IMAP Bicycle Network Model

Final Report - January 2020

Institute for Sensible Transport

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Glossary

ABS – Australian Bureau of Statistics

BIKE BOULEVARDS – Low motor vehicle volume streets with low speed limits.

CKT – Cycling Kilometres Travelled

DoT – Department of Transport (Victoria)

FUTURE PROPOSED NETWORK – Existing and proposed high quality parts of the bike network. High quality includes separated on road lanes, shared paths and bike boulevards.

FUTURE NEW NETWORK – Parts of the future proposed network that are yet to be built.

IMAP – Inner Melbourne Action Plan

SA1 – Statistical Area Level 1 (ABS)

SA2 – Statistical Area Level 2 (ABS)

STRAVA – An activity tracking App popular with bike riders, especially those interested in fitness/competitive cycling

VISTA – Victorian Integrated Survey of Travel and Activity

Executive Summary

Melbourne is experiencing rapid population growth, having recently surpassed 5 million inhabitants, and is on track to reach a population of 8 million by 2051. This growth brings enormous opportunities for Melbourne to cement its place as a global city. It also presents substantial challenges, such as increasing congestion and car use, urban sprawl, and climate change. A fundamental step-change is required to transform the way people travel throughout Melbourne, towards more sustainable and efficient modes of transport. This project has developed a model to estimate the uplift in bike riding if the full proposed bicycle network from Inner Melbourne Action Plan (IMAP) Councils and the *Strategic Cycling Corridors* was constructed. The safety impact of this proposed cycling network has also been modelled, enabling comparison of crash likelihood between the existing street design, and that under the proposed bicycle infrastructure network.

The five inner-city municipalities that comprise the IMAP are the City of Melbourne, City of Stonnington, City of Port Phillip, City of Yarra and Maribyrnong City Council. Figure 1 provides an illustration of the future bike network.

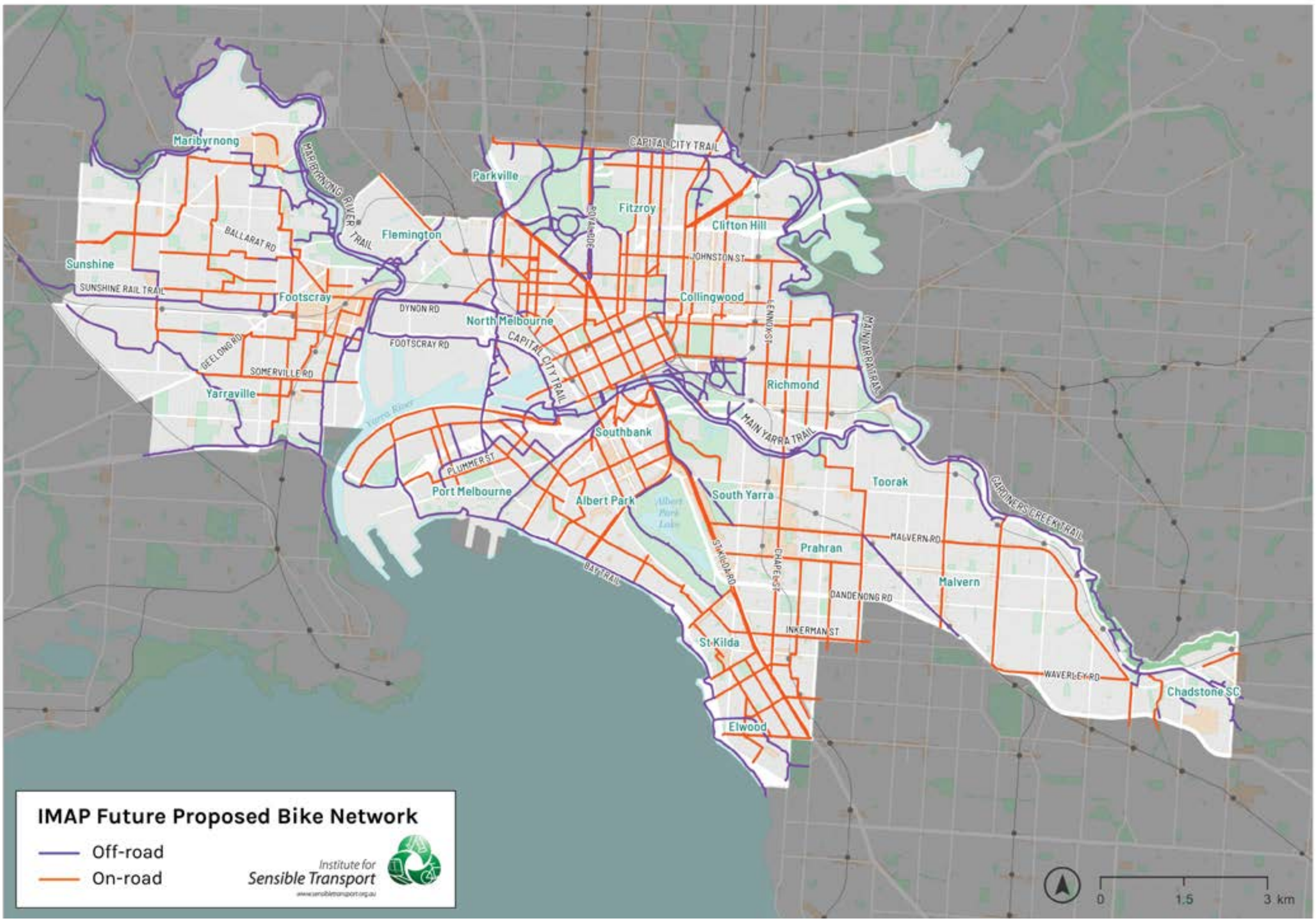

Figure 1 IMAP Future Bike Network

Figure 2 identifies the model's estimated daily bike riding in 2031 under the full build of the proposed bike network. This activity is estimated to occur only if the above network is implemented.

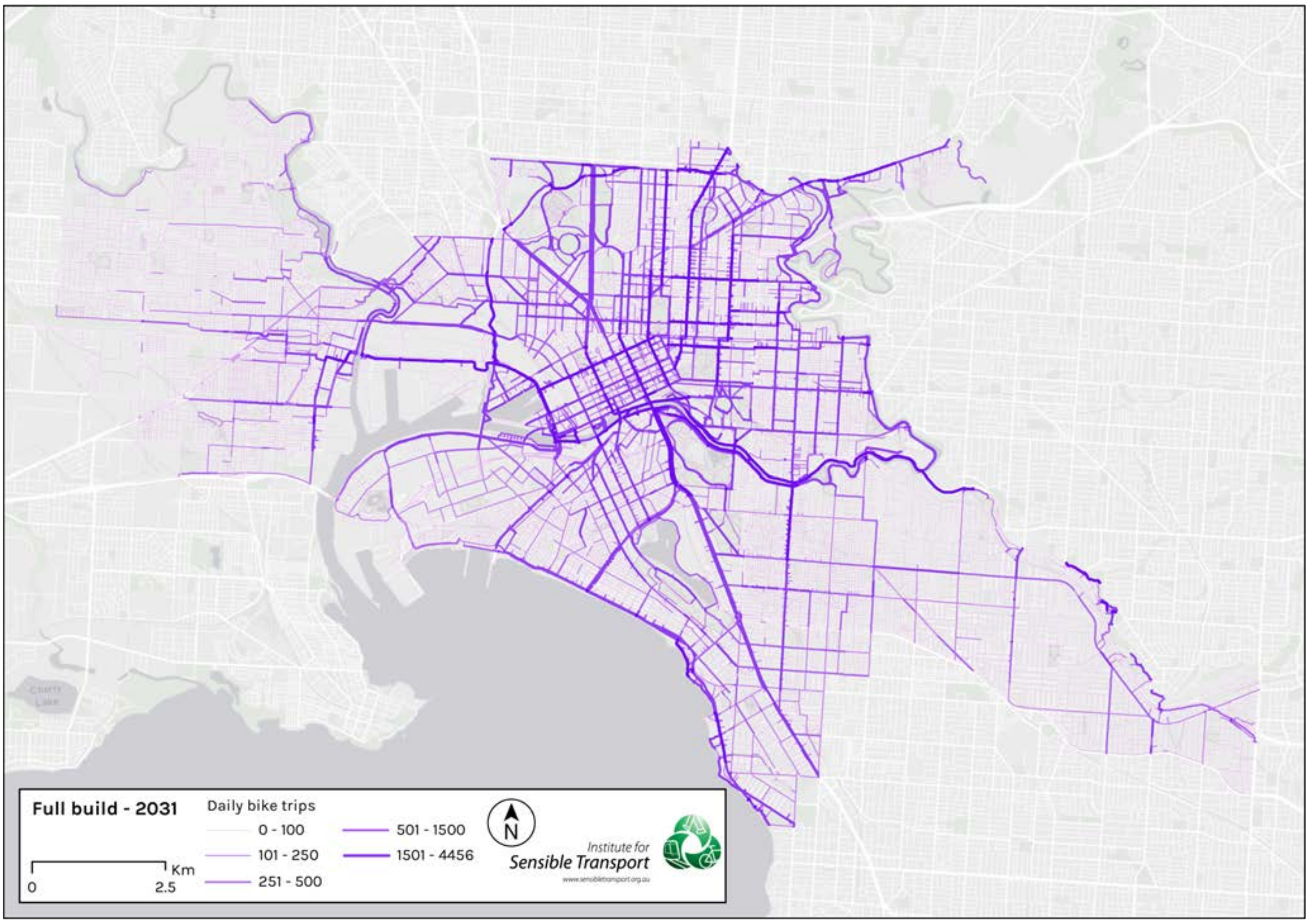

Figure 2 Estimated bicycle usage with future bicycle network, 2031

NB: The above estimates include population growth from ID.com.au

Figure 3 shows where the most growth in bicycle use is modelled to occur. This map expresses the *percentage change* in bike riding volumes between 2019 and the full build 2031 growth scenario. The figure only shows the future protected network or separated, off-road paths, or bike boulevards. Many sections of the future network are modelled to increase by 100% or more compared to 2019. In fact, many parts of the network that currently don't exist but are proposed as high-quality links in the future will see in excess of 300% growth in 2031 compared to 2019. It is important to note that *percentage* increases in cycling activity (Figure 3) can be very high on some streets, and this can be due to these streets starting from a very low base, rather than the total volume of estimated cycling being very high.

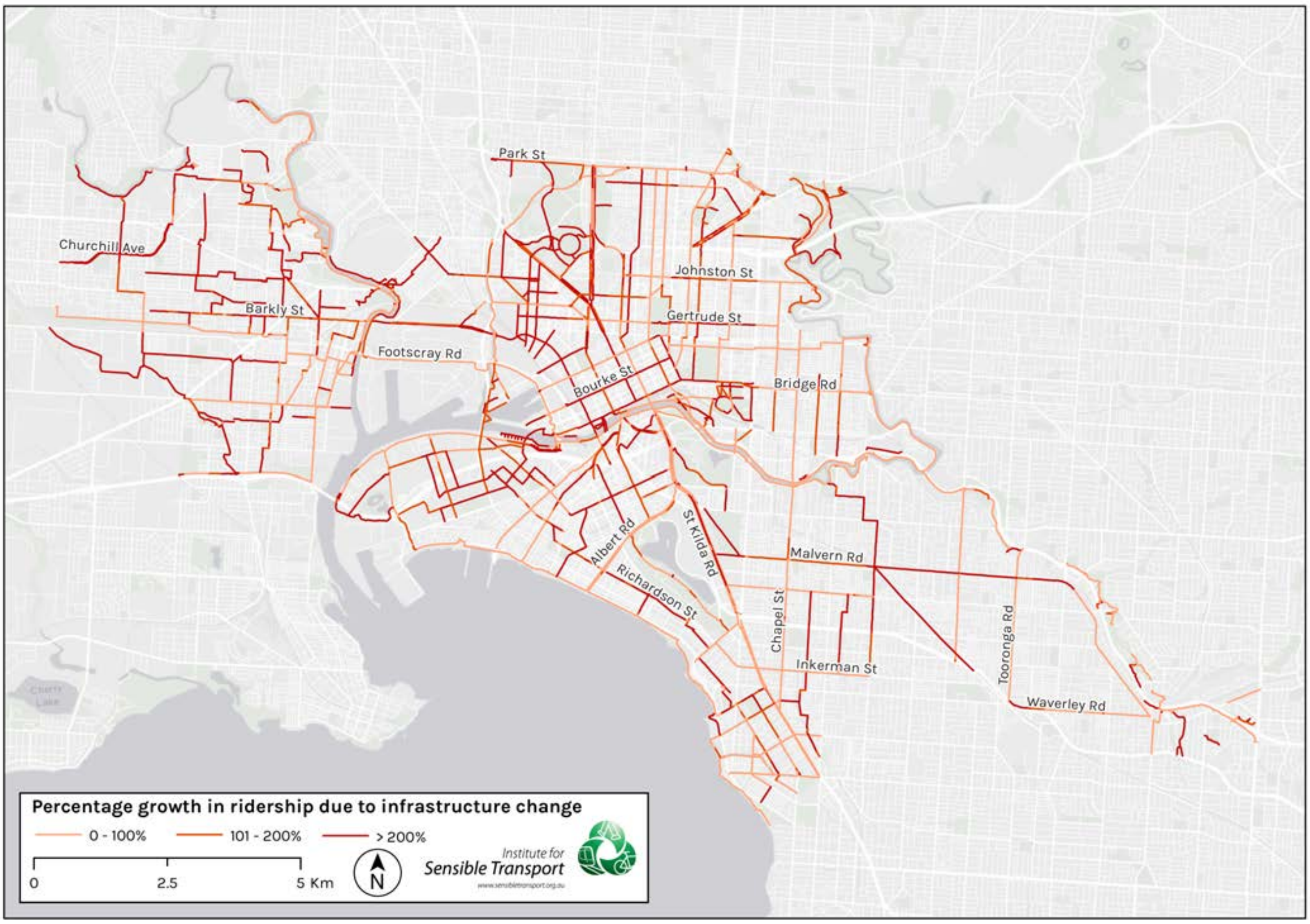

Figure 3 Growth (%) in bicycle usage 2019 to 2031 full build

This project highlights where the biggest increases in ridership are likely to occur if the full network is constructed. By undertaking the model at the IMAP level, opportunities have been identified for coordinating future bike riding corridors that cross municipal boundaries. Examples of this include the Langridge, Gertrude, Queensberry Street corridor, and Chapel/Church Street between the City of Port Phillip, City of Stonnington, and the City of Yarra.

Infrastructure is projected to deliver an 82% increase in bike usage compared to a 2031 no build scenario on the future proposed network in IMAP. Importantly, it also shows the growth estimated to occur on the new parts of the network, that do not currently exist. Figure 4 illustrates the estimated increase in cycling if the proposed network is built.

There will be an estimated 82% growth in cycling kilometres travelled on the future protected network within IMAP (Figure 1). This increases to 105% when isolating yet to be built sections of the network (Figure 5).

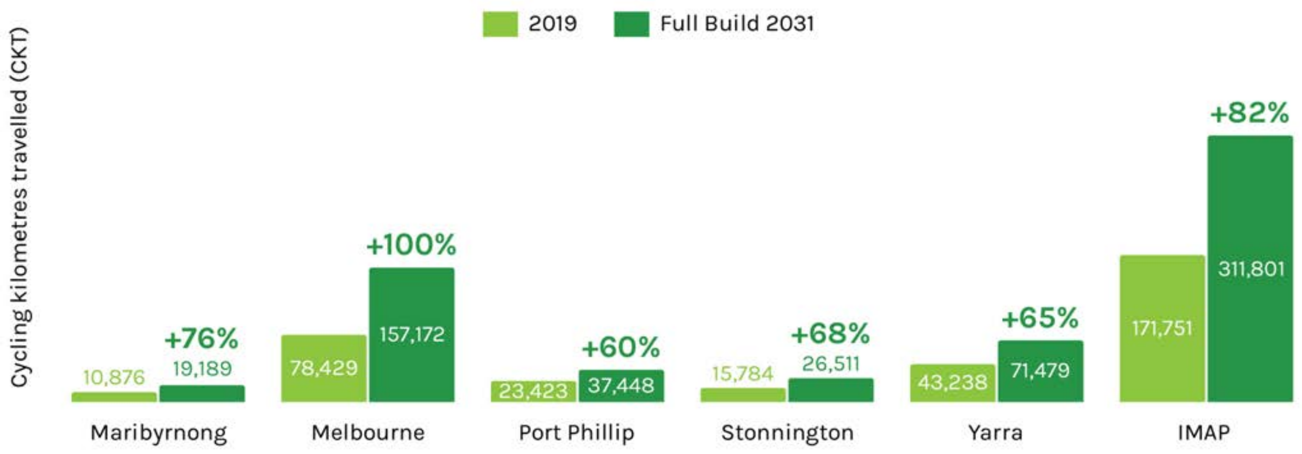

Figure 4 Percentage Increase in Riding on Future Proposed Network

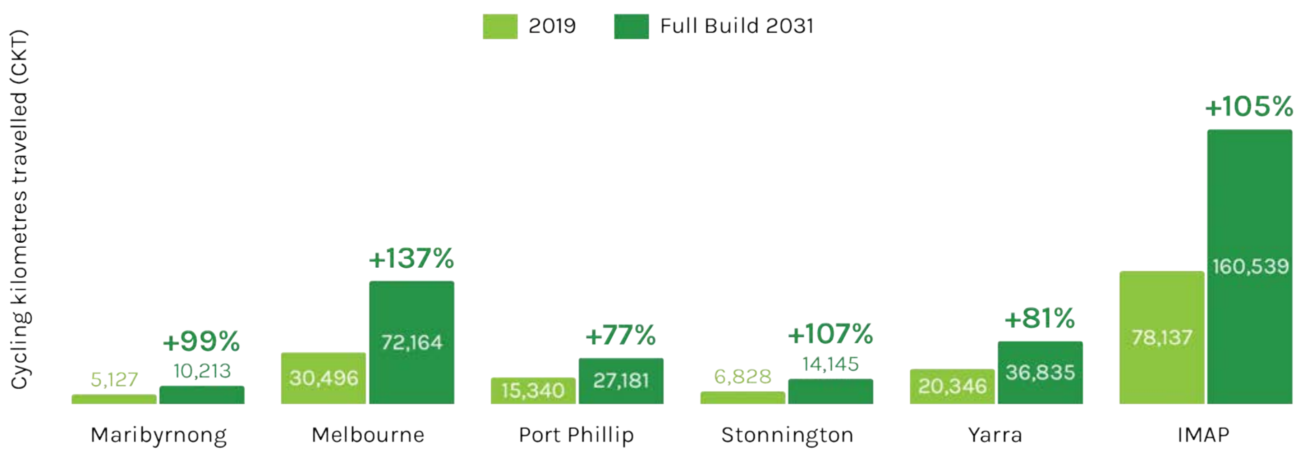

Figure 5 Percentage Increase in Riding on New Sections of the Network

Finally, a crash analysis was undertaken to determine the safety impacts that the full build scenario is estimated to have, relative to a no-build scenario. In the past five years, there has been over 3,000 crashes involving a person on a bike[1], including almost 700 hospitalisations and 10 fatalities.

[1] It is well recognized that this is likely to be an under-estimate, as it only includes police reported crashes.

Analysis conducted for this project found that fully constructing the proposed network is estimated to reduce the risk of bike crashes by 14% while increasing bike usage by 82% on the protected bike network.

The proposed infrastructure upgrades would provide an overall 14% reduction in risk exposure to bike riders in IMAP. That is, for every kilometre cycled, people are estimated to have 14% less chance of a crash. On some key streets that have no effective bike infrastructure today and are planned to have protected bike infrastructure, the exposure to crashes drops ~45%. Chapel Street in an example where the crash exposure is forecast to drop by this level due to the proposed protected bike lanes.[2]

The crash analysis also found that 80% of bike crashes in IMAP take place on only 10% of the road network (Figure 6).

80% of bike crashes in IMAP take place on just 10% of the road network.

The largest safety benefits could be realised through targeting infrastructure upgrades on the 10% of the street network where 80% of bike crashes occur. Each of the lines shown in Figure 6 represent the 10% of the street network where 80% of bike crashes occur within IMAP.

[2] Protected bike lanes for Chapel Street have been included in the proposed network for modelling purposes only and does not imply a commitment on the part of the City of Stonnington.

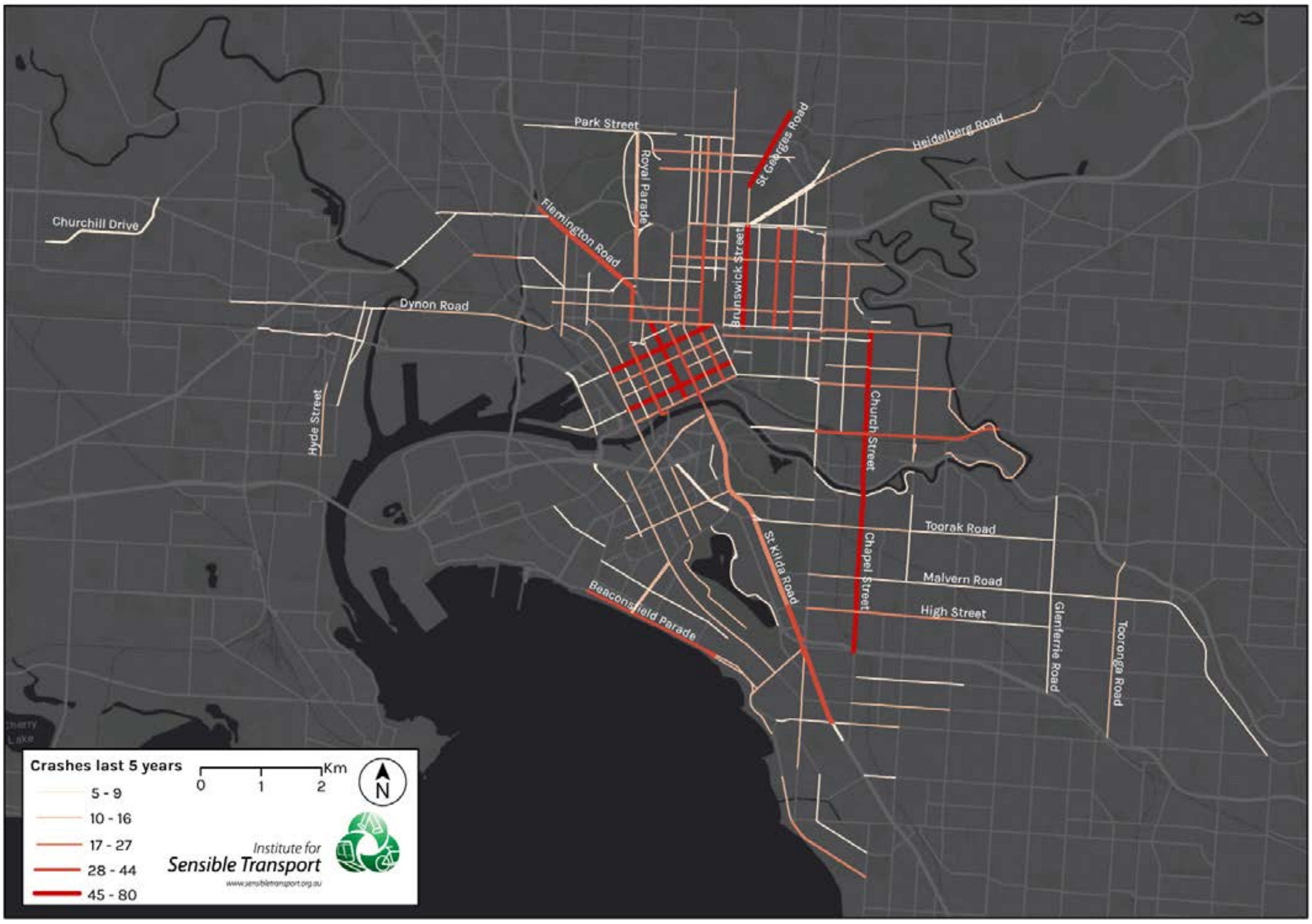

Figure 6 Number of bike crashes on key streets

Figure 7 shows the estimated reduction in crashes on key routes in 2031, compared to a no build scenario. When viewed in conjunction with Figure 6, it is clear that many of the streets with the greatest number of crashes become safer.

Figure 7 Change in estimated crashes per year

This report, by providing estimated outputs in bike riding activity and safety, combined with generalised costs of building different types of bicycle infrastructure, is able to offer high level cost benefit outputs for building the proposed network.

Some streets do not show a large projected decrease in crashes. This is due to a number of reasons, depending on the context of each individual street. In some instances, this may be due to riding volume increasing at a rate that is higher than the projected crash risk decrease – the street may become twice as safe but the number of riders may increase three-fold.

Synthesis of recommendations

Quick wins

This bicycle network model provided a number of insights at both the strategic level and on a street-by-street basis. A number of routes were discovered to provide the biggest uplift in bicycle usage, relative to other parts of the network. The five most important links for each IMAP member council has been provided in this report, in order to offer infrastructure priority guidance targeting the greatest uplift in bike riding. Completing a rapid roll out of the proposed network on the 10% of streets where 80% of the bike crashes occur is recommended as a targeted approach to supporting the State Government's *Safe Systems* and *Vision Zero* principles.

Target short distance car trips

In addition to the core outputs, the model has also been able to highlight areas that represent highly fertile parts of IMAP for converting short distance car trips to cycling. These areas, with demographics predictive of latent demand for riding bikes, high numbers of short distance car trips, and where bike riding is time competitive with other modes, is highlighted in Figure 8. Where a circle is shown, it indicates trips that start and finish within the given SA2 boundary, while the thickness indicates number of trips. Richmond is the standout – with very high numbers of short distance car trips at peak hour.

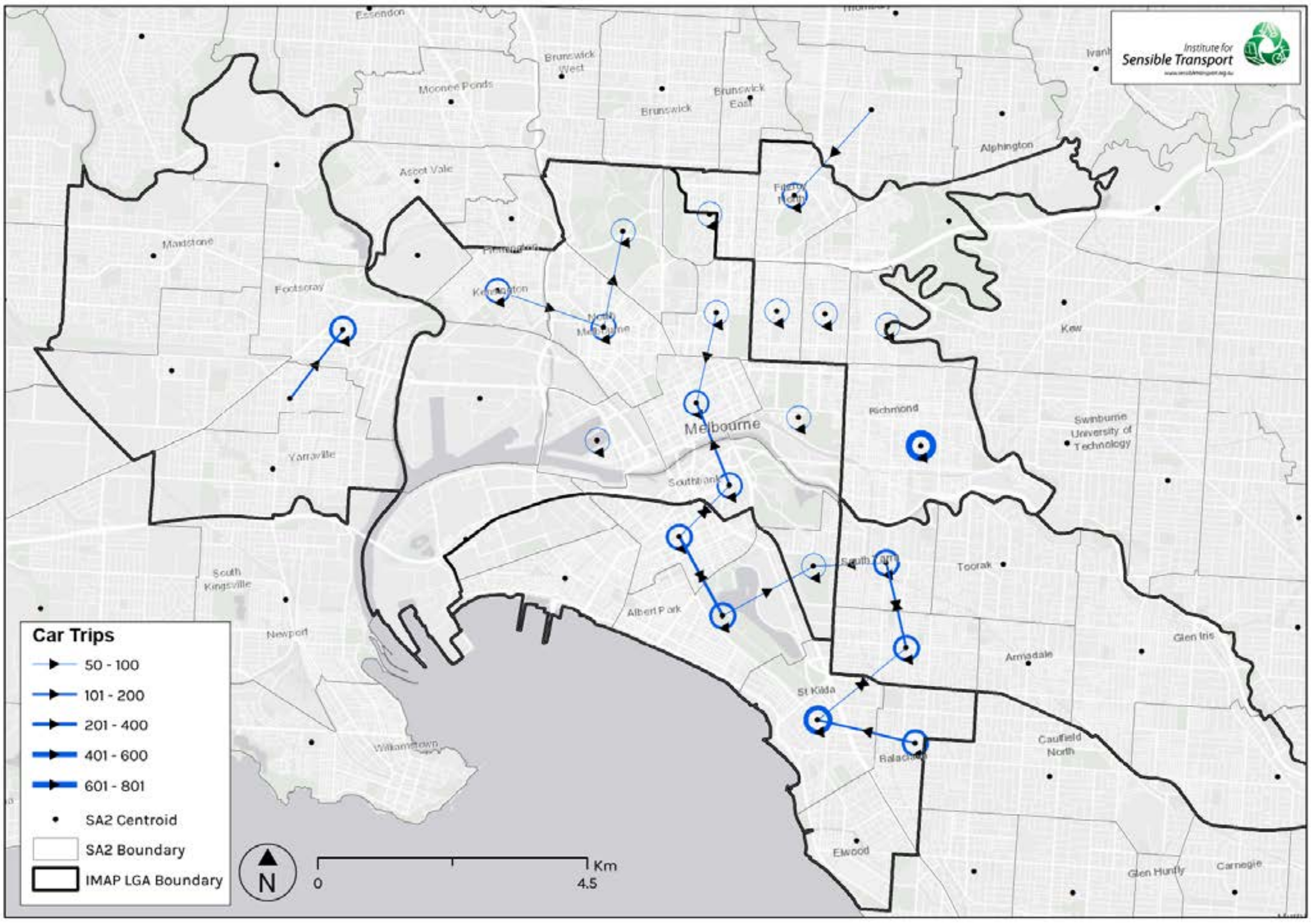

Figure 8 Areas with the greatest potential for converting short car trips to bike

Investigate low-cost separation

In order to speed up the creation of the proposed network, and reduce cost, lighter forms of delivering separated riding environments should be investigated.

Target areas where bike riding is time competitive to other modes

Identifying corridors in which bike riding is faster than competing modes will provide insights into where demand for bike riding is likely to be higher, helping to make more effective investment decisions.

Invest in bike counters

Expanding the network of bike counting devices will enable higher quality models to be developed in the future, offering a more reliable estimate of bike riding volumes. Moreover, installing counters *before* the installation of new bike riding infrastructure will enhance evaluation performance.

1. Introduction

1.1 Understanding the policy alignment

The transport sector is Australia's second largest greenhouse gas emitter and is the fastest rising source of emissions. Within the transport sector, private motor vehicles constitute the largest segment of existing emissions and forecast growth. Currently, transport emissions exceed the levels required for Australia to meet its commitments under the Paris Climate Agreement. Transport emissions will need to be reduced by 50% in the next 10 years to put Australia on track to meeting our international obligations. Figure 9 highlights both the emissions footprint of different modes of transport, and the *space* each mode occupies. It serves to highlight that the bike represents a space and energy efficient mode of transport.

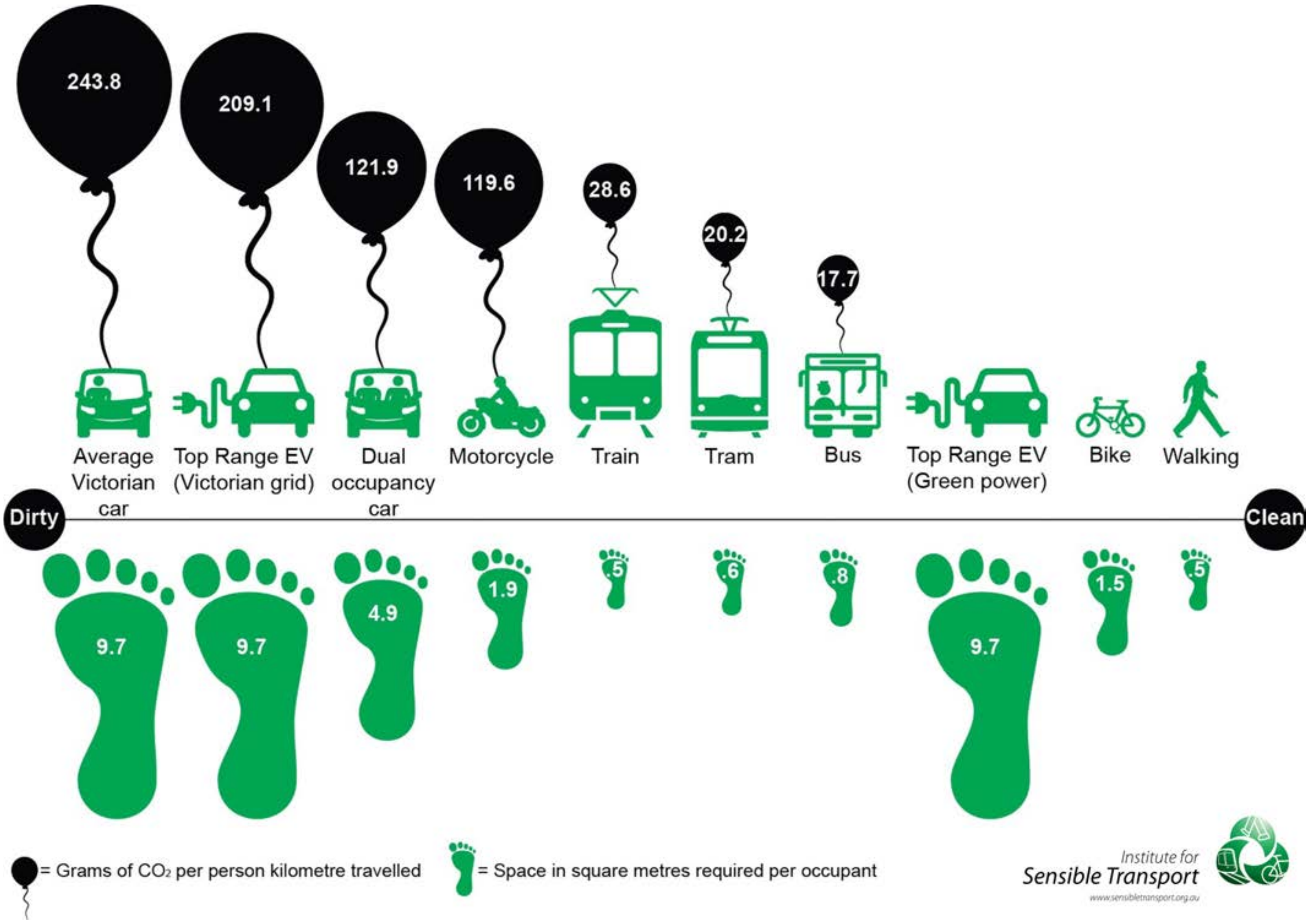

Figure 9 Emission and space consumption profile of different transport modes

Source: Institute for Sensible Transport for work commissioned by the City of Melbourne (See Davies et al., 2018)

The creation of a well-connected, safe bike riding network is essential for Melbourne to maintain and improve its liveability, especially at a future population of 8 million and the increasingly recognised need to reduce transport emissions in line with international obligations. A safe bike riding network will provide a genuine opportunity for bike riding to form a significant part of the transport mix. For this to be realised, a high-quality network that connects residential catchments to key destinations and transport hubs that is comfortable for all-ages and all-abilities will need to be built. To date, efforts to create such a network have been disparate and fragmented, often lacking the level of separation required to improve safety outcomes for people currently riding and to encourage new people to ride.

Gender and bike riding in Melbourne

It is well established that female participation in bike riding is far lower than the proportion of females in the general population and workplace participation (Pucher et al., 2010). Only around a fifth of the people who rode to work in Greater Melbourne on Census day 2016 were female. Females are more sensitive to the riding environment and less likely to be willing to ride on roads that do not offer separation from motor vehicle traffic (Dill, 2009). While it is not possible to fully incorporate gender within the Bicycle Network Model, it can be expected that growing the network of protected bike lanes and low speed routes will enhance the attractiveness of cycling for women, helping to close the gender gap.

Box 1 Gender and bike riding

1.2 Safety and perceptions of safety for bike riding

Safety concerns are the main reason people choose not to ride a bike (Götschi et al., 2015, Pucher et al., 2010). Data from the Australian Institute of Health and Welfare found that cycle injuries among middle aged people has increased rapidly in recent years, as shown in Figure 10. It is critically important that safe bike riding infrastructure is provided to support the growth in bike riding, especially for *'would be'* bike riders that are far more sensitive to riding conditions.

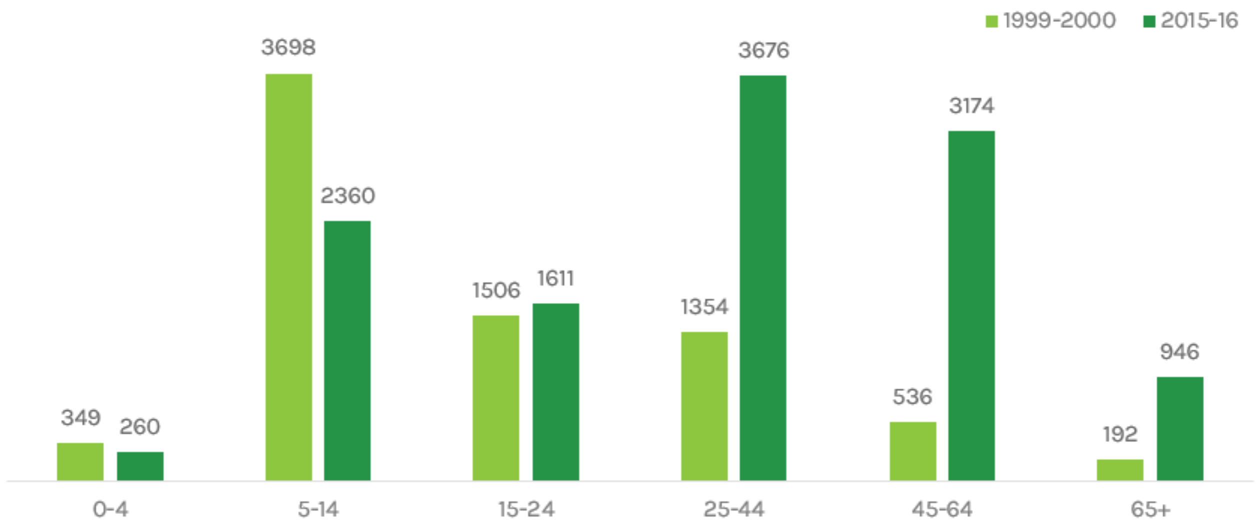

Figure 10 Hospitalised cases of people sustaining an injury while bike riding

Source: Australian Institute of Health and Welfare (2019)

Victoria saw a rapid increase in road transport deaths in 2019, as shown in Figure 11. It is important to note that the data for 2019 is only for the first 7.5 months, and across all transport categories, is higher than the full 12 months of 2018. Fatalities for people riding bikes have more than doubled the rate of increase compared to any of the other modes, highlighting the magnitude of the challenge of achieving a safer, more attractive riding environment.

Fatalities while riding a bike have more than double the rate of increase compared to any other mode.

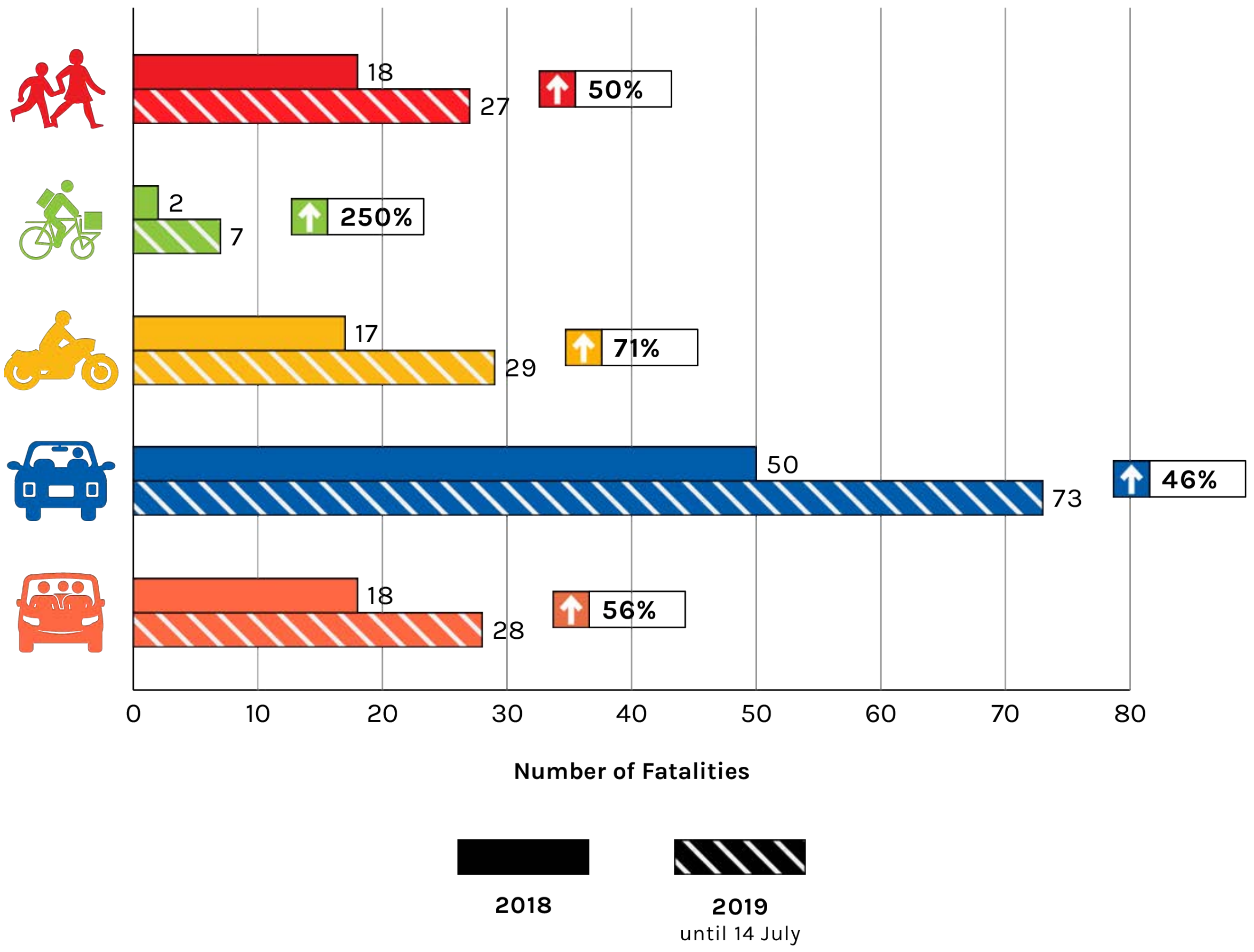

Figure 11 Fatalities in Victoria 2018 vs 2019 to 14 July

Source: Transport Accident Commission (2019)

The *Bicycle User Confidence* (Near Market) *Study* found that only 6% of people in inner Melbourne would feel confident riding on a road without a bike lane, 22% would feel confident on a standard bike lane but that 83% would feel confident on a protected bike lane. This provides important market information on what is required to make bike riding an attractive choice for more people. Figure 12 shows how respondents to the *Near Market* study stated their level of confidence on different bicycle infrastructure typologies. It is clear from these results that the greater the level of separation from motor vehicles, the higher people's confidence.

Recent research for Melbourne found only 6% of people would feel confident riding on a road without a bike lane.

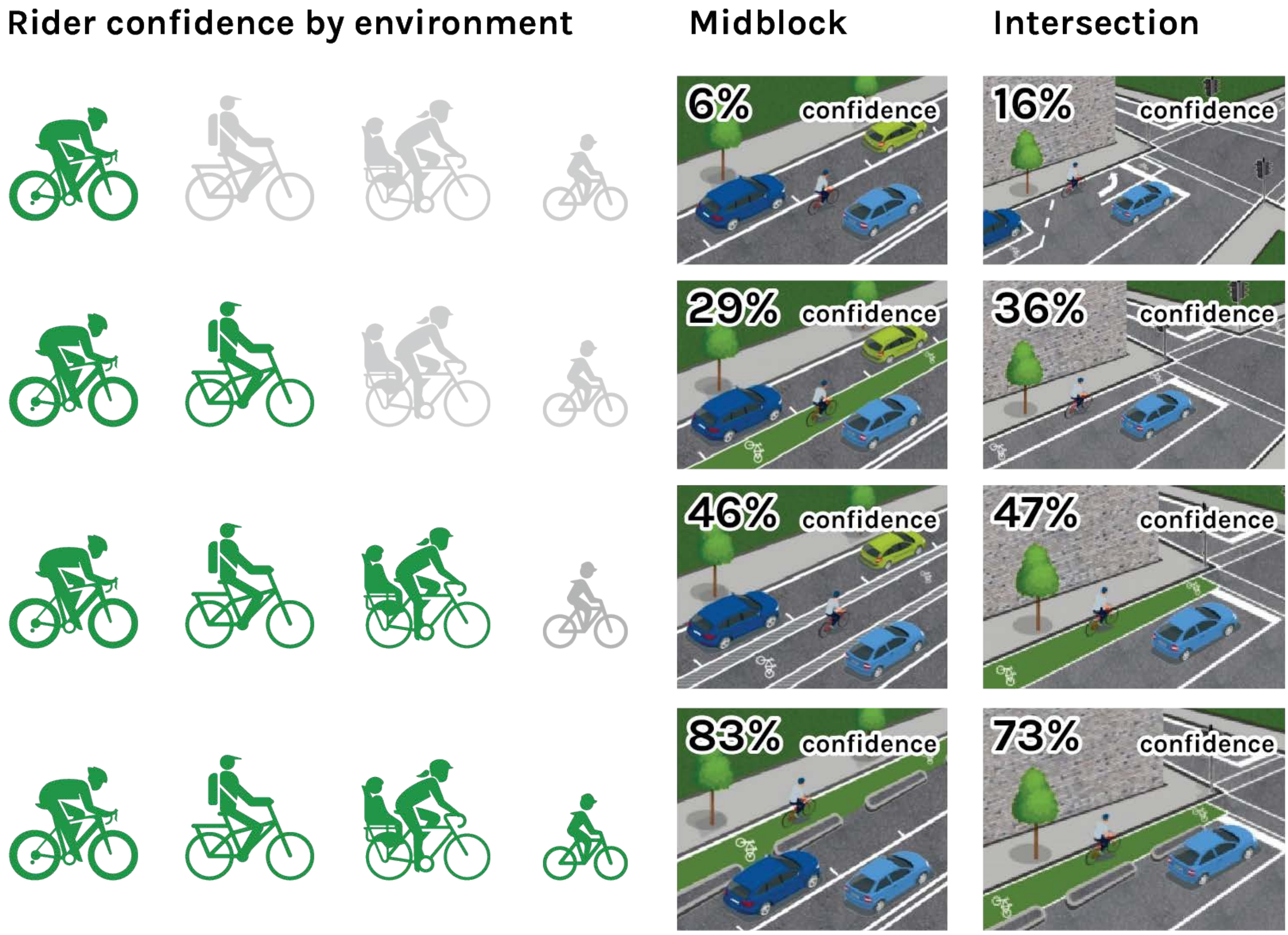

Figure 12 Rider confidence by environment

Source: Based on CDM Research & ASDF Research (2017)

Figure 12 also provides a snapshot of how confidence levels change depending on the intersection and mid-block typology. Again, it shows the higher the level of separation, the more confident respondents say they would feel. Importantly, females are significantly underrepresented in bike riding participation in Melbourne (Australian Bureau of Statistics, 2017) and females are known to be more sensitive to the riding environment and less inclined to ride in mixed traffic (Dill et al., 2014, Dill, 2009, Dill and Voros, 2007).

1.2.1 Government support for improved bicycle infrastructure

Councils within IMAP have recently made renewed commitments to make it easier to use more sustainable modes of transport, including bike riding. Each of these commitments includes plans to make bike riding safer and more accessible for existing and prospective bike riders.

The State Government has also begun a review of their Strategic Cycling Corridors in line with the recent Victorian bike riding Strategy. The proposed infrastructure from both the IMAP member councils and the State Government has been used in the development of the Bicycle Network Model.

The Victorian Government's Movement and Place framework offers an approach to street design that recognises the multi-dimensional role of streets, as both movement corridors, and places in their own right. On some streets, the provision of bike riding infrastructure will be prioritised. *Resilient Melbourne Metropolitan Cycling Network* intends to work with councils across metropolitan Melbourne to coordinate a metropolitan proposal for a network that is both holistic in scope and tailored to local needs. The planning and construction of bicycle infrastructure from all levels of government is an exciting prospect with the potential to transform our cities into a more sustainable and liveable future.

1.3 About this project

While the need for enhanced conditions for people to ride bikes has long been recognised, there has been a history of failing to deliver bike riding infrastructure in a coordinated, timely manner that accords with people's preferences for the type of infrastructure that would encourage them to cycle.

There is a clear need to bring a strategic, data led approach to bridge the knowledge gap, to provide insights regarding:

1. Existing bike riding patterns.
2. A centralised map of bicycle lanes and paths in Melbourne, differentiated by infrastructure type.
3. A spatial analysis of latent demand for people to ride bikes (from those not currently bike riding, but open to it as a possibility in the future).
4. How changes in the type of bike riding infrastructure would influence demand/usage of that infrastructure.
5. How to sequence the construction of new bike riding links that best improve bike network density and encourages the most people to take up bike riding for transport.
6. A model to estimate how changes to bike riding impact on travel by other modes, and a tool that can monetize how these changes may translate from a $/km (e.g. each additional km cycled brings $1.24 in benefit).
7. How changes to bike riding infrastructure would influence safety outcomes for people choosing to cycle.
8. Potential expansion to the entire metropolitan area, as well as regionally, per the request of individual councils.

This project focused on addressing the above issues/questions, in order to inform government understanding on existing and future network usage based on a full build and no build scenario, combined with population growth forecasts. It acts as a planning tool that provides the basis for future cost benefit analysis and safety outcomes.

2. Descriptive statistics of relevance

Transport data were analysed in the early development of the Bicycle Network Model, in order to gain insights into transport patterns within the IMAP region. A selection of descriptive statistics from this process is provided in this section, although it is not essential to absorb this information to understand the model outputs.

2.1 Journey to work

Table 1 shows the top 10 SA2s for bicycle journeys to work, by *origin*. The majority of SA2's with high bicycle usage came from the inner north of the study area, with St Kilda the sole exception. Brunswick has the highest number of bicycle commuters, while Fitzroy North and Carlton North – Princes Hill had the highest bicycle mode share, with 16%.

Table 1 Top 10 Cycling SA2's by *origin*, Journey to work

SA2	Number of trips	Percentage of Journey to Work
Brunswick	1839	14%
Northcote	1291	11%
Richmond	1008	6%
Fitzroy North	988	16%
Coburg	808	7%
Brunswick East	725	12%
Thornbury	699	8%
St Kilda	689	5%
Carlton North - Princes Hill	687	16%
Brunswick West	615	10%

Source: Australian Bureau of Statistics (2017)

Table 2 shows the top three SA2 for each LGA, in terms of bike riding by origin.

Table 2 Top 3 Cycling SA2's in each LGA by *origin*, Journey to work

SA2	LGA	Number of trips	Percentage of Journey to Work
Footscray	Maribyrnong	299	4%
Yarraville	Maribyrnong	241	4%
Seddon - Kingsville	Maribyrnong	239	4%
North Melbourne	Melbourne	545	6%
Kensington	Melbourne	419	8%
Carlton	Melbourne	411	7%
St Kilda	Port Phillip	689	5%
Port Melbourne	Port Phillip	515	7%
Elwood	Port Phillip	447	6%
Prahran - Windsor	Stonnington	474	4%
South Yarra - East	Stonnington	465	4%
Malvern - Glen Iris	Stonnington	211	2%
Richmond	Yarra	1008	6%
Fitzroy North	Yarra	988	16%
Carlton North - Princes Hill	Yarra	687	16%

Source: Australian Bureau of Statistics (2017)

Table 3 shows the top 10 SA2's for bicycle journeys to work by *destination*. Melbourne CBD had the largest number of bicycle commuters, with over 6,400. All the top 10 SA2s were centred around the inner city.

Table 3 Top 3 Cycling SA2's in each LGA by *destination*, Journey to work

SA2	LGA	Number of trips	Percentage of Journey to Work
Footscray	Maribyrnong	260	2%
Yarraville	Maribyrnong	74	2%
West Footscray - Tottenham	Maribyrnong	47	1%
Melbourne	Melbourne	6402	3%
Parkville	Melbourne	1987	8%
Docklands	Melbourne	1686	3%
Albert Park	Port Phillip	438	3%
St Kilda	Port Phillip	434	3%
Port Melbourne Industrial	Port Phillip	431	2%
Prahran - Windsor	Stonnington	301	3%
South Yarra - East	Stonnington	267	2%
Malvern - Glen Iris	Stonnington	111	1%
Richmond	Yarra	1196	4%
Fitzroy	Yarra	812	7%
Collingwood	Yarra	644	6%

Source: Australian Bureau of Statistics (2017)

Table 4 shows the top 3 strongest relationships for bicycle journeys to work between SA2's. All but one of the destination SA2s were Melbourne CBD, the exception being trips within Richmond.

Table 4 Top 3 strongest relationships in each LGA, SA2 - SA2, journey to work, cycling

SA2 Origin	SA2 Destination	LGA	Indicative Length (Km)	Number of trips	Percentage of Journey to Work
Yarraville	**Melbourne**	Maribyrnong	6.4	65	5%
Footscray	**Melbourne**	Maribyrnong	5.6	60	4%
West Footscray - Tottenham	**Melbourne**	Maribyrnong	8	52	6%
North Melbourne	**Melbourne**	Melbourne	2	146	6%
Carlton	**Melbourne**	Melbourne	1.5	124	8%
Kensington	**Melbourne**	Melbourne	3.5	105	8%
St Kilda	**Melbourne**	Port Phillip	5.1	162	6%
Port Melbourne	**Melbourne**	Port Phillip	3.3	142	9%
Elwood	**Melbourne**	Port Phillip	7	106	8%
South Yarra - East	**Melbourne**	Stonnington	3.7	129	5%
Prahran - Windsor	**Melbourne**	Stonnington	4.9	111	5%
Malvern - Glen Iris	**Melbourne**	Stonnington	8.5	70	4%
Richmond	**Melbourne**	Yarra	3.8	227	6%
Fitzroy North	**Melbourne**	Yarra	3.8	218	16%
Richmond	**Richmond**	Yarra	<4	160	6%

Source: Australian Bureau of Statistics (2017)

2.1.1 Understanding the potential – short car trips

It is important to develop an understanding of the opportunity to mode shift towards cycling, with a particular focus on short car trips. These trips are the most readily convertible to bicycle, and an area of direct interest for this project, given that it is concerned with understanding future cycling rates under an improved infrastructure scenario.

Table 5 shows the strongest SA2 relationships for car driver journeys to work. Surprisingly, many of the top 10 SA2 relationships consisted of trips that started and ended within the *same* SA2, including Richmond which had the highest number of car driver trips out of all SA2 – SA2s.

Table 5 Strong relationships, SA2 - SA2, journey to work, car driver

SA2 Origin	SA2 Destination	Number of trips	Indicative Distance (Km)	Percentage of Journey to Work
Richmond	**Richmond**	801	<4	31%
Kew	**Melbourne**	603	6.4	35%
Malvern - Glen Iris	**Malvern - Glen Iris**	519	< 4	62%
Essendon - Aberfeldie	**Melbourne**	442	8.6	24%
Malvern East	**Malvern East**	441	< 4	56%
St Kilda	**St Kilda**	404	< 4	31%
Richmond	**Melbourne**	391	3.8	11%
Malvern - Glen Iris	**Melbourne**	381	8.5	24%
Hawthorn	**Melbourne**	373	6.2	17%
Toorak	**Melbourne**	350	5.8	30%

Source: Australian Bureau of Statistics (2017)

Figure 13 shows the graphical distribution of car driver trips between SA2s for Journeys to Work. It shows a more diverse travel pattern than bicycle travel, with many more strong travel numbers for non-CBD trips. Again, many of the movements with the highest car trips are those that start and finish within the same SA2. In total, there are approximately 31,000 car trips that start and finish in the same SA2, with 7,500 of those within IMAP SA2s. Driving to work within the same SA2 has an average mode share of 55% within the study area, decreasing to 37% within IMAP only. The circles shown in Figure 13 indicate trips that begin and end within the same SA2. Richmond and the south east of inner Melbourne contains the strongest concentration of these intra-SA2 trips.

> There are approximately 31,000 car trips to work that start and finish in the same SA2 within the study area.

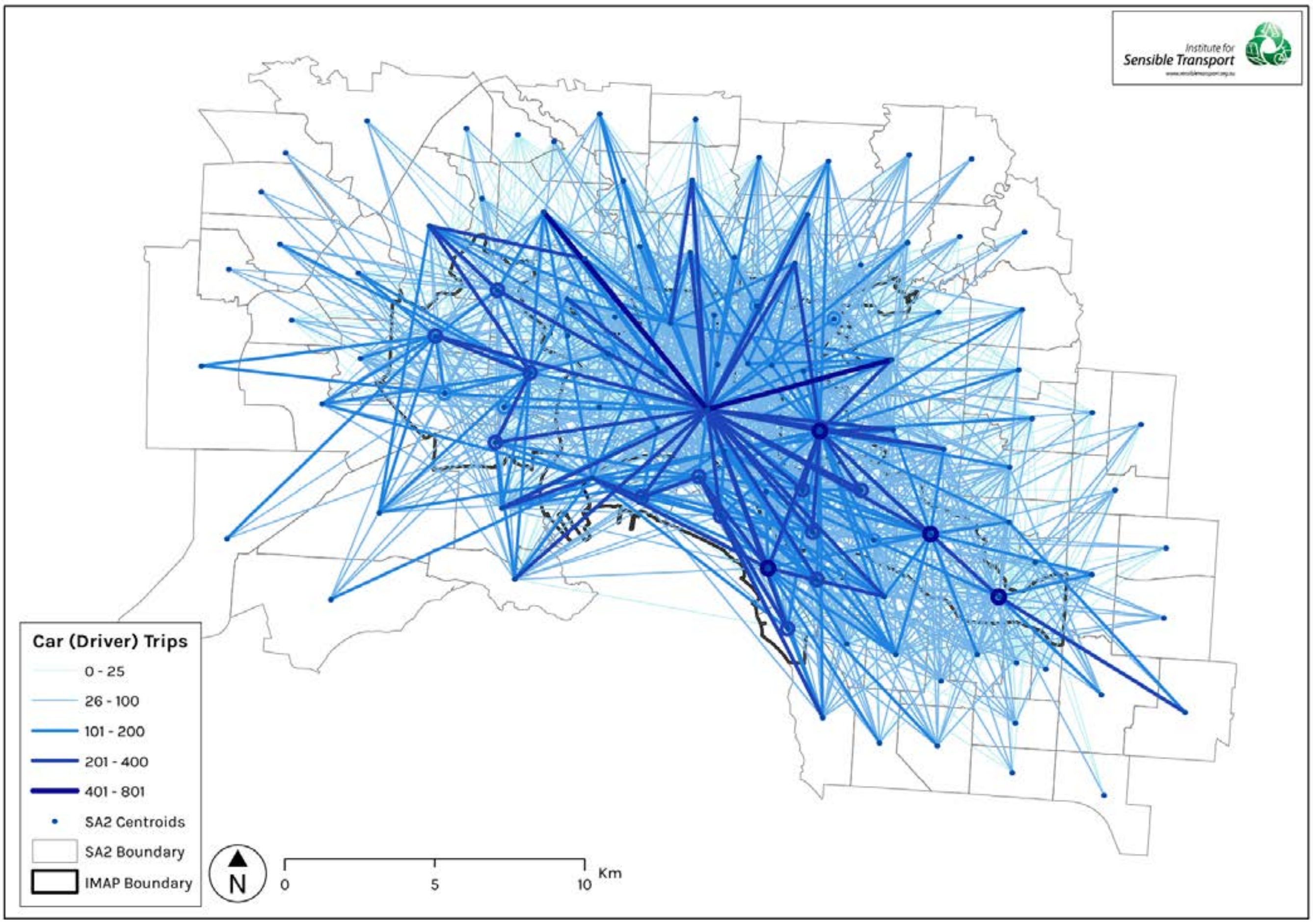

Figure 13 Car driver trips between SA2s within the study area

Nb. Circles indicate trips that start and finish in the same SA2

2.1.1.1 Cycle distances – Journey to work

The distances people are willing to cycle is an important input into the Bicycle Network Model. This section describes what the 2016 Census data says regarding the distances people cycle when travelling to work. This is a useful insight in terms of understanding cycling behaviour and what trips may be converted to bike. For example, a journey to work that is above 10km is unlikely to be mode-shifted to bike if the proposed route is upgraded, while journeys to work within a cyclable distance could be reasonably mode-shifted.

Figure 14 provides an analysis of the proportion of all trips to work by bike by LGA for the IMAP councils, by distance. This shows that for most of the IMAP LGAs, the common distance to travel to get to work is around 3 - 4km. An exception to this is Maribyrnong, in which a relatively low proportion of people cycling travel in the 3 – 5km band, with the most common cycling distance from Maribyrnong being ~8km.

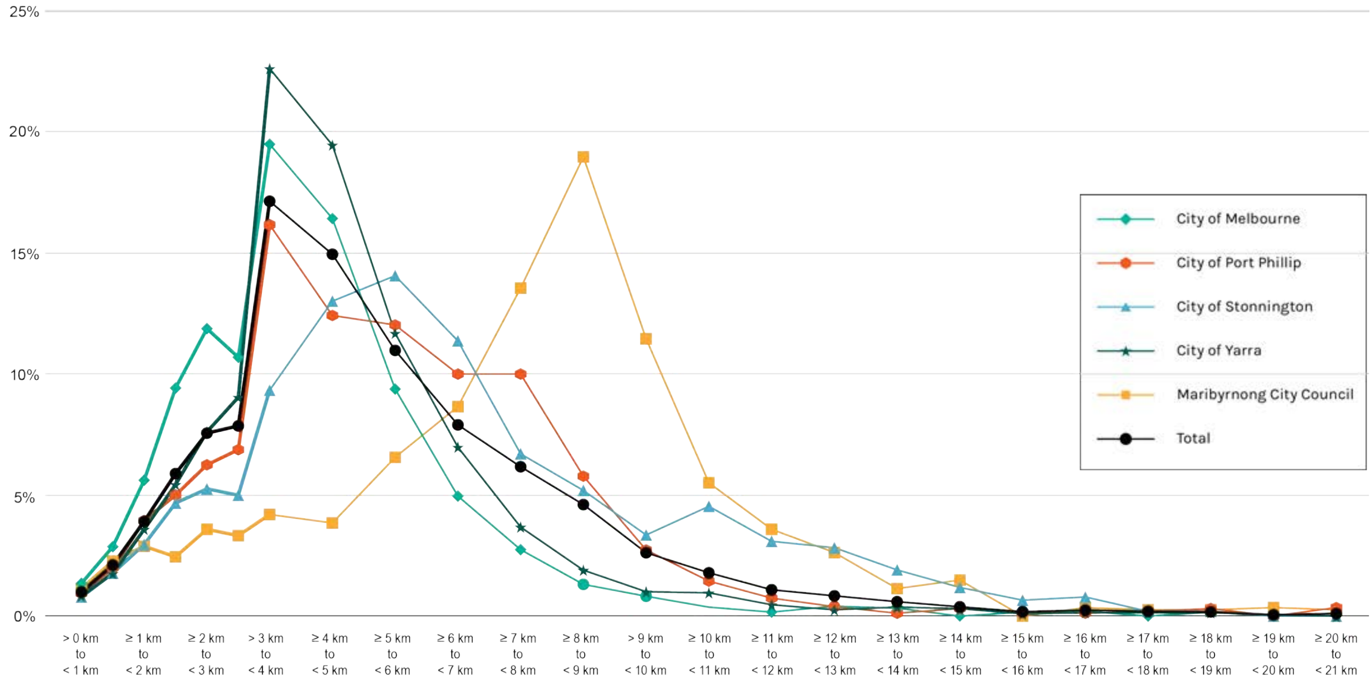

Figure 14 Percentage of cycle trips by distance, IMAP LGAs

Source: Australian Bureau of Statistics (2017)

Figure 15 provides an indication of the distance cycled to work for the IMAP member LGAs, expressed cumulatively. This shows that for most councils, around 75% of cycle trips are between 4 and 6km. Over 95% of cycle trips are under 10km. This insight justifies the inclusion of distance as a metric the model uses when determining future cycling estimates.

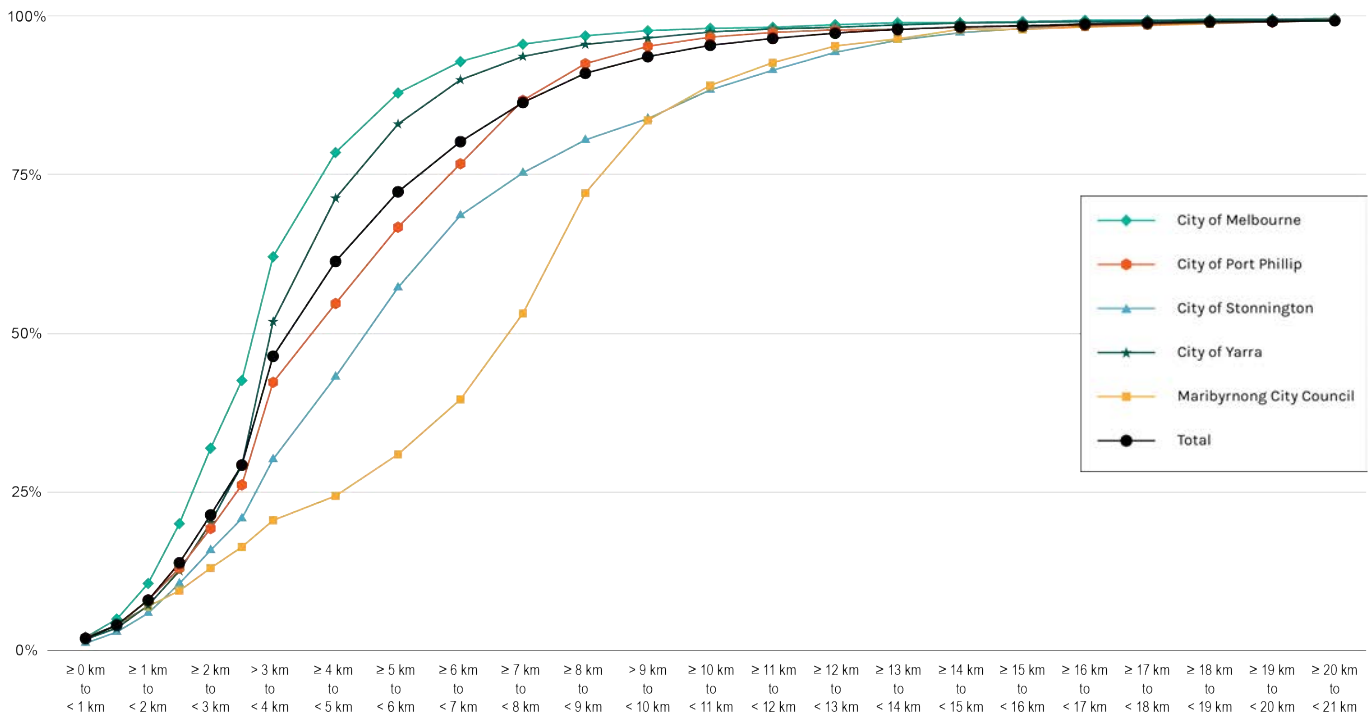

Figure 15 Cumulative cycle distances, IMAP LGAs

Source: Australian Bureau of Statistics (2017)

2.2 Victorian Integrated Survey of Travel and Activity (VISTA)

The VISTA dataset provides travel pattern information across all trip types, as distinct from the Census, which only provides information on the journey to work, which constitutes only ~18% of all trips.

VISTA was used for two distinct purposes in this project. First, it was used to scale up Census Journey to Work figures to include all trip purposes between SA2s. Second, it was used to estimate the trip time for different modes and trips purposes.

Using VISTA, we found that approximately 30% of all trips, regardless of mode or purpose, start and finish within the same SA2. Of those trips, approximately 50% are completed using a motor vehicle. These trips were taken over an average distance of 1.2km.

VISTA is a useful tool for analysing trip patterns and behaviours, particularly at the LGA and regional levels. It is noted that due to the limited travel surveys that were completed, VISTA may be limited in its accuracy in some geographic areas or for trip purposes. However, at present it provides the best publicly available dataset for undertaking this type of analysis.

A third of all trips, regardless of mode or purpose, start and finish within the same SA2 and half of these are by car, at an average distance of 1.2km.

3. Methodology

The Model uses observed data to predict changes in bike riding participation across Melbourne's inner LGAs, based on the bike infrastructure improvements that have been proposed by the local governments as well as the Victorian Department of Transport. The model has several discrete sub-modules that interact to generate a network wide model which estimates current and future bike riding activity, origin and destination of activity, relative changes to bike riding safety, and potential network effects of infrastructure.

Our approach has been developed in order to offer the IMAP councils a replicable, updatable *Bicycle Network Model* for the IMAP area that is capable of expansion to Greater Melbourne. We have used a range of data sources and standard GIS software, widely used by local government. Figure 16 provides an overview of our approach.

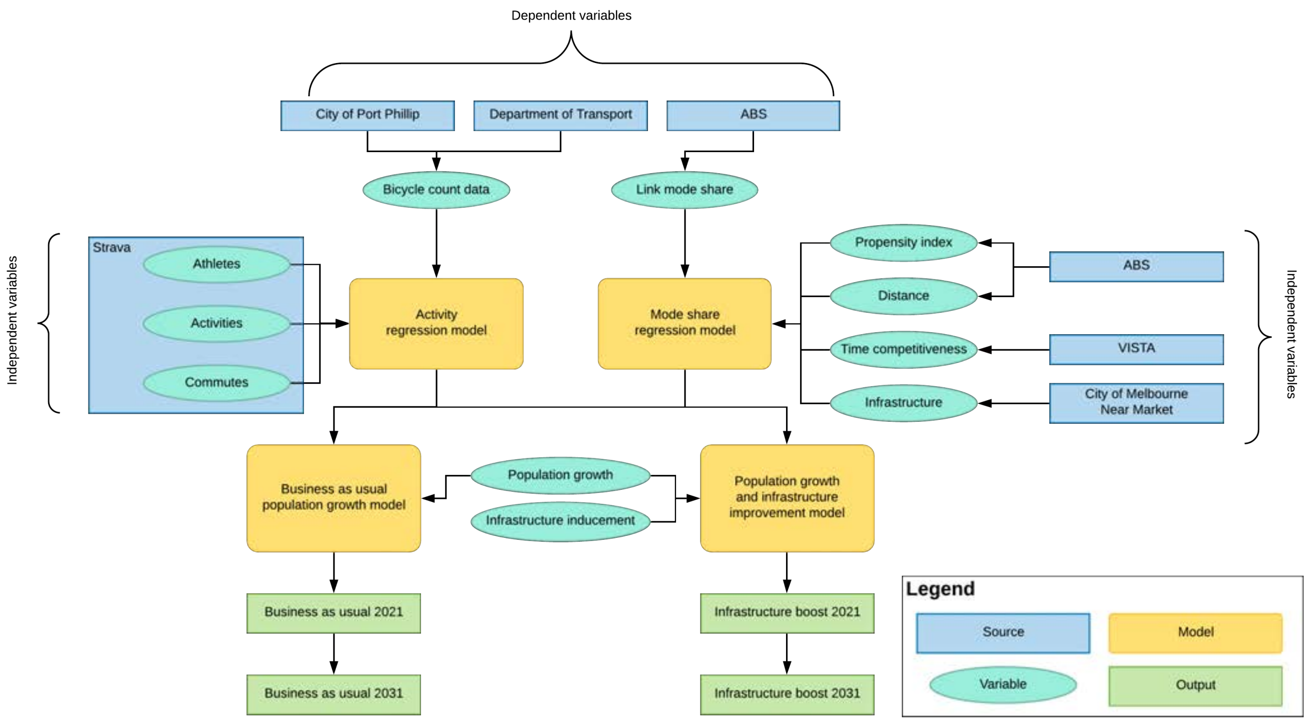

Figure 16 Flowchart of the Model methodology

The rest of this section will detail each of the key steps used in the development of the Model.

3.1 Baseline bike riding activity module

A baseline of bike riding activity across inner and middle Melbourne was generated using Strava (Strava, 2019), a bike riding activity tracking App, calibrated to existing road usage observations. Strava allows users to track their bike riding activity online. This data set has been calibrated using actual bike riding activity observations from 166 network segments within the study area, shown in Figure 17. The bike network was segmented into three categories: on road; off road; and circuit training (activity spots in the network known to attract disproportionately high levels of bike riding activity from Strava users). This segmentation recognises and ameliorates bias towards certain road typologies, and conversely, away from certain infrastructure typologies. For each of these three segments a multivariate regression analysis was undertaken, drawing on three Strava variables:

1. Activity (all movements over a section of network)
2. Commutes (movements self-selected by App users as commute trips); and
3. Athletes (the total number of users over a section of network).

The result was a network usage estimation across the entire road network of the study area, with an estimated total number of users per day, per section. From this, total bike riding kilometres travelled in 2019 can be estimated. This baseline was then increased with the other modules, to project future activity.

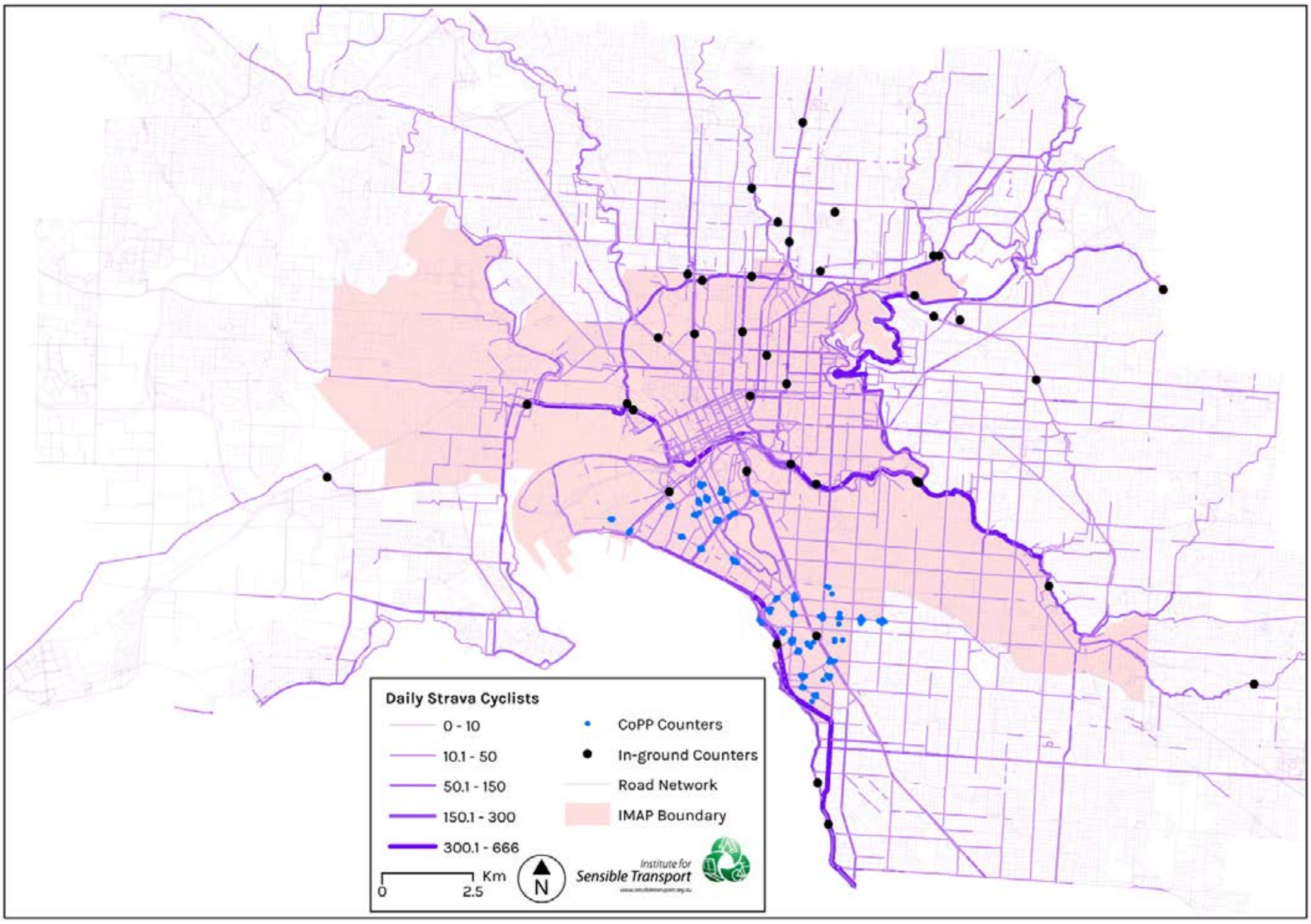

Figure 17 Daily Strava bike riding activity and Bicycle Counters, 2018

3.2 Mode share module

Commute journeys were mapped using Australian Bureau of Statistics 2016 Census data using Statistical Area Levels 2 (SA2) as the origin and destination. Euclidian (as the crow flies) lines were drawn between all SA2s in the study area to all other SA2s in the study area, with journeys by each major mode and in total recorded against each line. This generated a schematic of travel across the study area, with riding mode share of each link calculated (see Figure 18). The thickness of the line in Figure 18 is proportional to the number of bike riding trips between SA2s.

Increases in bike riding activity was predicted, with an increase to commute journeys modelled, and then scaled up using a combination of Australian Bureau of Statistics (Journey to Work) and Victorian Integrated Survey of Travel and Activity (all-purpose journey) data sets to represent a prediction of total bike riding activity in the study area. This method was adopted as it reliably shows where bike riding activity starts and ends within Melbourne.

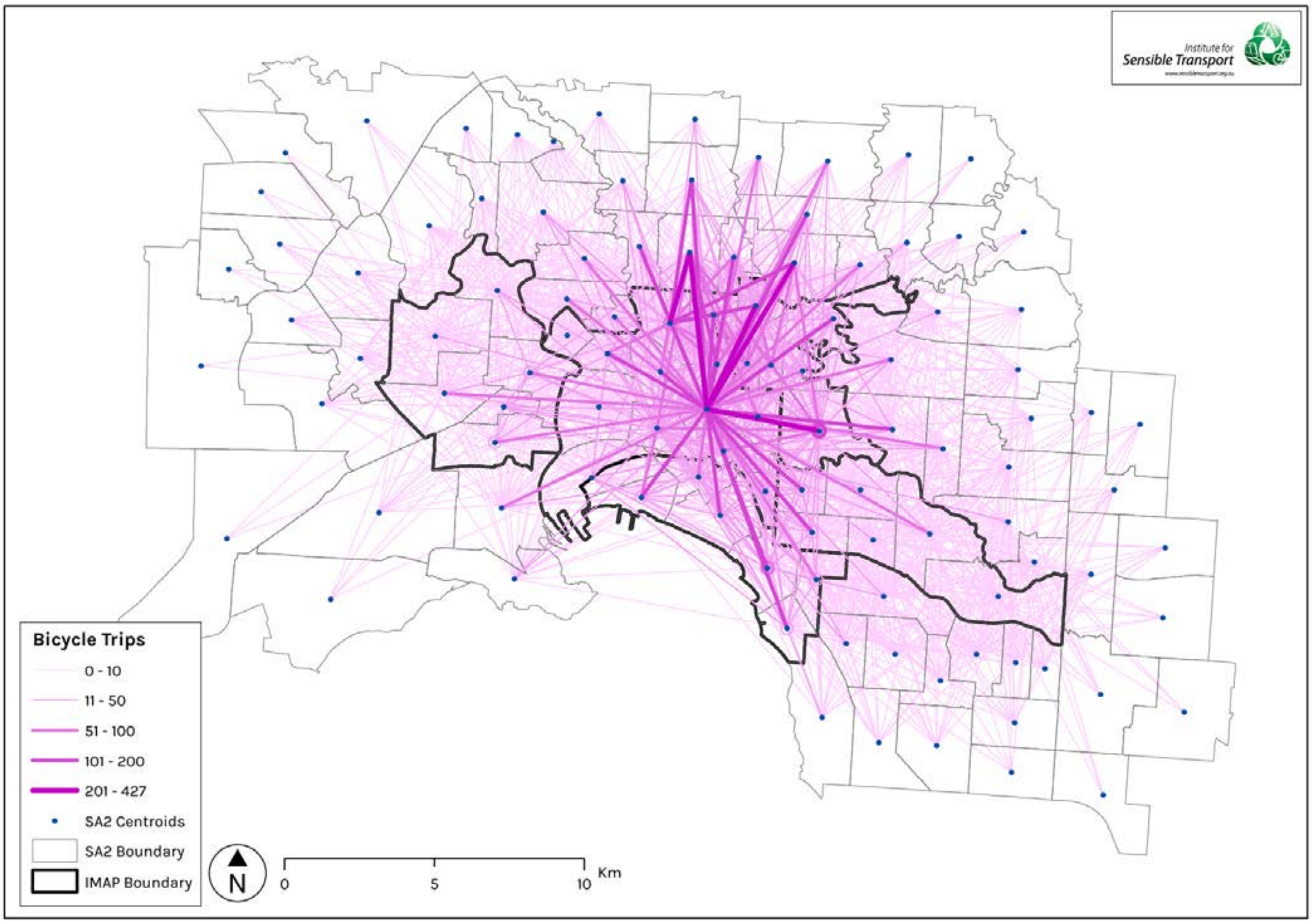

Figure 18 Bike trips between SA2s in study area

Nb. Circles indicate trips that start and finish in the same SA2

This mode share module was used in two predictions. Firstly, bike riding participation increases due to population growth was forecast. Population growth predictions were used to scale the number of journeys occurring from each SA2 accordingly (i.e., if an SA2 is predicted to increase in population by 10% between 2019 and 2031, it was estimated that this would lead to a proportional increase in travel along all links).

This method of adjustment was used to increase activity from 2016 levels to estimate activity in 2019, and then predict activity in 2021 and 2031.

Secondly, the increased bike riding participation, brought about by improvements to the bike infrastructure network were modelled. This modelling was based on projected growth in bike riding participation along each origin-destination link, due to infrastructure changes. This was modelled using regression analysis of existing observed travel mode share (as determined from analysis of ABS Census data) as the dependent variable, and four independent variables used as the predictors:

1. Distance: the length of the line between centroid of the origin SA2 and centroid of the destination SA2;
2. Bike Use Propensity: the propensity for cycle use of the link, determined by seven key demographic factors closely correlated to bike riding activity (See *Appendix 1: Bike Use Propensity Index* for further information).
3. Time Competitiveness: the ratio of bike riding time to that of the main travel mode of each link, calculated from VISTA's travel times (See *Appendix 2: Time Competitiveness* for further information); and
4. Attractiveness of infrastructure: the attractiveness of the link to bike riding, based on the Near Market report's findings, weighted to the network wide attractiveness of each SA2 in the link.

Each section of the network was coded with an existing and future infrastructure type. This allows a coding of *existing attractiveness* and *future attractiveness* of each network section. The attractiveness is based on City of Melbourne's Near Market research findings (see CDM Research & ASDF Research, 2017), showing that there is a higher level of attraction to bike riding when physical separation from motor vehicles exists. The distance weighted attractiveness of each section of the network was used to generate a SA2 wide attractiveness for east-west and north-south travel. This attractiveness score was joined to each link, weighted to the length of that link in each SA2. This generated an attractiveness of the link as a whole. This allowed the regression model to assess the attractiveness of each link, in relation to each other link, to assess how much of a difference to mode share the infrastructure attractiveness of the journey is (the other three variables, which all show correlation towards bike riding participation, were included to attempt to isolate the role that *infrastructure* has in attracting people to ride).

The calculation emerging from the regression modelling was used on each link, to project a modelled bike riding mode share of the link under existing conditions. Secondly, the calculation was used to estimate bike riding mode share under changed infrastructure. It should be noted that, as these are computer generated models of mode share, there was divergence from observed travel patterns, likely due to many exogenous factors such as cultural attitudes towards bike riding, which are not possible to quantify with reliability. For this reason, we have used the difference between an existing and change scenario as a projected mode share shift to bike riding. For instance, if a link is modelled to have a current mode share of 12% bike riding, increasing to 15% with improved infrastructure, but it is observed that currently the link has a 20% mode share, only the difference of 3% is modelled as the increase, projecting a future 23% mode share.

The change in mode share was then projected across all links and joined to each SA2, which was then assigned to the street network (using the Baseline as existing activity), based on future attractiveness. VISTA data was analysed to determine the ratio of commute trips to all trips, with the resulting ratio used (1 in 5 trips) to scale up bike riding activity, projecting total bike riding activity. This allowed for projected increases in bike riding, both from population growth, and infrastructure improvement, to be separately projected, and modelled to occur on streets with the greatest attraction. An integrated network flows from this, whereby improvements to the network allow a redistribution of bike riding, lowering the demand on some links. For instance, the installation of new or improved infrastructure parallel to existing routes of high demand will attract both new and existing bike riders, lowering the potential demand along current infrastructure corridors. In essence the model is able to draw bike riding activity towards newly improved network sections. An example of this is shown in Figure 19, where there is a projected decrease in ridership on Faraday Street, Carlton if the proposed network is constructed. This is because Grattan Street is proposed to be upgraded to separated lanes. The increase in riders along Grattan Street are not purely due to riders shifting from Faraday to Grattan, but also incorporate other trips such as Rathdowne to Grattan, Barkly to Grattan among others. This is consistent within known behaviours, where people on bikes will deviate from the shortest route in order to use higher quality infrastructure (Winters et al., 2010).

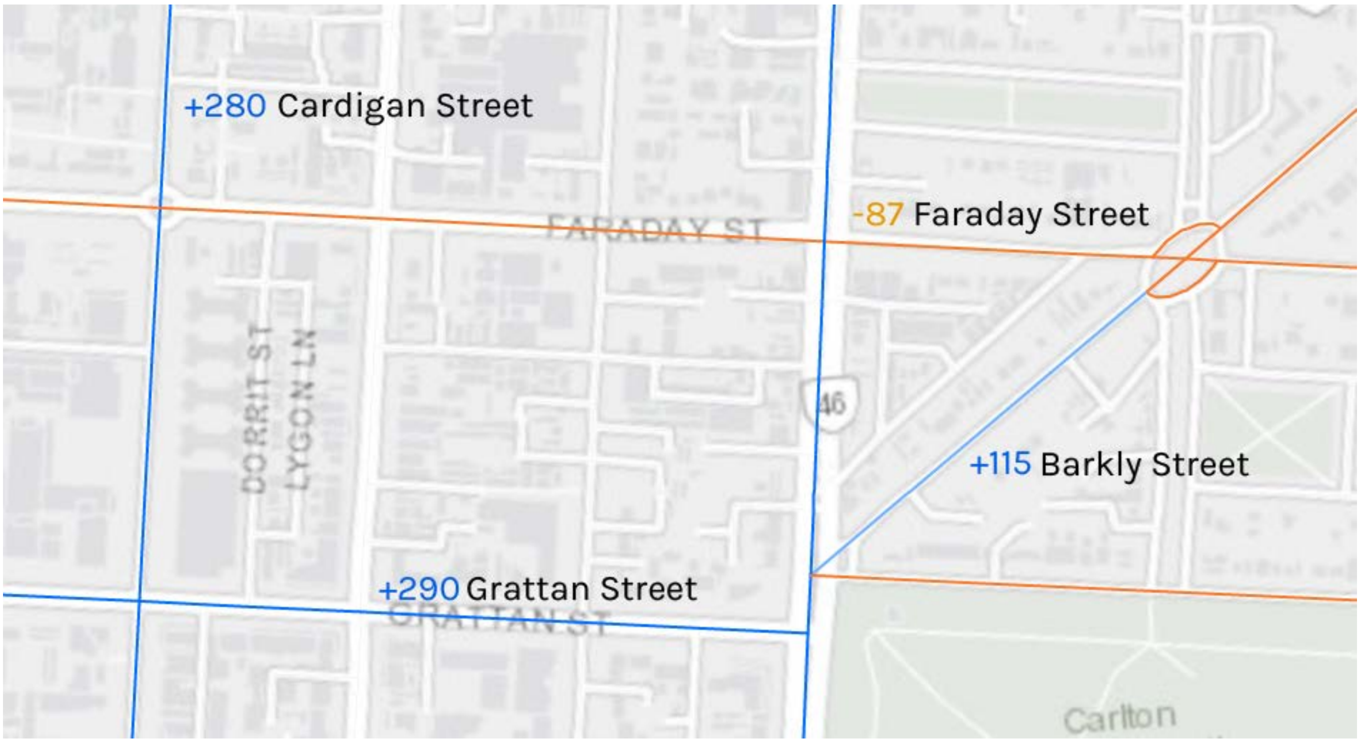

Figure 19 Example of how the model draws riders to more attractive infrastructure

Nb. This image is illustrative only and may not represent the most up-to-date projected changes in bike riding volumes

The combination of these two elements of this module allow for projections of bike riding kilometres travelled under the following scenarios, per SA2 and per network section, as shown in Table 6.

Table 6 Modelled scenarios

2019	2021	2031
Base line	No Build	No Build
Base line	Full Build	Full Build

3.3 Bike Rider Safety Module

The bike riding safety module uses the baseline bike riding activity module to calculate risk profiles for different bike riding infrastructure typologies. This delivers a network-wide risk to people riding, based on 100,000 bike riding kilometres travelled, from observed crash data (police reported crashes using the Crash Stats data base). The risk profile modelled is shown in Table 7. An unexpected finding from this analysis of the data was that *buffered* had a similar crash risk to *painted* lanes. A very small sample size and the fact that buffered lanes are generally installed on streets of relatively high risk may help explanation for this finding.

Table 7 Crashes per 100,000 Cycling Kilometres Travelled (CKT), IMAP

	Nothing	Painted Lane	Buffered Lane	Separated	Blvd
Crashes per 100K	1.2	0.8	0.8	0.5	0.3

This bike infrastructure safety profile is the basis for understanding risk profiles of the future network, in 2031, under a *no build* scenario and *full build* scenario. The change in risk profile is overlayed to the existing risk profile of each street. By scaling existing road trauma by the differential in road safety observed across the network, the model recognises that some network sections will be below average for crashes per 100K CKT, while others above average. Again, there are numerous factors which are not possible to accurately model (such as, road width, presence of tram tracks, frequency of side streets, crossovers, etc).

This module produces a total output of bike riding kilometres travelled, along each bike riding network type/road classification combination, and the number of modelled crashes predicted to occur in 2031. Comparison of the 2031 *no build* and *full build* scenarios provides a robust basis for future cost benefit analysis of bike riding infrastructure.

3.4 Population Growth

Population growth rates at the SA2 level were applied to the model, using figures from ID. Population figures from 2016, 2019, 2021, and 2031 were used to determine current and projected bike riding volumes. First, trips were scaled up from 2016 (Journey to Work Census data) to 2019 to estimate current bike riding. This was scaled up again to 2021 and 2031. This provided the basis for a *'No Build'* baseline to determine what changes to people riding bikes is expected to take place purely due to population growth.

4. Existing and Proposed Infrastructure

Understanding the existing and future bike network is the key aspect that this Model uses to estimate changes to the number of people riding bikes. These were sourced from each Council and the State Government and verified through desktop analysis and staff knowledge of the bike network.

Figure 20 shows the existing bicycle network in IMAP, while Figure 21 shows the future network.

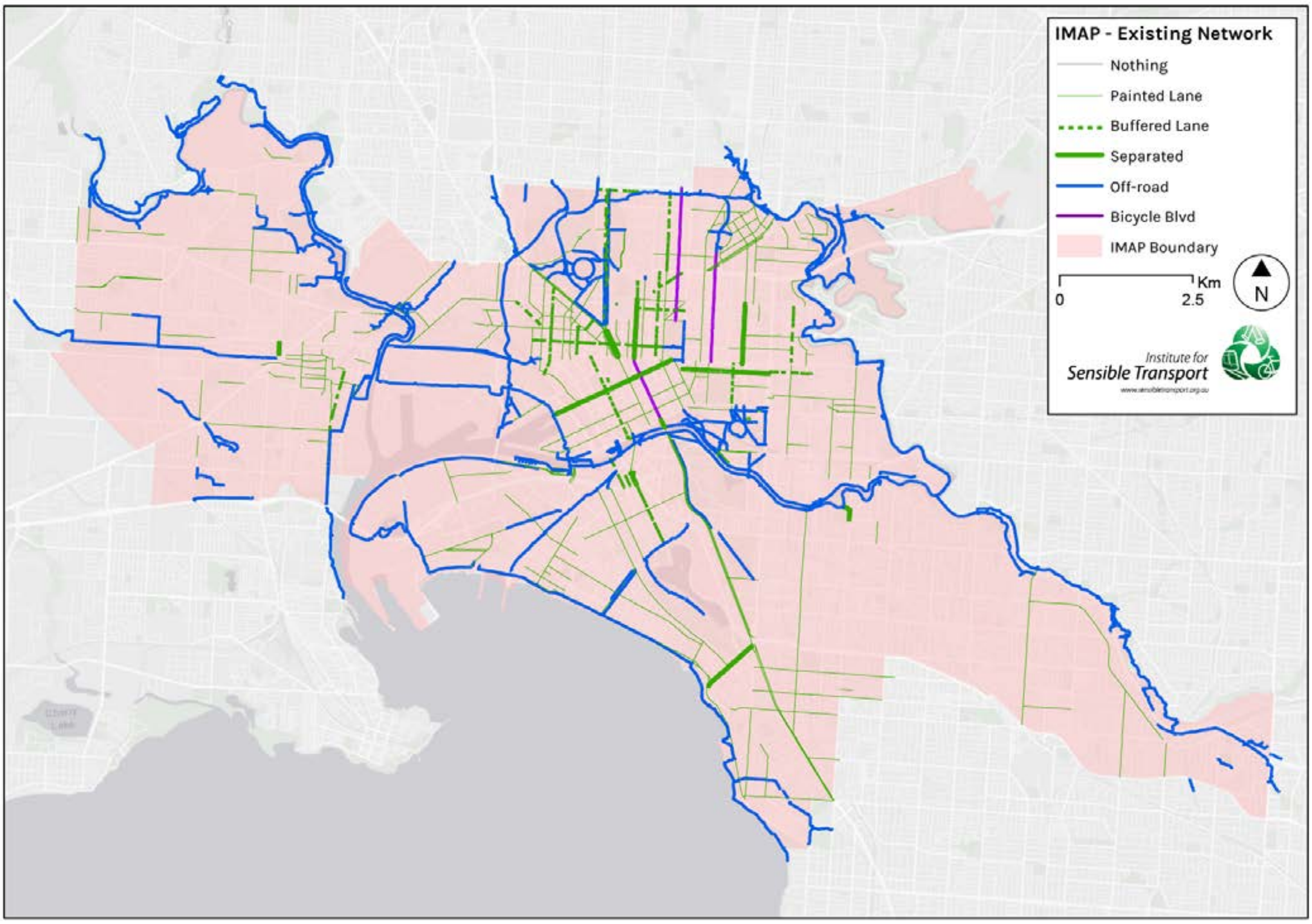

Figure 20 Existing Bicycle Network IMAP

Source: Based on data supplied by IMAP member councils

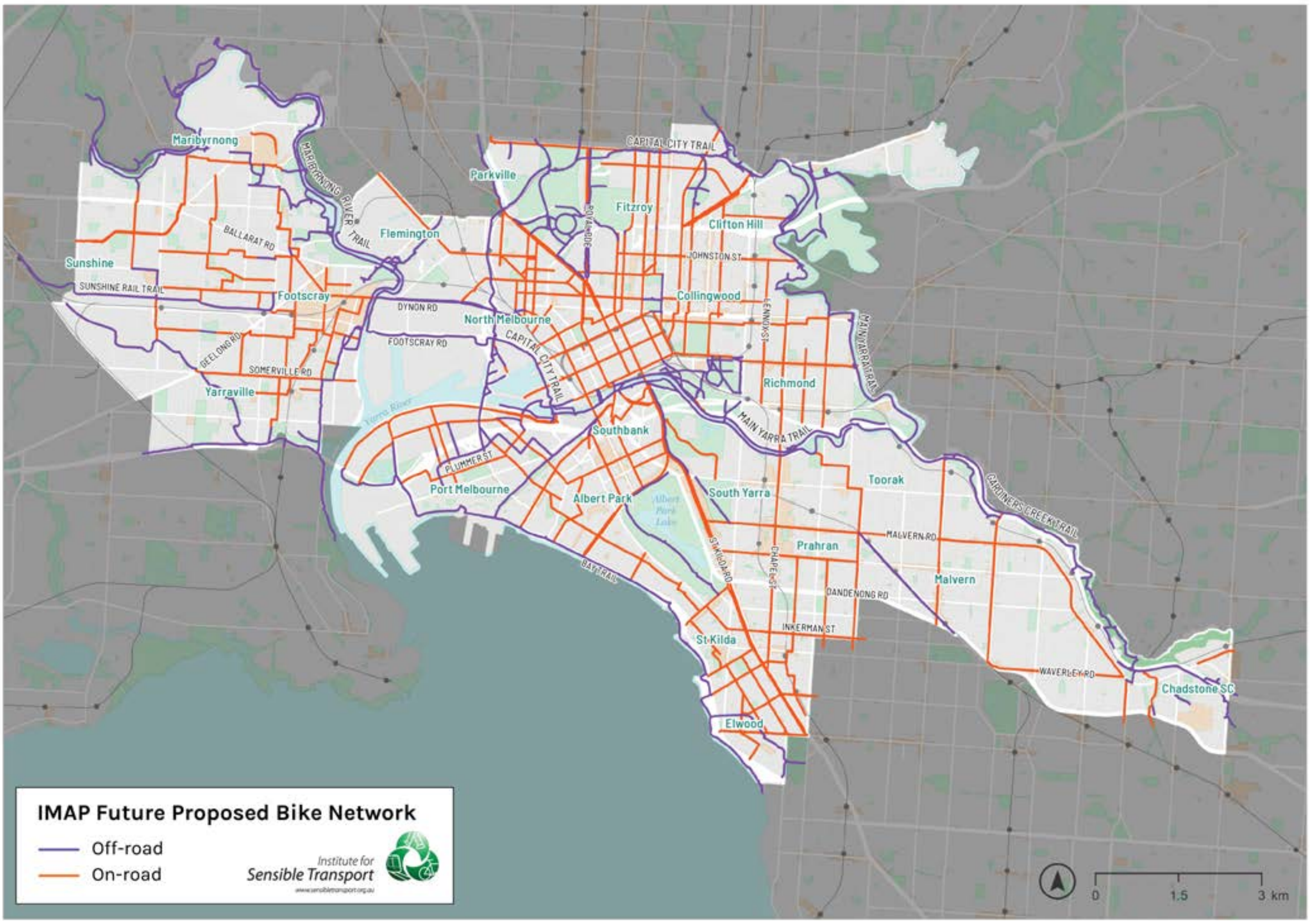

Figure 21 Future Bicycle Network IMAP

Source: Based on data supplied by IMAP member councils and the Department of Transport

The future bike network offers a denser set of protected bike routes across much of IMAP. Figure 22 shows the breakdown in new bike infrastructure by infrastructure type, for each IMAP council. The vast majority of the proposed infrastructure is separated on-road facilities, making up 85% of all new infrastructure.

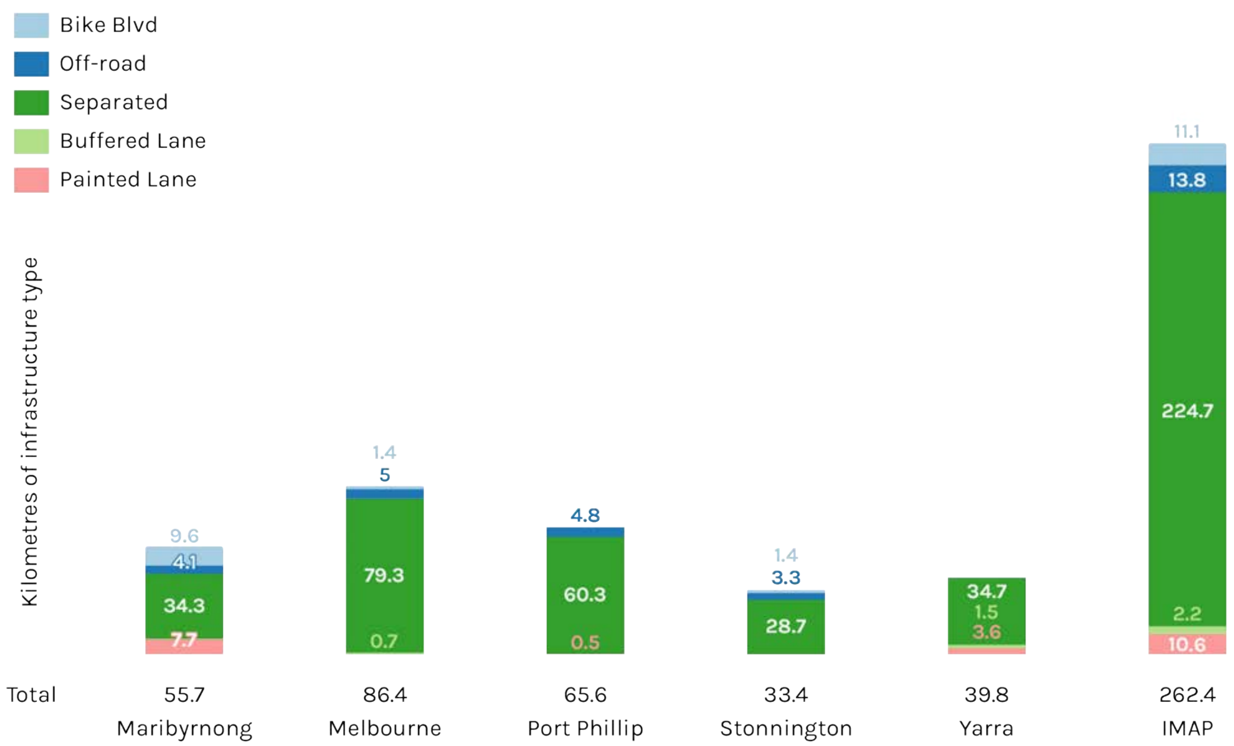

Figure 22 Kilometres of new bike infrastructure, by type and LGA

5. Bicycle Network Model

This section will provide an analysis of the results of the Bicycle Network Model. The model includes the five scenarios shown in Figure 23.

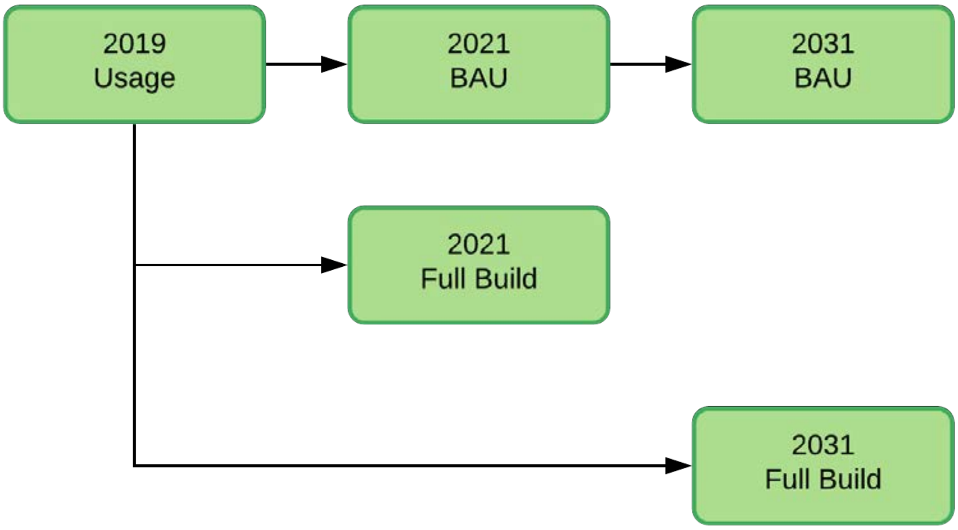

Figure 23 Model scenarios

The 2019 model provides a baseline of current bike riding usage across each street within the study area. Then, two business as usual (BAU) scenarios were modelled for 2021 and 2031. These BAU scenarios assume no new additional bicycle infrastructure. Increases in the number of people riding bikes come from population growth only. The final two scenarios show the changes in bike riding volume based on new bike infrastructure. For simplicity, it is assumed all proposed infrastructure is constructed by 2021 and projected population changes are applied. Then for the 2031 scenario, additional forecast population changes are applied. Finally, comparisons between the BAU and the full build, for both 2021 and 2031 will be provided to illustrate the areas within IMAP that are set to see the largest increases in bike riding. Figure 24 illustrates the estimated distance travelled in 2031 in two scenarios; with the network as it is now, and under the completion of the proposed network. Overall, is shows a 21% increase in cycling, should the proposed network be built. As will be shown in Figure 32

It is important to recognise that while the growth in estimated CKT may appear modest under the full build, this is partly a consequence of the model only considering changes to the infrastructure network *within* IMAP.

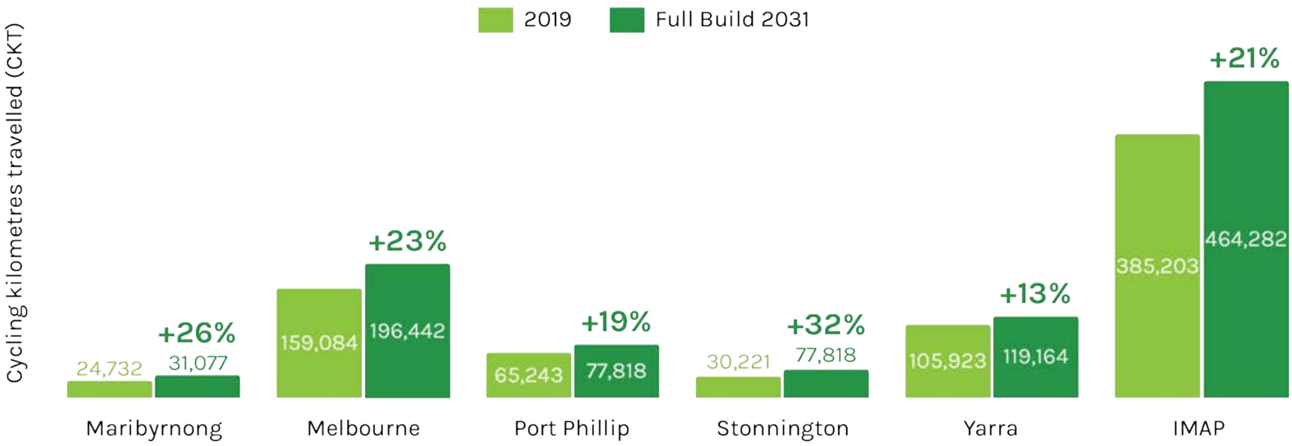

Figure 24 Increase in Cycling Kilometres Travelled (CKT) due to infrastructure changes

Table 8 provides the model outputs for the estimated change in daily cycling kilometres travelled across the different modelled scenarios. These scenarios show a growth in cycling, both from population growth, and the impact that infrastructure plays to encourage more people to cycle. Overall, if the full network is built, there is an estimated 60% growth in cycling by 2031, compared to 2019.

Table 8 Estimated change in daily Cycling Kilometres Travelled

Area	2019	No Build 2021	No Build 2031	Full Build 2021	Full Build 2031
Maribyrnong	19,987	20,858	24,732	26,000	31,077
Melbourne	108,253	119,164	159,084	149,630	196,442
Port Phillip	57,773	59,515	65,243	70,859	77,818
Stonnington	25,281	26,307	30,221	34,850	39,783
Yarra	77,111	83,420	105,923	94,800	119,164
IMAP	288,404	309,265	385,203	376,139	464,282

5.1 Baseline 2019

The first scenario provides an estimate of current bicycle volumes across the study area. This is the baseline for which the remaining four scenarios are built, based on the methodology described in 3.1 of this report. Figure 25 shows the estimated daily bike riding volumes on each street within the study area. The model estimates 288,404km of bike riding to currently occur each day within IMAP.

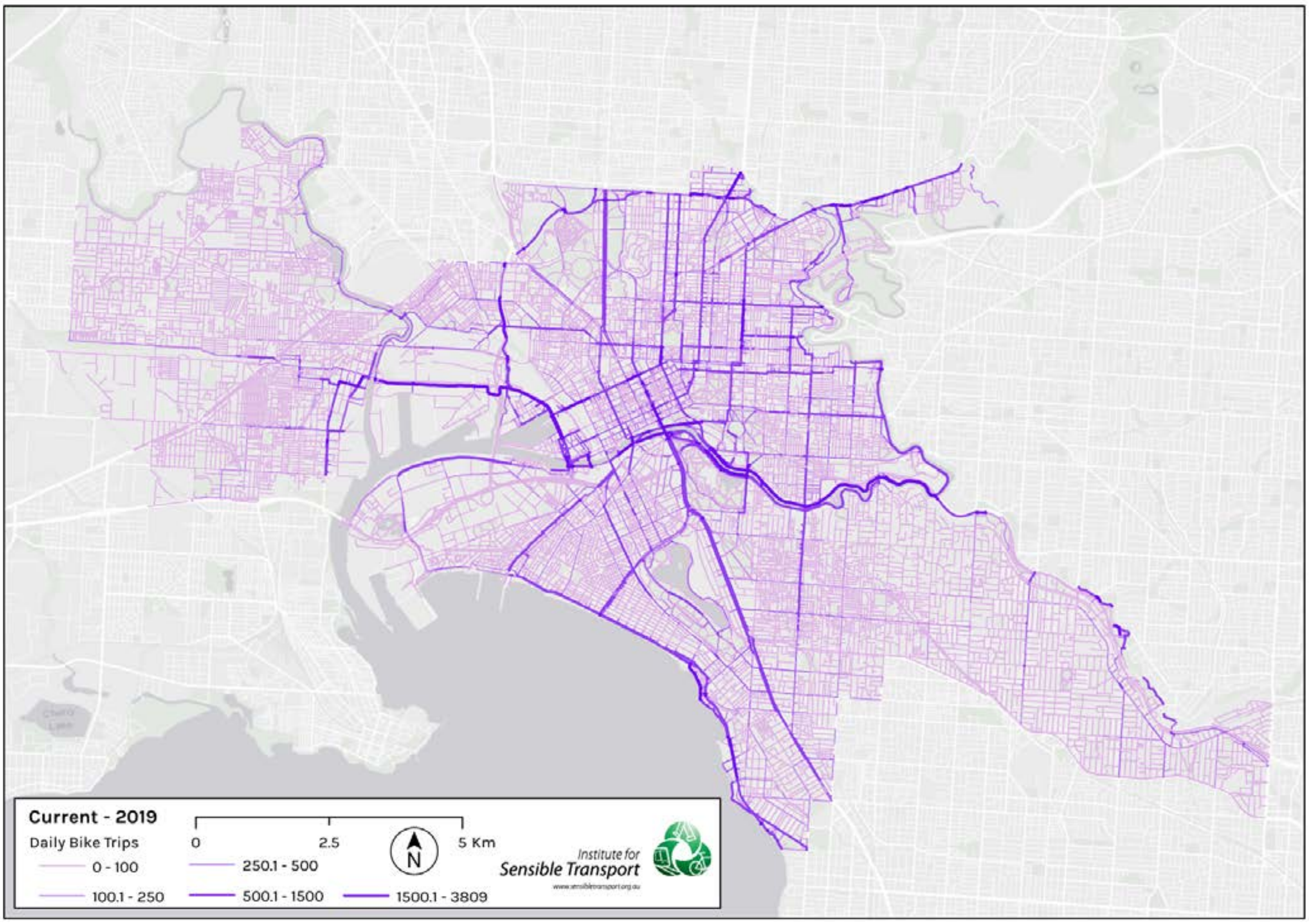

Figure 25 Estimated bicycle usage 2019

5.2 No build 2021

This scenario shows the estimated increase in bike riding volumes as a result of population growth to 2021. Under this scenario, no additional infrastructure is built. An estimated 309,265km of bike riding is modelled to occur within IMAP each day, with an indication of riding volumes shown in Figure 26.

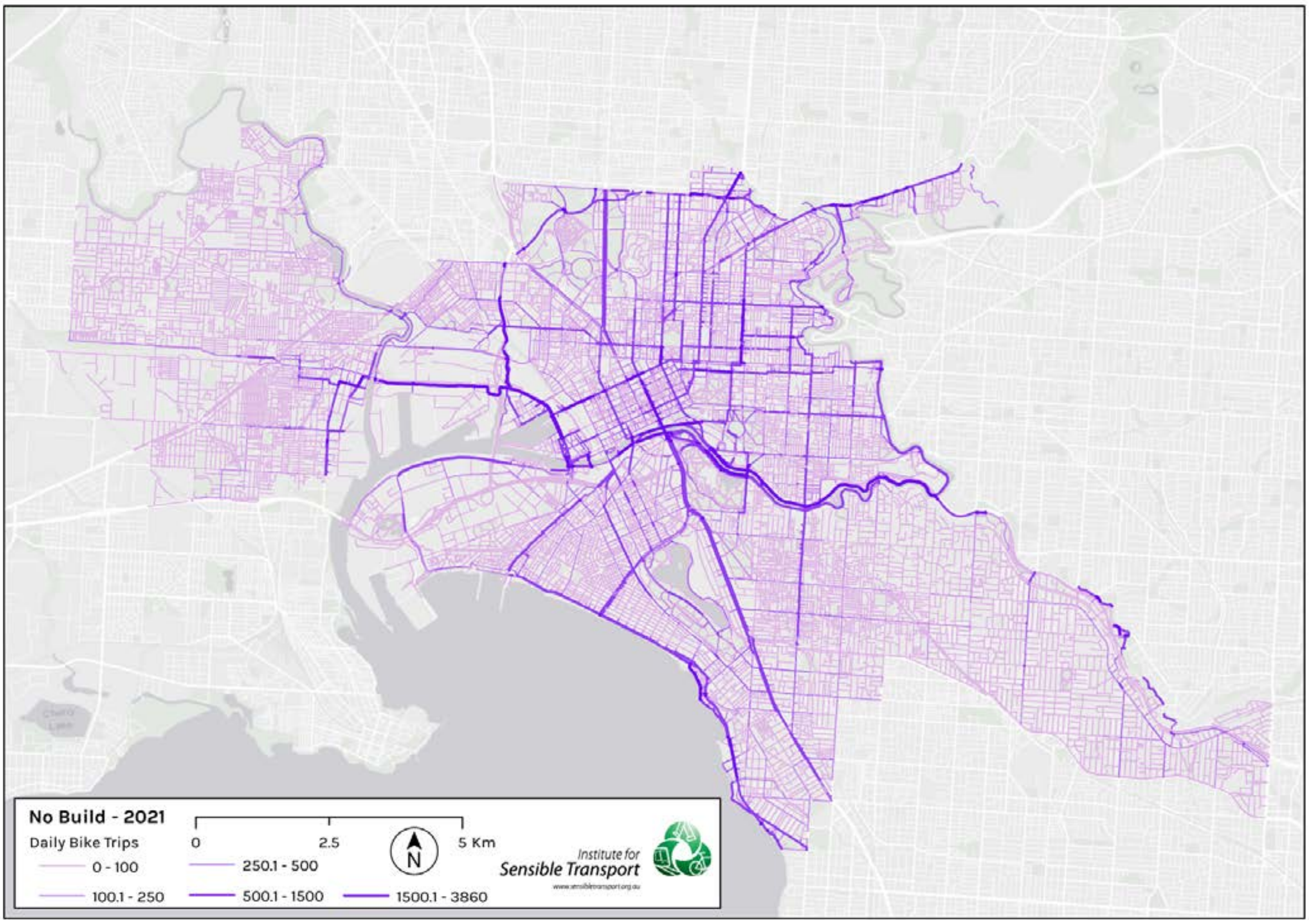

Figure 26 No build 2021 estimated daily bicycle volumes

5.3 No build 2031

This scenario shows the estimated increase in daily bike riding volumes as a result of population increases to 2031. Under this scenario, no additional infrastructure is built. An estimated 385,203km of bike riding is modelled to occur within IMAP each day (see Figure 27).

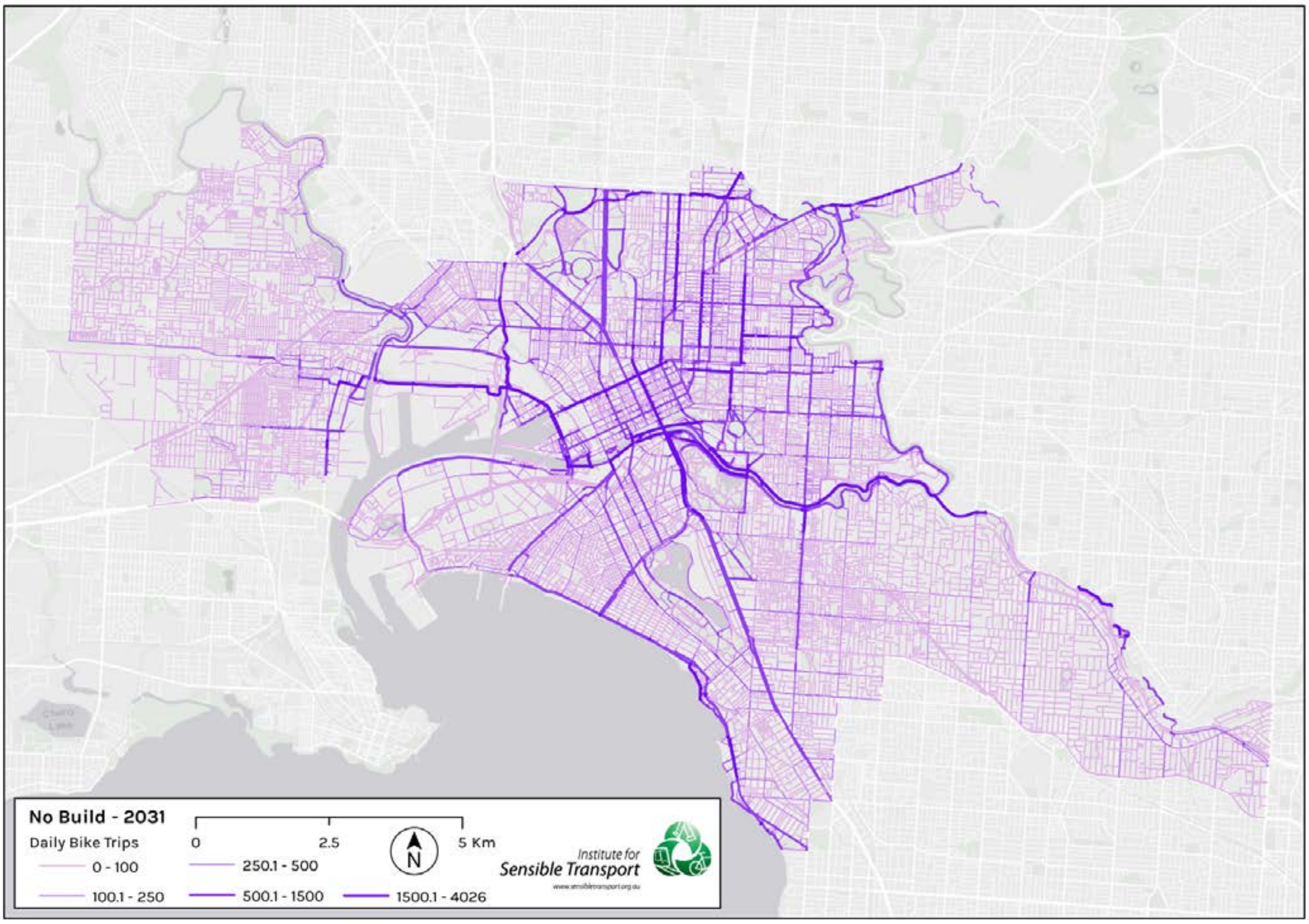

Figure 27 No build 2031 estimated daily bike volumes

5.4 Full build 2021

This scenario assumes that all the proposed bike infrastructure is constructed by 2021 and includes population growth from 2019 to 2021. Under this scenario, an estimated 376,139km of bike riding is modelled to occur within IMAP each day.

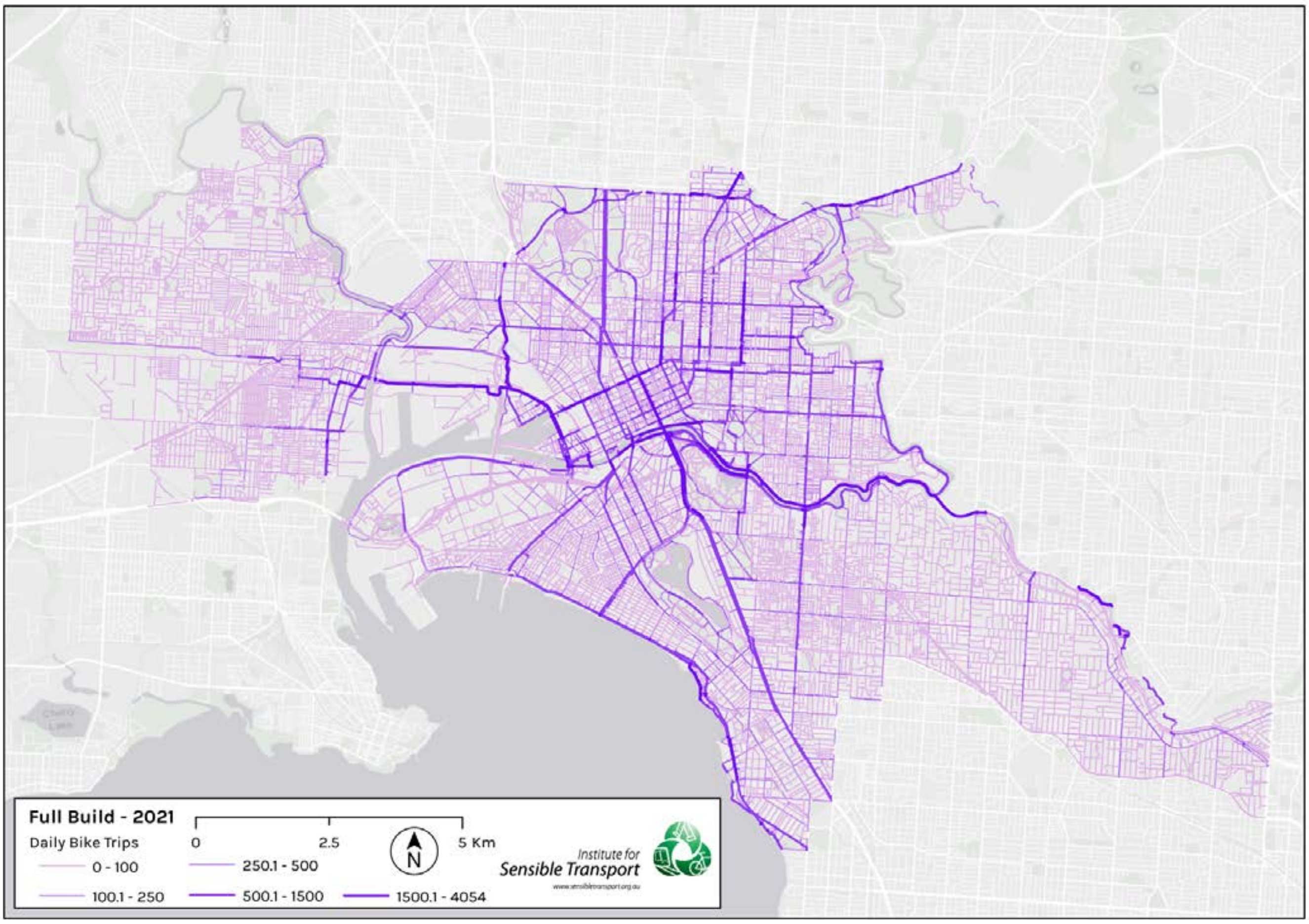

Figure 28 Full build- 2021 estimated daily bike riding volumes

5.5 Full build 2031

This scenario assumes that all the proposed bike infrastructure is constructed by 2021 and includes population growth from 2019 to 2031. Figure 29 shows the estimated daily bike riding volumes on each street within IMAP if all the proposed bike infrastructure was constructed by 2021. Under this scenario, an estimated 464,282km of bike riding is estimated to occur within IMAP. In total, a 60% increase in the number of people riding bikes is estimated to occur compared to 2019 figures and a 20% increase compared to a *No Build* 2031 scenario. This equates to approximately 80,000 additional kilometres of bike riding across IMAP every day, or nearly 30 million additional kilometres over the course of 2031.

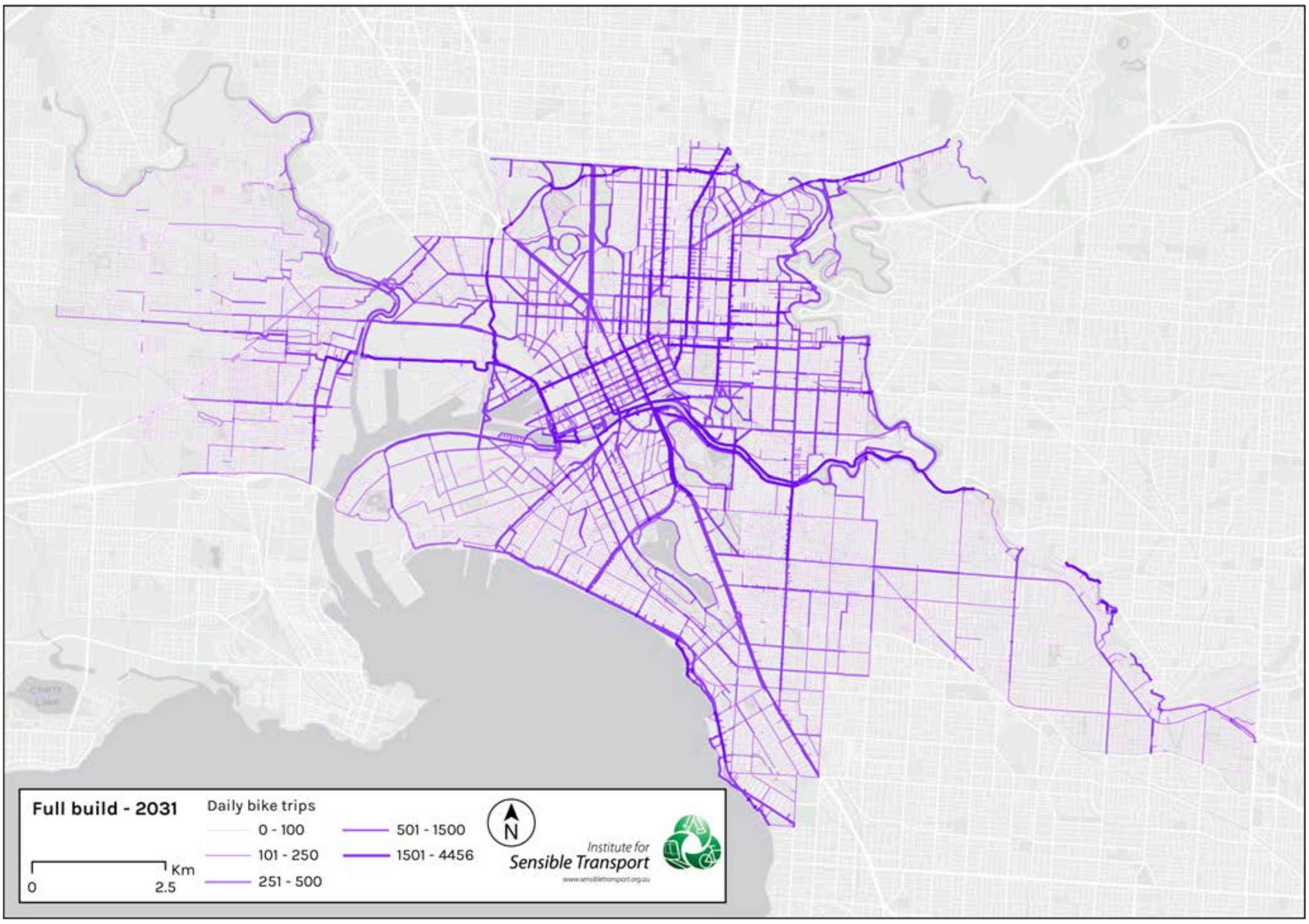

Figure 29 Full build- 2031 estimated daily bike riding volumes

5.6 Full Build 2031 – High Change

The Full Build 2031 scenario includes additional factors likely to take place as a result of building the network. These additional factors include:

- A 5% decrease in travel time for bike riders as a result of improved infrastructure, more direct routes, and traffic light sequence priority at key intersections.
- A 5% increase in motor vehicle travel time due to increasing congestion (based on Infrastructure Victoria modelling) within inner-Melbourne by 2031, improving time competitiveness for bike trips relative to car trips.
- A 10% contraction in perceived distance travelled as a result of increase e-bike usage due to improved infrastructure and e-bike promotion policies.

These three factors, when input into the model, result in a doubling of infrastructure induced bike activity. These results highlight the importance of including additional elements that contribute towards the three above factors when upgrading bike infrastructure to ensure the maximum uplift in bike usage is being achieved. Change in bike riding

Figure 30 provides a summary comparing the estimated bike riding in 2019, and under the full build in 2031, for each of the LGAs that form the IMAP, and for the IMAP region as a whole. When the proposed network is fully built, there will be an estimated 82% growth in cycling activity across the IMAP region, compared to 2019. The variation between different LGAs relates to; a) existing cycling levels, b) the extent of their proposed network, and c) population growth forecasts.

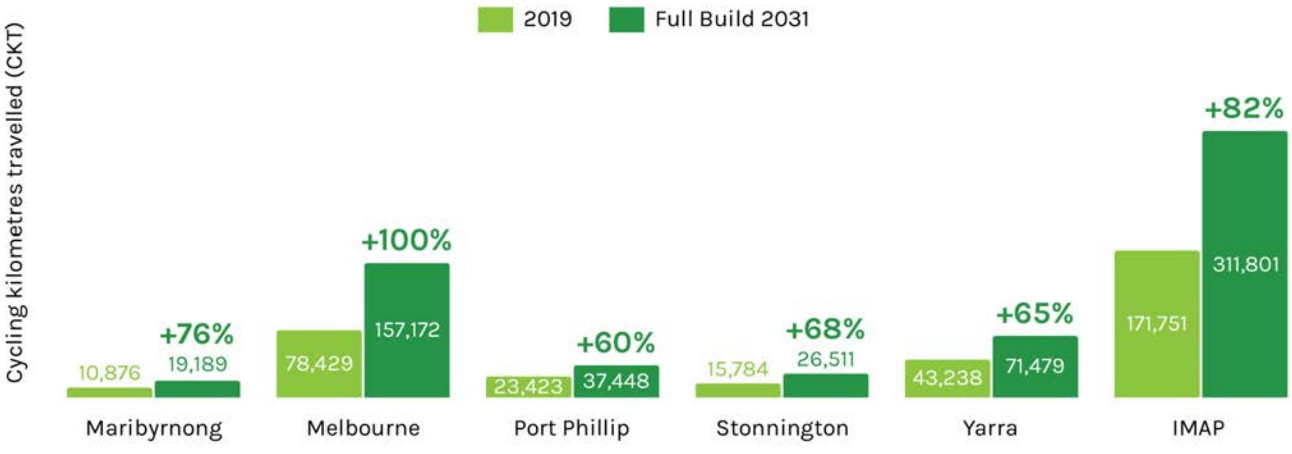

Figure 30 Increase in Riding on Future Proposed Network

When viewing the numbers shown in Figure 30, note that the modelling only considers increased usage from infrastructure improvements *within* IMAP. Infrastructure improvements made in LGAs outside of IMAP are likely to further increase bike riding participation. We estimate that an additional 14,000 CKT will be undertaken outside of IMAP each day as a result of infrastructure upgrades within IMAP. Further, exogeneous factors, such as cultural change, are likely to increase bike riding participation. As such, these are conservative estimates.

When isolating the estimated grow on the new sections of the network, a sharper increase in cycling will occur. Ridership is modelled to increase three-fold and Figure 31 provides an illustration of this.

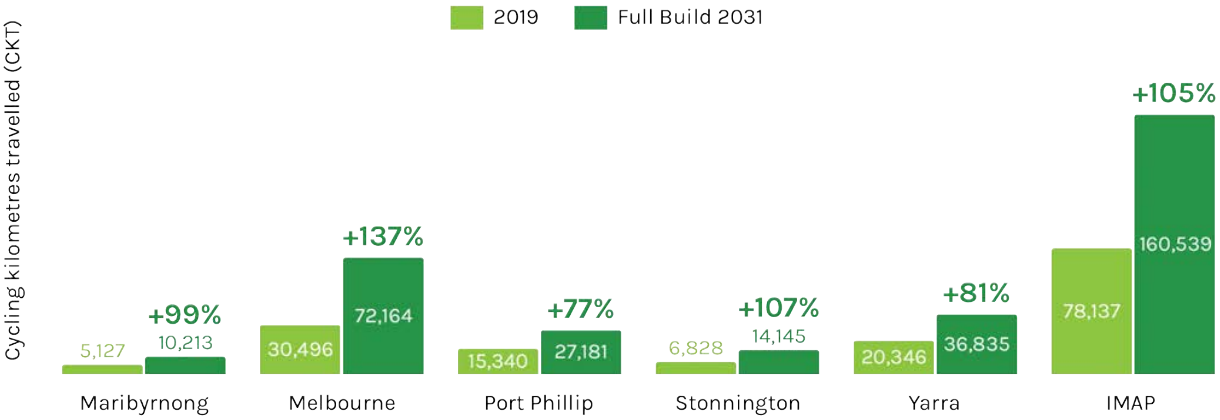

Figure 31 Increase in Riding on New Sections of the Network

Figure 32 shows where the modelled changes in the number of people riding within IMAP at 2031, comparing a *No Build* to a *Full Build* scenario. The majority of the new bike infrastructure is set to see net increases in the number of people riding compared to a *No Build* scenario. There are two key segments that have been identified as *decreasing* under a *Full Build* scenario in 2031 compared to the *No Build* scenario. These are Canning Street, North Carlton and Swanston Street. This model output is due to the creation of new, high quality parallel routes. New bike riders are attracted to these routes, as well as some pre-existing bike riders' diverting to the new route.

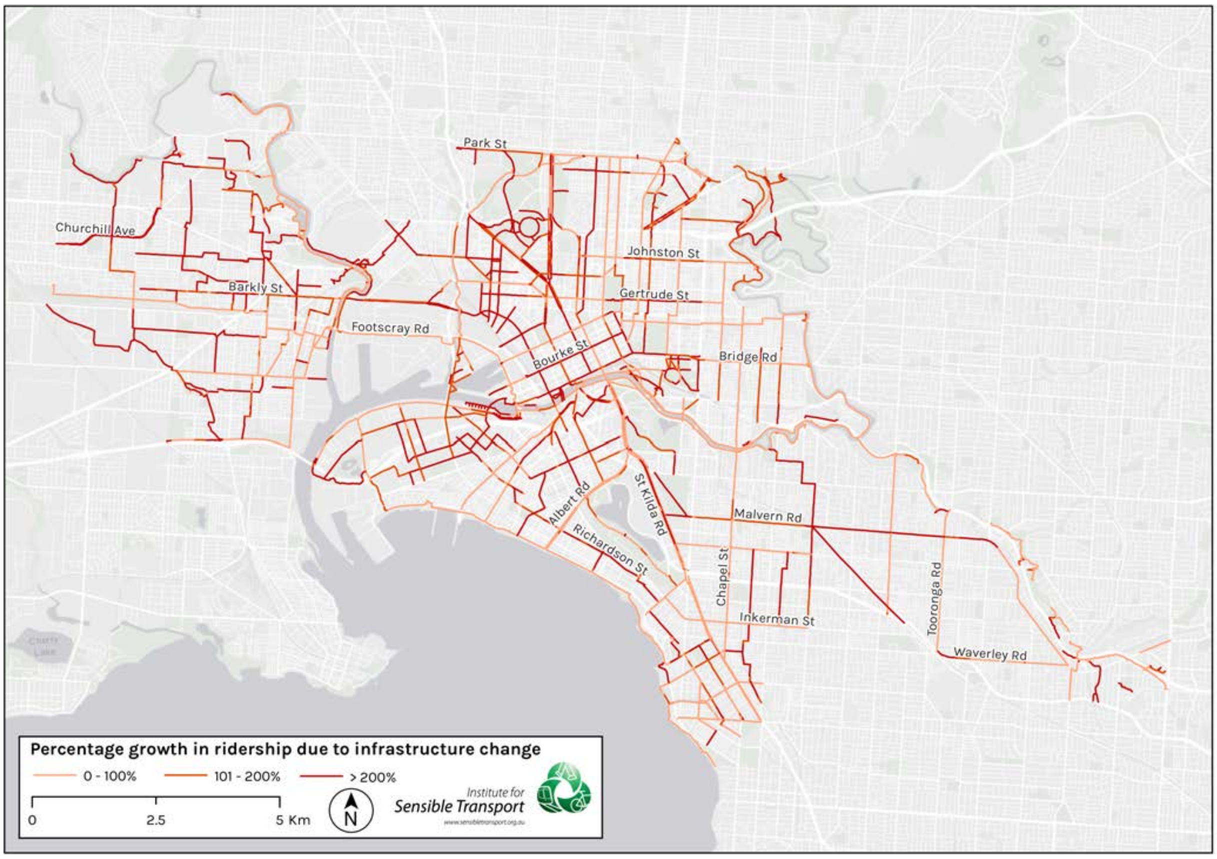

Figure 32 Percentage change in ridership between No build and Full build 2031

5.7 Using the outputs to guide bike infrastructure planning

The model, and the components that feed into the model, provide a range of analysis options beyond its original objectives. This includes highlighting areas with population demographics predictive of latent demand for riding bikes, converting short distance car trips, time competitiveness with other modes, among others. Figure 33 identifies the areas most viable for converting short distance car commutes to bike riding. Where a circle is shown, it indicates trips *within* the given SA2 boundary while the thickness indicates number of trips.

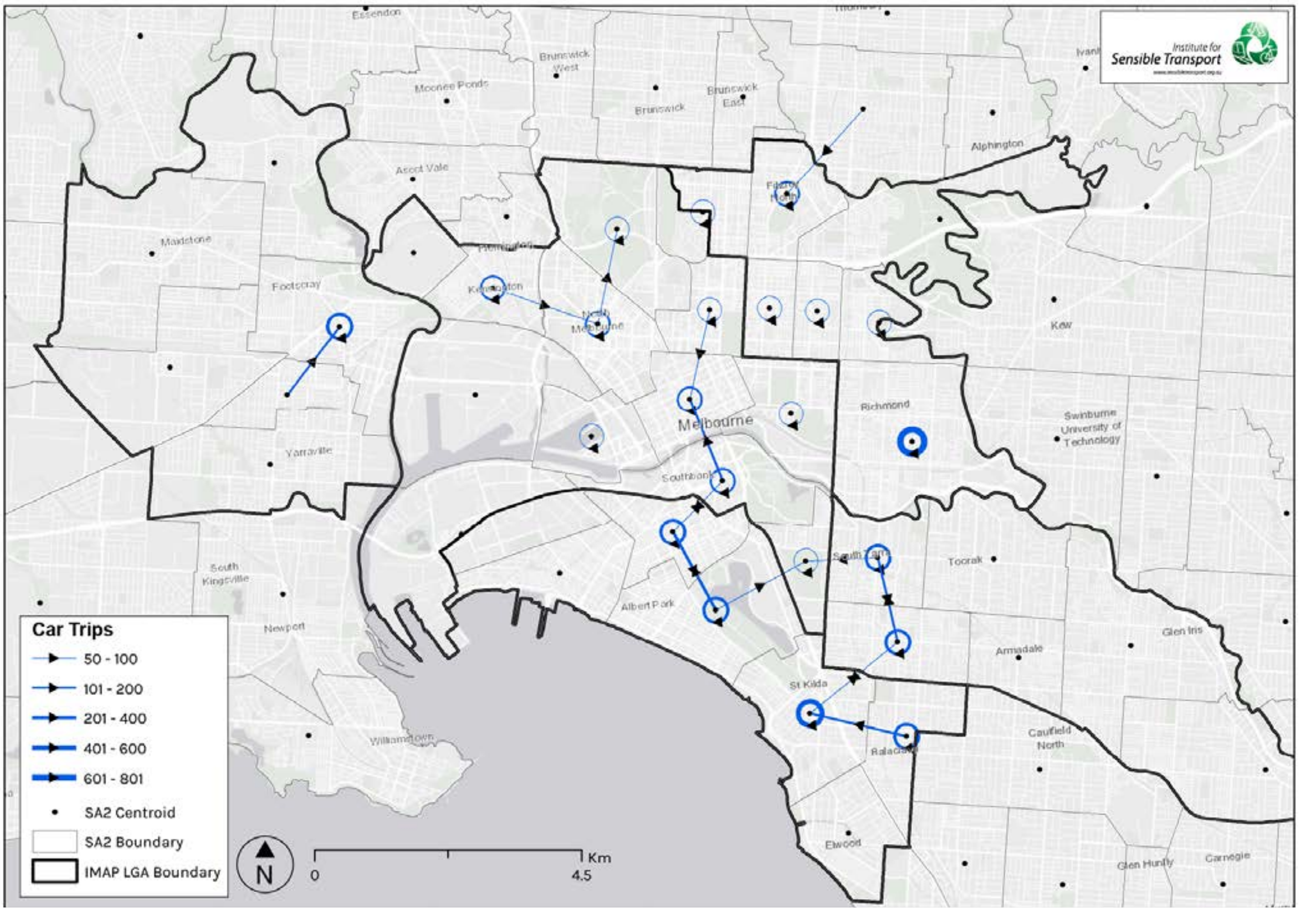

Figure 33 Areas of opportunity for converting car commutes

Nb. Circles indicate trips that start and finish in the same SA2

The map was generated by filtering the following factors:

- Where bikes are currently faster than cars (VISTA analysis)
- Within easily cycle-able distance (<4km)
- Where the demographics are most conducive for bike trips (Propensity Index[3] score of 4 or more)
- Where there are at least 50 car commutes that occur each day.

The Bicycle Network Model can provide a range of different outputs to help guide plans to increase bike riding. The output in Figure 33 helps provide a strategic lens for identifying areas where providing

[3] See Appendix 1 for more information on the Propensity Index.

improved conditions for bike riding is likely to be most effective in shift short car trips. This analysis is not only isolated to bike infrastructure planning but could also help identify areas for public transport improvement.

6. Crashes

Safety, both real and perceived, is a significant barrier to greater levels of bike usage (Bauman et al., 2008, Dill and Voros, 2007, Garrard, 2011, Götschi et al., 2015). This section will present the findings of a high-level analysis of recorded crash statistics involving a person on a bike within IMAP. This will include an overall picture of the number of crashes that occur within each municipality (Table 9), costs to society per crash (Table 10), as well as the estimated cost to society (Table 11). It will then detail bike crashes at a street-by-street level, outlining that 80% of all bike crashes in IMAP take place on 252km (10%) of the road network within IMAP. Many of these crashes are confined to high-risk corridors.

Table 9 Number of crashes in IMAP, last five years to March 2019

	Other injury	Serious injury	Fatality	Total
Maribyrnong	102	31	2	135
Melbourne	948	270	3	1221
Port Phillip	372	130	2	504
Stonnington	272	78	3	353
Yarra	638	173	0	811
IMAP	2332	682	10	3024

Source: Crash Stats (VicRoads, 2019)

Table 10 Cost to society by crash severity

Other Injury	Serious Injury	Fatality
$43,350	$646,933	$9,148,786

Source: https://www.atap.gov.au/parameter-values/road-transport/4-crash-costs.aspx

Table 11 Estimate cost of crashes in IMAP, last five years to March 2019

	Other injury	Serious injury	Fatality	Total
Maribyrnong	$3,359,608	$19,820,831	$18,384,420	$41,564,859
Melbourne	$31,224,592	$172,633,045	$27,576,630	$231,434,267
Port Phillip	$12,252,688	$83,119,614	$18,384,420	$113,756,722
Stonnington	$8,958,955	$49,871,769	$27,576,630	$86,407,353
Yarra	$21,014,019	$110,613,025	$0	$131,627,044
IMAP	$76,809,862	$436,058,284	$91,922,099	$604,790,245

Source: Crash Stats (VicRoads, 2019), and ATAP (Australian Transport Assessment and Planning, 2013) (2013), RBA (2019).

NB: Uses 2018 dollars.

6.1 High-risk streets

As highlighted earlier, this analysis found that approximately 80% of all bike crashes in IMAP take place on only 10% of the road network. The locations of these high-risk streets are shown in Figure 34, with a colour gradient showing the number of crashes in the last five years. Chapel Street, Stonnington recorded the highest number of crashes in the last five years; some 151 recorded crashes have taken place on Chapel Street, with 80 in the Prahran – Windsor section and 71 in the South Yarra section. Using the cost estimates provided in Table 10, bike crashes along Chapel Street in Stonnington have cost society approximately $31 million in the last five years. Approximately 5% (1 in 20) of all bike crashes within IMAP take place on Chapel Street. Other high-risk streets in IMAP include Church Street (Richmond), St Georges Road / Brunswick Street (North Fitzroy/Fitzroy), Elizabeth Street, La Trobe Street, and Collins Street (CBD).

Targeting these high-risk corridors shown in Figure 34 is likely to deliver high-impact results in terms of reducing road trauma.

Figure 34 Streets in which 80% of bike crashes occur in IMAP

Table 12 identifies the streets with the greatest number of bike crashes resulting in an injury and/or fatality in each IMAP municipality. Chapel Street (Stonnington) has the largest number of bike crashes, more than double the street with the second highest number of bike related road trauma.

Table 12 Streets with most bike crash injuries or fatalities for each LGA

Street Name	LGA	Crashes (persons Injured or fatality)
Chapel Street	Stonnington	151
Brunswick Street	Yarra	71
Collins Street	Melbourne	69
Beaconsfield Parade	Port Phillip	31
Hopkins Street	Maribyrnong	8

NB: Time period: Last 5 years to March 2019

Another way to look at bike riding risk is to identify streets based on their crash risk exposure profile. This is the level of risk on a street based on its level of infrastructure, recorded crashes, and volume of bike riding along a given corridor. Figure 35 shows the current crash risk exposure in IMAP, measured as crashes per 100,000 Cycle Kilometres Travelled (CKT). These streets are where there is a current high number of crashes involving a person on a bike, relative to the number of bike riders using the street.

Figure 35 Current Crash Exposure, IMAP

The crash exposure has also been measured for the proposed bike network in IMAP, based on 2031 estimated bike volumes, shown in Figure 36.

It shows where crash risk is likely to be highest based on the level of bike riding along a given corridor. The darker the red along the corridor, the higher the crashes per 100,000 CKT.

Figure 36 Future Crash Exposure, IMAP

Figure 37 shows where the key changes in estimated number of crashes per year are under a full build scenario. These corridors are projected to deliver the largest safety benefits as a result of upgrading bike infrastructure.

Figure 37 Estimate change in crashes per year, IMAP

6.1.1 High crash exposure corridors with no change in infrastructure

Table 13 highlights the top 20 streets with the highest projected crash exposure in 2031 that have no planned change in infrastructure. The crash profile for some of these streets relate to intersection collisions, while others are due to car dooring crashes. Some of these corridors may not be considered suitable for infrastructure upgrades (Hoddle Street, Princes Street, etc) and instead may require a greater focus on alternative corridors and improving intersections. In particular, Richardson / Reid Street, which is ranked number one in Table 13 is due to cross-traffic colliding with north-south bike activity. St Andrews Place, which has a similar number of crashes per 100K CKT, is likely due to conflicts with turning motor vehicles on Macarthur Place. Carlisle Street and Smith Street, however, are primarily due to car dooring crashes.

Table 13 High crash exposure corridors with no change in infrastructure (2031)

Rank	Street Name	SA2	Crashes per 100K CKT
1	**Richardson Street**	Carlton North - Princes Hill	15
2	**St Andrews Place**	East Melbourne	14
3	**Carlisle Street**	St Kilda East	10
4	**Reid Street**	Fitzroy North	8
5	**Kay Street**	Carlton	8
6	**Smith Street**	Collingwood	8
7	**King Street**	North Melbourne	7
8	**Victoria Street**	Melbourne	7
9	**Kings Way**	South Melbourne	6
10	**Hoddle Street**	Abbotsford	6
11	**Racecourse Road**	North Melbourne	6
12	**Ormond Road**	Elwood	5
13	**Toorak Road**	Toorak	5
14	**Alexandra Parade**	Yarra - North	5
15	**Collins Street**	Melbourne	4
16	**Princes Street**	Carlton	4
17	**Simpson Street**	East Melbourne	4
18	**Lygon Street**	Carlton	4
19	**Curzon Street**	North Melbourne	4

7. A street-level case study

This section will provide a case study of one street, to illustrate the potential benefits achieved through upgrading bike infrastructure.

7.1 Chapel Street, Stonnington

Chapel Street, Stonnington was found to be the most dangerous street in IMAP for people riding bikes. It has a relatively high volume of bike riders as of 2019 and is set to increase substantially by 2031. If the corridor was upgraded to separate motor vehicles and people on bikes, it would bring an estimated extra 2,000 bike trips per day. Chapel Street has a high level of existing bike riding despite recording the highest number of bike crashes in the last five years and the highest per kilometre risk of a crash.

In the last five years, there have been a total of 151 crashes involving a bike rider on Chapel Street. Of those, 26 were admitted to hospital and one bike rider was killed. Another 124 crashes involved 'other injuries'. The following points outline the key safety implications for Chapel Street:

- On average, a bike rider is involved in a crash that is reported to police on Chapel Street every 12 days
- For each police reported bike crash on Chapel Street, there is a 20% chance the bike rider will be hospitalised
- Every second bike crash reported to police on Chapel Street is caused by someone opening their car door into the path of a person on a bike
- In the last 5 years, bike crashes on Chapel Street have cost society approximately $30 million[4]
- If no change in infrastructure takes place, the rate of police reported bike crashes on Chapel Street will increase to one every 10 days by 2031
- If no change in infrastructure is undertaken and the same crash trends continue, the projected costs to society resulting from bike crashes on Chapel Street will be $72 million in the next 10 years.

[4] Using the metrics provided by ATAP shown in Table 10 and Table 11.

8. Recommendations

This section provides a suite of recommendations for bike network development within IMAP as well as actions to improve the outputs of the model developed for this project.

8.1 Quick wins

This Bicycle Network Model provided a number of insights at both the strategic level and on a street-by-street basis. A number of routes were discovered to provide the biggest uplift in bike use, relative to other parts of the network. This section will provide the five most important links for each IMAP LGA, based on potential to increase bike riding participation, improve safety outcomes and network cohesion.

8.1.1 Maribyrnong

Figure 38 shows the total estimated percentage growth in Maribyrnong if the full network was constructed, compared to 2019. The model highlighted several corridors where growth in bike riding is projected to increase substantially.

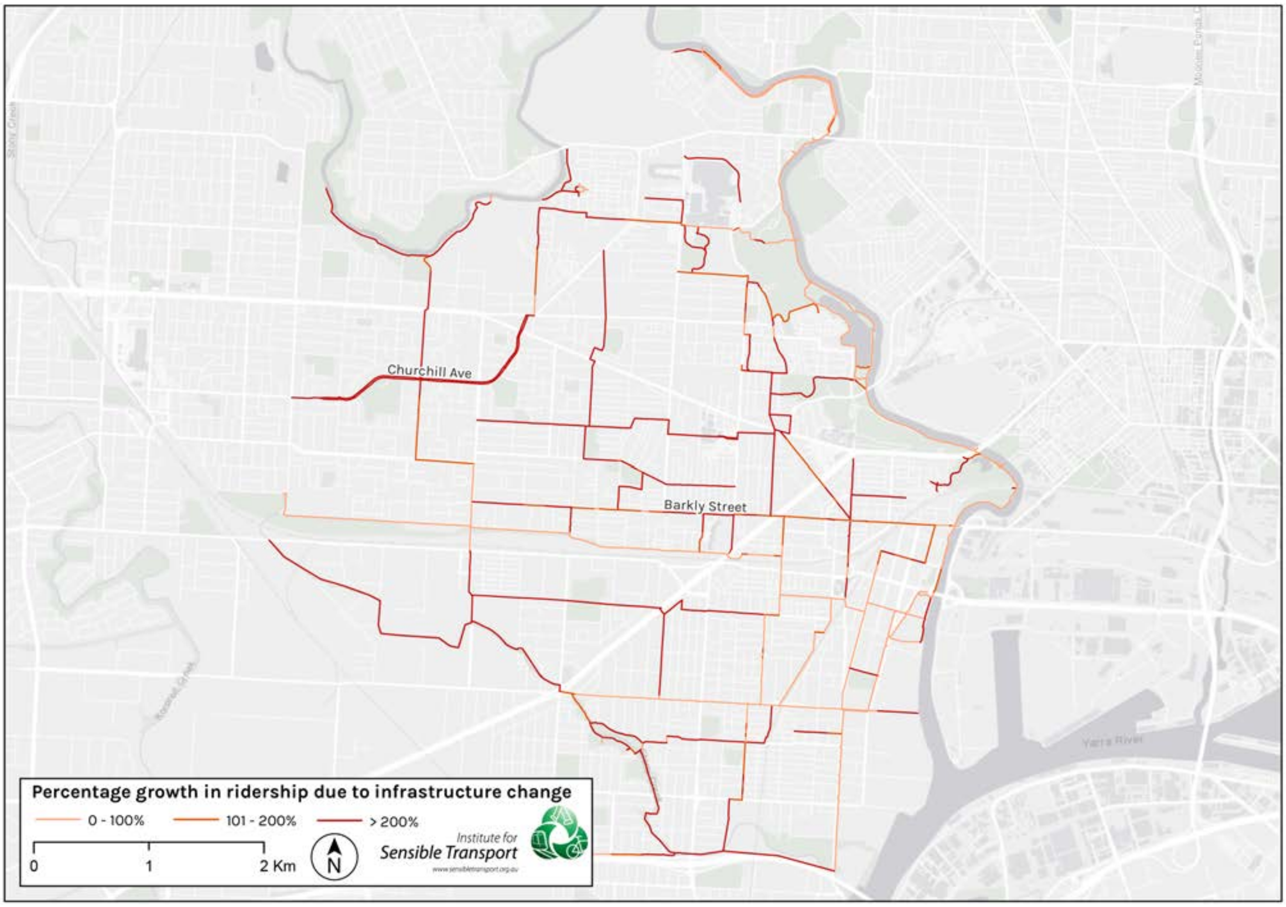

Figure 38 Maribyrnong growth in daily bike trips 2019 to 2031 Full build

Of the streets included in the proposed network, the following streets offer the greatest potential to increase bike riding numbers if infrastructure upgrades were undertaken:

1. Barkly / Hopkins Street
2. Essex Street
3. Jerrold Street
4. Bunbury Street
5. Churchill Avenue.

8.1.2 Melbourne

Figure 39 show the net increase in bike trips in the City of Melbourne between 2019 and 2031 if the full network was constructed.

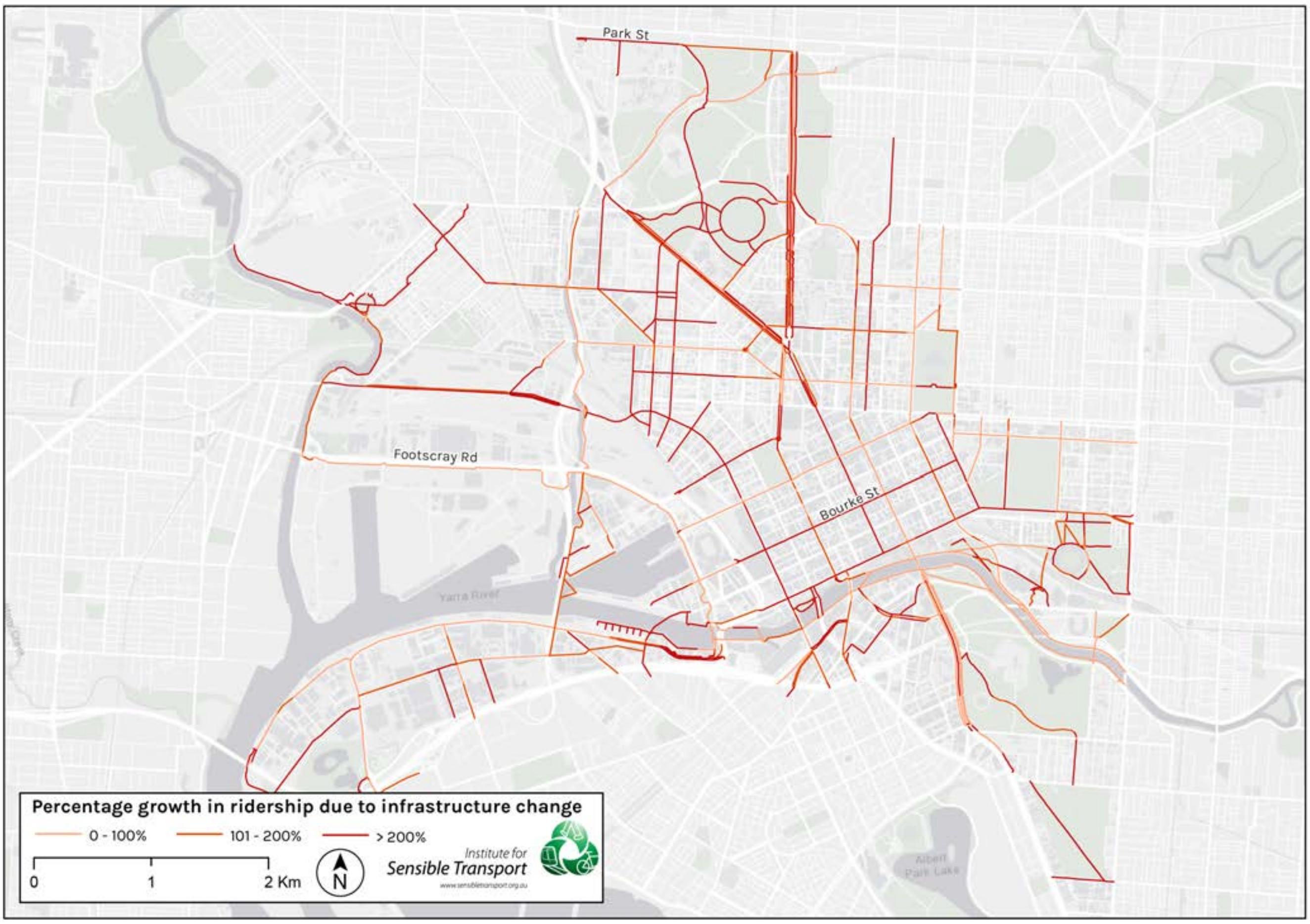

Figure 39 Melbourne growth in daily bike trips 2019 to 2031 Full build

The output from the model highlights the following routes as priorities:

1. Commercial Road
2. Bourke Street
3. Flinders Street
4. William Street
5. Dudley Street.

8.1.3 Port Phillip

Figure 40 provides an illustration of the net increase in bike trips in the City of Port Phillip between 2019 and 2031 if the full network was built.

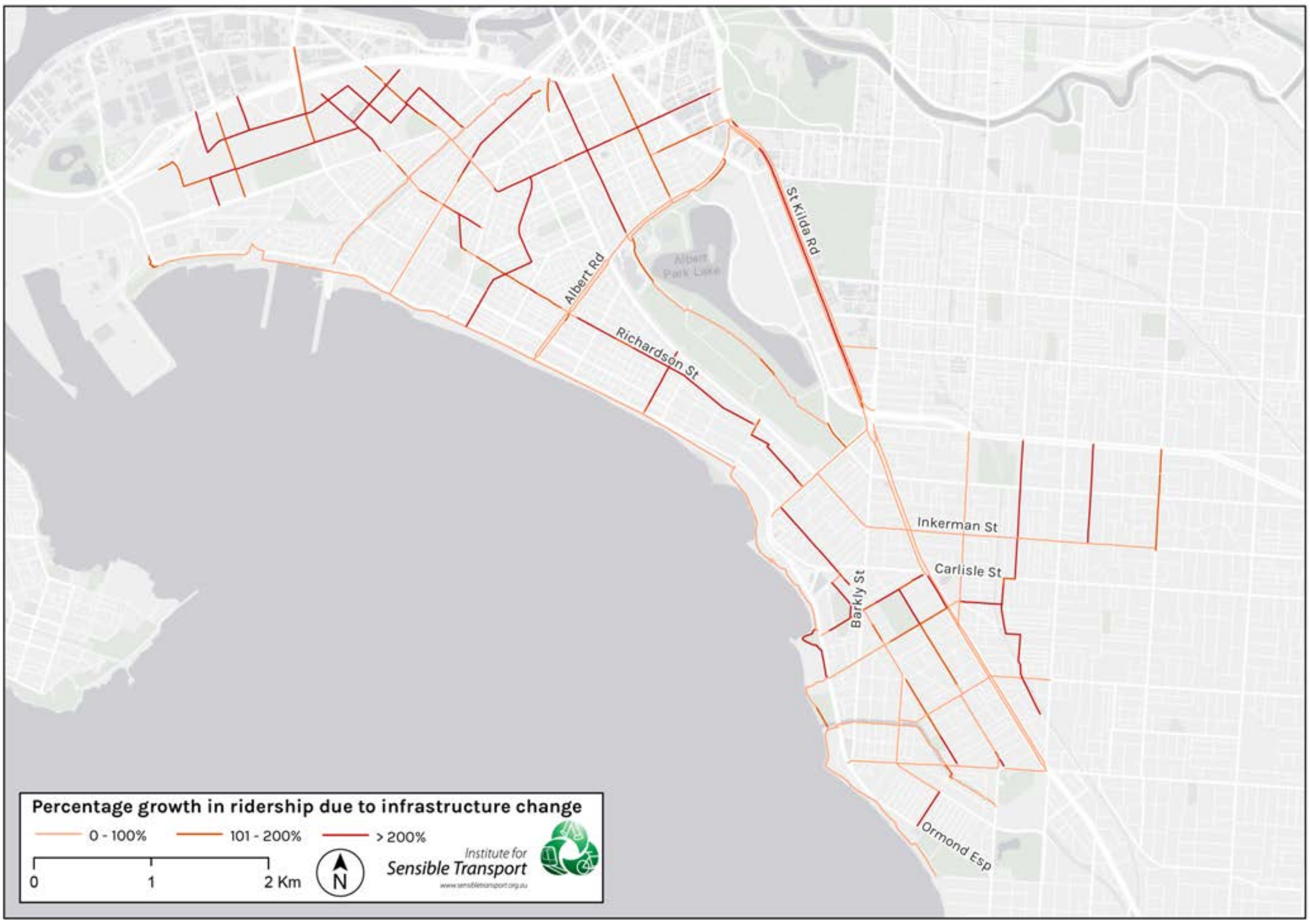

Figure 40 Port Phillip growth in daily bike trips 2019 to 2031 Full build

The output from the model highlights the following routes as priorities:

1. Moray Street
2. Cecil Street
3. Nelson Road
4. Armstrong Street
5. Kerferd Road.

8.1.4 Stonnington

Figure 41 shows the projected net increase in daily bike trips in the City of Stonnington between 2019 and 2031 if the full proposed network is constructed.

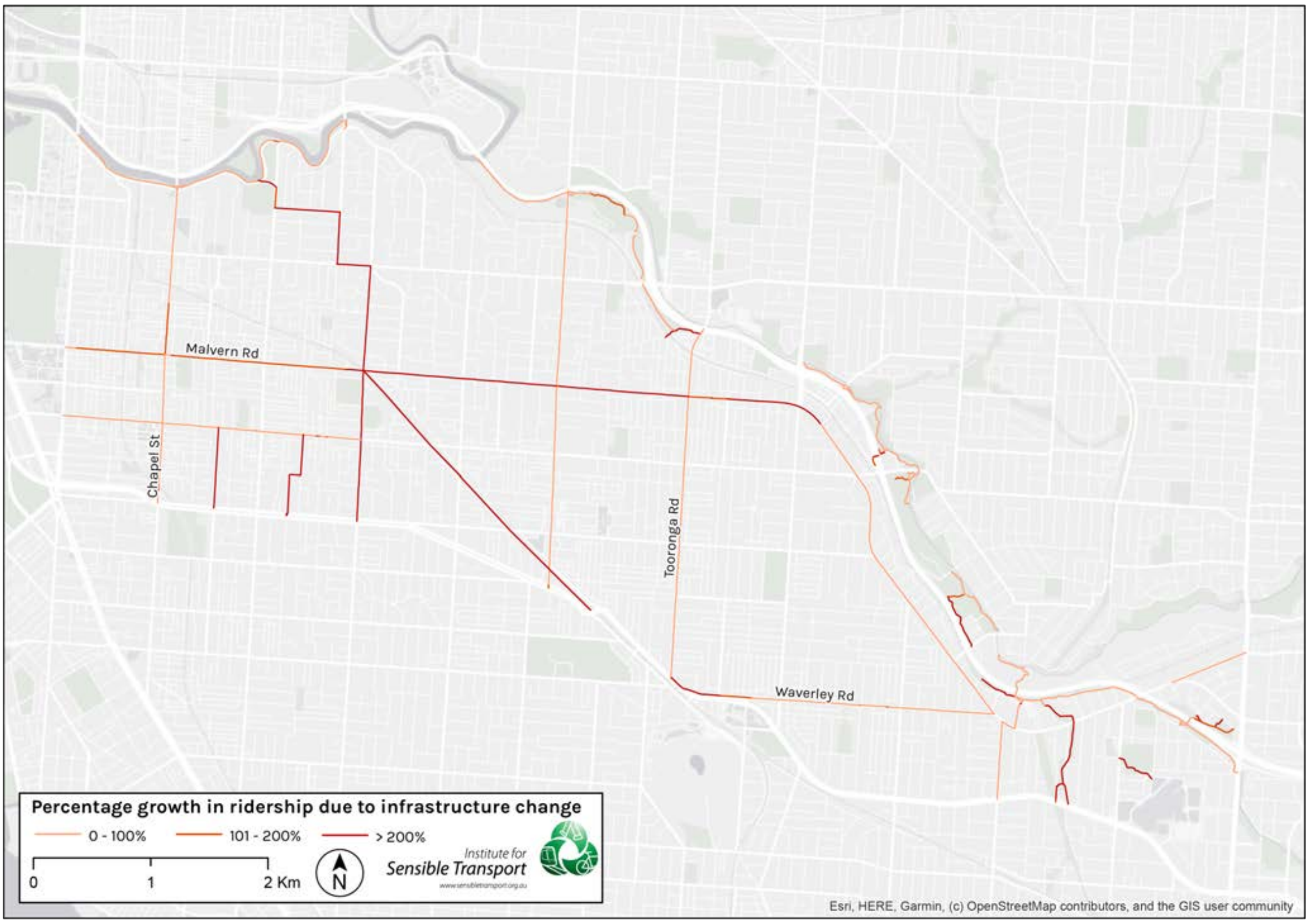

Figure 41 Stonnington growth in daily bike trips 2019 to 2031 Full build

The output from the model highlights the following routes as priorities:

1. Chapel Street
2. Orrong Road / Williams Road
3. Malvern Road / Commercial Road
4. Waverley Road
5. Glenferrie Road

Additional opportunities have been identified, including:

- Toorak Road between Orrong Road and St Kilda Road.

8.1.5 Yarra

Figure 42 shows the projected additional bike trips in the City of Yarra between 2019 and 2031 if the full network was constructed.

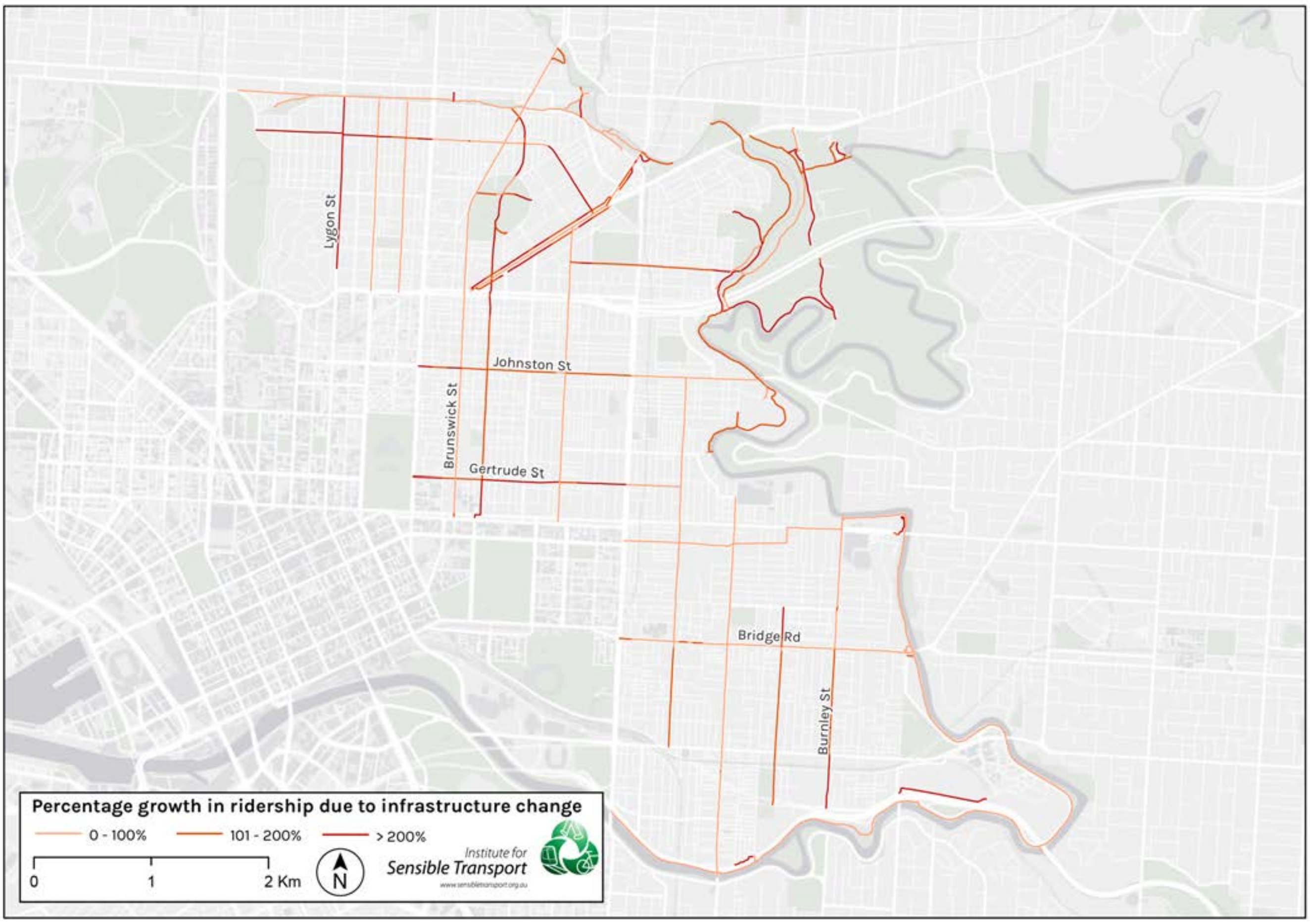

Figure 42 Yarra growth in daily bike trips 2019 to 2031 Full build

Much of the projected growth is modelled to occur on the north-south corridors in the north-west of the municipality. The output from the model highlights the following routes as priorities:

1. Johnston Street
2. Gertrude Street / Langridge Street
3. Brunswick Street / St Georges Road
4. Michael Street
5. Church Street.

Additional opportunities have been identified, including:

- Continuing Church Street separated lane
- Coppin Street and Highett Street
- Heidelberg Road separated cycling infrastructure.

8.2 Target crash heavy corridors

Targeting infrastructure upgrades on the most dangerous corridors is likely to deliver the biggest boosts to safety and ridership. This report has highlighted that 80% of bike crashes take place on 10% of the road network.

8.3 Investigate low-cost separation

Providing low-cost separation is likely to deliver most of the projected uplift at a fraction of the cost of a full street transformation. Full streetscape upgrades should be targeted to high-profile corridors where economic activity would also receive significant benefits from the road upgrade.

Low-cost upgrades could include light separation (E.g. Albert Street, East Melbourne) or filtered permeability (E.g. Napier Street, Fitzroy). Each of these approaches lower crash exposure and increase the attractiveness of a corridor for bike use.

8.4 Investigate corridors where bikes have the advantage

The strongest predictor for bike use uncovered in our model was the *time competitiveness* of bike riding compared to other modes for a given corridor (SA2 to SA2 combination). Identifying corridors where bikes outperform other modes, or undertaking changes that advantage bike riding in terms of time competitiveness would likely see large increase in bike usage.

8.5 Improving the model

8.5.1 More permanent bike counts

The reliability of the model is greatly improved by access to more permanent bike counters. It is recommended that more count sites be included, especially off the key bike corridors, to improve understanding of bike usage across the network and not just on high-volume corridors.

Counts should be conducted pre and post infrastructure upgrade to improve understanding of the role that infrastructure upgrades play in boosting bike riding participation.

8.5.2 Conformity of geospatial data

Each Council and DoT uses its own geospatial datasets for their current and future bike networks. It is recommended that all councils agree upon a standard road network geospatial dataset to ensure the seamless planning and delivery of infrastructure across municipalities. It is recommend Councils use of the TR Road dataset (managed by DoT) as a starting point.

8.5.3 Expand Near-Market Research

The boost rates for this model were based on City of Melbourne commissioned research identifying the stated preference for different infrastructure. It is recommended this be expanded to cover the IMAP or Greater Melbourne area and include a larger variety of street types and infrastructure typologies.

8.5.4 Undertake a study to determine where new bike riders mode shift from

This model is able to determine the amount of new bike riders on the network and what mode share bike riders will constitute for a link. However, we have assumed that those new bike riders come evenly from other modes. Further research is required to better understand the breakdown existing mode share plays in shifting to bike use. It is recommended that a study be undertaken within IMAP or expanded across Greater Melbourne to determine mode substitution.

8.6 Expand the Model to Greater Melbourne and key regional cities

To assist in making informed decisions regarding bike network planning beyond IMAP, it is recommended the Model be expanded across Greater Melbourne. Moreover, by creating a Model for key regional cities in Victoria, targeted investments in bike riding infrastructure can be made to maximise ridership and safety.

9. Limitations

This model was developed using a range of data sources, application of existing research, and the inclusion of new research undertaken by the project team. With all models that predict future behaviour, there are limitations. This section will identify the key limitations with this model and highlight steps undertaken during the project to minimise deficiencies. It will also provide recommendations for future steps that will improve iterations of the model.

9.1 Strava Normalisation

The Strava Normalisation process used Strava Metro data and bike count data to estimate existing bike use on every street/path within the study area. A known limitation of Strava Metro data is that the majority of users of the Strava App are sports-oriented bike riders. These riders are more likely to ride further than people riding for utilitarian purposes. They are also less risk adverse than the general population, and frequent routes that are conducive to exercise but not necessarily for utility trips. Some routes are also repeated several times in a training session (e.g. Yarra Boulevard or Albert Park Lake). A key part of the Strava Normalisation process is to use bike counter locations to scale estimate usage proportionally. Off-road trails also see different bike riding usage behaviour relative to the on-road network. To minimise variances in rider behaviour on different parts of the network, the network was coded into three separate categories: On-road, off-road, and training routes. The normalisation process was run separately for each category, allowing for a more nuanced normalisation of the network. This improved the reliability of the normalisation process by approximately 20%.

The reliability of this process could be improved further with more bike counters, particularly those that are not on the principal bike corridors in the study area. Additional counters should also be used before and after infrastructure upgrades to improve the infrastructure boost element of the model.

9.2 Journey to Work to All trips

ABS Census Journey to Work data was used as the baseline for understanding trip origin and destination. Journey to Work trips are the most complete dataset available for origin-destination trips. In the study area, trips to/from work make up approximately 25% of all trips. This was scaled up using VISTA (a sample survey travel diary dataset) to produce an estimate of all trip types. The VISTA dataset was produced from 46,562 people completing a diary of all trips in a given day. As it is a sample survey and some trip origins and destinations do not have many trips recorded, and many have no trips at all recorded. This becomes even smaller for bike trips, which constitute a minority of total trips. While we know that there are variances in the proportion of trip purpose between different origins and destinations (e.g. Melbourne CBD has a high proportion of commutes), there are not enough trips to scale journey to work to all trips by nuanced proportions across the study area. Instead, an average scaling of 25% work to all trips was used. A greater focus on increasing the number of recorded trips in VISTA would improve the ability to provide a more accurate scaling of trip purposes in the future.

9.3 The limitations of bike infrastructure to increasing bike use

High-quality bike infrastructure is a critical element to supporting increases in bike usage. However, it is not the only factor that encourages (or discourages) bike trips. This project has sought to isolate these other factors and focus on the impact provided by improving infrastructure and via population growth. Increases to bike use could also be achieved through focusing on these other factors, including time competitiveness of bike riding compared to other modes, limiting car parking, introducing road user pricing for motor vehicles, increasing density and developing an urban form conducive to bike riding, and shifting cultural attitudes towards bike riding.

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11. Appendix 1: Bike Use Propensity Index

The Propensity Index uses 8 statistically significant[5] Census variables to determine the propensity for bike use at an SA1 level. The factors that make up the Propensity Index are:

1. Residential population density, measured as *people per hectare.*
2. Employment density measured as number of *people working per hectare.*
3. Density of young adults measured as number of *people aged 18 - 34 per hectare.*
4. City based employment measured as number of *people working in the CBD per hectare.*
5. Short distance car trips, measured as number of *people with commutes of less than 5km.*
6. Low motor vehicle ownership measured as number of *people with one or zero cars per hectare.*
7. Bike use - origin measured as number of *people riding to work per hectare.*
8. Bike use – destination measured as *number of people riding to work by destination per hectare.*

Each of the 8 factors have been developed to form an Index, the result of which, at the SA1 level, can be seen in Figure 43. The darker the shade, the higher the latent demand for cycling in that area. It is important to note that the Index is calculated as a *relative* Index, meaning that the results can only be compared within the areas included in this map. The results are not comparable to other geographical areas.

[5] Statistically significant, based on a binary logistic regression analysis performed on survey responses from bike share users and non-users in Australia (see https://www.sciencedirect.com/science/article/pii/S0965856414002638)

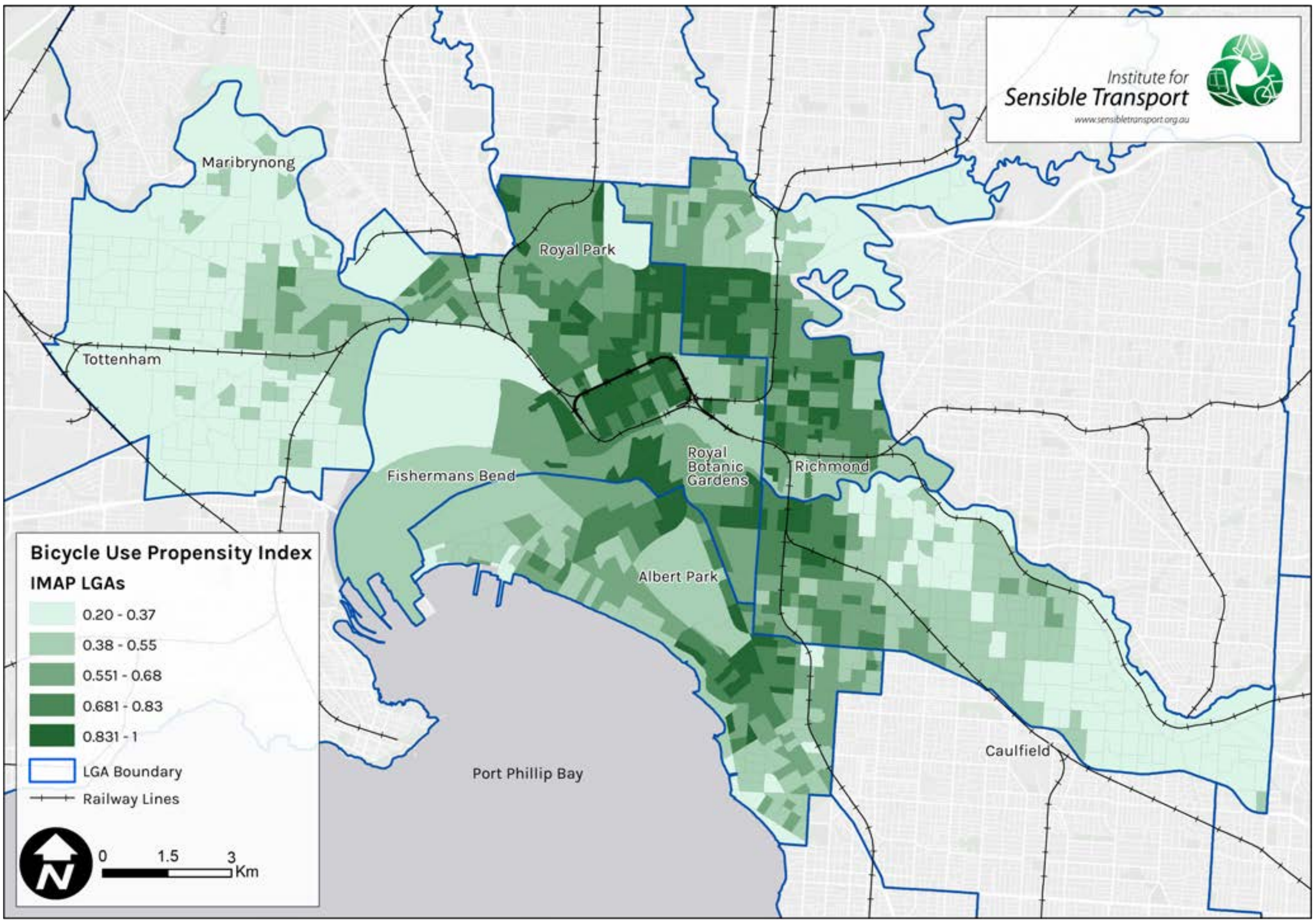

Figure 43 Bike Use Propensity Index SA1 Level

In order to meet the modelling needs of this project, the Propensity Index was adapted to provide mean Propensity Index scores for *each route* in the SA2 to SA2 matrix. This was undertaken to calculate the propensity for a trip to be taken between each SA2. By using the Propensity Index scores as a 'hand-brake', the boost rate figures were scaled depending on the underlying propensity for cycling in the area (e.g. population density) and activity generation differences found across the study area. For example, a separated bike lane in Braybrook is likely to see lower boost rates compared to the same facility within the Hoddle Grid. The mean Propensity Index score along a proposed bike route were calculated using ArcGIS. This was done using the following steps:

1. Recalculated the Propensity Index at an SA2 level, instead of the SA1 level used in the previous report
2. Every SA2 received a split propensity score, both as an origin and as a destination
3. The origin score was calculated based on its propensity for cycling trips to begin in an SA2
4. The destination score was based on the propensity for cycling trips to end in an SA2
5. Both the origin and destination scores were calculated together to determine the propensity of travel between SA2s.

Figure 44 provides the Propensity Index scores for each SA2 within the study area.

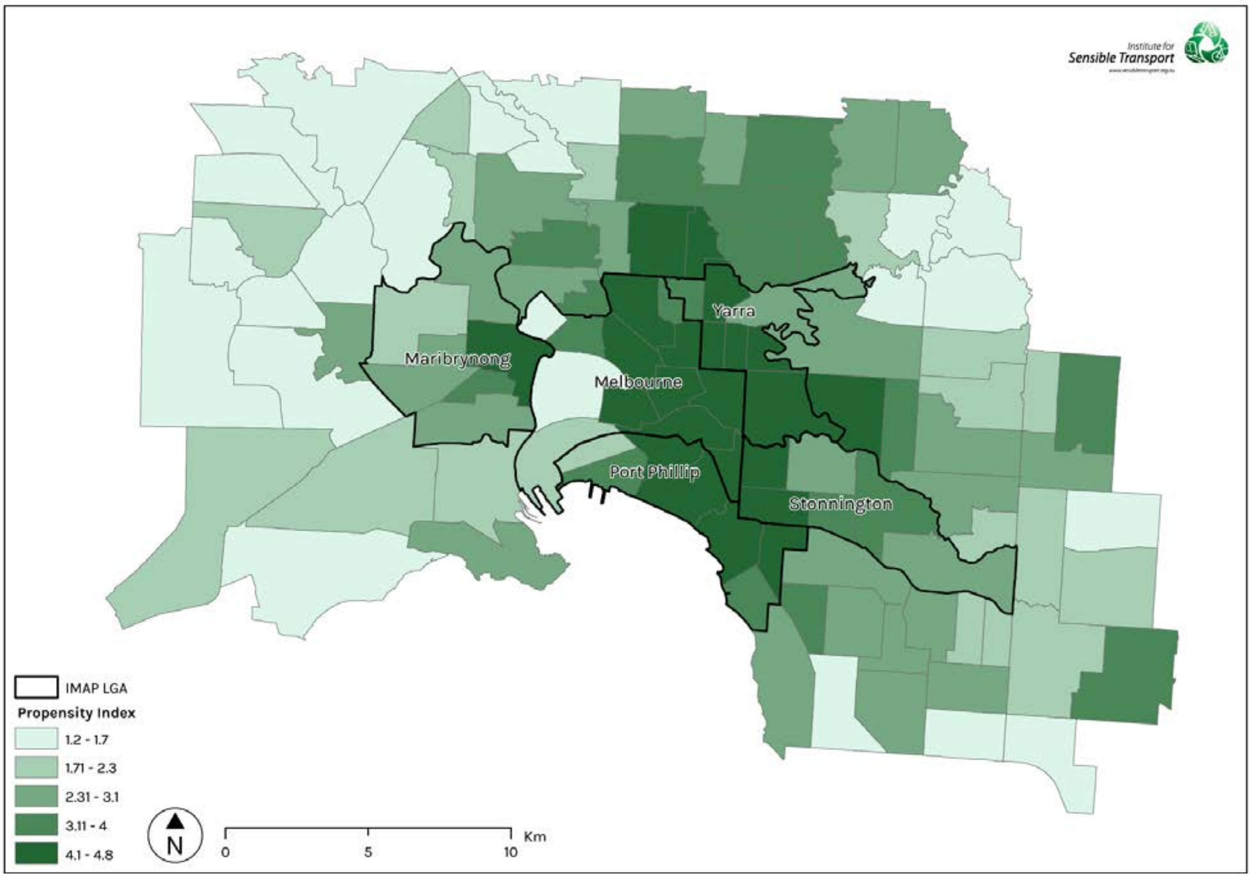

Figure 44 Propensity Index for SA2s within the study area

12. Appendix 2: Time Competitiveness

In order to test the validity of using the four inputs (bike mode share, infrastructure quality score, and line propensity score, distance) for estimating future cycling volumes, we undertook an analysis of five routes with similar line propensity scores, infrastructure quality scores, and within a cyclable distance. The selected routes are shown in Figure 45.

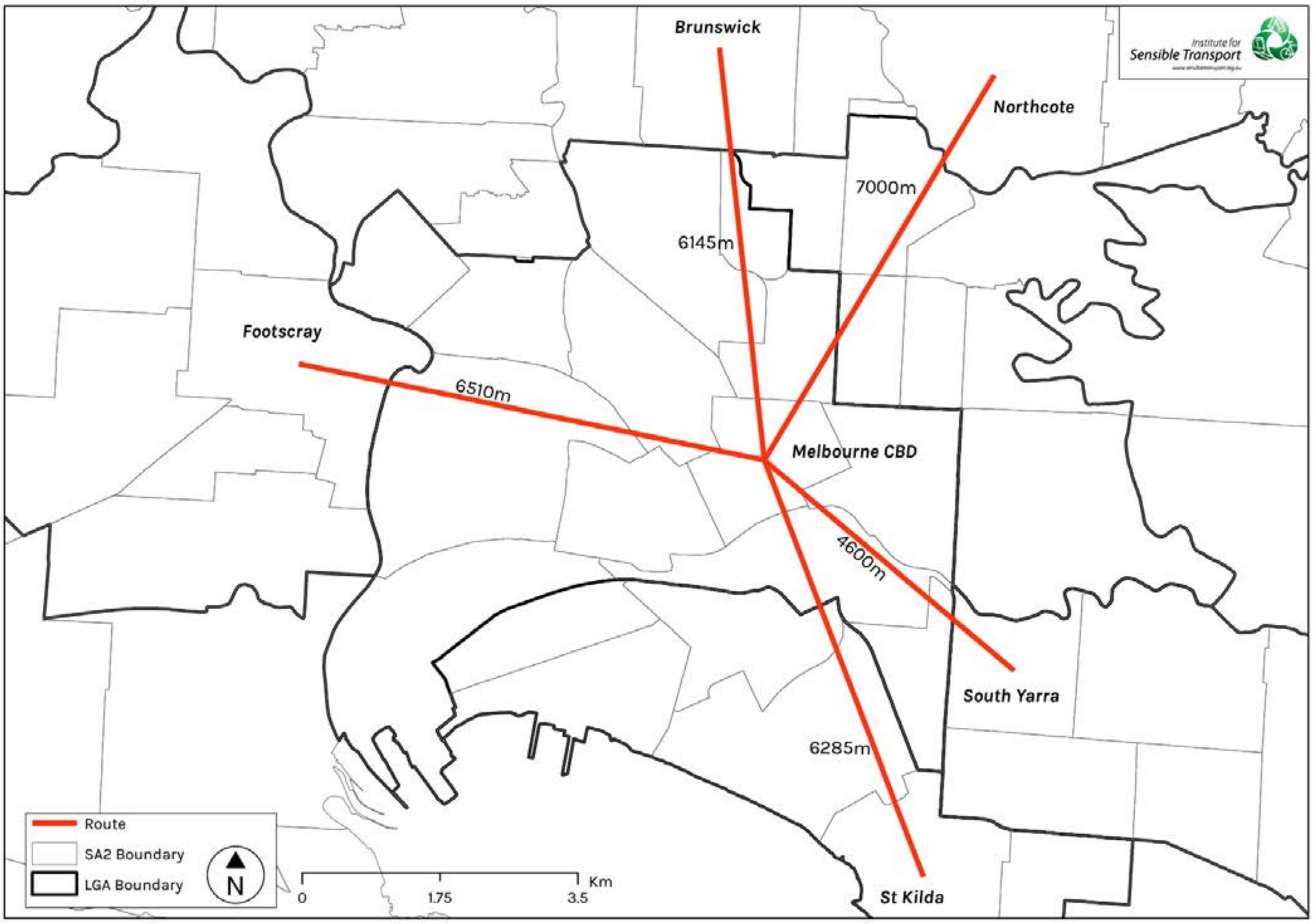

Figure 45 Five route analysis of factors for bike use

The results showed no significant correlation between propensity to cycle, infrastructure quality, distance and the mode share of bike trips. Further analysis was then undertaken using the *time competitiveness* between bike travel and the dominant mode share for that same route, shown in Table 14. The outcome of this analysis can be seen in the '*Bike Time Ratio*' column on the far-right hand side of Table 14. For each of these five routes, public transport was the dominant mode of travel and was used for this analysis. *Google Maps* was used to calculate the time for each of the routes. Where the *Bike Time Ratio* is 1, it indicates that bike and public transport take exactly the same time. Where the Ratio is below 1, bike travel is faster, while if it above 1 public transport is faster.

Table 14 Five Route Analysis

Origin SA2	Destination SA2	Propensity Score	Bike mode share (JtW)	Route confidence rating	Distance (m)	Bike Time Ratio
South Yarra - East	Melbourne	4.82	4.92%	3.62	4600	1.25
Brunswick	Melbourne	4.73	15.34%	3.15	6145	0.90
St Kilda	Melbourne	4.74	6.25%	2.54	6285	1.04
Northcote	Melbourne	4.41	13.49%	2.99	7000	0.81
Footscray	Melbourne	4.24	4.30%	3.94	6510	1.35

There was a significant correlation (R^2=0.88) between the time competitiveness of bike travel and public transport, as shown in Figure 46. This means that when public transport is faster, it depresses the mode share for cycling (e.g. South Yarra – East in Table 14), and when bike travel is faster than public transport, the bike mode share is amplified (e.g. Northcote to Melbourne). This finding has the potential to influence the way bike network planning is undertaken, to identify corridors where bikes are most competitive against other modes of transport to provide the most mode shift towards bike use. As a result of this analysis, time competitiveness has been factored into the *Bicycle Network Model*.

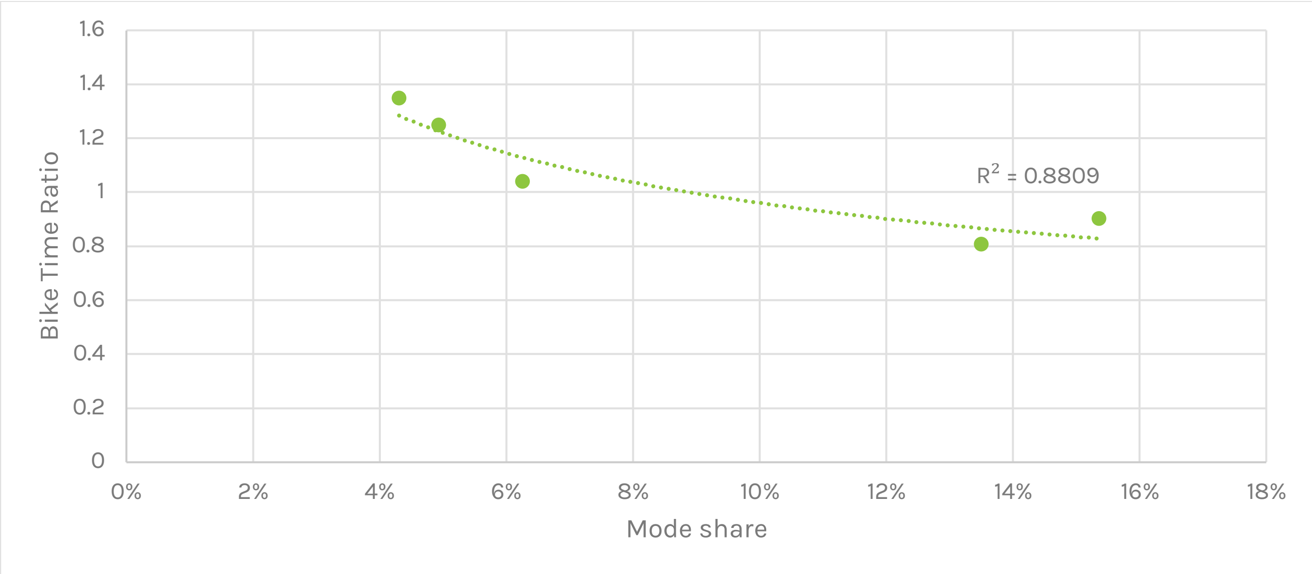

Figure 46 Statistical Correlation of Bike Time Ratio and Mode Share

To incorporate time competitiveness into the model, we used VISTA trips to determine the average trip time for each mode. The main mode of travel for a trip was based on journeys to work. Then the average bike time was divided by the average time for the main mode to determine the bike-time ratio that link. Where an average trip time could not be determined for either bikes or the main transport mode, a bike-time ratio of 1 was used. This is recognised as a limitation to the model in its current form and could be improved with additional network analysis.

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