler are just a few of the companies that are well advanced in their ambition to offer full driverless vehicle technology within the next five years. A 2015 report by Barclays suggests that by 2035, the majority of vehicles may be autonomous and that in such a scenario, car ownership would be reduced by 50%. Indeed Barclays suggest that one shared car could replace *at least* nine privately owned,[1] conventional vehicles (Barclays, 2015).

This has major implications for the City of Melbourne. It is widely suspected that fully autonomous vehicles could dramatically reduce the need for car parking. For the City of Melbourne, this creates an opportunity to re-purpose land currently dedicated to both on- and off- street parking. Autonomous vehicles do however hold the prospect of more VKT, and greater total emissions. As discussed in a City of Melbourne commissioned report (Fishman, 2016), the greater accessibility of travel by autonomous car (e.g. those without a driver licence), as well as the possibility of significant reductions in cost, may result in VKT *growth*. It is currently too early to definitively know the precise impact autonomous vehicles will have on VKT or congestion (Whiteman, 2015) however, the following considerations/scenarios cannot be discounted:

- People without a driver licence (e.g. those who are below driving age or have given up their licence) will be able to summon a ride. Some of these people may have been chauffeured previously, but some will be either making a trip they would not otherwise have made, or do so by autonomous vehicle rather than use another mode (e.g. public transport, bicycle).
- Pooled autonomous vehicles may be able to compete on price with public transport. For Melbourne, even if the cost is slightly higher than public transport, many trips may be competitive with the same trip by public transport and this may result in a drop in public transport use.
- By not having to focus on driving, the rider avoids the 'time cost' of driving, which may increase their willingness to travel further or spend more time in congested traffic. For someone working in the City of Melbourne, it is plausible that they may choose to relocate to more affordable housing (further from the CBD), knowing they can accomplish other tasks during their longer commute. Cumulatively, this could have a significant increase in metropolitan VKT and the emissions that occur in the City of Melbourne, if these trips replace trips formerly completed by public transport.
- Some cars will be able to drive without any occupants. Whilst this may reduce demand for car parking, it is likely to exacerbate emissions and congestion by increasing VKT. This is especially the case with those who choose to own an autonomous vehicle (as opposed to those accessing a fleet of vehicles). For instance, an owner may choose to travel in their autonomous vehicle from their home in suburban Melbourne to their workplace. Rather than parking their car near their workplace, the owner may simply send their car back to their home (empty), until it is time for them to travel home again, at which time it is summoned again, travelling from suburban Melbourne (empty) to their inner Melbourne workplace. Under this scenario, the VKT and emissions are at least doubled. Should this occur at a population level, the effect on the emissions that occur within the City of Melbourne would be dramatic. Moreover, because the owner is not 'exposed' to the congestion when the vehicle is driving empty, they may be more willing to have the vehicle exposed to the high levels of congestion such a practice may cause – a cost which is imposed on other road users, and consequently, emissions on a per kilometre basis once again rise.

It is theorised that driverless cars are likely to be divided into four categories, as captured in Figure 34.

[1] This is based on the work of Fagnant, Kockelman, & Bansal (2015) using a modelling approach for Austin, Texas.

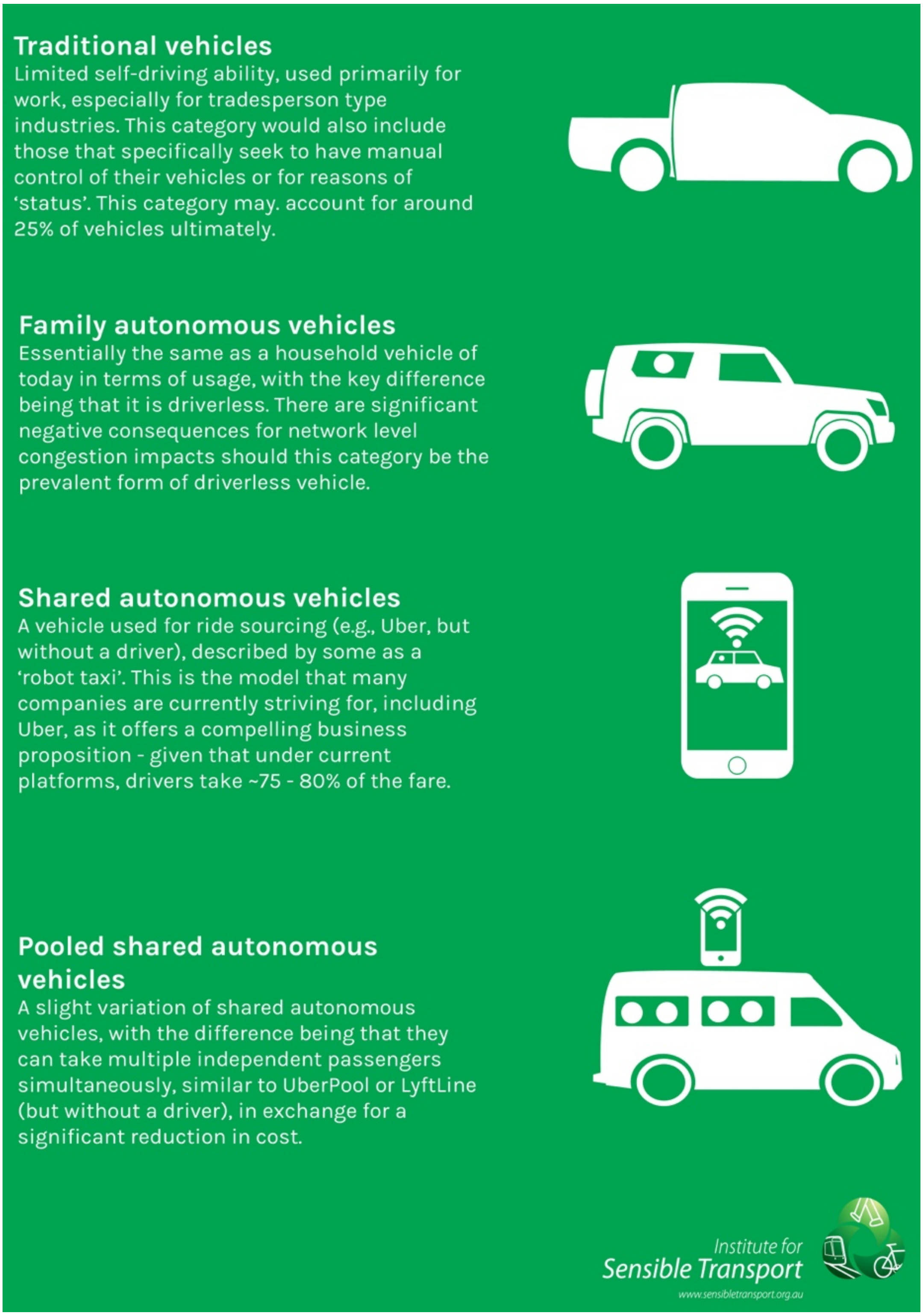

Figure 34 Future vehicle use classifications
Source: Based on descriptions provided by Barclays (2015) and Fagnant, Kockelman, & Bansal (2015)

The manner in which driverless vehicles are adopted and used in Melbourne is largely dependent on the government regulation to which they must adhere. Local, state and federal government can play a pivotal role in facilitating the outcomes that best support their strategic objectives. Section 6 will detail specific measures that can be put in place to ensure these technologies work to enhance rather than inhibit the ability of the City of Melbourne to realise its strategic ambitions, in regard to climate change, liveability and economic productivity.

4.7. Barriers to low emission transport technology

4.7.1. Motor vehicles

Adoption of low and no emission transport technologies face several barriers. From a motoring perspective, the transition to plug-in electric vehicles has four main barriers:

1. Cost

   The current cost of electric cars, coupled with lack of governmental support is hampering the uptake of electric cars (Energeia, 2016). In the year to June 2017 an estimated 1,100 (0.2 per cent) of the 463,765 passenger vehicles sold in Australia were plug-in hybrid or pure plug-in electric (Gardner, 2017). European countries have been providing incentives to purchase electric vehicles and some have begun phasing out ICE cars within the next two decades. These incentives and commitments are not present in Australia. Moreover, the decision to purchase an electric car is not made in isolation from the costs associated with ICE cars. Many of the top EV countries calculate annual ICE vehicle registration costs based on the size of the engine (a proxy for pollution). Electric vehicles are therefore more financially attractive in this pricing environment. Additionally, the cost of petrol is substantially higher in EU countries, strengthening the value proposition of EVs further. In Australis, the lone tax concession EV purchases were eligible for was removed in April 2017.

   A summary of the different policy support provided by Australian jurisdictions is provided in Table 4. It should be noted however that for Victoria, the *discounted parking* and *free charging* shown in Table 1 are not available across the vast majority of the State, and this includes within the City of Melbourne.

Policy type	QLD	NSW	SA	VIC	ACT	WA
Direct vehicle incentives	✖	✖	✖	✖	✖	✖
Charging infrastructure support	✔	✔	✔	✖	✖	✖
Registration incentives	✔	✔	✖	✔	✔	✖
Stamp duty discounts	✔	✖	✖	✖	✔	✖
Government fleet incentives	✖	✖	✖	✖	✖	✖
Vehicle lane privileges	✖	✖	✖	✖	✖	✖
Toll lane exemption	✖	✖	✖	✖	✖	✖
Discounted parking	✔	✖	✔	✔	✖	✔
Free charging	✔	✔	✔	✔	✖	✔

Table 4 Support for electric vehicles in mainland Australian states, and the ACT
Source: Energeia (2016)

2. Infrastructure

   There is a lack of charging infrastructure in Australian cities to support the take-up of electric cars. Range anxiety is a commonly listed barrier, and while batteries are improving the range of electric cars and reducing charging time, the number of charging stations is insufficient. To be viewed as a reliable replacement for ICE cars, EVs must be able to perform to a comparable level as ICE vehicles. This means being able to make journeys into regional areas and other major cities. Therefore, there needs to be an accessible network of charging stations. While this may be outside the purview of the City of Melbourne, increasing the number of charging stations within the City of Melbourne, and implementing planning controls that require a straightforward installation of charging points will position the City of Melbourne well for future up-take.

3. Renewable energy charging

   As highlighted earlier, there is also a need to ensure that EVs are charged by renewable energy. Failure to do so has the potential to simply shift emissions from the tail-pipe to a generator station. Electric cars will still have some benefit to local air quality however there will not be substantial reductions in GHG emissions. As highlighted earlier, a Tesla Model S powered by Victorian electricity is estimated to generate 209.05 grams of CO_2 for every kilometre travelled. This is only a small improvement on the average 243.8 grams of CO_2 per kilometre for the Victorian car fleet and much worse than the 96 grams per kilometre travelled emitted by a new Toyota Corolla hybrid.

4. Fleet turn over

   The last barrier to the uptake of low or no emission cars is the age of the fleet. In 2017, the average motor vehicle age in Victoria was 10.1 years, down slightly from 10.3 years in 2012 (Australian Bureau of Statistics, 2017b). However, 20% of the 3,750,484 passenger vehicles registered in Victoria were built before 2001. In 2012, 20% of the passenger vehicle fleet was built before 1996. It appears reasonably constant that 20% of the Victorian passenger vehicle fleet will be more than 15 years old (see Figure 35). As such, new vehicles purchased today are likely to make up a large portion of the fleet for years to come, and baring a major step change in purchasing habits, conversion of the fleet to electric will take more than 15 years from the point where electric vehicles become the only purchase option available to consumers.

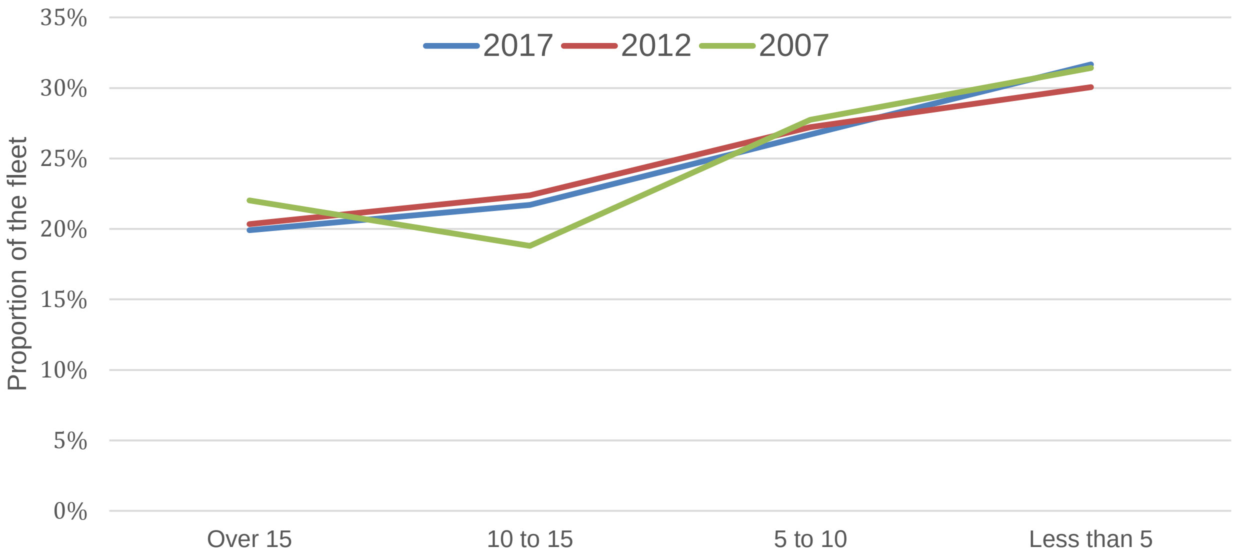

Figure 35 Car fleet age profile
Source: Australian Bureau of Statistics (2017b)

Finally, it is important to recognise that there are embodied energy costs in the production of new vehicles and while the emissions associated with the production of new vehicles are unlikely to be within the City of Melbourne, they do contribute to climate change.

4.7.2. Active transport

As previously mentioned, walking and cycling are the most climate-friendly modes of travel, with low embodied energy in the vehicles and no net emissions. Walking has grown as a form of transport to the City of Melbourne. However, cycling rates have shown only a very modest increase and in some instances, have declined slightly.

The key barriers to walking and cycling are (not exhaustive); infrastructure, safety, distance and social norms (Heinen, Maat, & van Wee, 2011). There needs to be a coherent, legible network of safe, direct and attractive bicycle routes that connect people from origin to destination. Intersection priority is also necessary, as these often present conflict points that are disproportionately represented in crash statistics (Teschke et al., 2012).

Safety concerns are the primary reason people offer for why they do not cycle, or do not cycle more often (Götschi, Garrard, & Giles-Corti, 2015; Pucher, Greaves, & Garrard, 2010; Rissel et al., 2010). A number of papers have documented the infrastructure required to overcome actual and perceived safety issues (e.g. see Schepers, Twisk, Fishman, Fyhri, & Jensen, 2015; Teschke et al., 2012; M. Winters, Teschke, Brauer, & Fuller, 2016; M. Winters, Teschke, Brauer, Grant, & Setton, 2010). To reduce the barrier a lack of safety represents, separation from motor vehicle traffic is critical (Deegan, 2018). Only in small streets with low speed, low volume motorised traffic should cycling occur without specific infrastructure.

As spatial analysis presented in Section 3.4 has shown, distance can be a crucial determinant of active travel participation. Increased urban densities within and surrounding the City of Melbourne will increase the population for which walking and cycling is a viable alternative to the car or public transport. A cohesive network of safe walking and cycling routes will support this density increase and decrease barriers to walking and cycling. Lastly, the current availability of reasonably priced, reliable electric bicycles now provides an option for those that live beyond a comfortable cycling distance from central Melbourne, and/or experience topographical challenges along their route. E-bikes are able to provide people with space and energy efficiency mobility, without the effort (and perspiration) of riding regular bicycles (Fishman & Cherry, 2015), which may further add to the attractiveness of cycling as an alternative to the car. Should bicycle infrastructure enhancements offer a level of attractiveness typically seen in best practice cycling cities (e.g. Amsterdam, Copenhagen), it is also likely people will be more willing to cycle longer distances (M. Winters et al., 2010).

4.7.3. Public transport

There are several barriers presented by Melbourne's public transport system to increasing mode share and improving environmental performance. From a climate change perspective, current emissions from fossil fuel powered buses and the carbon intensity of the Victorian electricity grid are key barriers.

Buses in Melbourne are largely powered by diesel. This acts as a barrier to the City of Melbourne achieving its GHG emissions goals. The electrified tram and train networks are reliant on the (carbon intensive) Victorian grid for power, so while they have lower emissions per passenger km travelled than cars, they are still GHG intensive. The Victorian Government has announced the construction of 35MW of solar farm capacity to offset the electricity usage of Melbourne trams (Minister for Energy Environment and Climate Change, 2017). This action will render the Melbourne tram system effectively carbon neutral, however, the train system will remain powered by carbon intensive power plants.

From a system wide perspective, Melbourne's public transport faces several barriers to increased utilisation. There has been little growth in coverage of the heavy or light rail networks since the 1930s (Mees, 2010). This has created an urban form which, particularly beyond the middle ring suburbs, is heavily car dependent by design (Currie et al., 2007). Expansion of the public transport system is required to increase coverage and therefore the percentage of the population within a reasonable distance of quality public transport. Frequency of services also needs to be improved in many cases, particularly with regards to the bus network, where it is not uncommon for services to run less than every half hour and not at all during the evening. The heavy rail system also faces major barriers to increasing service, such as capacity constraints caused be antiquated signalling, bottlenecks, and lack of track capacity. The tram system is hindered by the large amount of mixed traffic that trams must operate in and poor priority at traffic lights.

5. Case Studies

5.1. Introduction

The case studies detailed in this section are an important opportunity to identify examples of best practice. The case studies shown below provide valuable insights on the implementation of transport innovation intended to reduce transport emissions.

The case studies have been selected on three key factors:

1. Best practice, in terms of effectiveness in reducing transport emissions
2. Co-benefits, in terms of alignment with the City of Melbourne's wider strategic ambition; towards a greener, more prosperous city that better manages the demands of growth with the need to maintain and enhance liveability
3. A level of governance similarity with the City of Melbourne.

Ultimately, the cities included below have been selected because they have been able to implement a suite of measures that have either reduced car use, or reduced the emissions intensity of motor vehicles, and thereby lowered transport GHG emissions. They have also been selected because they offer transferability potential to the Melbourne context. Finally, the material examined in the development of the case studies showed that in general, the transport initiatives selected for this series of case studies do *not* have climate change mitigation as the primary outcome variable. More often, the initiatives are focused on urban vibrancy, enhanced space efficiency of road use or road safety benefits. These initiatives demonstrate that GHG reductions do not need to result in a reduction in liveability. However, because they are liveability-focused, there is a paucity of examples that have explicitly measured the GHG impact.

5.2. San Francisco

San Francisco, a city of 871,200 people[2], has experienced strong population growth over the last 20 years and is expected to house an additional 122,240 people by 2050 (Department of Transportation, 2017). San Francisco is also at the centre of the global tech boom, including many firms within the disruptive transport technology sector (e.g. Uber, Waymo). San Francisco is a test bed used by many of the world's leading transport technology firms and therefore the outcomes of these technologies are first seen (in the real world) in cities such as San Francisco. San Francisco is therefore a city that may offer a *window into the future* as it is likely to experience the impacts of these technologies before most other cities.

Transport emissions in San Francisco *grew* in the two decades to 2010, with a 3.2% increase in GHG emissions. Cars and trucks are responsible for 46% of San Francisco's total GHG emissions (SFMTA, 2017). Cars and trucks represent 91.3% of overall transport emissions (SFMTA, 2017), a situation which is broadly comparable to Melbourne.

San Francisco has very ambitious climate change targets. Its *Climate Action Strategy* (City and County of San Francisco, 2013) states an overall goal to source 100% of residential and 80% of commercial electricity from renewable sources, and reduce energy consumption overall through efficiency gains. Transport is also an important component of the *Climate Action Strategy*, with a target to achieve a 50% mode share for walking, cycling and public transport (City and County of San Francisco, 2013). At the time the Strategy was being prepared, GHG emissions had been dropping, even while the economy grew slightly.

The overarching goals of the San Francisco Municipal Transportation Agency (SFMTA), as articulated in the Strategic Plan are broadly similar to that of the City of Melbourne. These are:

1. Create a safer transport experience for everyone

[2] San Francisco County

2. Make transit, walking, bicycling, taxi, ridesharing, and car sharing the preferred means of travel
3. Improve the environment and quality of life in San Francisco.

The key performance indicators for San Francisco's climate change ambitions related to transport include:

1. By 2017, 50% of trips will be by means other than car[3], and to **grow this to 80% by 2030**
2. Expand the public transport system
3. Use 100% renewable energy to power the Bay Area Rapid Transit (BART)
4. Power the municipal railways (Muni) buses and taxi fleet by renewable fuels.

To achieve the transport mode shift to meet San Francisco's goal, a wide range of transport initiatives have been committed to, including:

1. Develop a network of protected bicycle paths and lanes, including the completion of the San Francisco bicycle plan
2. Expand bike share, including electric bicycles[4]. This has already begun, with two firms now piloting electric bike share in San Francisco (TechCrunch, 2018)
3. Boost car sharing options and enhance bike parking in new developments
4. Optimise the public transport system, including express corridors, enhance capacity and maintenance.
5. Develop *Complete Streets* in which levels of service for walking, cycling and public transport are enhanced, to improve the vibrancy, efficiency and safety of the street.

The most recent set of climate mitigation programs related to transport includes (SFMTA, 2017):

1. Transit: Much of the fleet is now powered by renewable fuels
2. Land use and transport integration
3. Pricing and congestion management
4. Transport Demand Management
5. Complete Streets
6. Zero emission vehicles and infrastructure
7. Emerging mobility services and technology.

One of the key challenges for San Francisco is the additional car use that occurs via platforms such as Uber and Lyft. It is estimated that on an average weekday, 170,000 vehicle trips occur via these platforms, culminating in 570,000 vehicle miles. Indeed 15% of all intra-San Francisco trips are estimated to be via ride sourcing platforms (SFMTA, 2017). While the emissions from these trips have not been quantified, a significant number of these journeys are replacing less carbon intensive modes, such as public transport (Rayle, Dai, Chan, Cervero, & Shaheen, 2016).

[3] This goal was met (SFMTA, 2017).
[4] Since the Strategy was published, the city's bike share program has expanded to 7,000 docked bikes, in addition to more recent dockless bike share providers.

5.2.1. Muni Forward

Muni Forward is a programme which brings together many projects and planning efforts to improve the Muni (municipal railway) public transport system. *Rapid Network* is the name given to several bus and tram lines which form the backbone of the Muni network and were upgraded to high frequency services. It is an aim of *Muni Forward* that 70% of passengers will be carried on Rapid Network. The Rapid Network uses priority lanes and stop spacing to ensure efficient movement of public transport services.

Muni Forward has seen multiple improvements to the public transport system of San Francisco. New routes have been implemented across San Francisco, increasing connectivity and the value proposition for using public transport. New buses, including 30 hybrid electric buses, have been introduced with the intention of having the entire Muni fleet replaced in coming years. Larger buses have also been introduced to busy lines to alleviate overcrowding. Frequencies on the most heavily patronised buses and trams have been increased. A transit signal priority project is under way, which detects oncoming trams and holds the green light. Transit only lanes have been installed, reducing travel time and increasing reliability. Finally, footpaths and crossings have been upgraded, improving the walking environment and increasing the accessibility of the Muni system.

5.2.2. SFpark and other pricing policies

SFpark was developed in 2010, with the goal of offering a *demand-responsive* pricing system that charges the lowest possible hourly rate to achieve a car parking vacancy rate of around 15%. Evaluation of SFpark found that the system resulted in less congestion by reducing the car travel that occurs when looking for an available parking bay. A 30% reduction in vehicle travel was found in the pilot area compared to comparable control areas (SFMTA, 2017). Opportunities to increase the performance of car parking in the City of Melbourne, in terms of supporting wider strategic objectives are discussed in Section 6.8.

A separate but related measure is a recently updated ordinance requiring all new residential, commercial, and municipal buildings to have sufficient electrical infrastructure to simultaneously charge vehicles in 20% of parking bays (SFMTA, 2017, p. 43). The SFMTA note that whilst electric vehicles, charged via renewable energy can make a meaningful impact on reducing emissions, electric vehicles still have the congestion and road safety issues associated with conventional ICE vehicles. In San Francisco's road use hierarchy, public transport and active modes continue to be prioritised over electric cars.

Pricing road use is a policy option San Francisco has begun to examine closely: *'Pricing and congestion management measures are one of the most powerful and underutilized policy tools to help change travel behaviour…emissions could be reduced by 25% through pricing measures'* (SFMTA, 2017, p. 35). The potential to lower carbon emissions in Melbourne through road user pricing is discussed in Section 6.5.2.

5.2.3. Road space allocation – 'Complete Streets'

Complete Streets are streets that serve the needs of a diversified mix of transport modes. In San Francisco, 97.6% of street space is either dedicated to private motor vehicle use, or mixed car use with public transport and/or cycling. Whilst the overwhelming majority of space is dedicated primarily to car use, car trips account for only 50% of trips. *Complete Streets*, by providing dedicated rights of way for public transport, protected bike lanes, and wider pedestrianised areas, increase the use of sustainable transport, lowering emissions and reducing road traffic injury (SFMTA, 2017). Many Complete Street projects also involving a greening of the street and this can help to sequester carbon dioxide, reduce the urban heat island effect and provide shade.

5.2.3.1. Cesar Chavez Street

Once described as the Berlin Wall of San Francisco (Smith, 2015), Cesar Chavez Street was a six-lane arterial road cutting through a working-class district of San Francisco (San Francisco Chronicle, 2011; Smart Growth America, 2015; Smith, 2015). It was originally widened in anticipation of a third bay crossing that never eventuated (Smart Growth America, 2015). By 2011 Cesar Chavez Street carried 53,000 vehicles per day (Smart Growth America, 2015), being one of the busiest streets in San Francisco (San Francisco Chronicle, 2011). The focus on facilitating traffic movements rendered the urban environment unappealing for active transport. Locals generally avoided walking or cycling down Cesar Chavez Street due to a disproportionate number of crashes involving pedestrians and cyclists and the unappealing built form (Smart Growth America, 2015). Following pressure from locals, the San Francisco Public Works Department released plans in 2011 to redesign Cesar Chavez Street. Following consultation with the community, the design was agreed upon which reduced the road from six-lanes to four, with turning lanes; included dedicated cycling infrastructure; improved pedestrian crossings; installed bulb-outs at intersections; installed a wider green median; and installed over 300 trees (Smart Growth America, 2015).

Figure 36 and Figure 37 provide before and after images of Cesar Chavez Street.

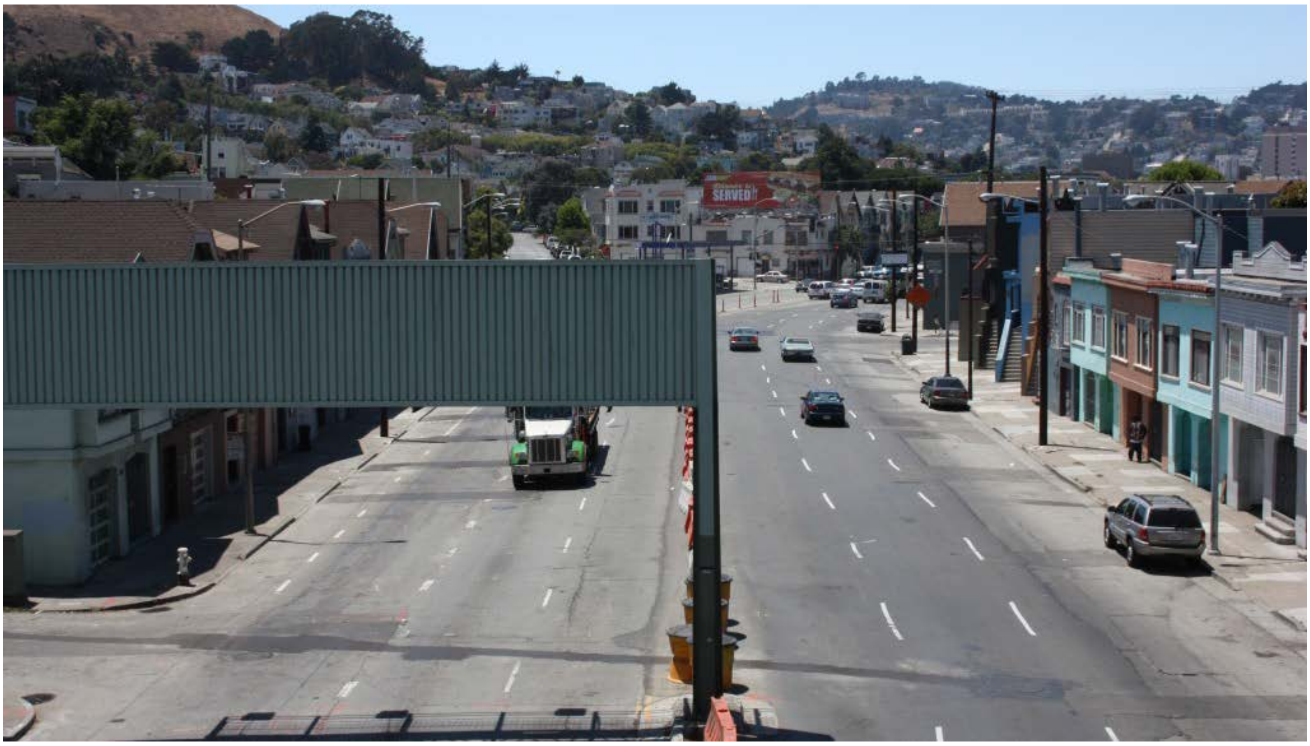

Figure 36 Cesar Chavez Street in 2012, before 'Complete Street' treatment
Photo: San Francisco Public Works

Figure 37 Cesar Chavez Street in 2015, following 'Complete Streets' treatment
Photo: San Francisco Public Works

Works were coordinated with water pipe renewals, and completed in 2014 (Smart Growth America, 2015). The new streetscape has provided a better walking environment, with shorter crossing distances, bulb-outs, and refuge islands installed at intersections (Smart Growth America, 2015). There are now 302 trees lining the street, which along with two new plazas and greenspaces have increased the attractiveness of Cesar Chavez Street and improved environmental performance by including Water Sensitive Urban Design characteristics (Smart Growth America, 2015). New bicycle lanes have also encouraged more people to cycle, with a 400% increase in cycling participation recorded (Smart Growth America, 2015). The project has been acclaimed by locals, and has won or been nominated for at least 99 awards (Smart Growth America, 2015).

5.3. Amsterdam

Amsterdam is recognised as one of the world's most successful cities in implementing transport initiatives designed to reduce emissions (Pojani & Stead, 2015). Over the last forty years Amsterdam has implemented increasingly ambitious projects designed to enhance the attractiveness of cycling, as well as public transport. More recently, Amsterdam has begun to enhance the pedestrian environment as well, and overall, the city is now seen as one of the best examples of sustainable mobility planning (Pojani & Stead, 2015). Like Melbourne, Amsterdam has experienced strong population growth over recent years (City of Amsterdam, 2015) but this popularity has placed pressure on its transport infrastructure, and a need has emerged to make pragmatic choices about how best to use its limited space.

This section provides a brief illustration of a small selection of projects Amsterdam has implemented, to bring about a lower emissions transport system. Importantly, the initial motivating force behind these initiatives has rarely been climate change. Whilst climate change is well recognised by Amsterdam and the Netherlands generally as a major public policy issue (Government of the Netherlands, 2018), it has been the desire to create a more human scale, people friendly and productive urban environment that has been the primary motivation for much of the projects undertaken in Amsterdam in recent years.

Figure 38 provides a mode share history for Amsterdam. This illustrates a gradual reduction in the proportion of trips by car (from 29% in 1986 – 1991 to 24% in 2015). Interestingly, walking and public transport has also been reducing, and cycling has been consequently increasing (from 21% in 1986 – 1991 to 36% in 2015).

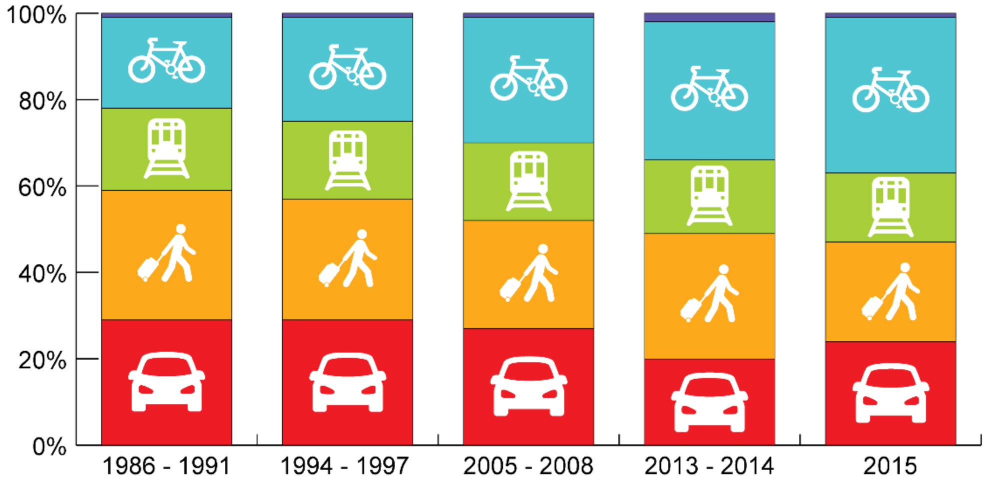

Figure 38 Mode share, Amsterdam
Source: City of Amsterdam (2017)
NB: top category is ‘moped’ at 1% - 2%.

Amsterdam is currently implementing a series of experimental, systematic redesign of streets and intersections. The City of Amsterdam’s *Mobility Implementation Plan*[5] offers the blueprint for the redesign of city streets focused on the following core outcomes:

- More space for pedestrians and cyclists
- Improve priority and reliability of public transport
- Manage demand for motor vehicle use (passenger and freight), to minimise negative impacts on congestion, safety and emissions.
- Safety: Improving safety is the starting point for all initiatives that take place under the Mobility Implementation Plan.

A good demonstration of Amsterdam’s commitment to enhancing safety is the widespread deployment of 30km/h zones for motor vehicles (City of Amsterdam, 2015).

Figure 39 provides an illustration of the *Amsterdam Mobility Implementation Agenda*, which the Institute for Sensible Transport has re-created from Dutch to English. It shows a combination key transport statistics, challenges facing the city, and opportunities to overcome these challenges.

[5] https://www.amsterdam.nl/parkeren-verkeer/uitvoeringsagenda/

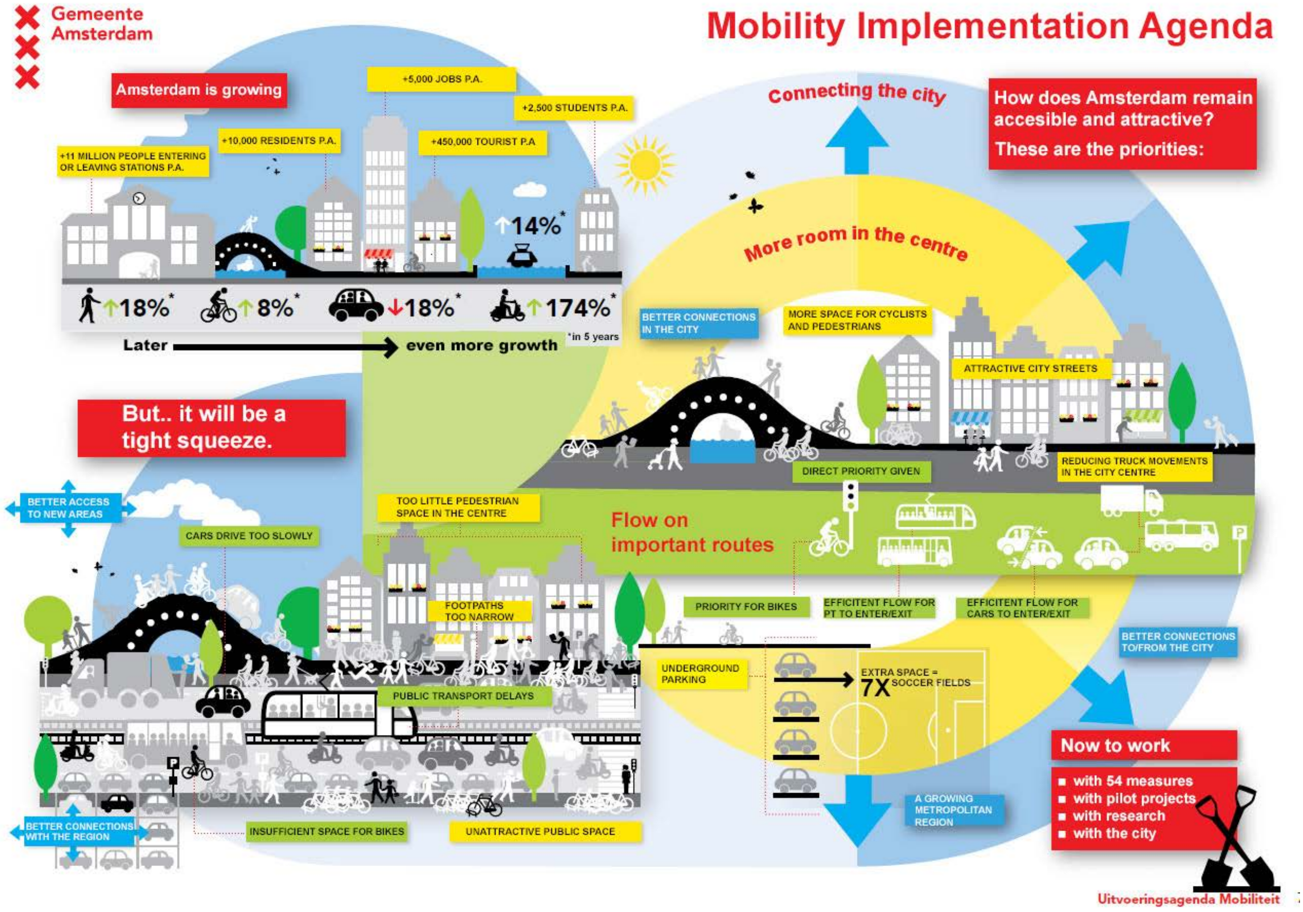

Figure 39 Amsterdam's Mobility Implementation Agenda
NB: This has been translated from Dutch to English by the Institute for Sensible Transport. Original source at: https://www.amsterdam.nl/parkeren-verkeer/uitvoeringsagenda/

5.3.1. The Red Carpet

The Red Carpet ('Rode Loper') is a recent, ambitious project involving the redesign of an important north-south corridor in central Amsterdam. Running for 3km, the *Red Carpet* is a joint project between business districts, public transport operators, the municipal transport authority and their spatial planning department. When complete it will connect Amsterdam Centraal Train Station in the north, to Cornelis Troostplein in the South. The project was linked to the construction of the Amsterdam north-south metro, which allowed for a radical rethink of how the corridor was to operate in the future. The objective of the Red Carpet project is to create more space for pedestrians and cyclists, combined with measures designed to reduce motor vehicle traffic volumes. This has been likened to an Amsterdam version of the 'Pavement to Plaza' program in NYC or the 'superblocks' in Barcelona.

Figure 40 provides an outline of the coverage of the Red Carpet project.

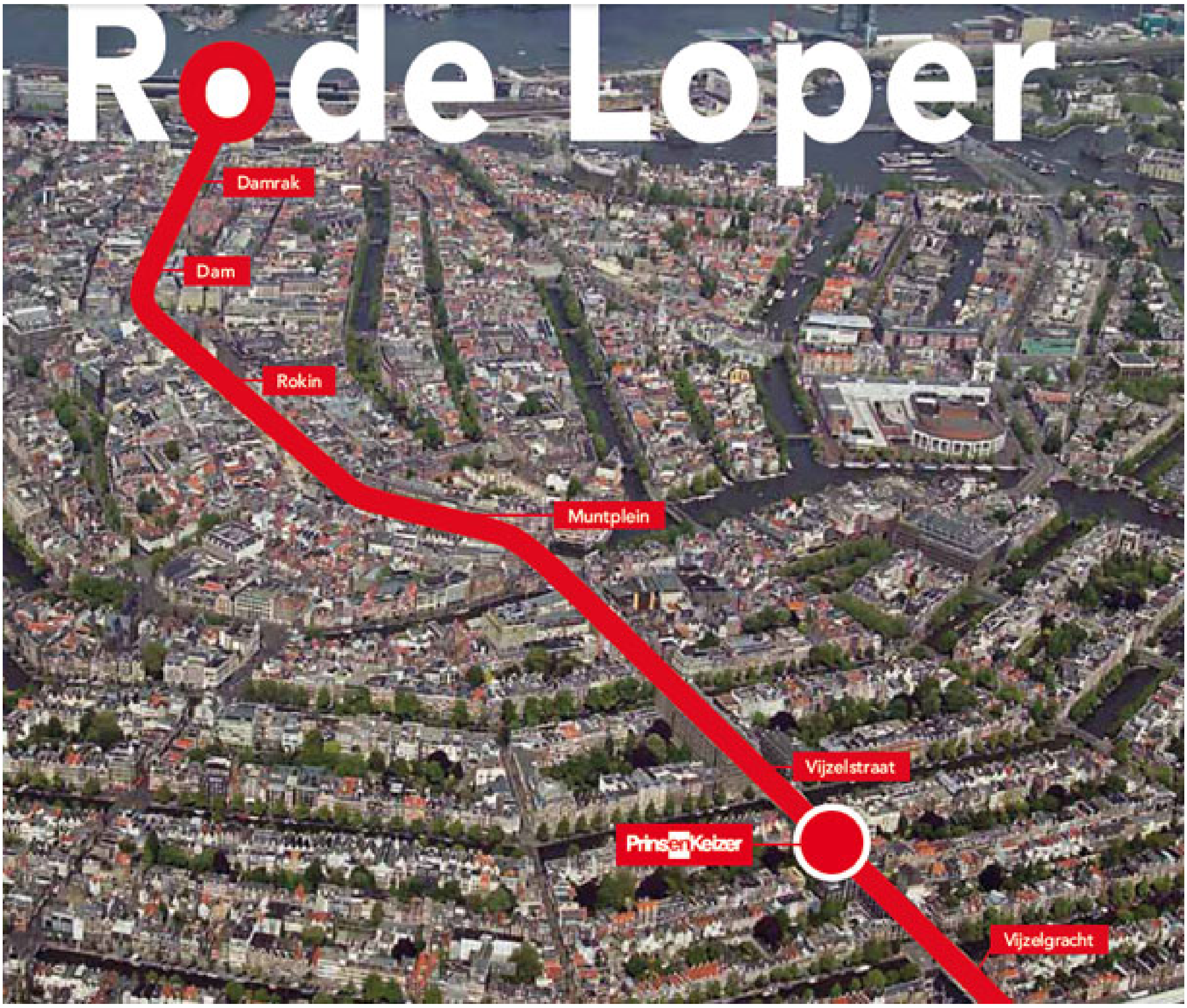

Figure 40 Coverage of the Red Carpet project
Source: https://amsterdamcentrum.pvda.nl/agenda/centrum-maakt-de-balans-op-van-rode-loper-loop-mee/

A typical section of street that now makes up the Red Carpet is shown in Figure 41, as it appeared prior to the development of works. As can be seen, the bicycle lane occupied the ‘car door zone’ and cars and trams were mixed.

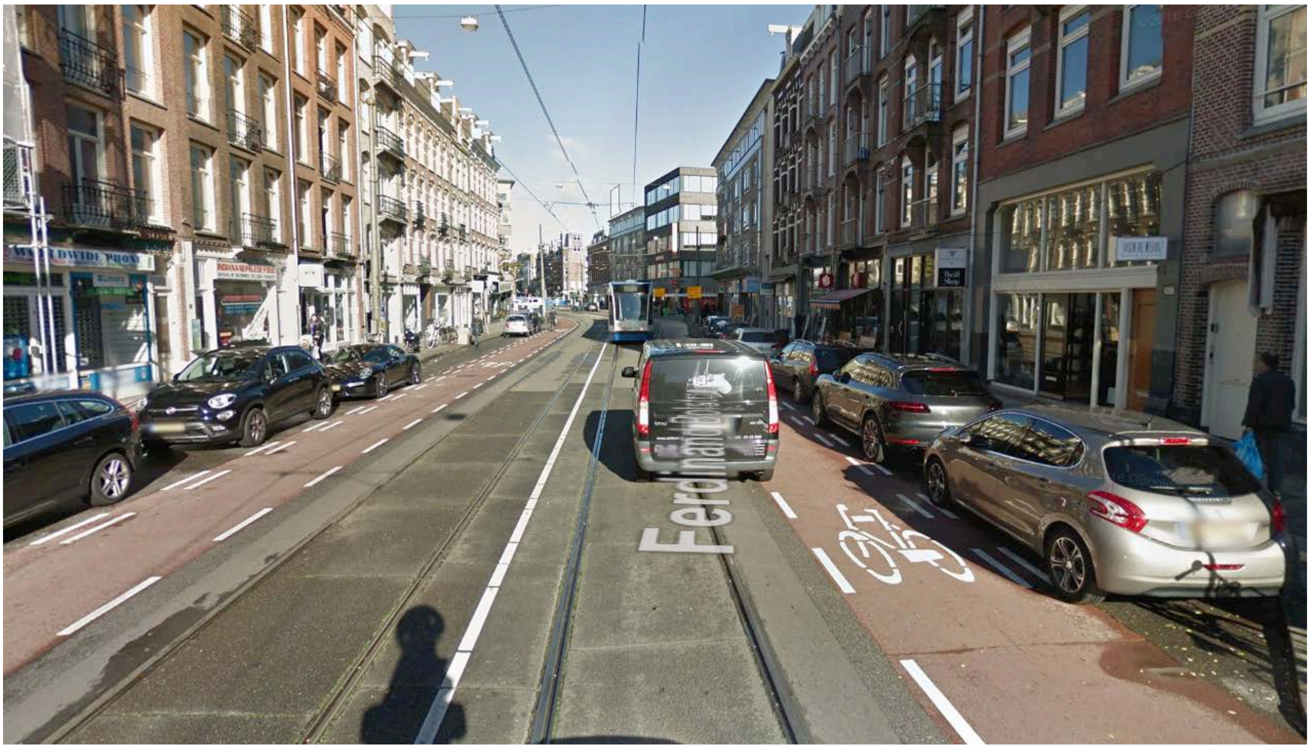

Figure 41 Ferdinand Bolstraat, prior to redevelopment
Source: Google Streetview, captured October 2016

The City of Amsterdam conducted an analysis of the cars using the corridor, prior to the creation of the Red Carpet project. The results revealed that more than 2/3 of cars using the corridor were *through traffic* vehicles, without an origin or destination in the area. This provided part of the impetus for reimagining how this corridor could function, and led to a greater level of acceptance for a design that transferred priority from cars to other modes of transport.

Recognising that the corridor provided a low level of service to people walking, cycling and using public transport was a central motivation behind the Red Carpet project. Just as importantly, the corridor was failing to offer an attractive environment for people to *linger* – to shop, socialise or relax. Like many areas within the City of Melbourne, the corridor forming the Red Carpet is home to many of the highest value retail precincts. It was therefore important to create an urban environment that was *sticky* (people enjoy spending time in the area). The twin objective of the Red Carpet project therefore was the enhancement of the public realm, to create a sense of place, and the provision of enhanced sustainable transport outcomes. By improving the attractiveness and safety of sustainable transport, the Red Carpet project is able to encourage low carbon forms of transport *and* boost economic performance of the businesses located along the corridor (van Damme, 2017).

An essential element of the Red Carpet project is the creation of a unique sense of space for each segment, with ‘red’ being the unifying theme. Further, to generate a tranquil environment, designers limit the number of different colours and materials used in redeveloped streetscapes. The theme of red is represented in different ways. For example, the new trees that will line the corridor have leaves that turn red in autumn. Road surfaces are also red, with ample usage of herringboned brickwork, which delineates the space for cyclists and can also act as a traffic calming measure. Figure 41 (above) and Figure 42 provide a comparison of what the streetscape looked like in Ferdinand Bolstraat (one of the streets that make up the Red Carpet) before and after the project.

Figure 42 Ferdinand Bolstraat, artist impression as part of Red Carpet
Source: Amsterdam City Council

The Red Carpet project is expected to be completed by mid-2018. Some sections have already opened, and although evaluation is still underway, those involved in the project are already happy with the results (van Damme, 2017). More space has been dedicated to cyclists which has improved safety and the streetscapes have been made more attractive and appealing (Litjens, 2017). In Section 6.3.6, selected streets within the City of Melbourne have been identified to conceptually describe how the Red Carpet project could be applied to Melbourne.

5.3.2. Car parking policy

Like the City of Melbourne, a significant proportion of Amsterdam's budget is dependent on car parking fees and fines. In 2009, more than €130m was collected by the City of Amsterdam in parking revenue, which amounts to almost a quarter of its total income (Mingardo, 2016). The entire inner city of Amsterdam has implemented paid parking, which generally costs €5 per hour in the city centre, to as low as €1.4 in outer areas. It is estimated that due to a lack of dynamic information, some 50,000km of car travel occurs in Amsterdam on a daily basis while looking for an available car parking bay (City of Amsterdam, 2015).

Amsterdam provides residential parking spaces. This is critically important as 90% of residents of Amsterdam do not have off-street parking, and are therefore reliant on Amsterdam City Council for car parking (Amsterdam City Council, 2017d). Residential parking permits within the core of Amsterdam (approximately 4km from Centraal Station) are only available to vehicles which comply with its emission standards, helping to meet Amsterdam's GHG emission targets. This policy is known as the *Milieuzone* (environmental zone) and is becoming common in large Dutch cities, as a response to air quality and climate change challenges (Amsterdam City Council, 2017b). Opportunities for applying car parking policies to enhance emissions performance in Melbourne are outlined in Sections 6.5.1, 6.8.2 and 6.8.3.

5.3.3. Electric vehicle charging

Amsterdam has 13 publicly available 50Kw fast chargers and 2,400 regular public chargers for EV users. The fast chargers can fully charge an EV battery within half an hour. All public chargers are powered by renewable energy sourced from local and regional wind farms. Amsterdam City Council will continue to expand the network of charging points, in cooperation with the private sector (Amsterdam City Council, 2017c). Transitioning to a full electric vehicle fleet is central to Amsterdam being able to meet its GHG emission and air quality ambitions.

Figure 43 Electric vehicle charging, Amsterdam
Photo: Institute for Sensible Transport

Fast charges are especially important for the taxi industry. Taxis need to drive many more kilometres per day than other cars and cannot wait long periods while their vehicles charge. Amsterdam estimate that ICE taxis generate 35 times the emissions of a private car due to the time spent driving each day (Amsterdam City Council, 2017d). There is a concerted effort to convert the taxi fleet to primarily plug-in electric in the short term. Given their substantially higher annual mileage, initiatives targeted at reducing the GHG intensity of taxis has been highlighted as a strategic opportunity for the City of Melbourne and this is described in Section 6.6.2.1.

By 2025, all taxis will need to be emissions free (plug in electric and charged by renewable energy) to operate in Amsterdam (Amsterdam City Council, 2017d).

5.3.4. Increasing the flow of bicycle traffic through intersections

Amsterdam has been making a variety of modifications to intersections to improve flow of cyclists (Aluvihare, Brommelstroet, & van der Horst, 2014). A prime example of these types of changes are at an intersection on Mr. Visserplein where a large number of cyclists were being impacted by a bottleneck (Amsterdam City Council, 2017a). The solution was to widen the waiting area, allowing more cyclists to queue nearer the white line. As the light turns green, cyclists form a narrower group, allowing oncoming cyclists to also pass through the intersection (see Figure 44, or a video). Other intersections have been modified to remove traffic islands which impacted flow of cyclists and constricted space. Traffic lights were also removed from an intersection on Alexanderplein, which resulted in fewer and shorter delays for cyclists (Glaser, 2017).

Figure 44 Before (left) and after (right) comparison of Mr. Visserplein
Source: Amsterdam City Council (2017a)

5.4. London

Greater London has 33 local government areas (including City of London) with most gazetted as boroughs. The overarching government body, the Greater London Authority, has responsibility over transport, policing, emergency services, and metropolitan strategic planning. From a transport perspective, Greater London Authority's role is more synonymous with the State of Victoria (albeit with less power), while the boroughs of London are largely synonymous with Melbournian LGAs.

London's role as a global, high density city and the role it plays as the commercial and cultural hub of the United Kingdom has required the development of policies targeted at improving the efficiency of its transport system.

5.4.1. Congestion Charge

London implemented a cordon based Congestion Charge in 2003. Interestingly, the catalyst for the introduction of the charge was the frustration many businesses working in London's financial sector experienced due to traffic congestion (Turner, 2004). Motorists who drive into the 8 mile^2 central area of London between 7am and 6pm, Monday to Friday pay £11.50 (Transport for London, N.D.-a), although discounts are available to some users (Transport for London, 2017b). The money raised by the Congestion Charge is hypothecated to transport improvements within London, with a majority of the revenue going towards sustainable transport (Transport for London, 2007, N.D.-a). Bus services were upgraded prior to the introduction of the Congestion Charge to provide a viable alternative to driving and accommodate the expected patronage increase (Transport for London, 2007). The objectives of the Congestion Charge are to (Transport for London, 2007):

- Reduce congestion;
- Make radical improvements to bus services;
- Improve journey time reliability for car users; and
- Make the distribution of goods and services more efficient.

Following implementation, traffic flow through the Congestion Charge area were faster due to a 27% reduction in volume (Transport for London, N.D.-a). There has also been a large shift towards public and active transport, with a 66% increase in cycling (Transport for London, N.D.-a), facilitated by increased investment and allocation of road space towards bus and cycling lanes.

The Congestion Charge has positively shifted the mode share balance within central London and generated revenue for sustainable transport options (Transport for London, 2007). The reallocation of road space which has occurred concurrently with the Congestion Charge has created more attractive opportunities for cycling and public transport. Such a change has undoubtedly reduced transport related GHG emissions attributable to the centre of London, increased liveability, and positively affected transport choice and mobility.

5.4.2. Mayor's Transport Strategy

Sadiq Khan, the Mayor of London, released an ambitious and thought-provoking transport strategy for public consultation in June 2017 (Mayor of London, 2017). The document recognises that transport objectives can coalesce with other urban objectives, such as to provide *'a fairer, greener, healthier and more prosperous city'* (p. 7). The Strategy detailed a shift towards zero emission vehicles, and a rethink of how the transport network supports wider city objectives. Creating the conditions that foster a greater role for public and active transport is central to the Strategy's aims. This shift will fulfil multiple objectives, making London more resilient to the effects of climate change, while improving the urban environment and social outcomes.

Central to the vision is an understanding that cars take up a lot of space for the number of people they move. Reliance on cars has made London's streets congested, increased pollution, lowered amenity of streets and decreased safety. Further, congestion also impacts public transport and commercial trips vital to the economy.

The vision has a focus on improving the performance and reliability of buses, recognising that the current quality of experience is sub-optimal. There is also a recognition that areas of outer London are disadvantaged by poor transport connections, which limits economic and social opportunity. To overcome these constraints, there needs to be a high-quality public system that connects to active transport to be able to provide a viable alternative to cars.

London is forecast to grow from 8.7 million to 10.5 million over the next 25 years. This growth is expected to add 5 million trips daily, and place pressure on housing affordability. Transport is key to both moving new residents and unlocking housing supply. In context, Melbourne is expected to grow from 4.5 million in 2015 to 7.9 million in 2051 (City of Melbourne, 2017a).

There are hundreds of policies and proposals, with the following being a small selection of the most pertinent to Melbourne's ambitions related to lowering transport related GHG emissions:

- For walking, cycling and public transport to have a combined 80% mode share by 2041, up from 64% in 2015.
- For all Londoners to make 20 minutes of active travel per day by 2041.
- To have 70% of Londoners live within 400m of high-quality safe cycling routes by 2014.
- To promote and enhance walking routes
- To increase the use of bike share, especially its role in supporting public transport
- To work with schools, employers and community groups to promote walking and cycling
- To promote one-off, regular, and trial street closures to show Londoners how streets could perform differently
- To improve road safety by: lowering speed limits; making improvements to the road environment; and through public awareness campaigns;
- To promote car share as an alternative to private ownership
- To work with boroughs to implement Traffic Demand Management measures such as road user charging or parking levy schemes.
- To reallocate road space away from cars towards walking, cycling and public transport.
- To implement policies to encourage the uptake of electric vehicles
- To improve bus journey times and reliability by: reviewing times of operation of bus lanes; greater priority for buses at junctions and signals; developing bus priority corridors
- To encourage the Department for Transport to deliver High Speed 2, a HSR link to Manchester, Leeds and beyond.
- To ensure the public transport system services the night-time economy.
- To focus new residential and commercial development around transport infrastructure. Both surrounding existing infrastructure and extending public transport services to new areas as a method of encouraging development.

5.4.3. Cycle Superhighways

Cycle Superhighways connect outer areas of London to the central city with fast, safe routes. The concept was unveiled in 2008 by former London Mayor Ken Livingston, who outlined a vision of 12 Cycle Superhighways at an expected cost of £400 million (Taylor, 2008). The first two Cycling Highways opened in 2010 (Li, Graham, & Liu, 2017), with four completed by 2015, when funding for an additional four was provided (Transport for London, 2016). There are currently six Cycle Superhighways, with two under construction and three proposed (Transport for London, 2017a). Implementation of the Cycle Superhighway network is highly dependent on the local Boroughs, which must consent and collaborate with the Mayor and Transport for London in order for them to be implemented (Moore, 2016). Travel time for motorists on Cycle Superhighway routes are affected by construction, but generally return to pre-construction times following opening of the Cycle Superhighways (Transport for London, 2016).

Figure 45 Victoria Embankment stretch of London's east-west cycle superhighway
Photograph: Martin Godwin (Moore, 2016)

The Cycle Superhighways have led to increased cycling participation, with some routes seeing a 50% increase in usage within five months of opening (Transport for London, 2016). After one year of operation CS3 had seen a usage increase of 83% (Li et al., 2017). Li et al (2017) studied the safety outcomes of the Cycle Superhighway network and found painted cycling lanes increased cycling participation but there was a commensurate increase in crashes involving cyclists. Painted Cycle Superhighways may do little to increase safety, but do increase the attractiveness of cycling by increasing the perceptions of safety (Li et al., 2017). Li et al (2017) found the CS3, which is 78% segregated from motorised traffic, improved safety outcomes over the previous road conditions.

5.4.4. Mini Hollands

Mini-Hollands is a programme by Transport for London to encourage a mode shift away from car use towards walking, cycling and public transport (Transport for London, N.D.-b). Funding is available to three Boroughs for infrastructure improvements, with 90 schemes being proposed (Transport for London, N.D.-b). Projects include the redevelopment of Enfield town centre with segregated cycling routes being installed; a transformation of the area around Kingston Station to improve cycling accessibility and public space attractiveness; and the development of a fully segregated route along Lea Bridge Road providing cycling infrastructure to residential areas (Transport for London, N.D.-b). A novel application of Mini-Holland funding is a 'light' segregation for 6km to create a cycling route through Enfield (Deegan 2018). Separation from traffic was achieved through light weight, cheaper components such as flexible bollards and low level vertical separators, such as that shown in Figure 46 (Deegan 2018). This tactic lowered construction cost and allowed driveway access to adjacent dwellings while still providing a safe and separated cycle lane (Deegan 2018).

Figure 46 Combination of light segregation objects past crossovers
Source: Deegan (2018)

5.4.5. Innovation at the Borough level: Hackney

Hackney is a London Borough to the north east of City of London. It covers 19.06km^2 with a population of 273,500. It has some parallels to the City of Melbourne, in that it is an inner urban council which is part of a much larger metropolitan region, has limited autonomy with regards to major transport infrastructure and operation of the transport system. The Borough of Hackney also has very high sustainable transport mode share with 85% of travel by active or public transport (Hackney Council, 2015).

5.4.5.1. Electric vehicles

The Borough of Hackney has installed 22 *Source London*[6] charging stations, as well as an additional four *rapid chargers* (Hackney Council, 2017), with an interim goal of having everyone living within 500m of a charging point by 2025 (Hackney Council, 2017). Hackney recognises that EVs will not solve congestion issues, but view EVs as a way of minimising GHG emissions (when powered with renewable energy), improving air quality, reducing noise associated with motor vehicles, and increasing energy security. Electric charging stations are implemented in collaboration with the private sector. Motorists use the charge stations with an access card and are charged a £1.80 connection fee and £0.30p per kWh (Hackney Council, 2017).

[6] https://www.sourcelondon.net/

5.4.5.2. Travel Plans

The Borough of Hackney requires new developments to implement travel plans. All schools and nurseries, and developments which meet certain criteria are required to implement travel plans (Hackney Council, 2016b). Travel plans are unique to each development, but are required to include a site context and background; scope of the plan identifying travel types and accessibility; objectives regarding mode shift towards sustainable transport; actions to support objectives; management procedures; targets; and review procedures.

School travel plans have specific requirements aiming to reduce car journeys, improve air quality, encourage sustainable transport, and increase knowledge of sustainable transport options. Schools covered by the School Travel Plan Programme saw a decrease in car mode share from 19% to 9% from 2007-08 to 2013-14 (Hackney Council, 2016a).

5.4.5.3. Car share

Car share has two main types in Hackney *round-trip* and *one way*. Over 100 round-trip car share vehicles are located in Hackney, provided by two operators. These car share companies charge membership fees and rates for hourly usage, with cars picked up from and returned to designated space. This operating model is the same as car share operators in Melbourne (e.g. Flexicar, GoGet, GreenShareCar, Popcar, RACV Car Share).

Hackney is also one of four London boroughs to permit *one-way* car share. There are two operators that have a combined fleet of over 1,100 cars, including some fully electric cars. These cars operate without the need to reserve the vehicle or park in designated car share spaces. Using their smartphone to locate the nearest available car, members undertake their journey, then park the vehicle in a residential or paid parking bay. The pricing model of one-way car share also differs from the typical car share found in Melbourne. One operator only has a joining fee and then a per mile usage rate, with no ongoing or monthly fees if the user does not use a car share vehicle. Given that a typical Melbourne car share rental period lasts for 6 hours, but is driven for less than an hour (City of Melbourne, 2015b), one way car share offers substantial value proposition benefits over round-trip car share. Moreover, the *asset utilisation* of each vehicle is greater, resulting in less cars required to perform the same transport task. Section 6.8.4 recommends the creation of a policy environment to enable one-way car share to operate successfully in Melbourne.

5.4.5.4. Managing dockless bike share parking

Like Melbourne, Hackney has both docked and dockless bike share systems operating within its boundaries. The Santander (‘Boris bike’) scheme is a traditional docked scheme, where bicycles are picked up and returned to bicycle docking stations. There are Santander docks in the southern part of Hackney.

In September 2017 Ofo launched 200 dockless bike share bikes into Hackney as part of a one year trial. The trial has a memorandum of understanding which stipulates location of bikes, maintenance standards, and safety standards. As part of the trial, designated bike parking areas have been established, guiding users where to leave the dockless bikes, reducing negative amenity impacts that sometimes arise from the operation of dockless bike share. Designated dockless bike share parking areas appear to be replacing car parking spaces (see Figure 47) and can be very prominent, using the bright Ofo yellow. The Ofo App alerts users where these areas are and when users are required to park bikes in them.

Figure 47 Dockless parking in Hackney, London
Photo: Ofo

6. Strategic opportunities to lower transport emissions

6.1. Pathways for lowering transport emissions

There are four main ways that transport related GHG emissions can be lowered, captured in Figure 48 and discussed below. The table in Appendix 1 provides a list of each recommendation and a rating of estimated impact, based on six indicators that broadly align with the City of Melbourne's strategic objectives.

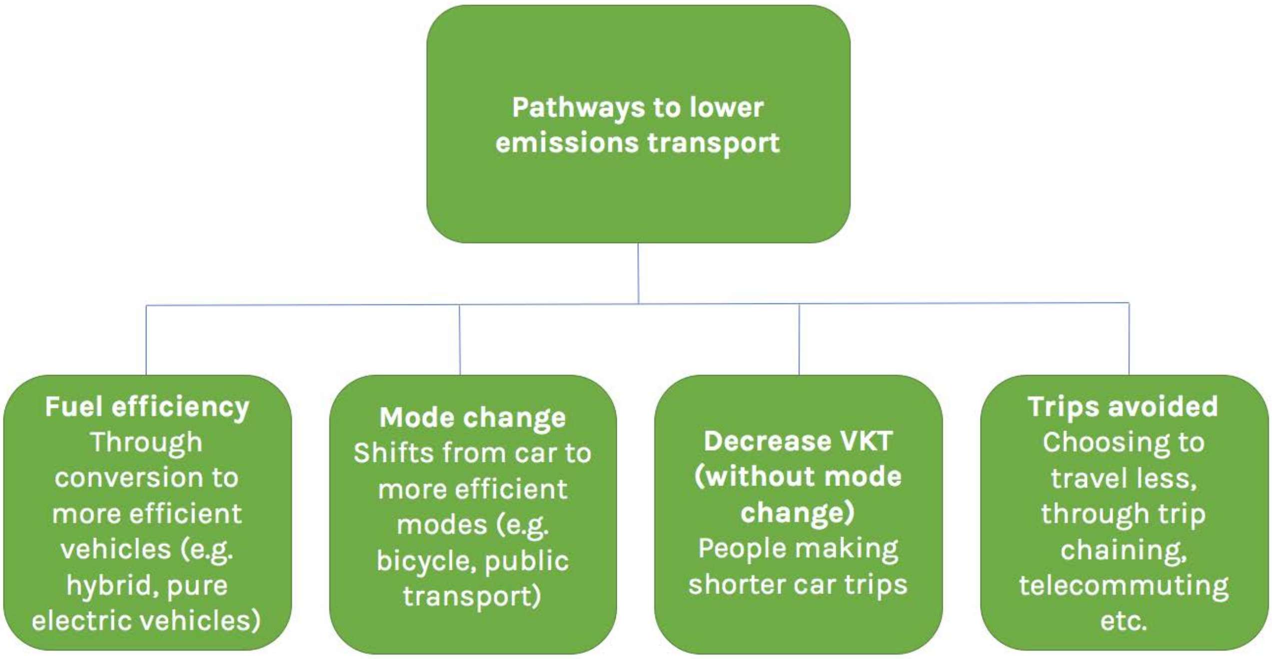

Figure 48 Pathways for lowering transport emissions

6.1.1. Fuel efficiency

Fuel efficiency can be improved, moving from fossil fuel sources such as Internal Combustion Engine (ICE) vehicles or public transport powered by brown coal power stations. Electric cars are key to this transformation, but only if they are charged using renewable energy. As highlighted in Section 3.6, when electric vehicles are charged using Victorian electricity grid power, their emissions intensity is no better than petrol powered vehicles. Similarly, transitioning the Victorian power grid from fossil fuel power stations towards renewable energy will decrease the GHG emissions attributable to electrified rail services.

6.1.2. Mode change

Transferring trips from motor vehicle to other modes provides emission reduction and space efficiency improvements (refer to Figure 49 below). Mode share shifts towards walking, cycling and public transport is seen to have a variety of co-benefits supportive of the City of Melbourne's wider strategic ambition related to street amenity, increased physical activity, road safety and productivity and accessibility enhancement (Giles-Corti et al., 2016; Goenka & Andersen, 2016; Sallis et al., 2016; Stevenson et al., 2016).

6.1.3. Reducing vehicle kilometres

Reducing trip lengths for journeys by car reduces total VKT. Whilst workers may not be able to reduce trip length, other forms of travel can have trip lengths reduced (e.g. shopping locally).

6.1.4. Avoiding trips

Avoiding trips entirely removes negative impacts of the journey, including all GHG emissions. In this regard trip avoidance can appear to be a desirable outcome. There is capacity for people to chain trips together, shortening overall travel distance by reducing the total number of trips. Trip avoidance is therefore a useful tool, however it is important to recognise that transport is a critical factor is people's ability to participate in commercial, social and recreational activities. Therefore whilst excessive travel (hypermobility) is undesirable (Adams, 2004), mode change or VKT reductions are more socially sustainable methods of achieving reductions in transport emissions.

6.2. Aligning transport policy with broader strategic goals

It is critical for any transport GHG reduction policy to be consistent with broader strategic goals of the City of Melbourne. While changing the entire vehicle fleet to EVs charged from renewable sources may mitigate GHG emissions entirely, it would do nothing to decrease congestion or increase the mode share of active and public transport. The City of Melbourne's strategic ambition to become a connected, creative eco-city will depend partly on the degree to which it can create the conditions in which walking, cycling and public transport thrive. The eight goals that form the basis of the Council Plan 2017 – 2021 (City of Melbourne, 2017a) are:

1. A city that cares for its environment
2. A city for people
3. A creative city
4. A prosperous city
5. A connected city
6. A deliberative city
7. A city planning for growth
8. A city with an Aboriginal focus.

Many of the above goals have a direct relationship to transport and emissions and it is the focus of this section to identify opportunities the City of Melbourne can take to align its transport and carbon reduction policies and support many of the goals identified above.

Figure 49 offers an illustration of the *emissions* and *space intensity* of various modes of land transport. The black balloons show CO_2 emissions per person kilometre travelled, with the balloon's size proportion to the emissions generated. The lower portion of Figure 49 offers a footprint representation of the space requirements per person, for each mode.

Figure 49 provides a clear demonstration that the average Victorian car and an electric car powered by Victorian electricity grid both have very high CO_2 emissions and take up considerably more space than public and active transport (9.7 m^2 for cars compared to 0.5 – 0.8 for public transport and walking). The impact of single occupancy car journeys may be lowered through car pooling or riding a motorcycle, however GHG emissions are still significant. **An electric car powered by renewable energy eliminates all GHG emissions but still requires the same, large amount of space that an ICE car consumes. Conversely, walking, cycling, and public transport, even without changes to fuel sources, have vastly lower GHG emissions and space requirements per person transported.** A shift towards renewable energy (such as the planned tram system renewable energy scheme) will reduce GHG emissions, but will not change space requirements. As such, **walking, cycling, and public transport best align with the City of Melbourne climate change targets and strategic objectives related to the efficient movement of people in the Central City.**

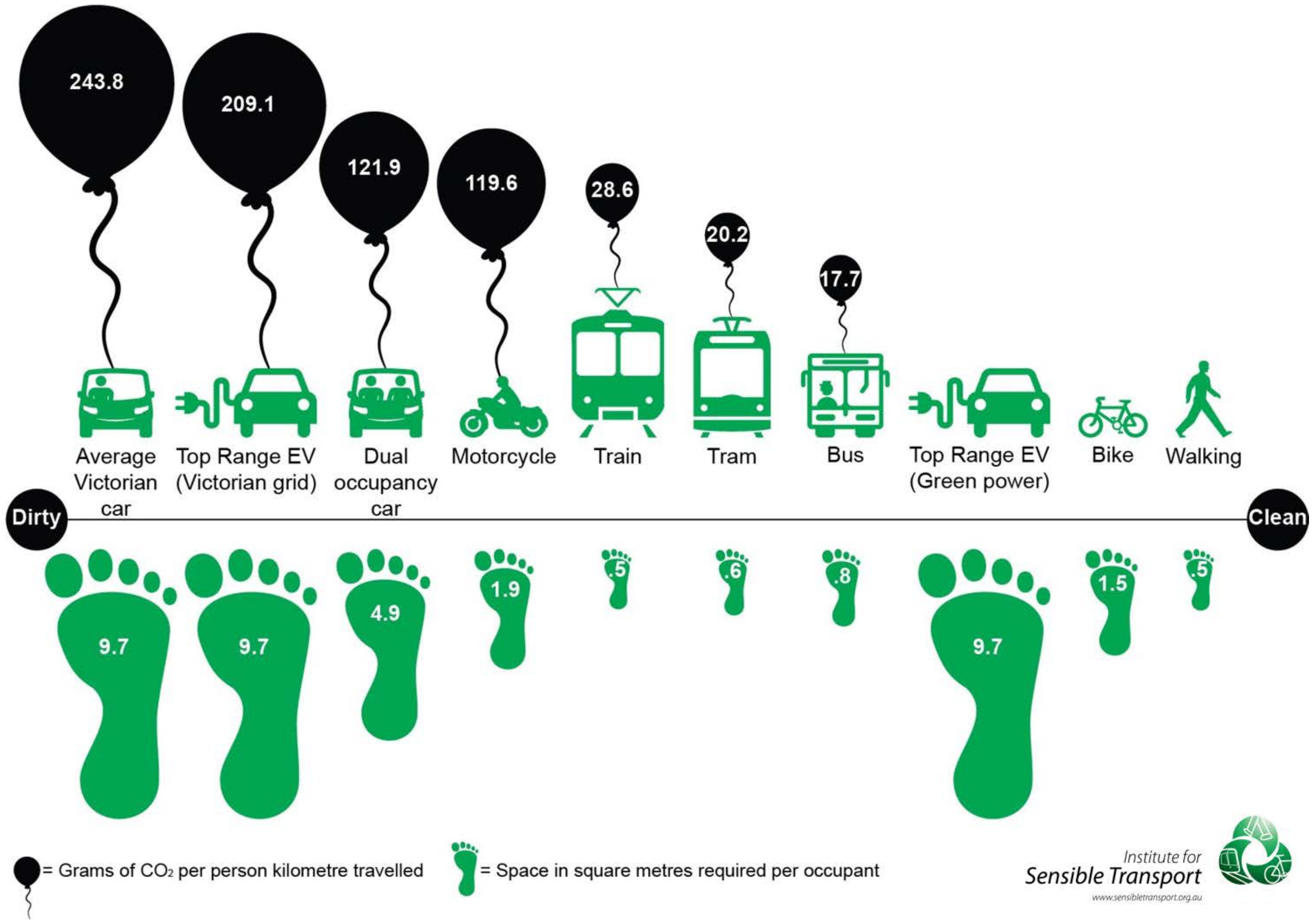

Figure 49 Emissions and space intensity, various modes

NB: These figures have been generated from transport data presented in *Defining the Problem,* a background report developed for this project, as well as data collected as part of the Melbourne Metro Rail Project (AJM Joint Venture, 2016). Occupants for public transport rates were 900 (train), 110 (tram) and 40 (bus) based on PTV load standards for capacity and average seats on a bus (see Public Transport Victoria, 2017).

Previous sections of this report have demonstrated the enormity of the challenge associated with bringing transport related carbon emissions in line with the City of Melbourne's carbon reduction targets. Australia's transport emissions have been rising over previous years and are projected to continue to rise until at least 2030 (Department of the Environment and Energy, 2017). For the City of Melbourne to meet its commitment to the Paris Agreement and assist in limiting global temperature rises to 1.5^{o}C, substantial, unprecedented action will be required.

The strategic opportunities contained in this section are focused on policy directions capable of making significant cuts to transport emissions associated with the City of Melbourne. Figure 50 captures the four elements that encompass the suite of strategic opportunities this report has identified to align the City of Melbourne's transport actions with its climate change ambition.

Figure 50 Strategic policy directions to reduce transport emissions

6.3. Strategic reallocation of road space

Current road space allocation in the City of Melbourne is a legacy of car orientated planning which emerged from the post-war boom. There is significant scope to reallocate road space to focus on creating more conducive conditions for walking, cycling, and public transport. Reallocating road space towards walking, cycling and public transport will achieve the twin goals of lowering GHG emissions from transport and enhance central Melbourne's role as the economic and cultural hub of Victoria.

By converting motor vehicle travel lanes or parking bays towards enhanced conditions for sustainable transport (e.g. priority bus lanes, wider footpaths, protected bicycle infrastructure), greater numbers of people will be able to access the city centre, whilst at the same time emitting less carbon. Although there will always be a need for the parking of motor vehicles, including deliveries and other commercial activities, current levels of car parking are higher than optimal (City of Melbourne, 2008).

6.3.1. Footpath widening

Walking is the most accessible, sustainable travel mode. There is no specialised equipment or knowledge needed, and almost everyone can walk or use wheelchairs or mobility aids. Having a high quality, DDA compliant walking environment will benefit almost all visitors to the City of Melbourne, including those reliant on mobility aids. As highlighted in Section 4.1.4, 66% of all internal trips in the City of Melbourne are made on foot and there are several areas within the City of Melbourne that consistently have pedestrian overcrowding issues (City of Melbourne, 2014a). As pedestrian traffic is expected in increase in the future (City of Melbourne, 2014a) overcrowding is expected to detract from the walking environment unless measures are taken to address this issue.[7]

The City of Melbourne has been widening footpaths for many years, key examples being Swanston Street and Collins Street, two of Melbourne's premier streets. Increasing the attractiveness and capacity of the walking network is key to improving the walking mode share, improving the local economy, lowering GHG emissions, and increasing the efficiency of road space. In areas where footpaths cannot be widened, shared zones should be investigated or total road closures and conversions to pedestrianised zones[8].

6.3.2. Expanding and enhancing the cycling network

The cycling mode share for trips to, from, and within City of Melbourne have been essentially stagnant since 2010, as illustrated in Section 3.4. Across Greater Melbourne the mode share for cycling to work is around 1.6% and has been largely stagnant over the past decade (Australian Bureau of Statistics, 2017a). The main reason people say they do not cycle is safety concerns of sharing the road with motor vehicles (Bauman et al., 2008; Garrard, 2003, 2009, 2011; Götschi et al., 2015; Pucher et al., 2010). To boost the numbers of people cycling and thereby reduce GHG emissions, it will be necessary to increase the provision of protected bicycle infrastructure which has been shown to boost levels of cycling and reduce injury risk (Teschke et al., 2012; Meghan Winters, Davidson, Kao, & Teschke, 2011; M. Winters & Teschke, 2010).

There is significant potential to boost the role cycling plays within Melbourne's transport system, especially for those trips between one and seven kilometres. Census data identified in Section 3.4.3 was able to demonstrate that the inner north of Melbourne (e.g. City of Yarra, City of Moreland, and City of Darebin) had significantly higher bicycle mode share than suburbs to the south of the City of Melbourne, and this was associated with a more cohesive cycling network.

There is a strategic opportunity to improve cycling infrastructure through a reallocation of road space to permit separated, protected cycling lanes. Eliminating current gaps in the existing network, and then expanding the network should be the focus. Enabling residents on the periphery of the City of Melbourne and in neighbouring LGAs to access and travel through the CBD on a comprehensive network of high quality cycle routes should be the priority.

The following provides a brief set of examples to illustrate the conceptual direction to maximise cycling's contribution to reducing emissions.

6.3.2.1. Canning Street/Rathdowne Street

The Canning Street route offers a quality, safe cycling path into the city from the inner northern suburbs. It is one of the most heavily used cycling corridors in Melbourne (VicRoads, 2016). At the southern end, cyclists are required to travel along Carlton Street and then either Nicholson Street (which has a shared path on the western side of the street) or Rathdowne Street (which has painted bike lanes but offers little in a way of physical separation) to access the CBD. This last mile offers a lower quality level of service, and may act to detract from the appeal of cycling, especially for less confident cyclists (Götschi et al., 2015). Safety concerns are amplified at intersections, as there is no easy way for north-bound cyclists on Rathdowne Street to access Carlton Street, and the south-bound cycle lane on Rathdowne Street at Victoria Street being less than one metre wide. Reallocating road space along Rathdowne Street would alleviate this issue, providing a strong north-south connection from Melbourne's inner northern suburbs into the Hoddle Grid (see Section 6.3.5 below for more information on space reallocation for Rathdowne Street).

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[7] See: https://participate.melbourne.vic.gov.au/walkingplan?_ga=2.118442505.1468587340.1515641587-1558856754.1493775181 for information on walking in the City of Melbourne.

[8] Pedestrianised zones where appropriate can still accommodate cycling, but pedestrians have priority, with cyclists treated 'as guests'.

6.3.2.2. Exhibition Street

Exhibition Street has clearways during peak hours to provide space for part-time bike lanes. Exhibition Street connects to cycling infrastructure at both ends (Rathdowne Street in the north and Batman Avenue in the south). It also connects to east-west cycling lanes through the Hoddle Grid on La Trobe Street, Bourke Street and Collins Street. Reconfiguration of the road space to an Albert Street style 'light separation' would improve the attractiveness and safety outcomes of cycling along Exhibition Street. This re-configuration would maintain similar rates of car parking for off peak times, but would become a clearway at peak times, to enable two lanes of motor vehicle traffic in each direction during peak hour. The protected bicycle lane would be operational throughout all hours of the day/night. There would also be wider benefits in alleviating pressure on the Swanston Street cycling corridor and increase the cycling permeability of the Hoddle Grid.

6.3.2.3. Swanston Street north

The last two decades have seen large improvements in the cycling conditions along the Swanston Street/St Kilda Road corridor. 'Copenhagen style' cycling lanes between RMIT and Melbourne University were installed in 2007, with a redevelopment of Swanston Street between Flinders Street and Victoria Street that included accessible tram stops and dedicated space for cyclists completed in 2012. There are still gaps in the Swanston Street corridor. One example is the area surrounding Melbourne University. There are no protected lanes operating north of Grattan Street, and no bike lanes at the intersection of Swanston Street and Elgin Street. Elgin Street also lacks west-bound cycling lanes between Swanston Street and Lygon Street. This lack of infrastructure decreases the appeal of cycling through these areas, and also lowers the actual and perceived safety outcomes. A reallocation of road space, through the removal of parking and dedicated turning lanes would provide the space required for protected cycling lanes in the area.

6.3.3. Public transport priority lanes

Public transport is the most sustainable method of motorised travel, having low or no GHG emissions per person kilometre travelled, depending on energy source, and low space requirements relative to the numbers of people transported (see Figure 49). Tram services within the City of Melbourne generally run on dedicated track. Buses however largely operate in mixed traffic. Mixed traffic operation is a problem across Greater Melbourne's tram and bus networks, with some 60% of trams lines and most bus lines being mixed traffic. Created segregated lanes for street-based public transport will increase punctuality while decreasing overall travel times, thus helping to boost the competitive advantage of public transport over more space and emissions intensive car use. As the City of Melbourne is the responsible authority on many streets with buses that do not have bus lanes, it is possible to take a leadership position and create bus priority, and thereby strength their position to advocate for enhanced bus services on these routes.

The following provides a brief set of examples to illustrate the conceptual direction to maximise public transport's contribution to reducing emissions.

6.3.3.1. Trams

Almost all tram lines within the City of Melbourne boundaries have dedicated lanes which largely separate their operation from other vehicles. Trams operate in a mixed traffic environment with cars in three streets: Sturt Street, South Melbourne, Toorak Road, South Yarra; and High Street, Windsor. Toorak Road and High Street are both VicRoads declared roads, minimising the change that City of Melbourne can affect, while Sturt Street is a Council street, where City of Melbourne has greater opportunity to effect change. Tram services would be improved through the implementation of fairways along all three streets, even if that requires removal of parking.

6.3.3.2. Buses

Unlike trams, buses within the City of Melbourne generally operate in mixed traffic, without dedicated lanes. Many bus frequencies are not sufficient to warrant dedicated lanes, or operate of VicRoads declared roads which are outside City of Melbourne control. Lygon Street and Rathdowne Street in Carlton carry 16 and 12 buses during the morning peak, respectively, and both feed into the busy Lonsdale Street/Queen Street bus cordon. Potential reconfigurations of Lygon Street and Rathdowne Street are discussed in more detail below, in Section 6.3.6.1.

6.3.3.3. Shared operation

Where trams and buses operate on the same street, there is scope to have buses operate in tram fairways. This ‘shared operation’ is common internationally, yet rare in Australia. One such location within the City of Melbourne is on Queensbridge Street, where tram route 58 and six bus routes share a fairway and accessible stops (Yarra Trams, 2017). There is further potential to integrate fairways and stops between trams and buses on Collins Street and Spencer Street.

6.3.4. Public space

As Melbourne works towards achieving the eight goals set out in the Council Plan (City of Melbourne, 2017a), new opportunities should be sought that convert streets that are performing sub-optimally (in terms of supporting the City of Melbourne’s wider strategic ambitions) into more vibrant, intensified, greener corridors. Returning such streets to linear parks, gardens, plazas, and outdoor malls provide potential opportunities for enhancing the area’s appeal as a destination, and may offer new opportunities for improving the attractiveness of walking and cycling. Moreover, closing carefully selected streets to motor vehicles will also help to improve the competitive advantage of sustainable transport and reduce the appeal of using the CBD for through-traffic motor vehicle trips. These re-purposing activities will also help to support the City of Melbourne’s existing policies such as the urban forest project (e.g. see City of Melbourne, 2012b).

The following provides an example of a re-purposing of public space to support a low emissions public realm.

6.3.4.1. Spring Street outside the Princess Theatre

The area outside the Princess Theatre is identified in the Walking Plan as a potential public space, closed from traffic. Closing this section of road would increase the public realm in a vibrant area of Melbourne, while also increasing safety outcomes for cyclists and creating more space for pedestrians.

6.3.5. Complete Streets

A Complete Streets are integrated, multimodal street reconfigurations to meet broader objectives than simply the movement of motor vehicles (see Section 5). Some streets within the City of Melbourne could be altered to enhance their role in supporting wider strategic objectives. An example, to illustrate a potential application of the Complete Streets concept within the City of Melbourne can be found in Lygon Street and Rathdowne Street. These streets present strategic opportunities to couple streetscape improvements with improved flow of public transport. Currently, both streets carry buses, and have two motor vehicle lanes in each direction, as well as kerbside car parking. Lygon Street has widened footpaths while Rathdowne Street has painted cycling lanes. In both cases travel lanes and/or parking bays could be replaced with a combination of dedicated cycling facilities, dedicated bus lanes, and widened footpaths (including for café seating, planters, street art and bicycle parking) while still maintaining traffic flow. Investigating and undertaking street redevelopments of this nature is vital to ensure Melbourne’s street network evolves to meet the challenges posed by climate change and the pressure of population growth. A complete streets project on Lygon Street could be tailored in each section to support the objectives of Melbourne Planning Scheme Clause 22.15 (City of Melbourne, 2006).

City of Melbourne can take inspiration from the Amsterdam *Red Carpet* project (see Section 5.3.1) to improving corridor wide public and active transport performance. Typically, space that is not actively enhancing the vibrancy of the street (e.g. kerbside car parking) should be considered for re-purposing to create dedicated public transport lanes, and protected bicycle infrastructure and/or wider footpaths.

6.3.6. Red Carpet

6.3.6.1. Lonsdale Street and Queen Street

As demonstrated in Figure 51, Lonsdale and Queen Streets are the busiest bus corridors in terms of number of routes, with over 20 bus routes using Lonsdale and/or Queen Streets, including Doncaster Area Rapid Transit routes. Lonsdale Street and Queen Street both have peak hour bus lanes, however buses continue to experience delay outside of peak hour or in contra-peak directions. There is also a lack of coordination between stops, with buses grouped together in stopping patterns. This reduces the ease and therefore appeal of interchanging between buses and other modes of transport. This is especially a deterrent for new users to the bus system (Schmitt, Currie, & Delbosc, 2015).

Figure 51 CBD Bus Route density

There is an opportunity to redesign the operation and streetscape of Lonsdale and Queen Streets to replace kerbside car parking with a protect cycling lane and the left travel lane with a dedicated bus lane. This redesign would still leave angle parking in the middle of both streets and one lane of travel in each direction (see Figure 52 and Figure 53). This would improve the performance and appeal of sustainable transport. Consolidation of stops will give clarity to users of where buses operate and will allow for the provision of devices such as myki machines and information to assist existing and new bus patrons (see Figure 54).

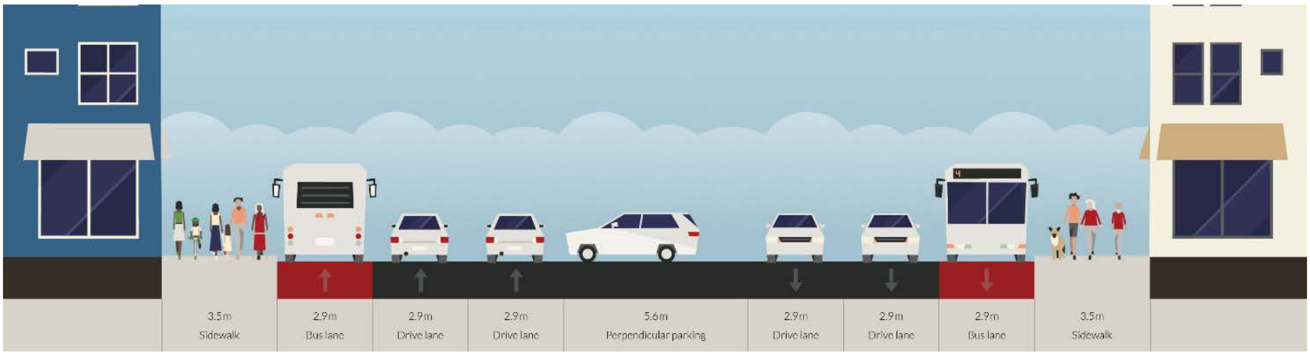

Figure 52 Example of a typical Lonsdale Street or Queen Street cross-section

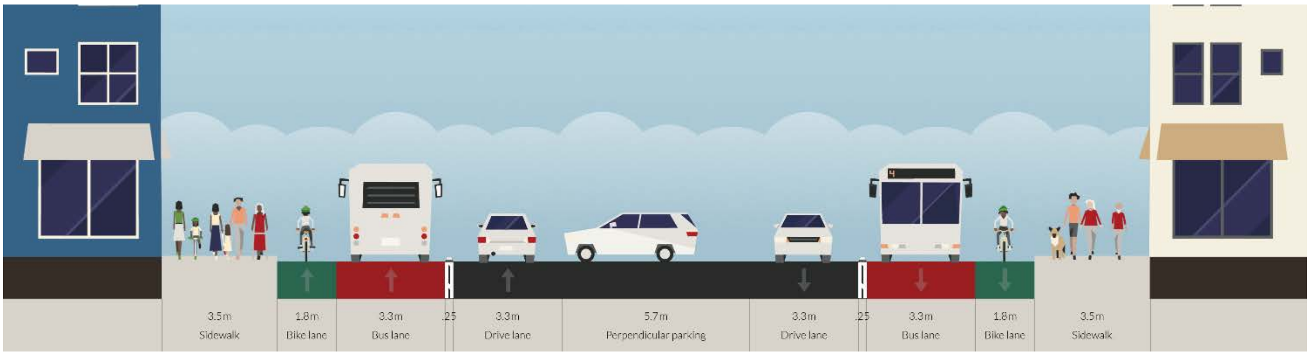

Figure 53 Potential reconfiguration of Lonsdale Street and Queen Street

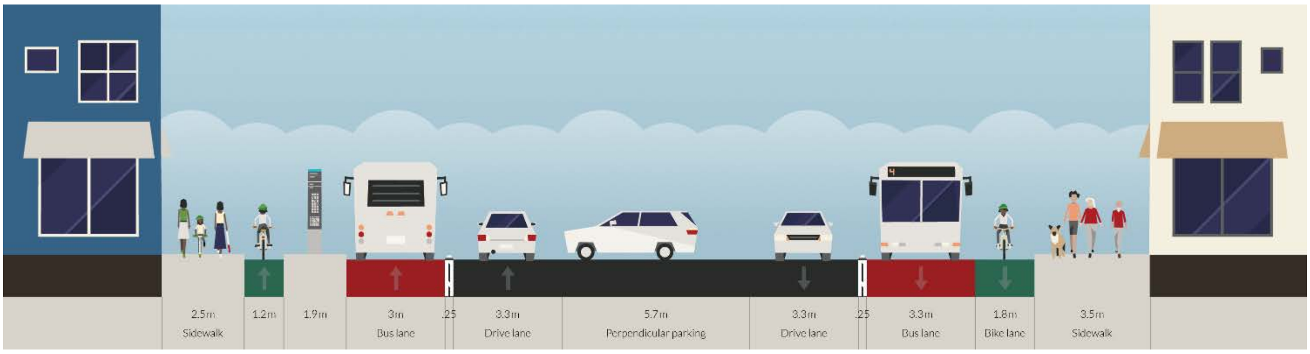

Figure 54 Potential reconfiguration incorporating bus stop waiting area

A Red Carpet approach should look further than just Lonsdale and Queen Street, in an effort to improve connectivity to streets which buses feed into the corridor. These streets include Spencer Street, Dudley Street, Flinders Street/Queens Bridge, Russel Street, Exhibition Street, Collins, Spring Street, and Victoria Parade. In instances where buses run along streets with tramway reservations, such as Collins Street, investigation as to whether having buses run along these reservations and share stops should be undertaken. This may work to increase interchange ability and maximising the efficiency of the street.

6.3.6.2. Swanston Street and St Kilda Road

Swanston Street/St Kilda Road is one of the busiest tram corridors in the world, with almost one tram every minute during peak hour. Significant efforts have been made in recent years to improve public transport performance and the user experience. Examples are installation of ‘Copenhagen style’ bike lanes on Swanston Street between Melbourne University and the City Baths; the reconfiguration of Swanston Street between the City Baths and Federation Square; installation of level access stops; and installation of dedicated turning tracks at key junctions. A cordon wide approach, looking at cycling and public transport operation from Melbourne University to St Kilda Junction should be undertaken, determining current deficiencies and developing remediation actions. Such actions could involve installing protected cycling facilities on St Kilda Road; installing vertical separators adjacent to tram tracks to deter vehicle incursions or U-turns; conversion of prowl protected safety zones with DDA compliant level access stops and transponder technology that gives trams higher levels of priority at intersections, especially for trams turning off St Kilda Road which hold up following trams.

6.3.7. Removing the attractiveness of the CBD for through traffic

Maintaining motor vehicle access, but inhibiting through traffic for motor vehicles is a highly effective technique for improving the vibrancy of the city centre (Bratzel, 1999) In the early 1970s, the Dutch town of Groningen began what has become known in Dutch transport planning as the '*Groningen Model',* in which motor vehicle access in maintained within the city centre, but through traffic is prohibited. In essence, the Groningen Model compartmentalises the city into four quadrants, with travel between each quadrant only possible by returning back the way one came, and using an outer circuit road (Perch, 2016).

There is an opportunity for the City of Melbourne to achieve the same outcomes via a slightly different approach to the *Groningen Model.* The 'Little' streets of Melbourne (i.e. Little Lonsdale Street, Little Bourke Street, Little Collins Street and Flinders Lane) are currently one way (mostly). Little Lonsdale Street runs west to east while the other three operate east to west. Figure 55 and Figure 56 provide an illustration of the current and proposed operation of these *'Little streets'.* Swapping the direction of travel on these four streets every block[9], and only permitting left turns in or out of these lanes. This concept would still permit full motor vehicle accessibility but would remove through traffic and simplify the operation of intersections (especially on streets with trams, where hook turns are impractical and right turns can lead to accidents between vehicles and trams). Such a reconfiguration could be the first step towards conversion of sections of lanes to shared zones (including removal of kerb and installation of pavers replacing asphalt), installation of bi-directional cycling lanes, or complete closure to motorised vehicle traffic (except deliveries during certain times).

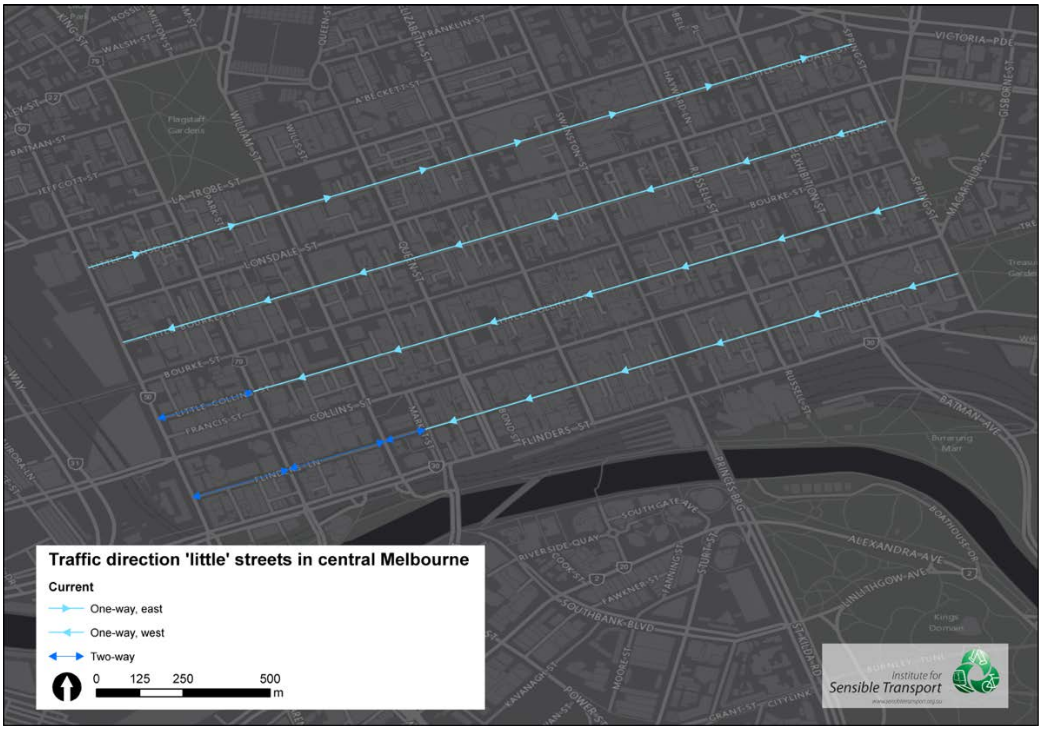

Figure 55 Current direction of travel, 'little' streets

[9] Swanston Street would not count, with all vehicles required to proceed straight across Swanston Street

Figure 56 Proposed direction of travel, 'little' streets
NB: this is simply a concept rather than a detailed design and a comprehensive investigation is required to assess the full impacts and possible refinements.

6.4. Intersection priority for sustainable modes

There are several important reasons intersections are vital opportunities in which to implement sustainable transport initiatives. Firstly, intersections have a disproportionate number of crashes, and in the City of Melbourne, many of these crashes involve pedestrians and cyclists (City of Melbourne, 2014a; VicRoads, 2017). Secondly, intersections are a cause of delay, and given the importance of travel time to transport mode choice (Sener, Eluru, & Bhat, 2009), intersections offer an excellent opportunity to reduce travel delay for the modes an authority seeks to enhance. This approach will complement road space allocation initiatives that also prioritise walking, cycling and public transport.

Cycling can also be further encouraged through the implementation of a *green wave* program. A number of cities have implemented this in recent years, in which the light sequences are timed to allow a cyclist travelling at average speed to have a constant set of green lights. The St Kilda Road corridor is the obvious place to trial such an initiative.

6.4.1. Walking

The development of the City of Melbourne's *Walking Plan 2014 – 2017* provided a detailed set of data collection, analysis and actions designed to enhance the pedestrian environment, particularly in the CBD (City of Melbourne, 2014a). Implementing the comprehensive set of Actions detailed in the *Walking Plan* will serve to support walking as a mode of transport, helping to reduce emissions and make more efficient use of the limited space available in the Central City area. As shown in Figure 49, walking is both emission free, and among the most space efficient mode of transport.

6.4.2. Cycling

The City of Melbourne's *Bicycle Plan 2016 – 2020* sets out ambitious targets designed to increase cycling participation. One goal highlighted in the Bicycle Plan is to eradicate serious injury crashes and fatalities involving cyclists (City of Melbourne, 2016a) by 2020. **Eliminating all fatalities and serious injury crashes involving cyclists within 24 months is commendable, but unlikely to be achieved without the implementation of an unprecedented set of actions.** Figure 57 shows the number of crashes involving cyclists from mid 2012 to mid 2017, resulting in three deaths and 310 serious injuries. This serves to highlight the scale of the challenge associated with eliminating serious and fatal crashes involving people on bikes in the City of Melbourne.

Figure 57 Crashes involving cyclists in the City of Melbourne, 2012 – 2017
Source: VicRoads (2017)

For the City of Melbourne to achieve its safety outcomes targets for cycling, a transformation in street design, intersection treatments, motor vehicle speed limits and access, based on best practice principles will need to be implemented urgently. These principles, drawn from the Dutch bicycle planning manual (see CROW, 2017) include network design focused on:

- Coherence
- Directness
- Safety
- Attractiveness and
- Comfort.

The above principles are broadly consistent with the policy and actions included in the *Bicycle Plan 2016 – 2020,* although the scale and speed with which they must be implemented are heightened due to both the climate change and safety ambitions committed to by Council.

A suite of measures can be applied to enhance the degree to which intersections in the City of Melbourne accommodate people cycling. These include advanced green lanterns for cycling, bike boxes, hook turns, green wave, reconfiguration of intersections to create protected space; and LED strips to warn turning drivers when crossing high volume bicycle lanes/paths. Roundabouts can be particularly hazardous for people cycling and there are a variety of designed that minimise risk, particularly at approaches (Sakshaug, Laureshyn, Svensson, & Hydén, 2010).

On major bicycle routes a principle should be applied to require vehicles entering from cross streets to give way to traffic on these routes. Examples of where this principle is in place include Canning Street (City of Yarra primarily), and Napier Street, Fitzroy.

The intersection of Canning Street and Princes Street, Carlton is one of Melbourne's busiest bicycle routes. Grade separating this intersection, with a shared path running underneath Princes Street would reduce road safety risk and eliminate travel delay to cyclists, pedestrians and motorists. Whilst the cost associated with such a project is not insignificant, the benefits, primarily in terms of time savings suggest such a project is worthy of a more detailed investigation, to better understand the full costs, benefits, risks and feasibility.

6.4.3. Trams

There is a significant opportunity to improve the speed and reliability of Melbourne's trams though intersection priority. A prime example of successful traffic light priority is Zurich which has had tram prioritisation measures in place since the 1980s (Mees, 2010). These measures have caused a dramatic increase in tram usage (Mees, 2010). Zurich gives absolute priority at traffic lights and allocates dedicated road space to trams, with the ideal situation being one where trams need only stop to set down or pick up passengers (Mees, 2010; Morton, 2007). As such, **Zurich trams spend only 6% of their time at traffic lights, compared to Melbourne trams which spend 17% of their time at traffic lights** (Yarra Trams, 2011). There are two primary methods of traffic light priority; full and partial (Zhang & Garoni, 2013). Melbourne uses a partial priority system, whereby the induction circuits detect trams and insert tram phases into traffic light sequences; conversely, full priority systems like Zurich extend green lights, or call sequences to run early, significantly minimising waiting times at traffic lights (Mees, 2010; Morton, 2007; Zhang & Garoni, 2013). Major time savings for Melbourne trams could be achieved through better traffic light priority, and this is especially true in the City of Melbourne's CBD, where tram speeds drop to 11km/h. By comparison, the average tram speed in Melbourne is 16km/h, while Hong Kong and Berlin have speeds of 19km/h and 20km/h respectively (Yarra Trams, 2011).

Further improvements to tram travel times and safety could be achieved by the separation of right hand turning vehicles from trams. In the CBD all right hand turns across tram tracks should be hook turns. Where hook turns are impractical, such as into laneways, right hand turns should be banned. Outside of the CBD right turns across tram tracks should be controlled by traffic lights or other traffic control measures.

6.4.4. Buses

Bus reliability and travel speeds could be improved by reprioritisation or reconfiguration of intersections. Although there are bus lanes along streets in the City of Melbourne, there is, as with the tram system, a dearth of priority measures to minimise wait times for buses. Induction loops or transponder technology could be incorporated into bus lanes, giving priority to buses in a similar method as described for trams above.

Right hand turning buses could be aided by allowing them to perform hook turns. Such a manoeuvre is encouraged by VicRoads Manual of uniform traffic control devices Part 12 (see VicRoads, 2015) in assisting with right hand turns. Suggested intersections to implement bus hook turns are:

- Lonsdale Street and Exhibition Street

- Lonsdale Street and Russel Street
- Lonsdale Street and Queen Street, and
- Lonsdale Street and Collins Street.

6.5. Changing the way we pay for motor vehicle use

6.5.1. Parking pricing structures

6.5.1.1. On street parking

On street parking fees and restrictions vary across City of Melbourne. Payment is required to use roughly half of the ~30,000 parking spaces within the City of Melbourne. In the CBD 3,077 of the 4,192 short-stay spaces are metered (unmetered spaces are disabled parking, loading zones, bus parking, taxi zones, and short-term spaces) (City of Melbourne, 2008, p. 5). In the CBD most spaces have a one hour time limit during the day, two hours after 6:30pm and no restrictions after 8:30pm. Parking is mostly charged at $5.50 per hour in the CBD and surrounding suburbs, while areas outside the CBD are typically $3.20 per hour for short stay and 80 cents per hour for all-day parking spaces (City of Melbourne, 2017c).

The strategy for managing demand has hitherto been to extend the maximum stay for areas where spaces have low occupancy. This concentrates short stay spaces near areas where they are in high demand and provides longer term spaces for commuters in areas of low demand. Short stay spaces (two hours or less) have a target occupancy rate of 60-85%, with a target turnover of five vehicles per day (City of Melbourne, 2008).

Short stay on-street parking provided by City of Melbourne is generally charged at a lower rate than short stay commercial parking garages (City of Melbourne, 2008). Similarly, at 80 cents per hour, a daily stay would be under $8.80, less than half what is charged for 'early bird' all day commuter parking. The Parking Strategy (City of Melbourne, 2008) notes that commercial operators have had difficulty attracting short stay visitors, leading to more targeting towards commuters, who have a disproportionate effect on congestion.

The City of Melbourne should alter its pricing regime to remove financial benefits for parking on-street as opposed to in off-street dedicated parking facilities. Increasing parking fees will act as a disincentive to drive into the CBD, while also going some way to filling budget gaps due to a decrease in parking spaces resulting from reallocation of road space. SFpark presents a framework for City of Melbourne to follow, adjusting parking costs to maximise usage and cashflow to Council.

Within the CBD and Docklands, paid parking should be made 24 hours (either with or without time restrictions). Parking spaces in the CBD and Docklands are always in demand and attract congestion and emissions, regardless of time of day and pricing signals should reflect this.

6.5.1.2. Residential permits

Parking permits allow residents to park vehicles for unlimited duration without fee in permit zones and certain timed spaces. Residential properties built before 2005, 2010 or 2011 (depending on area) are eligible for one or two permits linked to cars and a booklet of 18 visitor permits (City of Melbourne, 2017d). Residents must pay for 12 month long parking permits, with the first permit costing $30 and the second (if eligible) being $120 (ibid). Parking permit fees are waived for residents who hold Pensioner Concession Card, Veteran's Affairs Pensioner Concession Card, Repatriation Health Card for either Totally and Permanently Incapacitated (TPI) or War Widow. The City of Melbourne should encourage the uptake of EVs by waiving parking permit fees for plug-in electric vehicles.

6.5.2. Road user pricing

Road user pricing is increasingly considered an effective response to the management of motor vehicles on city streets, and has been advocated by a number of agencies in Australia in recent years (Infrastructure

Victoria, 2016; Productivity Commission, 2017). Ostensibly designed to 'tackle congestion', a road user price may also be an effective method of reducing transport emissions by providing pricing signals to encourage smarter vehicle use. It is likely the policy debate on road user pricing will continue and it is therefore important that the City of Melbourne take a leadership role in influencing the debate, to ensure its strategic objectives are advanced, in relation to creating a more accessible, sustainable city that manages growth efficiently.

6.6. Lowering the emissions intensity of motorised transport

Improving the efficiency of the vehicle fleet is required as part of the overall effort of reducing transport related GHG emissions. This is also an area where the City of Melbourne has relatively little power to affect change. Emission standards are set at a Commonwealth level and cars move freely across jurisdictional borders. Recent trends have seen only minor improvements in fuel efficiency, and fleet age is still at an average age of 10 years. Electric vehicle sales in Australia are low by international standards, with a lack of policy support being a factor, according to the Chief Scientist (Hasham, 2018).

For EVs to make large scale decreases in emissions, it is of critical importance that they be charged from renewable energy. As discussed in Section 3.2.1, the Victorian electricity grid is very emissions intensive by international standards. **Charging EVs with the average mix of Victorian electricity is almost as polluting as the average Victorian car, and more polluting than a modern petrol-electric hybrid or diesel car.** However, if coupled with initiatives to green the electricity grid, EVs have a huge potential to cause marked reductions in GHG emissions.

The City of Melbourne should create some incentives for residents to purchase EVs, making some progress in improving the fuel efficiency of the vehicle fleet and ensure they are powered with renewable energy. The largest policy level at the City of Melbourne's disposal is *parking policy*, discussed below.

6.6.1. Greening the grid

Reducing the emissions intensity of the electricity supply in the City of Melbourne is critical to achieving climate change objectives from a range of sectors, including transport. Victoria has a privatised electricity market, regulated by the Victorian Government's Essential Services Commission. The City of Melbourne has partnered with other local governments, cultural institutions, universities and corporations through the Melbourne Renewable Energy Project to bulk purchase renewable power from a wind farm in regional Victoria. There are further opportunities for the City of Melbourne to increase the attractiveness of renewable energy through a variety of means including; working with commerce and industry in the City of Melbourne to encourage the take-up of renewable energy; and potentially intervening in the electricity market to purchase electricity directly off small scale producers, as the Greater London Authority is doing (Mayor of London, 2016).

6.6.2. Passenger cars

Passenger vehicles contribute most to congestion and GHG emissions in the City of Melbourne. A transition to EVs is a critical component of a broader transport GHG emissions reduction strategy. As highlighted earlier, the Australian EV market share is small by global standards, and much of this is attributed to low levels of inducements. While there is limited scope for the City of Melbourne to intervene in the broader car market, there are actions available which could encourage local adoption.

The City of Melbourne should develop a policy that relates to charging EVs from residential properties without car parking. Without such a policy, residents will have difficultly charging their EVs, creating a barrier to adoption. Potential solutions could be co-payments from residents to help defuse the cost of installing public charging stations; guidelines related to conditions where power cables may or may not be run from dwellings to vehicles parked on-street (potentially over-head or along the footpath contained in Disability Discrimination Act and Electrical Safety Victoria compliant housings); or partnering with the private sector to incentivise the installation of privately owned and operated but publicly accessible charging stations.

As a broader objective, the City of Melbourne should partner with the private car parking sector and EV charging companies to refit private car parking lots with charging capabilities. In high turnover, high demand parts of the City of Melbourne, which see large visitor numbers, publicly available rapid charging stations should be installed, reserving prime spots for EVs, served by renewable electricity. This would help to reduce range anxiety, and serve to increase awareness of EVs among those walking/driving past these spots.

New residential developments in the City of Melbourne should include EV charging capacity, 'future proofing' them and providing incentives for residents. Potential policy mechanisms to achieve this is discussed in Section 6.8.2.

6.6.2.1. Taxis and Mobility as a Service

As highlighted earlier, taxis travel significantly more than the average motor vehicle and as such, should be targeted for efficiency enhancements. The City of Melbourne should develop a program of rapid EV charging stations, using renewable energy, at the rear of taxi ranks. If made free for taxis to use, this will give a strong signal to the taxi industry that they should invest in EVs. Taxis will be able to charge for a 15-20 minutes at a taxi rank, then drive hundreds of kilometres on green, emissions free electricity.

In the future, the City of Melbourne should signal an intention to restrict access to lucrative taxi ranks (or future taxi/MaaS pick up points) to only be usable by EVs, with a five year advanced notice to the market.[10] This would provide a further inducement for the industry to adopt technology which reduces GHG emissions. To provide operators ample time to make purchasing decisions.

6.6.3. Land freight

Freight is a large contributor to transport GHG emissions, and is more difficult to move to a different mode than personal transport. Based on the methodology set out earlier in this report, heavy vehicles account for approximately one quarter of all on-road transport GHG emissions. The challenge of transforming the fleet to electric are similar to that of electric cars, but are compounded by the need for longer range vehicles and high average ages. For example, while the average Victorian car is 9.7 years old, the average Victorian heavy rigid truck age is 16.7 years old and the average Victorian articulated truck is 12.3 years old (with average age increasing year-on-year) (Australian Bureau of Statistics, 2017b). The distances travelled by trucks is also greater than passenger cars, with Victorian articulated trucks travelling 79,100 km per year (Australian Bureau of Statistics, 2017b). However, emerging vehicles, such as the Tesla Semi may address range anxiety, with an expected range of approximately 800km per charge (Tesla, 2017).

The City of Melbourne can collaborate with the trucking industry and the Port of Melbourne to trial and evaluate low-emissions road freight vehicles. Small grants could be offered to participating companies to assist in purchasing plug-in electric trucks. The City of Melbourne can partner with the Port of Melbourne to install a fast charging station, so plug-in electric trucks involved in the trial can charge up while awaiting freight. Evaluation data from the trial can be used to encourage trucking companies to purchase plug-in electric trucks. Consideration should also be given to exempting plug-in electric trucks from truck ban signs, as they do not cause tail pipe emissions or have loud engine brakes.

Light commercial vehicles have lower usage, and will be more easily replaced by available or soon-to-be available EVs. The City of Melbourne can encourage uptake of plug-in electric vehicles by installing charging stations at selected load zones and restricting usage of some loading zones exclusively for EVs.

6.6.4. Maritime

There is little scope for the City of Melbourne to affect change in GHG emissions from commercial maritime activities. However, the City of Melbourne may have some capacity to influence decisions of the Port of

[10] Victorian taxis are replaced at 6.5 years of age (Monash University, 2015) while Uber has a maximum vehicle age of 10 years (Uber, 2018).

Melbourne. The City of Melbourne should work with the Port of Melbourne to ensure ships are powered by renewable energy from the supply system when berthed, rather than run on fossil fuel generators.

The City of Melbourne should encourage commercial ferry and nautical tourism operators to offset emissions and use the cleanest possible fuels. As electric boats become viable, the City of Melbourne should work with operators to encourage uptake of these vessels, and install charging equipment to support their use.

The City of Melbourne should work with marina operators to ensure that when berthed, vessels are powered by renewable energy.

6.6.5. Aviation

The City of Melbourne has little capacity to change the GHG emissions associated with aviation within the City of Melbourne boundaries. Several helipads are located in the City of Melbourne, but there are currently no widely available commercial alternatives to fossil fuel powered helicopters. There is scope to work with helipad operators to investigate the offsetting of emissions until such a time as electric aviation vehicles become commercially available.

6.7. Optimising public transport

Public transport is the most spatially efficient transport mode, able to move the largest number of people for the amount of space it occupies (see Figure 49). Although currently powered by the Victorian electricity grid, which is dependent on lignite power stations, electrified rail has lower GHG emissions per passenger km travelled than ICE vehicles. While City of Melbourne does not have control over the operation of public transport in Melbourne, it should enter into discussions with the State Government and operators to lobby for change. There are two separate sets of actions related to public transport, the first relate to the GHG emissions intensity of public transport, the second relate to the coverage and accessibility of the public transport network. For public transport to aid in reducing GHG emissions it needs to both have a low GHG emissions intensity and to be accessible to all residents. The actions below have the greatest capacity to reduce the GHG emissions profile of public transport in City of Melbourne and increasing coverage of greater Melbourne's public transport system.

6.7.1. Greening public transport

6.7.1.1. Electrification of Regional Rail Link

Completion of Regional Rail Link (RRL) is the first major step towards fully separating Victoria's regional rail network from the Metropolitan commuter rail network. Trains towards Geelong and Ballarat are now totally separated from the MTM network. Although V/Locity trains cannot be operated on electricity, future trains could be diesel-electric with electronic switching, which would permit operation on a variety of voltages and diesel where overhead power is not available. This could allow for the electrification of RRL with 25kVAC (the international standard for long distance rail), with trains able to operate on 25kVAC when under RRL, 1500VDC on the MTM system and diesel where electrical overhead is not available.

6.7.1.2. Regenerative breaking

Regenerative braking occurs when an electric vehicle uses its motors to apply braking force, generating electricity which can be stored or fed into an electricity grid. Regenerative braking in a rail system feeds electricity back into the electricity supply system for other rail vehicles to use, and can significantly reduce power consumption of the system. The tram system currently partially implements regenerative braking, while the train system does not (Energy Safe Victoria, 2014).

MTM have estimated that regenerative braking will decrease network wide power consumption by up to 20%, and have previously stated an intent to implement regenerative braking (Carey, 2014). The current Melbourne train fleet is made up of three vehicle types: Comeng trains, which are not able to regenerate power from the braking system as they use rheostatic braking (Office of the Chief Investigator, 2009); and Alstom and

Seimens trains which are compatible with regenerative braking (Energy Safe Victoria, 2014). The High-Capacity Metro Trains (HCMT) currently being built will have regenerative braking capabilities as will Melbourne Metro (Melbourne Metro Rail Authority, 2016). It is estimated that HCMTs running on Melbourne Metro will consume 27% less power than under a business as usual scenario without HCMTs or Melbourne Metro (Melbourne Metro Rail Authority, 2016).

Conversion of the entire tram and train fleets and power supply stations to be compatible with regenerative braking has the potential to radically reduce power consumption of electrified rail public transport in the City of Melbourne. This will allow the system to be converted to renewable power for less ongoing cost, ultimately eliminating GHG emissions from electric rail public transport, while in the interim it will reduce GHG emissions from portions of the rail system dependent on lignite power.

6.7.1.3. Purchasing/installing green energy to power vehicles and ancillary uses.

Electrified public transport can be made totally emissions free if powered by renewable energy. The construction of 35MW of solar capacity to offset the electricity consumption of the tram system is a productive move towards a carbon free future. The Melbourne Metro project will be 20% powered by GreenPower renewable energy (Melbourne Metro Rail Authority, 2016), but the remaining 80% of Melbourne Metro operations and all of Metro Train Melbourne operations will continue to be powered by standard Victorian grid electricity. A move towards renewable energy to power the Metro Trains Melbourne system would significantly reduce GHG emissions.

Stations and ancillary uses, such as staff facilities and control rooms can similarly have GHG emissions reduced by shifting to renewable energy. Yarra Trams Green Depot programme involves lowering the water and energy consumption of tram depots by installing water tanks, efficient lighting, and renewable energy generating capacity (http://www.yarratrams.com.au/media-centre/news/articles/2014/new-green-depots-for-world-environment-day/). A program similar to Green Depot could be undertaken in collaboration with Metro Trains Melbourne, aimed at reducing the energy consumption and associated emissions at railway stations and other buildings.

6.7.1.4. High speed rail linking major cities

High Speed Rail (HSR) has the capacity to reduce air travel between major cities and can therefore reduce GHG. Air travel is the hardest form of travel to move away from reliance on fossil fuels. Commercial production of jumbo jet sized electric planes are not envisioned in the near to medium future, while alternative power sources such as hydrogen or biofuels are accompanied by additional climate change considerations such as release of water vapour into the stratosphere or deforestation. The best way, with current or envisioned technology, to reduce GHG emissions associated with air travel is through mode shift, and the only comparable technology available is HSR. The development of HSR connecting the Melbourne and Sydney CBDs can also reduce congestion to and from Melbourne Airport and decrease the need for a second airport.

6.7.1.5. Electric bus technology – under road charging / catenary for charging and hill assist

In the last 10 years, electric buses have previously been trialled in Melbourne, but not adopted. Substantial advances in technology have occurred in the last five years and multiple options available. Bio-fuel hybrids will remove GHG emissions, but will not have the same positive effect on air quality. Plug-in battery has air quality improvements but requires renewable energy to completely reduce emissions and range is restricted. Battery with charging capabilities either at stops, along the route or both have the potential to offer the best of both worlds, with improved air quality, and potentially unlimited range (like a tram); electric infrastructure need only be installed on strategic corridors, with batteries powering buses for the remainder (e.g. power lines along Eastern Freeway to provide charge and motive power, off Freeway buses continue DART service on battery). Prague has a good example of a battery trolley bus, Adelaide has a solar/battery bus that charges at stops[11]. A number of Dutch cities have recently renewed their bus fleets with large numbers (i.e. 100's) of electric buses.

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[11] See https://www.cityofadelaide.com.au/assets/documents/FACTSHEET-tindosolar-bus.pdf

6.7.1. Increasing the coverage of public transport

Although the City of Melbourne lacks direct control over the operation or network development of Melbourne's public transport system, there are still opportunities for expanding public transport coverage. The City of Melbourne should use demographic data showing the strong correlation between proximity to public transport infrastructure and public transport usage as a means of journey to work to lobby the State Government for expansion of public transport services, especially in 'black spots'. Advocacy should take the form of supporting public transport projects such as Doncaster Rail, a rail link to Melbourne Airport, Rowville Rail, and Melbourne Metro stage 2. Conversely, the City of Melbourne should continue to oppose city shaping road projects such as East-West Link and the West Gate Tunnel project which will allow more cars to enter the city centre and encourage urban sprawl into areas poorly served by public transport.

Implementation of dedicated public transport lanes, such as tram and bus lanes, will increase the performance of public transport and build high capacity corridors in the City of Melbourne. Decreased running times and increased punctuality will lower the costs of delivering public transport. The City of Melbourne should leverage these improvements, requesting savings be reinvested into better public transport services. Further, implementation of bus lanes can be used to leverage the State Government, PTV and bus operators to improve services to make full potential of dedicated bus infrastructure.

6.8. Land use changes to encourage sustainable mobility

Land use policies promulgated by the City of Melbourne have the potential to decrease transport GHG emissions by encouraging a built form that reduces the need for car travel and encourages the uptake of electric vehicles.

6.8.1. Transit Orientated Development

Urban renewal areas, current and proposed, as listed in MSS 21.13 (City of Melbourne, 2016c) and 21.14 (City of Melbourne, 2015a) have the potential to include elements from Transit Oriented Development. Increased density, activated street frontages with a variety of commercial uses, and lower capacity to store cars will lead to vibrant communities consistent with a 20-minute city ideal. This will reduce the dependence on cars and the associated GHG emissions.

6.8.2. Parking Overlays

Planning controls with regards to parking have the potential to decrease car ownership, increase space for bicycles, and facilitate EVs. The City of Melbourne has implemented Parking Overlays, which vary the parking requirements of Victorian Planning Provision Clause 52.06 – Car Parking. Parking Overlays allow Council to set maximum parking rates as well as minimums, tailored to individual parts of the municipality. Parking Overlays are an effective measure for reducing car ownership and car usage, and should be implemented in all areas of the City of Melbourne.

In order to successfully promote the uptake of EVs, charging points must be available for electric car owners. Schedules to Parking Overlays can be used to facilitate this change. Victorian Planning Provision Clause 45.09 – 8 allows a schedule to a Parking Overlay to specify 'additional design standards' and 'other requirements for the design and management of car parking'. All Parking Overlays Schedules shall have an objective 'to facilitate the uptake of plug-in electric vehicles' in sub-clause 'Parking objectives to be achieved'. Parking Overlay Schedules shall have sub-clause 'Design standards for car parking' which requires all buildings which contain over 20 parking spaces to provide one plug-in electric vehicle charging point for every five parking spaces. Sub-clause 'Decision guidelines' should include 'Whether plug-in electric vehicle charging facilities are available and conveniently located'. This policy will directly support Municipal Strategic Statement 21.09 – 5, Objective 1, Strategy 1.3 'Support provision of re-charging facilities powered by renewable sources of energy for electric powered vehicles'.

The current bicycle parking rates included in Victorian Planning Provision Clause 52.34 are one space for every five dwellings (in developments of four or more storeys). This is insufficient to achieve a large mode share of cycling in new apartment buildings, as less than one in every five residents will have secure storage facilities for a bicycle, depressing bicycle ownership and thus cycling participation rates. While Victorian Planning Provision Clause 45.09 allows for a variation in car parking rates otherwise required by Victorian Planning Provision Clause 52.06, no such variation is mentioned for bicycle space rates listed in Victorian Planning Provision Clause 52.34. The City of Melbourne should advocate to the Department of Environment, Land, Water and Planning to alter Victorian Planning Provision Clause 45.09 to allow for variations in bicycle space rates listed in Victorian Planning Provision Clause 52.34. If implemented, **the City of Melbourne should require one bicycle space per bedroom in multi dwelling buildings.**

6.8.3. Public charging facilities

The City of Melbourne should develop a policy for on-street publicly accessible charging facilities to be installed in the City of Melbourne. Options for delivery should be investigated, including the option to partner with the private sector, as Hackney in London is doing, or for the City of Melbourne to own and operate its own charging infrastructure and pricing system. The policy should include provisions for accessibility and distribution of charging infrastructure, and to ensure that charging stations are powered by renewable energy. To maximise potential benefits, charging infrastructure could be located adjacent to car share spaces, encouraging adoption of EVs by the car share industry and allow for electricity to be feed back into the grid from EVs to assist with load balancing.

6.8.4. Car share

The City of Melbourne currently has 350 car share vehicles, operated by five companies, with plans for 2,000 vehicles by 2021. It is estimated that every car share vehicle removes nine privately owned vehicles and reduces VKT per user (City of Melbourne, 2015b). Car share plays a critical role in reducing automobile dependency, and also provides a method of lowering GHG emissions by using electric rather than fossil fuel vehicles. The City of Melbourne should work with car share companies to encourage the uptake of EVs in their fleet by assisting with the provision of charging infrastructure and potentially charging less per space for EV bays than fossil fuel spaces. An additional consideration of this is the potential to draw power from car share vehicles into the grid to assist with load balancing and avoiding power shedding during high demand periods; it is of note that 2,000 electric cars with 100kWh battery packs would deliver 200MWh of stored energy, double the capacity of the newly installed Tesla battery in South Australia.

All car share vehicles are currently round-trip, with users required to leave vehicles in the same space they picked them up from, and pay to hire the vehicle the whole time, even when parked. Previous analysis completed for the City of Melbourne showed that the average car share hire period is six hours, while driving time is only 50 minutes (City of Melbourne, 2015a). This is a disincentive to car share, which would be ameliorated by working with the car share industry to implement one-way car share.

6.8.5. Green Travel Plans

Green Travel Plans can be powerful tool to encourage more sustainable transport habits. All multi-dwelling and commercial development in the City of Melbourne should be required to prepare and submit a Green Travel Plan developed by a suitably qualified consultant. Green Travel Plans should include information about public and active transport modes which is to be disseminated to tenants and/or employees.

6.8.6. Increased pedestrian permeability

The City of Melbourne Walking Strategy (City of Melbourne, 2014a) recognises the importance of permeability through the CBD. This can be along main streets, through lane ways, or through buildings. Increased permeability is a critical way of facilitating increases in walking participation rates. Existing Council policies, such as the Walking Strategy and Municipal Strategic Statement Clause 21.12 – Hoddle Grid, have objectives and actions which will support Council’s GHG emissions ambitions by increasing walking mode share. City of

Melbourne policies and planning scheme amendments should ensure that the walking environment is improved through urban development and changed land uses.

7. Future transport scenarios

To better understand GHG emissions performance of on-road transport within the City of Melbourne, a scenario based modelling exercise has been undertaken. Three scenarios have been modelled, representing various degrees to which the transport and energy generation landscape may change over the next two decades. The scenario are:

1. *Business as usual*, forecasting a continuation of current trends;
2. *Moderate emissions reduction*, forecasting a medium level of EV uptake and greater shifts away from private vehicles;
3. *Strong emissions reduction*, forecasts the City of Melbourne's existing mode shift targets being met and a higher uptake of EVs.

All three assumptions have estimated Vehicle Kilometres Travelled (VKT) and GHG emissions for 2017, 2027 and 2037 for all on-road transport. The key assumptions underpinning the three modelled scenarios are shown in Table 5. This task has only been undertaken for road based transport as other forms of transport lack sufficient data. Whilst aviation, shipping and rail are important to the City of Melbourne's overall emissions calculation, a paucity of data precludes inclusion in this modelling. See Section 3.5 for a detailed methodology for calculating all transport related GHG emissions in the City of Melbourne.

Table 5 Comparison of scenario assumptions

	Business as usual	Moderate emissions reduction	Strong emissions reduction
Electric vehicles fleet percentage in 2027	1.9%	5.3%	10.7%
Electric vehicles fleet percentage in 2037	5.6%	10.2%	24.7%
Electric vehicle energy source	Victorian electric grid average	Certified renewable power	Certified renewable power
Mode share	Continuation of mode shift trend observed in VISTA data	City of Melbourne target met in 2037	City of Melbourne target met in 2030 and trend continues to 2037
Private car mode share in 2027	32.4%	28%	23.7%
Private car mode share in 2037	28.7%	20%	11.2%
Fuel consumption of internal combustion engine (ICE) vehicle decrease	10% every ten years	20% every ten years	30% every ten years

7.1. Assumptions

A number of important assumption have been made regarding the transport and energy generation landscape over the next 20 years. Whilst there is considerable uncertainty regarding Australian policy related to vehicle efficiency, urban transport policy and energy generation, assumptions have been made based on trends detected in the data (see Section 2, 3 and 4) across several areas that determine GHG emission outcomes for transport.

7.1.1. Fuel efficiency

Over the last 40 years, the fuel consumption of ICE vehicles has become slightly more efficient. However, in recent years newer technologies such as petrol-electric hybrid vehicles and efficient diesel engines have become more popular. Increased adoption of lower consumption vehicles will gradually increase the fuel efficiency of the vehicle fleet operational in the City of Melbourne. This modelling assumes that these technological advances will decrease fuel consumption of the fleet under each of the three scenarios. Government policies are a key determinant of the extent to which the vehicle fleet becomes lower consumption. Electric vehicles are an emerging technology which have the potential to radically decrease GHG emissions, if powered by renewable energy. This modelling uses EV uptake projections based on AEMO research on the impact of EVs in Australia. The AEMO report, produced in collaboration with Energeia models three scenarios with weak, neutral, and strong uptake (Australian Energy Market Operator, 2016a). These three scenarios are shown in Figure 58.

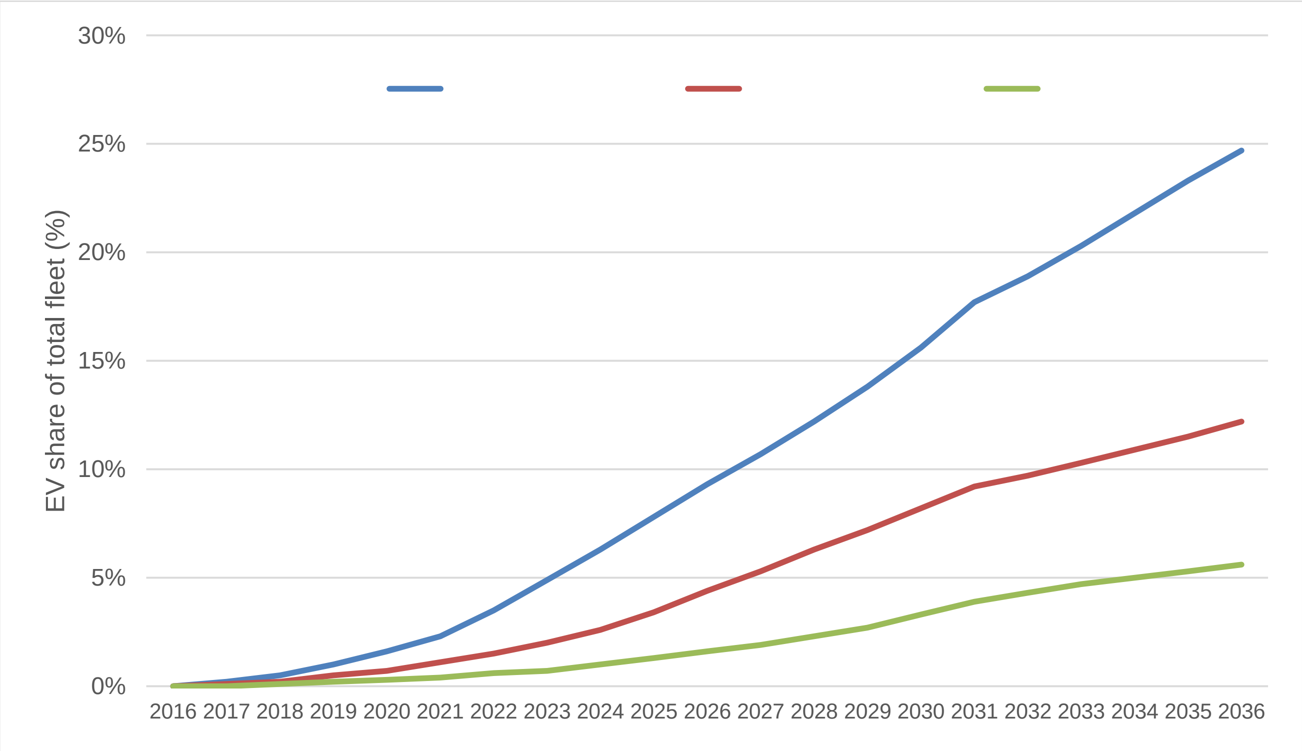

Figure 58 AEMO projected EV fleet share in Victoria
Source: Australian Energy Market Operator (2016a)

7.1.2. Energy generation

Power sources are critical to the success of EVs in reducing GHG emissions. The *business as usual* scenario assumes EVs to be charged by Victorian grid power, reflecting a low level of policy intervention, while the *moderate emissions reduction* and *strong emissions reduction* scenarios assume policy interventions which ensure that EVs are charged with 100% renewable energy.

It is assumed under all scenarios that rail public transport is operated by renewable energy. This is because a plan for the entire tram system to be powered by renewable energy has been announced (Minister for Energy Environment and Climate Change, 2017), and the Melbourne Metro will be operated by at least 20% renewable energy (Melbourne Metro Rail Authority, 2016).

7.1.3. Mode shift

Mode shift assumptions are based on current trends (for *business as usual*), and the fulfilment of City of Melbourne's mode share targets on different time lines (for *moderate emissions reduction* and *strong emissions reduction*). This modelling has not attempted to calculate how mode shifts will occur (e.g., tram to bike; car to train; walking to cycling; etc.). Due to the nature of travel to, from, or within the City of Melbourne, it is unlikely that the original mode affects the overall GHG emissions.

We have not attempted to calculate the length of a journey to the City of Melbourne, as it is irrelevant for Scope 1 and Scope 2 emissions calculation (see Section 3.5 for more detail). Only the segment of the journey which occurs inside the City of Melbourne is relevant. For example, the VKT that takes place in the City of Melbourne is the same if the journey originates in Richmond or Craigieburn; any shift from car to active or public transport will effect a reduction in VKT and GHG emissions.

7.1.4. Number of trips

All scenarios have the same number of trips modelled in 2027 and 2037. It is assumed that the number of trips per person remains the same, with trips scaled up commensurately with City of Melbourne forecasts for total daily population (City of Melbourne, 2017b).

7.1.5. Climate change targets

The Australian Government's target under the Paris Climate Change Accord is to reduce emissions by 26-28% from 2005 levels by 2030. This is estimated to require a per capita GHG emission reduction of 50% from 2005 levels by 2030 (Department of Environment amd Energy, 2015).

7.1.6. Freight

There has been an average annual increase of 2.3% in heavy vehicle traffic since 1990. Over a rolling ten-year period, this equates to an approximate 25% increase every 10 years. As such, heavy vehicle movements are modelled to rise by 25% every ten years into the future (BITRE table T4.2). Under this assumption, growth in heavy vehicle VKT is roughly in line with growth in personal transport. Vehicle efficiency improvements in heavy vehicles are assumed to be low (Sims et al., 2014), with a 5% decrease in fuel consumption assumed every 10 years. This is a conservative assumption which reflects the slow turn over of vehicles and high replacement costs, compared to private vehicles. This set of assumptions have been used in all three scenarios.

7.2. Business as Usual

A *Business as Usual* (BAU) scenario envisages minimal change from today, with mode share following recent trends and similar levels of Governmental intervention. The assumptions underpinning this scenario are:

- Electric vehicle composition of fleet is 1.9% by 2027 and 5.6% by 2037
- Electric vehicles to be charged from the grid (consumption based at 150wH per km, the current average for electric vehicles)
- Continuation of mode share changes seen in VISTA analysis
- Fuel consumption of internal combustion engines decreases 10% every ten years.

There is a slight mode share shift towards public and active transport projected, in line with the overall mode shift observed between the 2009 and 2015/16 VISTA surveys. It is projected that private vehicle mode share will drop from 36% in 2017 to 29% in 2037, with rises in active and public transport mode share, as shown in Table 6.

Table 6 Change in mode share 2017 – 2037 (BAU scenario)

	2017	2027	2037
Vehicle Driver	27.6%	24.5%	21.4%
Vehicle Passenger	8.5%	7.9%	7.3%
Walking	21.8%	25.5%	29.2%
Bicycle	3.9%	3.7%	3.6%
Train	26.8%	28.3%	29.9%
Tram	8.2%	5.6%	3.1%
Bus	1.6%	2.4%	3.2%
Other	1.6%	2%	2.4%

Under the BAU scenario electric vehicle uptake is low, based on the AEMO Energeia weak EV uptake model (Australian Energy Market Operator, 2016a). Electric vehicles are expected to make up 1.9% of the fleet by 2027 and 5.6% of the fleet by 2037. This scenario also assumes that electric vehicle owners charge their vehicles of standard Victorian grid electricity. AEMO project that emissions from the grid to reduce by roughly 27% by 2030, in line with Australia's climate change commitments (Australian Energy Market Operator, 2016b). As such an emissions reduction from 1.13kg per kWh to 0.85kg per kWh is modelled by 2027, dropping further to 0.82kg per kWh in 2037 (Department of the Environment, 2015). This assumption is based on modelling for the Victorian Renewable Energy Target (VRET), which sees most renewable energy being built by the late 2020s, and transition from coal to gas taking place in the 2030s (EY, 2017). It is further assumed that rail based public transport will be run on renewable energy, with buses captured in the on-road heavy vehicle category.

Finally, the BAU scenario sees the efficiency of the ICE car fleet increase by 10% every ten years. This rate of consumption decrease is consistent with the long term trend and assumes vehicle purchasing habits to follow existing trends.

Figure 59 shows the total trip numbers by mode under the BAU scenario. Although the mode share of active and public transport is expected to rise, the overall increase in daily population rises at a *higher* rate than this mode shift, resulting in more usage of all modes.

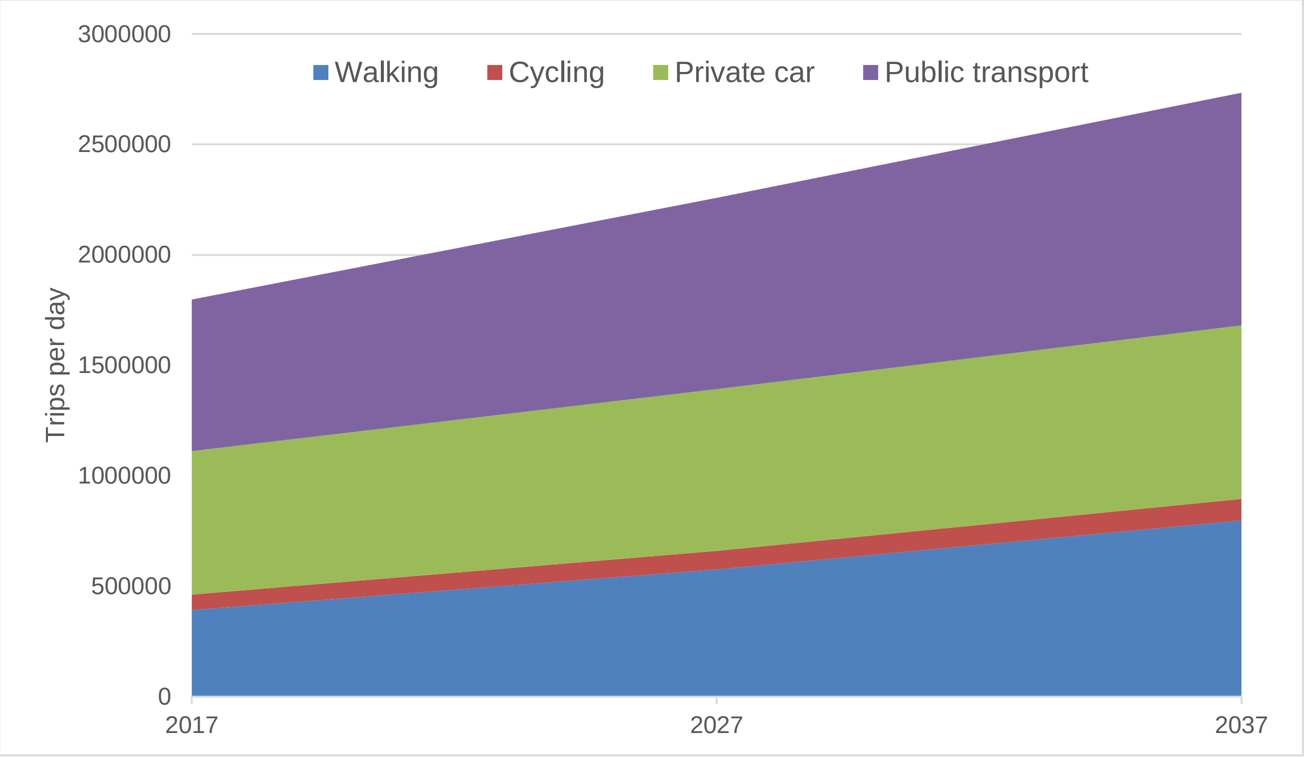

Figure 59 BAU trips per day, per mode type

There is an overall rise in VKT within the City of Melbourne, and an increase in CO_2 emissions, as shown in Figure 60. The right vertical axis relate to CO_2 emissions, while the left vertical axis concerns VKT. The increase in emissions is not large; due to increased VKT negating the positive impacts of increased vehicle efficiency and decreased emissions intensity.

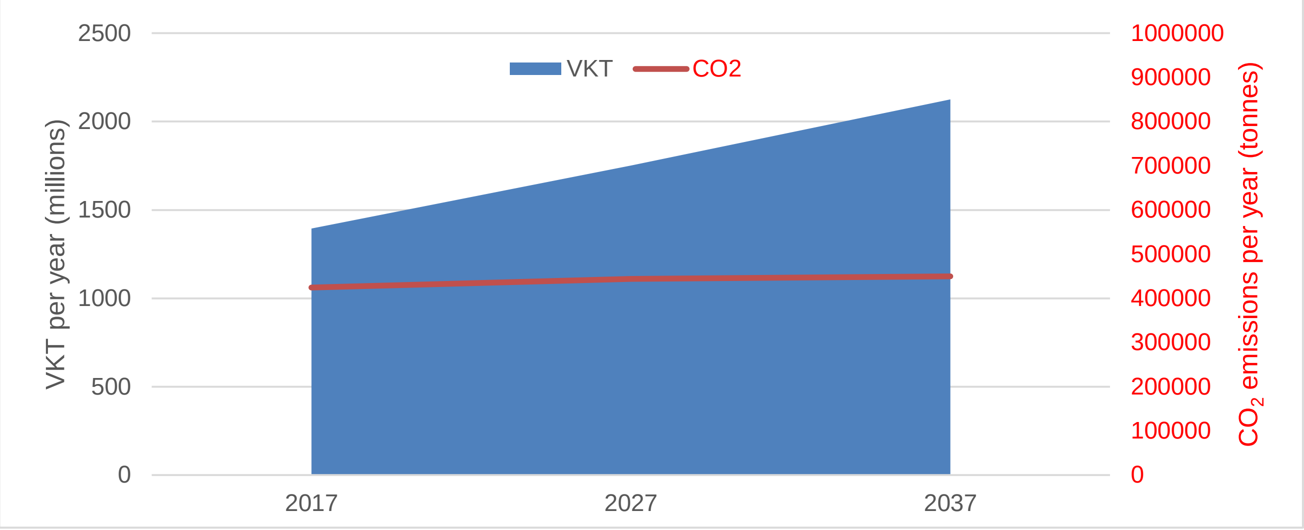

Figure 60 BAU total VKT and CO_2 emissions

Figure 61 shows VKT and CO_2 segmented by motor vehicle type. It is clear that improvements in light vehicle efficiency, coupled with a shift towards electric vehicles mean that the increase in CO_2 emissions is not proportional to the increase in light vehicle VKT (i.e. light vehicle VKT increases faster than CO_2 emissions).

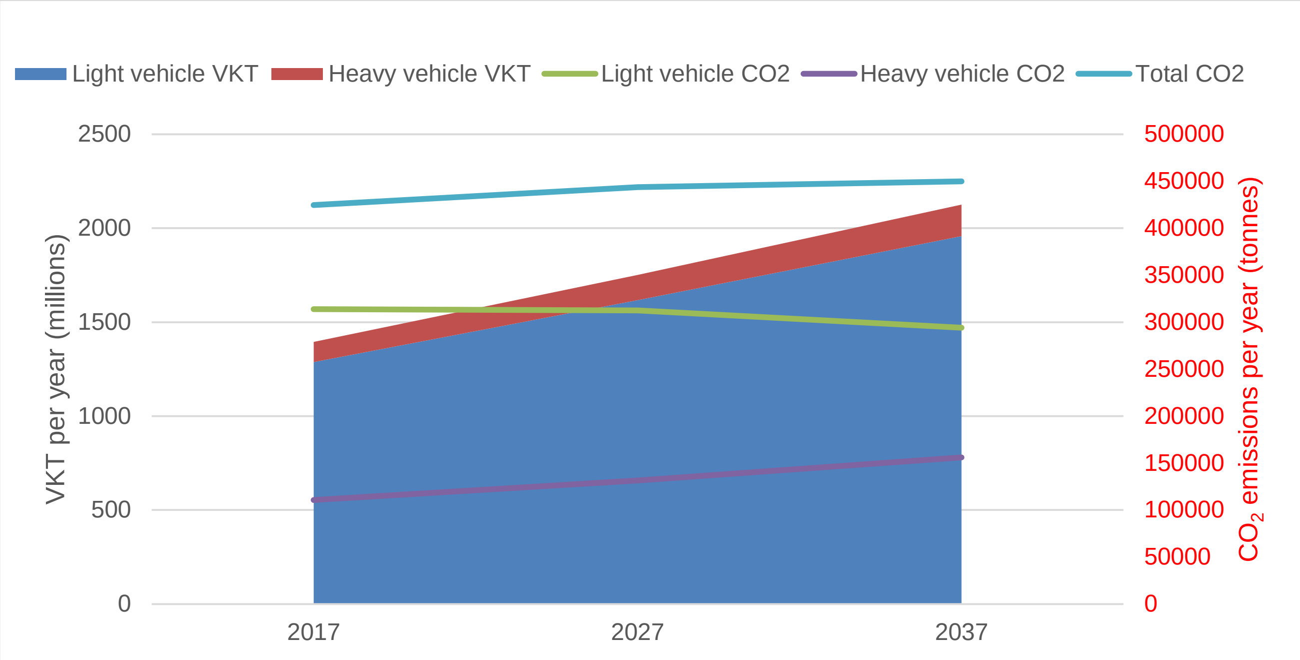

Figure 61 BAU VKT and CO_2 emissions, by vehicle type

Overall, there is an increase of 6% in on-road transport GHG emissions under this BAU scenario, from 424,525 tonnes in 2017, to 443,804 tonnes in 2027 and 449,947 tonnes in 2037. Per capita, emissions are projected to decrease from 460.3kg per year in 2017, to 383.2kg per year in 2027, and 320.9kg per year in 2037. While this will lower the per capita intensity of transport, it is only a 17% reduction by 2027, short of the 50% by 2030 required to meet Australia's per capita reductions in line with the Paris Climate Accord.

It is clear that the BAU approach will result in a failure to meet current reduction commitments. Changes to mode share and vehicle fleet, beyond what is projected under current government policies are required to lower emissions sufficiently for the City of Melbourne to meet its reduction ambitions in line with the Paris Climate Accord.

7.3. Moderate Emissions Reduction

A *Moderate Emissions Reduction* scenario envisages a moderate change from today, with mode share meeting City of Melbourne mode share targets on an extended timeline and increased levels of governmental intervention. The assumptions underpinning this scenario are:

- Electric vehicle composition of fleet at 5.3% by 2027 and 10.2% by 2037
- Electric vehicles to be charged with renewable energy
- An increased mode shift away from private motor vehicles towards active and public transport
- Fuel consumption of internal combustion engines decreases 20% every ten years.

There is a moderate mode share shift towards public and active transport projected to meet the City of Melbourne's mode share targets (seven years after the 2030 targets identified in the City of Melbourne's 2012 Transport Strategy). This mode shift is above the overall mode shift observed between the 2009 and 2015/16 VISTA surveys. It is projected that private vehicle mode share will drop from 36% in 2017 to 20% in 2037, with rises in active and public transport mode share, as shown in Table 7.

Table 7 Moderate emissions reduction mode share projections

	2017	2027	2037
Vehicle Driver	27.6%	21.4%	15.3%
Vehicle Passenger	8.5%	6.6%	4.7%
Walking	21.8%	25.9%	30%
Bicycle	3.9%	6.9%	10%
Train	26.8%	28%	29.3%
Tram	8.2%	8.6%	9%
Bus	1.6%	1.7%	1.7%
Other	1.6%	0.8%	0%

Under the *Moderate Emissions Reduction* scenario, EV uptake is in line with the neutral scenario developed by AEMO Energeia. Electric vehicles are expected to make up 5.3% of the fleet by 2027 and 10.2% by 2037. This scenario also assumes that electric vehicle owners charge their vehicles with renewable energy as a result of local government policies. As such, the use of EVs are considered to have no associated GHG emissions. It is further assumed that rail based public transport would also be run on renewable energy, with buses captured in the on-road heavy vehicle category.

This *Moderate Emissions Reduction* scenario forecasts that the efficiency of the ICE car fleet increases by 20% every ten years. This rate of consumption decrease is *inconsistent* with the long term trend and would require a rise in petrol costs and greater availability and lower price for hybrid vehicles. This represents a departure from existing purchasing habits, which would be at least partially dependent on policy interventions to encourage fuel efficient vehicles.

Figure 62 shows the total trip numbers by mode under the *Moderate Emissions Reductions* scenario. Unlike the *Business as Usual* scenario, the *Moderate Emissions Reductions* scenario projects a slight decrease in motor vehicle trips each day, and a commensurate decrease in motor vehicle VKT. The mode share of active and public transport is expected to rise (as shown in Figure 62) at a rate which exceeds overall increases in daily population, this projects in increase in all total trips per day on public transport, walking and cycling.

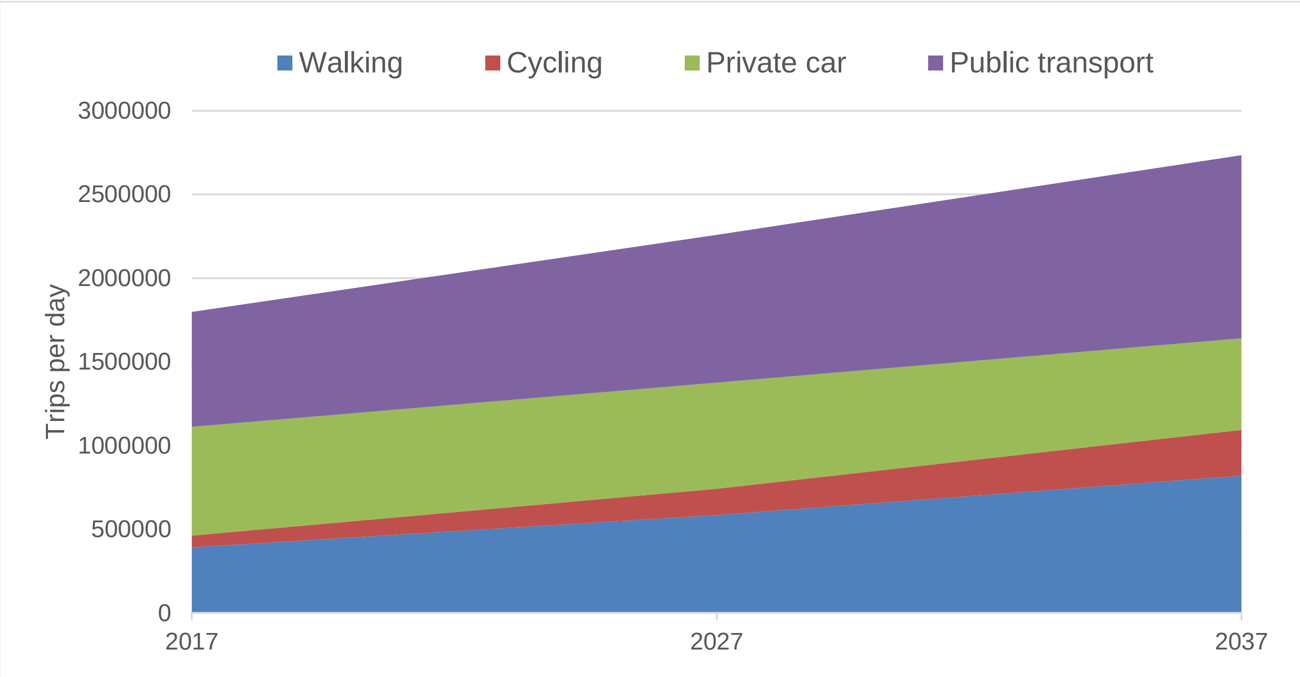

Figure 62 Moderate Emissions Reductions scenario: trips per day, per mode type

There is a small decrease in motor vehicle VKT within the City of Melbourne, and a substantial decrease in CO_2 emissions, as shown in Figure 63.

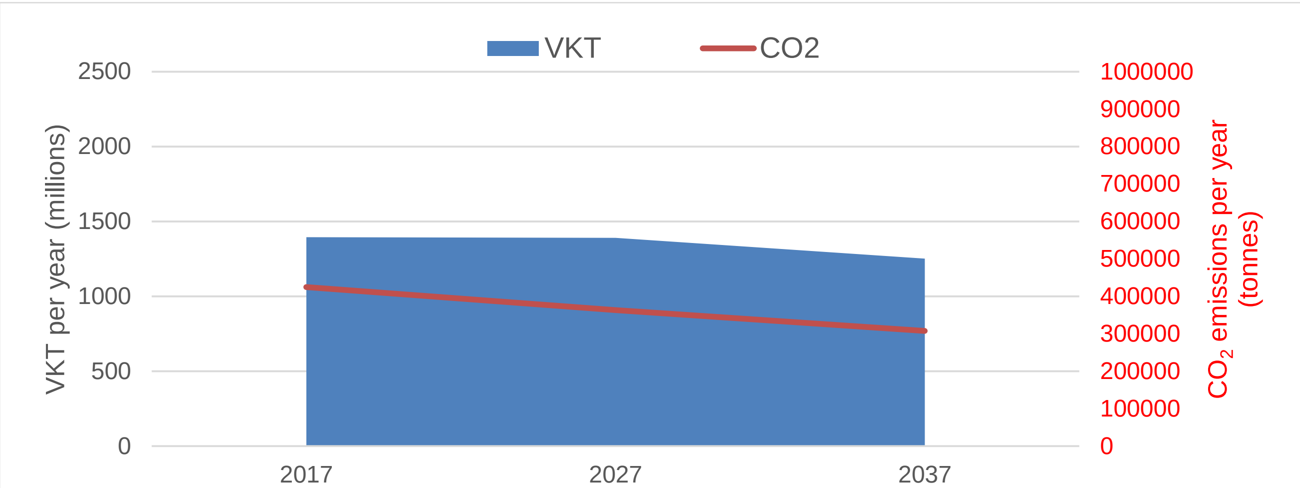

Figure 63 Moderate Emissions Reductions scenario: total VKT and CO_2 emissions

Figure 64 shows the motor vehicle and CO_2 emissions segmented by motor vehicle type. The decreases in on-road emissions are entirely due to decreased emissions from light vehicles. This is due to improvements in

ICE light vehicle efficiency, coupled with a shift towards EVs, meaning that the CO_2 emissions decrease from reduced light vehicle VKT and lower GHG emission intensity.

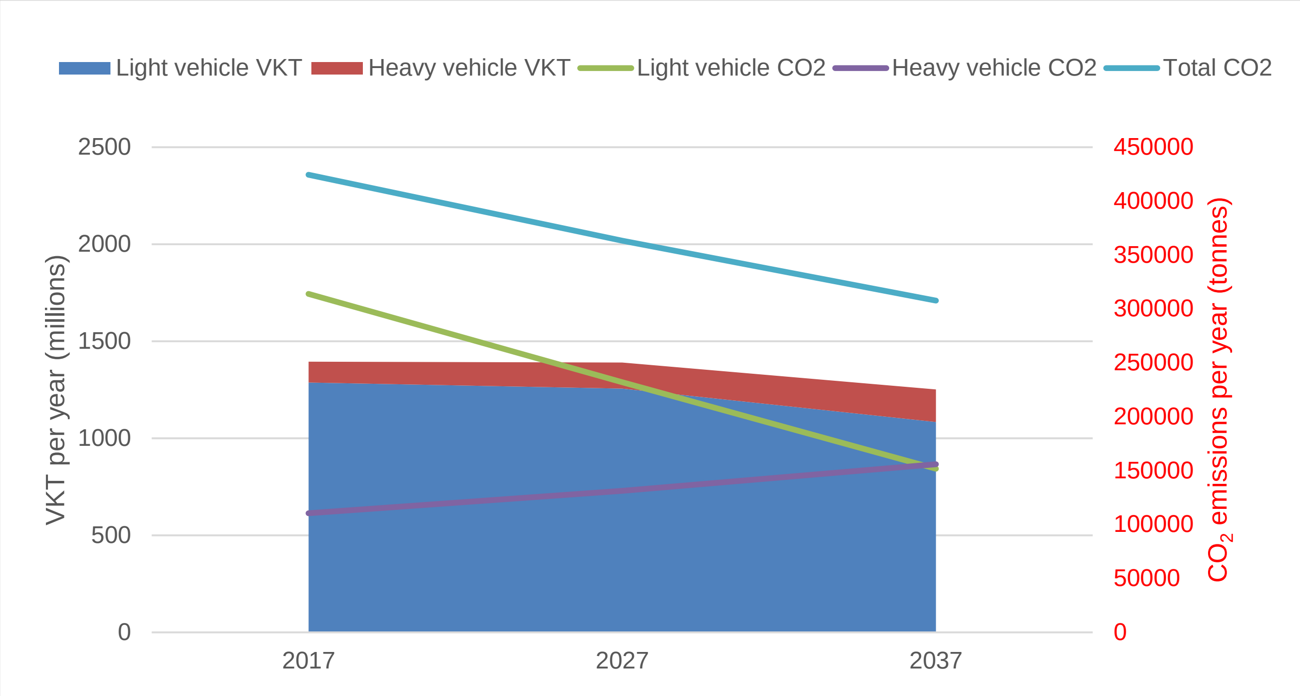

Figure 64 Moderate Emissions Reductions scenario: total VKT and CO_2 emissions, by vehicle type

The *Moderate Emissions Reduction* scenario estimates a decrease of 27% in on-road transport GHG emissions, from 424,525 tonnes in 2017, to 363,394 tonnes in 2027 and 307,883 tonnes in 2037. Per capita, emissions are projected to decrease from 460.3kg per year in 2017, to 313.8kg per year in 2027, and 219.6kg per year in 2037. There is a substantial decrease in the per capita intensity of transport, however, the reduction is only 32% by 2027, short of the 50% by 2030 required to meet Australia's per capita reductions in line with the Paris Climate Accord.

The *Moderate Emissions Reduction* scenario leads to significant GHG emission reductions from transport. Reductions are much larger than the BAU scenario, while VKT within the City of Melbourne decrease only slightly. The changes forecast within the *Moderate Emissions Reductions* scenario will not be sufficient for the City of Melbourne to meet its ambitions in line with the Paris Climate Accord. More substantial shifts towards cleaner transport will be required and these have been modelled in the final scenario described in the following section.

7.4. Strong Emissions Reduction

A *Strong Emissions Reduction* scenario envisages a substantial change from today, with City of Melbourne mode share targets being met on time and then continued and increased levels of governmental intervention. The assumptions underpinning this scenario are:

- Electric vehicle take up of 10.7% by 2027, 24.7% by 2037
- Electric vehicles to be charged with renewable energy
- A substantial mode shift away from private motor vehicles towards active and public transport
- Fuel consumption of internal combustion engines decreases 30% every ten years.

There is a strong mode share shift towards public and active transport projected to meet the City of Melbourne's mode share targets in accordance with the goals included in the 2012 Transport Strategy to 2030, and then extend these mode share gains for an additional seven years to 2037. This mode shift is well above the overall mode shift trends observed between the 2009 and 2015/16 VISTA surveys. It is projected that private vehicle mode share will drop from 36% in 2017 to 11% in 2037, with rises in active and public transport mode share, as shown in Table 8.

Table 8 Strong emissions reductions mode share projections

	2017	**2027**	**2037**
Vehicle Driver	27.6%	18.1%	8.6%
Vehicle Passenger	8.5%	5.6%	2.6%
Walking	21.8%	28.1%	34.1%
Bicycle	3.9%	8.6%	13.2%
Train	26.8%	28.7%	30.4%
Tram	8.2%	8.8%	9.3%
Bus	1.6%	1.7%	1.8%
Other	1.6%	0.4%	0%

Under the *Strong Emissions Reduction* scenario, EV uptake is highest, based on the AEMO Energeia *'strong EV uptake'* model. Electric vehicles are expected to make up 10.7% of the fleet by 2027 and 24.7% of the fleet by 2037. This scenario also assumes that EV owners charge their vehicles with renewable energy as a result of state and local government policies. As such, the use of all EVs is considered to have no associated GHG emissions. It is further assumed that rail based public transport would also be run on renewable energy, with buses captured in the on-road heavy vehicle category.

The *Strong Emissions Reduction* scenario sees the efficiency of the ICE car fleet increase by 30% every ten years. This rate of consumption decrease is *inconsistent* with the long term trend and assumes a significant increase in fuel costs, coupled with greater availability and affordability of efficient vehicles, and accelerated fleet turn-over. This represents a departure from existing purchasing habits, which would be dependent on policy interventions to encourage fuel efficient.

Figure 65 shows the total trip numbers by mode under the *Strong Emissions Reduction* scenario. Meeting the City of Melbourne mode share targets in 2030, then continuing the prevailing trend (to 2037) is projected to lead to a significant decrease in motor vehicle usage. Concurrently, the mode share of active and public transport is expected to markedly rise, at a rate which exceeds overall increases in daily population.

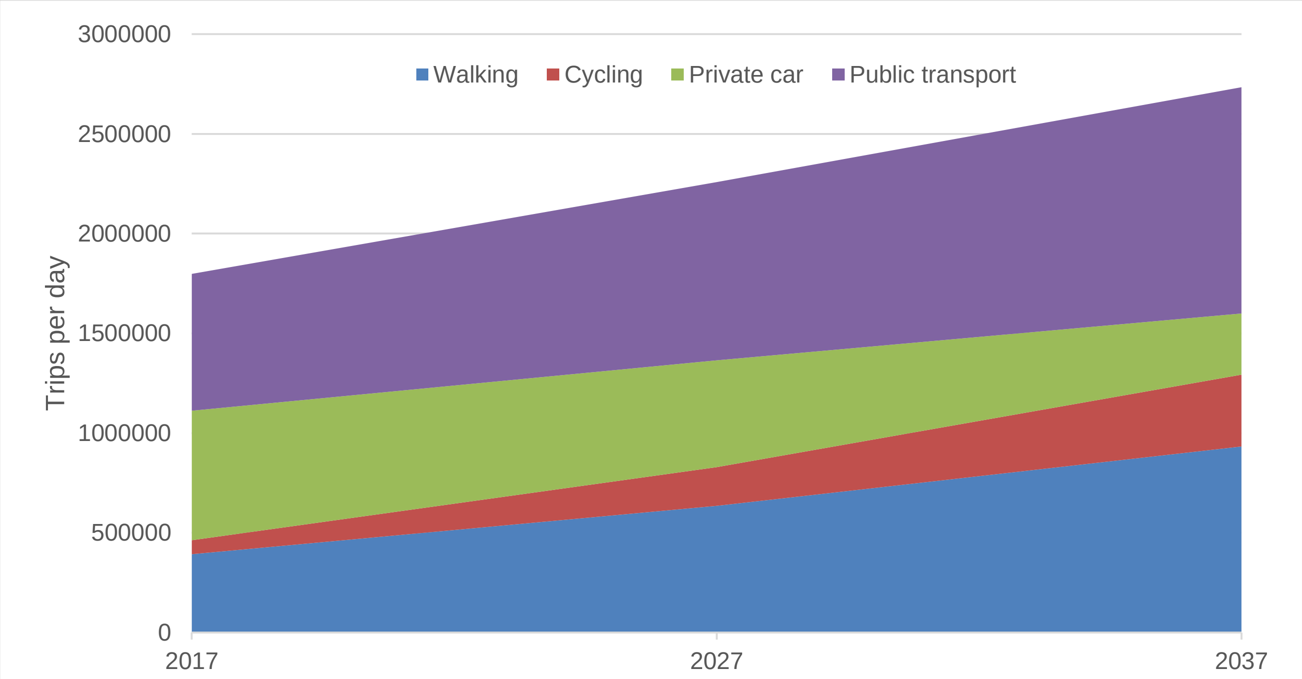

Figure 65 Strong Emissions Reductions scenario: trips per day, per mode type

There is a large decrease in VKT within the City of Melbourne, and a substantial decrease in CO_2 emissions, as shown in Figure 66.

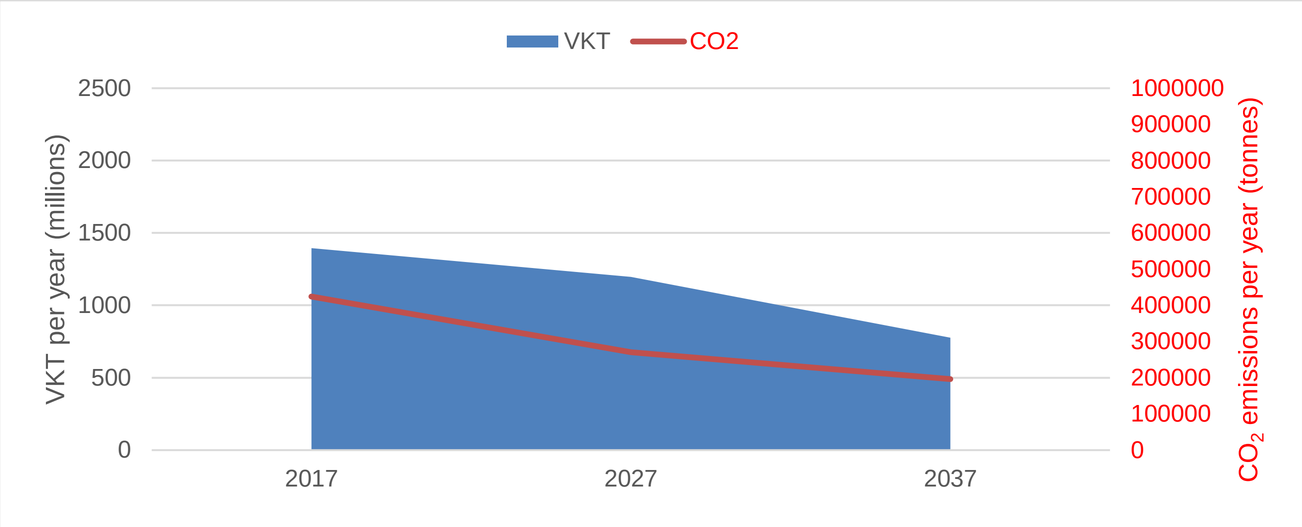

Figure 66 Strong Emissions Reductions scenario: total VKT and CO_2 emissions

Figure 67 shows the projected VKT and CO_2 emissions for on-road transport segmented by vehicle type. As is the case with the *Moderate Emission Reductions* scenario, improvements in light vehicle efficiency, coupled with a shift towards electric vehicles and a significant decrease in VKT are the leading factor which decrease in CO_2 emissions.

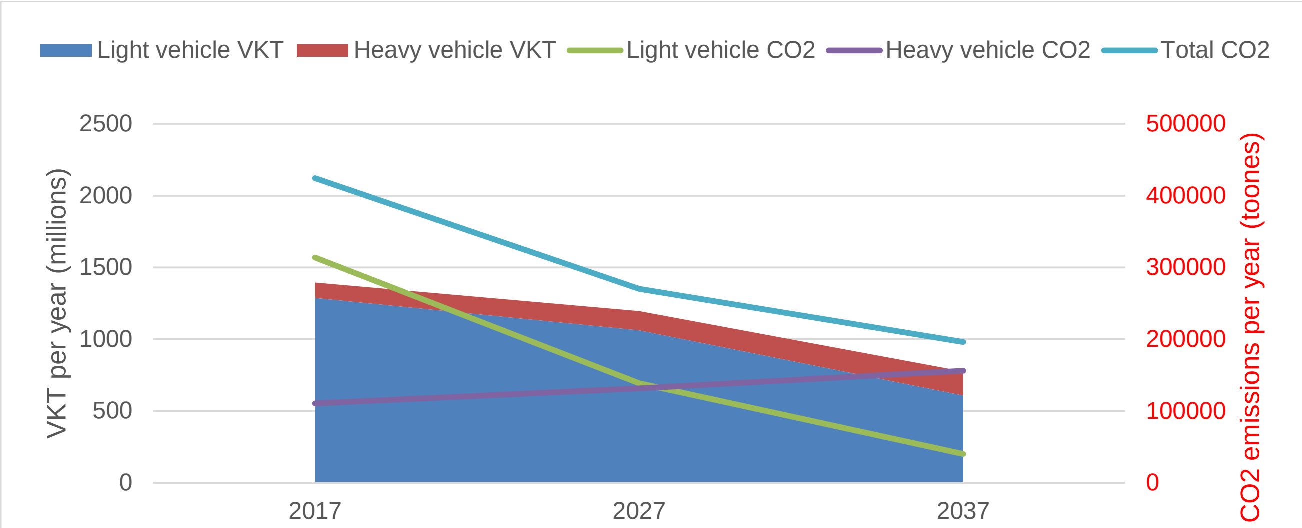

Figure 67 Strong Emissions Reductions scenario: total VKT and CO_2 emissions, by vehicle type

The *Strong Emissions Reduction* scenario projects a decrease of 53% in on-road transport GHG emissions, from 424,525 tonnes in 2017, to 270,078 tonnes in 2027 and 196,182 tonnes in 2037. Per capita, GHG emissions are projected to decrease from 460.3kg per year in 2017, to 233.2kg per year in 2027, and 139.9kg per year in 2037. **The *Strong Emissions Reduction* has a significant decrease in the per capita intensity of transport, indeed, the reduction is 49% by 2027, consistent with the 50% by 2030 required to meet Australia's per capita reductions in line with the Paris Climate Accord**.

The *Strong Emissions Reduction* scenario leads to significant GHG emission reductions from transport. Reductions are larger than either of the two other scenarios. Importantly, the *Strong Emissions Reduction* scenario also leads to a large *decrease* in VKT within the City of Melbourne. Decreased traffic flows through the City of Melbourne will allow more road space for active and public transport and improving the urban amenity. **To achieve the outcomes modelled in this scenario, substantial changes in road space allocation, towards more space and emissions efficiency modes will be required. The mode shift changes that are required in this scenario require a transformation in road space allocation, to provide the priority for walking, cycling and public transport to encourage a substantial increase in the use of these modes.** By implementing the changes to produce the transport and energy generation outcomes included in this scenario, the City of Melbourne's on-road transport emissions will be in line with the Paris Climate Accord.

7.5. Discussion

This modelling has shown that if current trends continue, traffic and emissions within the City of Melbourne will rise. A comparison of VKT and CO_2 emissions project under each scenario is shown in

Figure 68. It should be noted that, due to population growth, a mode shift in excess of population growth is required to cause a decrease in VKT and emissions.

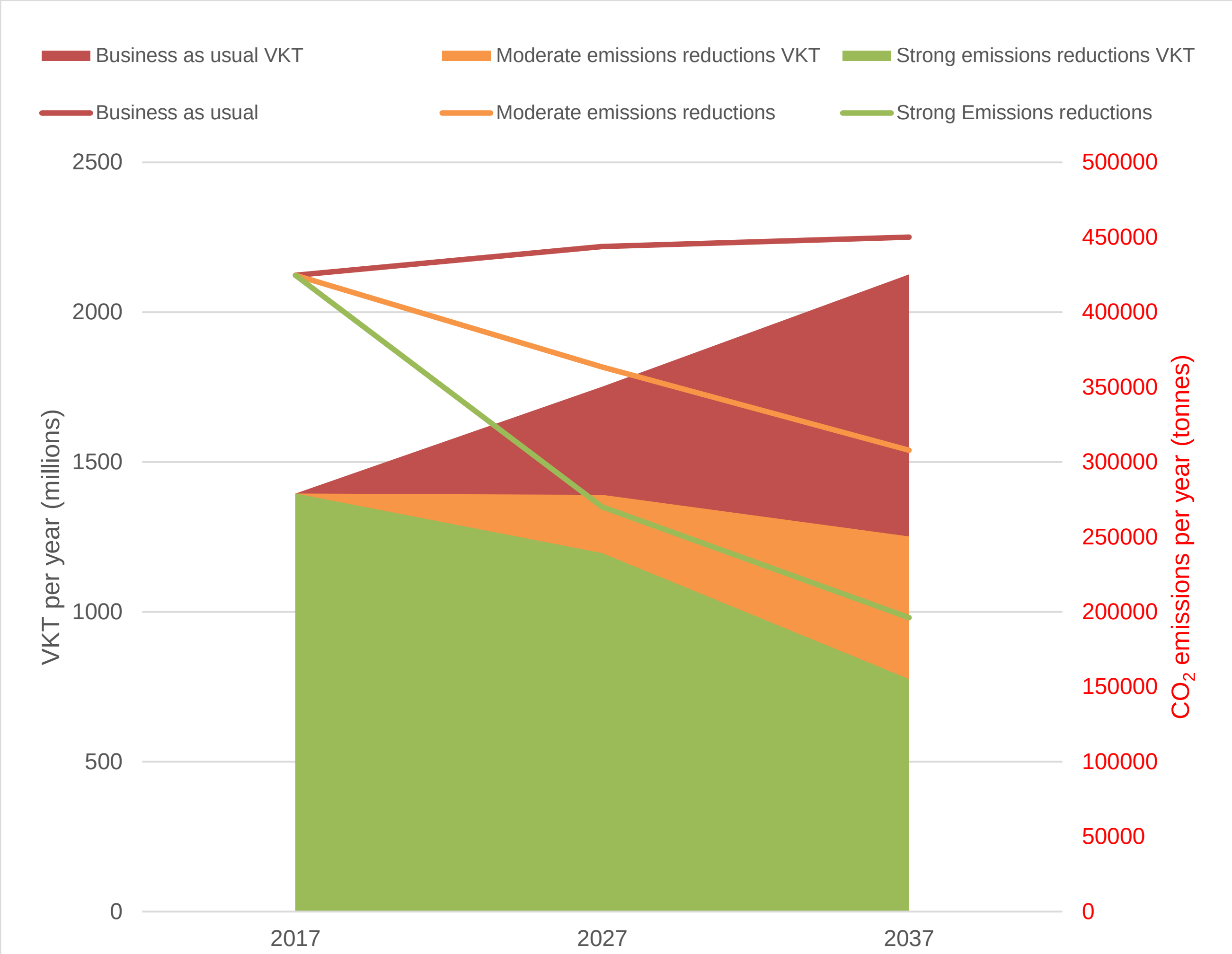

Figure 68 Comparison of VKT and CO_2 emissions projections

While electric vehicles appear to provide a promising way of reducing GHG emissions, the projected slow uptake of electric vehicles in Victoria, means that they are unlikely to create the types of changes required. This modelling has also assumed that in the moderate emissions reduction and strong emissions reduction scenarios that all electric vehicles are charged by renewable energy. Failure to ensure this will cause an increase in emissions. While electric vehicle uptake is low, the electricity system will be able to cope (AEMO forecast the average uptake scenario to increase energy consumption by approximately 4% by 2036), however, mass adoption of electric vehicles may create undesirable consequences, such as a shortfall of energy resources delaying the closure of carbon intensive power plants.

The per capita emissions and mode share of each scenario is graphically represented in Figure 69. **Only the strong emissions reduction scenario provide the per capita emissions drop necessary to meet the Paris Climate Accord target (50% per capita reduction by 2030).** The strong emission reduction gains are primarily from mode shift, and a highly dependent on a reallocation of road space which will constrain vehicle throughput in the City of Melbourne while simultaneously providing the space for alternative modes of travel. While the moderate emissions reduction scenario projects a minor decrease in VKT, other modes will not be able to increase sufficiently without a substantial re-allocation of road space.

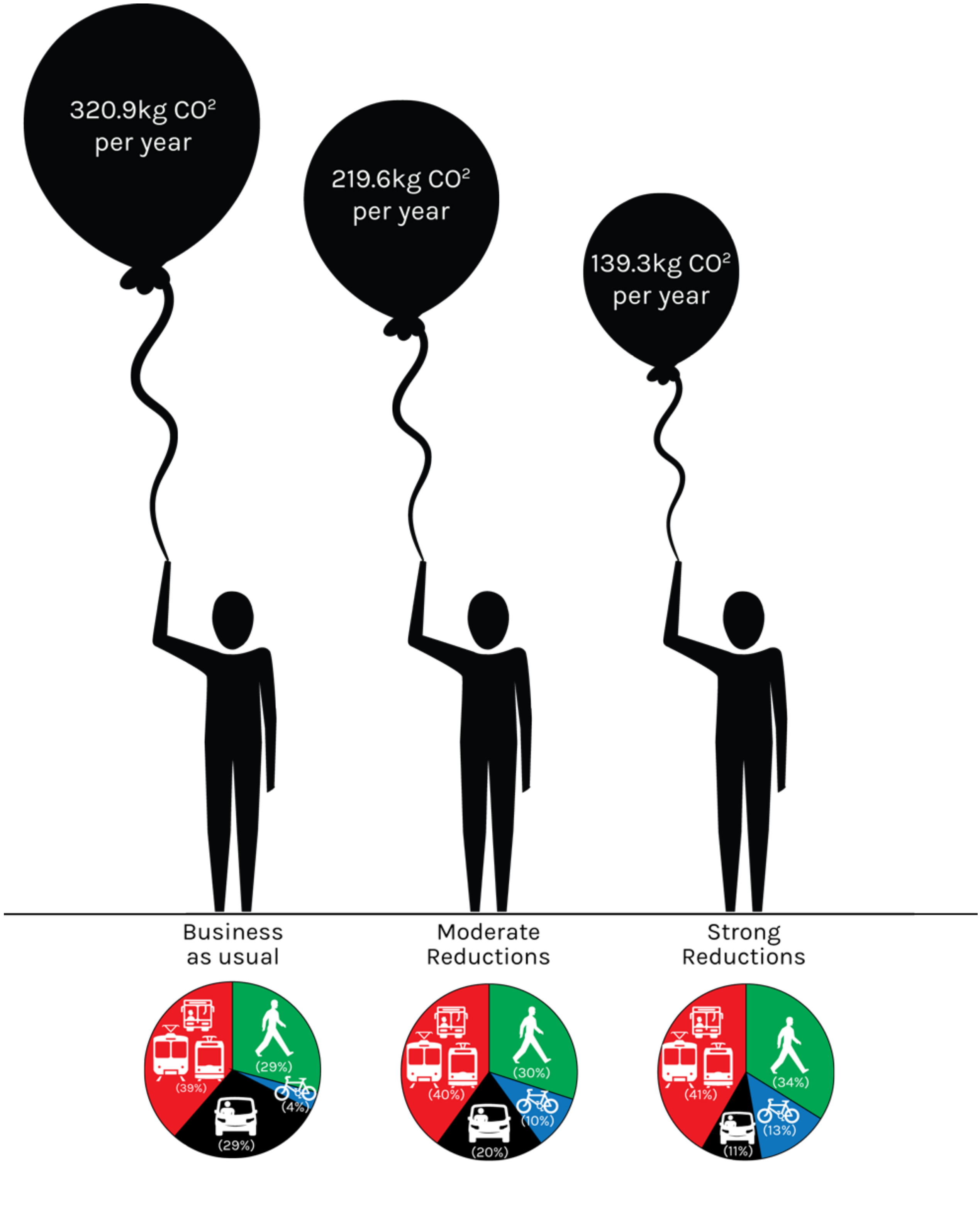

Figure 69 Comparison of projected per capita GHG emissions and transport mode share in 2037

8. References

Adams, J. (2004, 19th July). *Hypermobility: Further Thoughts Towards Carfree Cities Conference.* Paper presented at the Car Free Cities Conference, Berlin.

AJM Joint Venture. (2016). *Melbourne Metro Rail Project*. Retrieved from Melbourne: http://metrotunnel.vic.gov.au/__data/assets/pdf_file/0016/51091/MMRP-Technical-Appendix-V-Greenhouse-Gas.pdf

Aluvihare, R., Brommelstroet, M., & van der Horst, I. (2014). *Plan Amsterdam*. Retrieved from Amsterdam: http://urbantransform.eu/wp-content/uploads/sites/2/2014/09/PlanAmsterdam-Cycling-policy-and-design-PDF-2MB.pdf

Amsterdam City Council. (2017a). Bicycle projects: smoother through the city. Retrieved from https://www.amsterdam.nl/parkeren-verkeer/fiets/fietsprojecten/ - hf282f1a1-7487-7074-9285-195720e18266

Amsterdam City Council. (2017b). Environment. Retrieved from https://www.amsterdam.nl/parkeren-verkeer/milieuzone/

Amsterdam City Council. (2017c). Four new public fast chargers open. Retrieved from https://www.amsterdam.nl/parkeren-verkeer/luchtkwaliteit/nieuws/4-nieuwe-snelladers/

Amsterdam City Council. (2017d). General information on electric transport. Retrieved from https://www.iamsterdam.com/en/our-network/media-centre/city-hall/dossier-electric-transport/electric-transport-general-information

Ang, B. W., & Su, B. (2016). Carbon emission intensity in electricity production: A global analysis. *Energy Policy, 94*, 56-63.

Australian Bureau of Statistics. (2017a). Census 2016. from Australian Government http://www.abs.gov.au/websitedbs/censushome.nsf/home/2016

Australian Bureau of Statistics. (2017b). Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2017. from Australian Government http://www.abs.gov.au/ausstats/abs@.nsf/mf/9208.0

Australian Energy Market Operator. (2016a). *Electric vehicles*. Retrieved from http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEFR/2016/AEMO-insights_EV_24-Aug.pdf

Australian Energy Market Operator. (2016b). *National Electricity Forecasting Report*. Retrieved from http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEFR/2016/2016-National-Electricity-Forecasting-Report-NEFR.pdf

Barclays. (2015). *Disruptive Mobility*. Retrieved from Barclays: http://www.investmentbank.barclays.com/our-insights/disruptive-mobility.html

Bauman, A. E., Rissel, C., Garrard, J., Ker, I., Speidel, R., & Fishman, E. (2008). *Cycling: Getting Australia Moving: Barriers, facilitators and interventions to get more Australians physically active through cycling*. Retrieved from

Bratzel, S. (1999). Conditions of success in sustainable urban transport policyPolicy change in 'relatively successful' European cities. *TRANSPORT REVIEWS, 19*(2).

Carey, A. (2014). geing train system leads to soaring power costs. Retrieved from http://www.theage.com.au/victoria/ageing-train-system-leads-to-soaring-power-costs-20140112-30oov.html

Carse, A., Goodman, A., Mackett, R. L., Panter, J., & Ogilvie, D. (2013). The factors influencing car use in a cycle-friendly city: the case of Cambridge. *Journal of Transport Geography, 28*(0), 67-74. doi:http://dx.doi.org/10.1016/j.jtrangeo.2012.10.013

City and County of San Francisco. (2013). *San Francisco Climate Action Strategy*. San Francisco: City and County of San Francisco Retrieved from https://sfenvironment.org/sites/default/files/engagement_files/sfe_cc_ClimateActionStrategyUpdate2013.pdf.

City of Amsterdam. (2015). *Uitvoeringsagenda Mobiliteit*. Retrieved from Amsterdam:

City of Amsterdam. (2017). Cycling Matters: How Bicycles Power Amsterdam. In C. o. Amsterdam (Ed.). Amsterdam.

City of Melbourne. (2006). *Melbourne Planning Scheme: Lygon and Elgin Street Shopping Centre*. Melbourne Retrieved from http://planningschemes.dpcd.vic.gov.au/schemes/melbourne/ordinance/22_lpp15_melb.pdf.

City of Melbourne. (2008). *CBD and Docklands Parking Plan 2008 - 2013*. Melbourne: City of Melbourne Retrieved from http://www.melbourne.vic.gov.au/SiteCollectionDocuments/cbd-docklands-parking-plan-2008-2013.pdf.

City of Melbourne. (2012a). *Transport Strategy 2012*. Melbourne: City of Melbourne Retrieved from https://www.melbourne.vic.gov.au/AboutCouncil/PlansandPublications/strategies/Pages/transportstrategy.aspx.

City of Melbourne. (2012b). *Urban Forest Strategy: Making a great city greener 2012 - 2032*. Melbourne: City of Melbourne Retrieved from http://www.melbourne.vic.gov.au/SiteCollectionDocuments/urban-forest-strategy.pdf.
City of Melbourne. (2014a). *Walking Plan 2014-17*. Retrieved from Melbourne:
City of Melbourne. (2014b). *Zero Net Emissions by 2020: Update 2014*. Retrieved from Melbourne: http://www.melbourne.vic.gov.au/SiteCollectionDocuments/zero-net-emissions-update-2014.pdf
City of Melbourne. (2015a). *Proposed Urban Renewal Areas: Municipal Strategic Statement Clause 21.14*. Melbourne Retrieved from http://planningschemes.dpcd.vic.gov.au/schemes/melbourne/ordinance/21_mss14_melb.pdf.
City of Melbourne. (2015b). *Report to the Future Melbourne (Transport) Committee: Car Share Services Review*. Retrieved from Melbourne: http://www.melbourne.vic.gov.au/AboutCouncil/Meetings/Lists/CouncilMeetingAgendaItems/Attachments/12533/JUL15 FMC2 AGENDA ITEM 6.7.pdf
City of Melbourne. (2016a). *Bicycle Plan 2016 - 2020*. Melbourne: City fo Melbourne Retrieved from http://www.melbourne.vic.gov.au/SiteCollectionDocuments/city-of-melbourne-bicycle-plan-2016-2020.pdf.
City of Melbourne. (2016b). *Last Kilometre Freight Plan*. Retrieved from Melbourne: http://www.melbourne.vic.gov.au/sitecollectiondocuments/last-kilometre-freight-plan-june-2016.pdf
City of Melbourne. (2016c). *Urban Renewal Areas: Municipal Strategic Statement Clause 21.13*. Melbourne: Melbourne Planning Scheme Retrieved from http://planningschemes.dpcd.vic.gov.au/schemes/melbourne/ordinance/21_mss13_melb.pdf.
City of Melbourne. (2017a). *Council Plan 2017 - 2021*. Melbourne: City of Melbourne Retrieved from http://www.melbourne.vic.gov.au/sitecollectiondocuments/council-plan-2017-21.pdf.
City of Melbourne. (2017b). *Daily Population Estimates and Forecasts*. Retrieved from Melbourne: http://www.melbourne.vic.gov.au/SiteCollectionDocuments/daily-population-estimates-and-forecasts-report-2017.pdf
City of Melbourne. (2017c). Parking locations and fees. Retrieved from http://www.melbourne.vic.gov.au/parking-and-transport/parking/parking-locations-fees/Pages/parking-locations-and-fees.aspx
City of Melbourne. (2017d). Resident parking permits: Carlton, North and West Melbourne. Retrieved from http://www.melbourne.vic.gov.au/parking-and-transport/parking/parking-permits/residential-parking-permits/pages/resident-parking-permits-carlton-and-north-and-west-melbourne.aspx
ClimateWorks Australia. (2017). *The state of electric vehicles in Australia*. Retrieved from Melbourne: https://climateworks.com.au/sites/default/files/documents/publications/state_of_evs_final.pdf
CROW. (2017). *Design manual for bicycle traffic*. Utrecht: CROW.
Currie, G., Stanley, J., & Stanley, J. (2007). *No way to go: transport and social disadvantage in Australian communities* Melbourne: Monash University ePress.
Davison, G. (2004). *Car wars: How the car won our hearts and conquered our cities*: Allen and Unwin.
Deegan, B. (2018). *Light Segregation*. Retrieved from Paris:
Department of Environment amd Energy. (2015). Australia's 2030 climate change target. Retrieved from http://www.environment.gov.au/climate-change/publications/factsheet-australias-2030-climate-change-target
Department of Infrastructure and Regional Development. (2016). *Australian Infrastructure Statistics - Yearbook 2016*. Retrieved from Canberra: https://bitre.gov.au/publications/2016/yearbook_2016.aspx
Department of Infrastructure and Regional Development. (2017). Vehicle Emission Standards. Retrieved from https://infrastructure.gov.au/roads/environment/emission/index.aspx
Department of the Environment. (2015). *National Greenhouse Accounts Factors*. Canberra: Australian Government Retrieved from https://www.environment.gov.au/system/files/resources/3ef30d52-d447-4911-b85c-1ad53e55dc39/files/national-greenhouse-accounts-factors-august-2015.pdf.
Department of the Environment and Energy. (2017). *Australia's emissions projections*. Canberra: Australian Government Retrieved from http://www.environment.gov.au/system/files/resources/eb62f30f-3e0f-4bfa-bb7a-c87818160fcf/files/australia-emissions-projections-2017.pdf.
Department of Transportation. (2017). *San Francisco County Economic Forecast*. Retrieved from San Francisco: http://www.dot.ca.gov/hq/tpp/offices/eab/socio_economic_files/2017/SanFrancisco.pdf
Dora, C., & Phillips, M. A. (2000). *Transport, environment, and health* (9289013567, 9789289013567). Retrieved from Copenhagen: http://libcat.library.qut.edu.au/record=b2999557&searchscope=8
Energeia. (2016). *Shifting Gears: The Australian Electric Vehicle Market to 2030*. Retrieved from http://energeia.com.au/wp-content/uploads/2014/02/Shifting-Gears-The-Australian-Electric-Vehicle-Market-to-2030.pdf
Energy Safe Victoria. (2014). *VEC Resource Manual*. Retrieved from http://www.esv.vic.gov.au/wp-content/uploads/2016/12/VEC_Resource_Manual-July2014-1.pdf

Enoch, M. P. (2015). How a rapid modal convergence into a universal automated taxi service could be the future for local passenger transport. *Technology Analysis & Strategic Management, 27*(8), 910-924. doi:10.1080/09537325.2015.1024646

Environment Protection Authority. (2016). Air legilsation. Retrieved from http://www.epa.vic.gov.au/about-us/legislation/air-legislation

EY. (2017). *Modelling of the Victorian renewable energy target scheme scenarios*. Retrieved from Melbourne: https://www.energy.vic.gov.au/__data/assets/pdf_file/0021/83091/EY-modelling-report-VRET.pdf

Fagnant, D. J., Kockelman, K., & Bansal, P. (2015). Operations of a shared autonomous vehicle fleet for the Austin, Texas Market. *Transportation Research Record: Journal of the Transportation Research Board*, 98–106.

Fishman, E. (2016). *Emerging transport technologies: Assessing impacts and implications for the City of Melbourne*. Retrieved from Melbourne: http://sensibletransport.org.au/project/test-project-1/

Fishman, E., & Cherry, C. (2015). E-bikes in the Mainstream: Reviewing a Decade of Research. *TRANSPORT REVIEWS*, 1-20. doi:10.1080/01441647.2015.1069907

Fishman, E., Washington, S., & Haworth, N. (2014). Bike Share's Impact on Car Use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport & Environment, 31*, 7. doi:10.1016/j.trd.2014.05.013

Gardner, D. (2017). How many EVs are Australians really buying? Retrieved from https://www.wheelsmag.com.au/news/1707/how-many-evs-are-australians-really-buying

Garrard, J. (2003). Healthy revolutions: promoting cycling among women. *Health Promotion Journal of Australia: Official Journal of Australian Association of Health Promotion Professionals, 14*(3), 213-215.

Garrard, J. (2009). *Active transport: Adults: An overview of recent evidence*. Retrieved from Melbourne:

Garrard, J. (2011). *Make it feel safe and they will come: addressing the actual and perceived risks of cycling*. Paper presented at the Asia Pacific Cycle Congress., Brisbane. . http://www.scribd.com/fullscreen/80977058?access_key=key-22zzmxaqdhn59lglz9u2

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., . . . Owen, N. (2016). City planning and population health: a global challenge. *The Lancet*. doi:10.1016/S0140-6736(16)30066-6

Glaser, M. (2017). What happens if you turn off the traffic lights? *The Guardian*. Retrieved from https://www.theguardian.com/environment/bike-blog/2017/sep/22/what-happens-if-you-turn-off-the-traffic-lights

Goenka, S., & Andersen, L. B. (2016). Urban design and transport to promote healthy lives. *The Lancet*. doi:10.1016/S0140-6736(16)31580-X

Götschi, T., Garrard, J., & Giles-Corti, B. (2015). Cycling as a Part of Daily Life: A Review of Health Perspectives. *TRANSPORT REVIEWS*, 1-27. doi:10.1080/01441647.2015.1057877

Government of South Australia. (2016). Driverless Vehicles [Press release]. Retrieved from http://dpti.sa.gov.au/driverlessvehicles

Government of the Netherlands. (2018). Dutch vision on global climate action. Retrieved from https://www.government.nl/topics/climate-change/dutch-vision-on-global-climate-action

GreenVehicleGuide. (2017). GreenVehicleGuide. from Australian Government https://www.greenvehicleguide.gov.au/

Hackney Council. (2015). *Hackney Transport Strategy 2015 - 2025*. London: Hackney Council Retrieved from https://www.hackney.gov.uk/media/7004/Hackney-transport-strategy-2015-2025/pdf/Transport-Strategy-2015-25.

Hackney Council. (2016a). School travel plans. Retrieved from https://www.hackney.gov.uk/stp

Hackney Council. (2016b). Travel plans for new developments. Retrieved from https://www.hackney.gov.uk/travel-plan-for-new-developments

Hackney Council. (2017). Our commitment to electric vehicles. Retrieved from https://www.hackney.gov.uk/our-commitment-to-electronic-vehicles

Hasham, N. (2018). Chief scientist Alan Finkel hits back at electric car doubters. *The Age*. Retrieved from http://www.smh.com.au/federal-politics/political-news/chief-scientist-alan-finkel-hits-back-at-electric-car-doubters-20180209-p4yzu8.html

Heinen, E., Maat, K., & van Wee, B. (2011). Day-to-Day Choice to Commute or Not by Bicycle. *Transportation Research Record*(2230), 9-18. doi:10.3141/2230-02

Infrastructure Victoria. (2016). *The Road Ahead: How an efficient, fair and sustainable pricing regime can help tackle congestion*. Retrieved from Melbourne: http://www.infrastructurevictoria.com.au/sites/default/files/images/The road ahead final web.pdf

Infrastructure Victoria. (2017). Providing advice on autmated and zero emission vehicle infrastructure [Press release]. Retrieved from http://www.infrastructurevictoria.com.au/node/104

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from Geneva:

Li, H., Graham, D. J., & Liu, P. (2017). Safety effects of the London cycle superhighways on cycle collisions. *Accident Analysis & Prevention, 99*, 90-101. doi:https://doi.org/10.1016/j.aap.2016.11.016
Litjens, P. (2017) *Interview on transport poilicy in Amsterdam with the Alderman responsible for transport/Interviewer: E. Fishman*. Institute for Sensible Transport for the City of Melbourne, Melbourne.
Litman, T. (2015). Congestion Reduction Strategies: Identifying and Evaluating Strategies to Reduce Traffic Congestion. from Victoria Transport Policy Institute http://www.vtpi.org/tdm/tdm96.htm
Litman, T. (2016). Automobile Dependency. Retrieved from http://www.vtpi.org/tdm/tdm100.htm
MacIntyre, E. A., Gehring, U., Molter, A., Fuertes, E., Klumper, C., Kramer, U., . . . Heinrich, J. (2014). Air pollution and respiratory infections during early childhood: an analysis of 10 European birth cohorts within the ESCAPE Project. *Environ Health Perspect, 122*(1), 107-113. doi:10.1289/ehp.1306755
Mayor of London. (2016). Mayor takes step forward in plan to power Tube with clean electricity. Retrieved from https://www.london.gov.uk/press-releases/mayoral/mayor-plans-to-power-tube-with-clean-electricity
Mayor of London. (2017). *Mayor's Transport Strategy: Draft for public consultation*. London: Mayor of London Retrieved from https://consultations.tfl.gov.uk/policy/mayors-transport-strategy/user_uploads/pub16_001_mts_online-2.pdf.
Mees, P. (2010). *Transport for suburbia: beyond the automobile age*: Earthscan.
Mees, P., & Groenhart, L. (2012). *Transport Policy at the Crossroads: Travel to work in Australian capital cities 1976 - 2011*. Retrieved from Melbourne:
Melbourne Metro Rail Authority. (2016). *Greenhouse Gas Impact Assessment*. Retrieved from Melbourne: http://metrotunnel.vic.gov.au/__data/assets/pdf_file/0016/51091/MMRP-Technical-Appendix-V-Greenhouse-Gas.pdf
Mingardo, G. (2016). *Articles on Parking Policy.* Technische Universiteit Delft, Netherlands. Retrieved from http://www.verkeerskunde.nl/Uploads/2016/11/ProefschriftGiulianoMingardo.pdf
Minister for Energy Environment and Climate Change. (2017). Solar Trams Transporting Victoria To A Brighter Future [Press release]. Retrieved from https://www.premier.vic.gov.au/solar-trams-transporting-victoria-to-a-brighter-future/
Monash University. (2015). *Research on the safety implications of taxi and hire car age limits*. Retrieved from Clayton: http://taxi.vic.gov.au/__data/assets/pdf_file/0014/36212/MUARC-Report-Research-on-the-safety-implications-of-taxi-and-hire-car-age-limits.pdf
Moore, R. (2016). Superhighway to cycling heaven – or just a hell of a mess? Retrieved from https://www.theguardian.com/lifeandstyle/2016/aug/07/london-cycle-superhighways-heaven-or-hell
Mortimore, A. (2015). Australia's weaker emissions standards allow car makers to 'dump' polluting cars. Retrieved from http://theconversation.com/australias-weaker-emissions-standards-allow-car-makers-to-dump-polluting-cars-48172
Morton, A. B. (2007). *Observational Analysis of Tram Delays in Inner Melbourne.* Paper presented at the 30th Australasian Transport Research Forum, Melbourne.
Newman, P., & Kenworthy, J. (1999). *Sustainability and Cities: Overcoming Automobile Dependence*. Washington, D.C.: Island Press.
Office of the Chief Investigator. (2009). *Overrun of Connex Train Cranbourne*. Retrieved from https://economicdevelopment.vic.gov.au/__data/assets/word_doc/0006/1326489/2009-01-09-Train-Overrun-Cranbourne.docx
Owen, D. (2012). *The Conundrum: How Scientific Innovation, Increased Efficiency, and Good Intentions Can Make Our Energy and Climate Problems Worse*: Riverhead Books.
Perch, J. (2016). How Bicycles Became the Primary Mode of Transport in the Dutch City of Groningen. Retrieved from https://greenerideal.com/news/0106-bicycles-primary-transport-groningen/
Pojani, D., & Stead, D. (2015). Going Dutch? The export of sustainable land-use and transport planning concepts from the Netherlands. *Urban Studies, 52*(9).
Productivity Commission. (2017). *Shifting the Dial: 5 Year productivity review: Chapter 4: Better functioning towns and cities*. Retrieved from Melbourne: http://www.pc.gov.au/inquiries/completed/productivity-review/report/4-towns-cities
Public Transport Victoria. (2017). Passenger load surveys. Retrieved from https://www.ptv.vic.gov.au/about-ptv/ptv-data-and-reports/passenger-load-surveys/
Pucher, J., Greaves, S., & Garrard, J. (2010). Cycling down under: a comparative analysis of bicycling trends and policies in Sydney and Melbourne. *Journal of Transport Geography, 19*(2), 332-345.
Rayle, L., Dai, D., Chan, N., Cervero, R., & Shaheen, S. (2016). Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. *Transport Policy, 45*, 168-178. doi:http://dx.doi.org/10.1016/j.tranpol.2015.10.004
Rissel, C., Merom, D., Bauman, A., Garrard, J., Wen, L. M., & New, C. (2010). Current cycling, bicycle path use, and willingness to cycle more-findings from a community survey of cycling in southwest sydney, australia. *Journal of physical activity & health, 7*(2), 267-272.

Rojas-Rueda, D., de Nazelle, A., Tainio, M., & Nieuwenhuijsen, M. J. (2011). The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *British Medical Journal*.
Roy Morgan Research. (2017). Uber soars and well-placed to tackle rising competition [Press release]. Retrieved from http://www.roymorgan.com/findings/7444-uber-growth-last-two-years-2015-2017-september-2017-201712150309
Sakshaug, L., Laureshyn, A., Svensson, Å., & Hydén, C. (2010). Cyclists in roundabouts--Different design solutions. *Accident Analysis & Prevention, 42*(4), 1338-1351. doi:10.1016/j.aap.2010.02.015
Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. *The Lancet*. doi:10.1016/S0140-6736(16)30068-X
San Francisco Chronicle. (2011). San Francisco's Cesar Chavez Street gets makeover. Retrieved from http://www.sfgate.com/bayarea/article/San-Francisco-s-Cesar-Chavez-Street-gets-makeover-2462327.php - photo-2024731
Schepers, P., Twisk, D., Fishman, E., Fyhri, A., & Jensen, A. (2015). The Dutch road to a high level of cycling safety. *Safety Science*.
Schmitt, L., Currie, G., & Delbosc, A. (2015). Lost in transit? Unfamiliar public transport travel explored using a journey planner web survey. *Transportation, 42*(1), 101-122. doi:10.1007/s11116-014-9529-2
Sener, I. N., Eluru, N., & Bhat, C. R. (2009). An analysis of bicycle route choice preferences in Texas, US. *Transportation, 36*(5), 511-539. doi:10.1007/s11116-009-9201-4
SFMTA. (2017). *San Francisco Transportation Sector Climate Action Strategy*. San Francisco Retrieved from https://www.sfmta.com/sites/default/files/reports-and-documents/2017/12/cap_draft_full_document-final1.pdf.
Sift Research. (2017). *City of Melbourne – Analysis of the Victorian Integrated Survey of Travel and Activity*. Sift Research.
Sims, R., Schaeffer, R., Creutzig, F., Cruz-Núñez, X., D'Agosto, M., Dimitriu, D., . . . Tiwari, G. (2014). *Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from
Smart Growth America. (2015). Change in Plans. Retrieved from https://smartgrowthamerica.org/change-in-plans/
Smith, S. (2015). Cesar Chavez Street. Retrieved from https://critical-sustainabilities.ucsc.edu/cesar-chavez-streetscape/
Startrack. (2017). Inside Australian Online Shopping 2017. Retrieved from https://acquire.startrack.com.au/pdf/Inside Australian Online Shopping 2017.pdf
Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., . . . Woodcock, J. (2016). Land use, transport, and population health: estimating the health benefits of compact cities. *The Lancet*. doi:10.1016/S0140-6736(16)30067-8
Taylor, M. (2008). City's two-wheel transformation. *The Guardian*. Retrieved from https://www.theguardian.com/uk/2008/feb/09/transport.world1
TechCrunch. (2018). Jump will be the first stationless, e-bike-sharing service to launch in SF. Retrieved from https://techcrunch.com/2018/01/09/jump-will-be-the-first-stationless-e-bike-sharing-startup-to-launch-in-sf/?ncid=rss
Teschke, K., Harris, M. A., Reynolds, C. C. O., Winters, M., Babul, S., Chipman, M., . . . Cripton, P. A. (2012). Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study. *American Journal of Public Health, 102*(12), 2336-2343. doi:10.2105/AJPH.2012.300762
Tesla. (2017). Tesla Semi. Retrieved from https://www.tesla.com/semi?redirect=no
Transport for London. (2007). *Central London Congeston Charging*. Retrieved from London: http://content.tfl.gov.uk/fifth-annual-impacts-monitoring-report-2007-07-07.pdf
Transport for London. (2016). *Update on the implementation of the Quietways and Cycle Superhighways programmes*. Retrieved from London: http://content.tfl.gov.uk/pic-161130-07-cycle-quietways.pdf
Transport for London. (2017a). *Cycle Superhighways*. Retrieved from London: https://tfl.gov.uk/modes/cycling/routes-and-maps/cycle-superhighways
Transport for London. (2017b). Discounts & exemptions. Retrieved from https://tfl.gov.uk/modes/driving/congestion-charge/discounts-and-exemptions
Transport for London. (N.D.-a). *Congestion Charge Fact Sheet*. London: Transport for London Retrieved from http://content.tfl.gov.uk/congestion-charge-factsheet.pdf.
Transport for London. (N.D.-b). Mini-Hollands. Retrieved from https://tfl.gov.uk/travel-information/improvements-and-projects/cycle-mini-hollands
Turner, D. (2004). *Implementing the London Congestion Charge*. Paper presented at the Towards Car Free Cities, Berlin.
Uber. (2018). Melbourne vehicle requirements. Retrieved from https://www.uber.com/en-AU/drive/melbourne/vehicle-requirements/

United Nations. (2013). *Review of Developments in Transport in Asia and the Pacific*. Retrieved from http://www.unescap.org/sites/default/files/TransportReview_2013_full_text.pdf
United Nations. (2015). The Paris Agreement. Retrieved from http://unfccc.int/paris_agreement/items/9485.php
van Damme, E. (2017) *Interview on Red Carpet project/Interviewer: E. Fishman*. Institute for Sensible Transport for the City of Melbourne, Melbourne.
VicRoads. (2015). *Supplement to AS 1742.12:2000 Manual of uniform traffic control devices: Part 12 Bus, transit, tram and truck lanes*. Melbourne: VicRoads Retrieved from https://www.vicroads.vic.gov.au/~/media/files/technical-documents-new/traffic-engineering-manual-v2/tem-vol-2-part-212--as174212-bus-transit-tram-and-truck-lanes.pdf.
VicRoads. (2016). *Bicycle Volumes - VicRoads*. Retrieved from: https://www.data.vic.gov.au/data/dataset/bicycle-volumes-vicroads
VicRoads. (2017). *Crash Stats*. Retrieved from: https://www.data.vic.gov.au/data/dataset/crashes-last-five-years
Victorian Government. (2010). *Transport Integration Act*. Melbourne: Victorian Government Retrieved from http://economicdevelopment.vic.gov.au/transport/legislation/transport-integration-act.
Whiteman, J. (2015). *Transport system impacts of autonomous vehicles*. Paper presented at the Workshop on Smart Mobility: Mapping the value beyond the hype, Melbourne.
Winters, M., Davidson, G., Kao, D., & Teschke, K. (2011). Motivators and deterrents of bicycling: comparing influences on decisions to ride. *Transportation, 38*(1), 153-168. doi:10.1007/s11116-010-9284-y
Winters, M., & Teschke, K. (2010). Route preferences among adults in the near market for bicycling: findings of the cycling in cities study. *Am J Health Promot, 25*(1), 40-47.
Winters, M., Teschke, K., Brauer, M., & Fuller, D. (2016). Bike Score®: Associations between urban bikeability and cycling behavior in 24 cities. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1). doi:10.1186/s12966-016-0339-0
Winters, M., Teschke, K., Brauer, M., Grant, M., & Setton, E. (2010). How Far Out of the Way Will We Travel? *Transportation Research Record: Journal of the Transportation Research Board, 2190*(-1), 1-10. doi:10.3141/2190-01
World Resources Institute. (2014). *Greenhouse Gas Protocol*. Retrieved from http://www.ghgprotocol.org/
Yarra Trams. (2011). Tram priority trial makes news [Press release]. Retrieved from http://www.yarratrams.com.au/media-centre/news/articles/2011/tram-priority-trial-makes-news/
Yarra Trams. (2017). Route 55 - Network upgrade work - Saturday 23 to Friday 29 May. Retrieved from http://www.yarratrams.com.au/using-trams/service-changes/service-changes/2015/route-55-network-upgrade-work-saturday-23-to-friday-29-may/
Zhang, L., & Garoni, T. (2013). *A Comparison of Tram Priority at Signalized Intersections*. Retrieved from https://arxiv.org/abs/1311.3590

9. Appendix 1 – Summary of Actions

The table on the following page provides an indication of the relative impact of each of the recommendations contained in this report. Each recommendation has been rated according to six indicators that broadly align with the strategic objectives of the City of Melbourne with a rating of 1 – 3 applied (3 = strong impact).

		GHG emission reduction	Air quality improvement	Congestion reduction	Supports economy	Vibrancy	Safety	**Total**
Strategic reallocation of road space	Footpath widening	3	3	3	3	3	3	**18**
	Expanding and enhancing the cycling network	3	3	3	3	3	3	**18**
	Public transport priority lanes	3	3	3	3	3	2	**17**
	Public space	3	3	2	3	3	3	**17**
	Complete streets	3	3	3	3	3	3	**18**
	Red Carpet	3	3	3	3	3	3	**18**
	Removing the attractiveness of the CBD for through traffic	2	2	1	3	3	3	**14**
Intersection priority for sustainable modes	Pedestrians	3	3	3	3	2	3	**17**
	Cyclists	3	3	3	3	2	3	**17**
	Trams	3	3	3	3	2	2	**16**
	Buses	3	3	3	3	2	2	**16**
Changing the way we pay for motor vehicle use	Parking pricing structures	2	2	3	3	3	2	**15**
	Road usage pricing	2	2	3	3	3	2	**15**
Lowering the emissions intensity of motor vehicles	Greening the grid	3	3	na	na	na	na	**6**
	Passenger cars	3	3	1	2	1	1	**11**
	Land freight	2	2	1	3	1	1	**10**
	Maritime	1	1	na	na	na	na	**2**
	Aviation	1	1	na	na	na	na	**2**
Optimising public transport	Greening public transport	3	3	1	1	1	1	**10**
	Increasing the coverage of public transport	2	2	3	3	2	3	**15**
Land use changes to encourage sustainable mobility	TOD/Urban redevelopment	3	3	2	3	3	2	**16**
	Parking controls	3	3	2	1	2	1	**12**
	Public EV charging facilities	3	3	1	2	1	1	**11**
	Car share	3	3	2	2	1	1	**12**
	Green Travel Plans	3	3	3	2	3	2	**16**
	Increased pedestrian permeability	3	3	3	2	3	3	**17**