Association between network characteristics and bicycle ridership across a large metropolitan region

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Keywords: bicycling, participation, transportation, spatial variation.

ABSTRACT

Background: Numerous studies have explored associations between bicycle network characteristics and bicycle ridership. However, the majority of these studies have been conducted in inner metropolitan regions and as such, there is limited knowledge on how various characteristics of bicycle networks relate to bicycle trips within and across entire metropolitan regions, and how the size and composition of study regions impact on the association between bicycle network characteristics and bicycle ridership.

Methods: We conducted a retrospective analysis of household travel survey data and bicycle infrastructure in the Greater Melbourne region, Australia. Seven network metrics were calculated and Bayesian spatial models were used to explore the association between these network characteristics and bicycle ridership (measured as counts of the number of trips, and the proportion of all trips that were made by bike).

Results: We demonstrated that bicycle ridership was associated with several network characteristics, and that these characteristics varied according to the outcome (count of the number of trips made by bike or the proportion of trips made by bike) and the size and characteristics of the study region.

Conclusions: These findings challenge the utility of approaches based on spatially modelling network characteristics and bicycle ridership when informing the monitoring and evaluation of bicycle networks. There is a need to progress the science of measuring safe and connected bicycle networks for people of all ages and abilities.

INTRODUCTION

To advance bicycling as an active and sustainable mode of transport, cities across the world are increasing investment in bicycling infrastructure. [1, 2] The presence and quality of bicycling infrastructure has a significant impact on bicycling,[3] and there is considerable scope for increases in bicycling participation when high-quality and connected infrastructure is provided.[4]

The length of bicycling infrastructure and the extent of newly implemented bicycling infrastructure are commonly used in planning documents and academic studies to assess a city's bicycling network.[5, 6] However, there is growing recognition of the importance of how 'connected' the network is; that is, enabling people to use continuous, safe and low-stress routes to access everyday destinations.[5, 7, 8] Fragmentation in the network may force riders into mixed traffic, require lengthy detours, and may discourage bike riding altogether, primarily due to safety concerns.[9, 10]

Understanding the role that bicycle infrastructure network characteristics have on bicycling is therefore necessary to advance knowledge of how to plan the implementation of safe and connected networks, and to benchmark networks across jurisdictions. Recent developments in measuring bicycle network connection include the use of indicators developed using graph theory, such as density, directness and centrality.[9, 11, 12] Such approaches offer systematic methods for measuring network quality for comparison within and between cities. For example, Schoner and Levinson demonstrated that connectivity and directness were important factors in predicting bicycle commuting,[9] Osama *et al.* suggested more connected, dense, flat, continuous and off-street bicycle networks yield higher bicycling,[11] and Kamel and Sayed showed that network centrality, assortativity, weighted slope, directness, length, complexity and connectivity were associated with bicycle ridership.[12] While these studies have been important in advancing knowledge on the role of various network characteristics, they have commonly been conducted in inner metropolitan regions, such as inner Vancouver[11, 12] or inner Seattle,[8] or have used single city-wide network measures to contrast these factors between cities.[9] As such, there is limited knowledge on how various characteristics of bicycle networks relate to bicycle trips within and across entire metropolitan regions, and how the size and composition of study regions impact on the association between bicycle network characteristics and bicycle ridership.

Using population-weighted travel survey data and robust measures of bicycle network characteristics, this study aimed to: 1) quantify the association between bicycle network characteristics and bicycle ridership across the metropolitan region of Greater Melbourne, Australia; and 2) explore the impact of the geographical study region on these associations.

METHODS

Study design

We conducted a retrospective analysis of household travel survey data and bicycle infrastructure in the Greater Melbourne region, Australia.

Setting

The State of Victoria, Australia, has a population of 6.7 million people of which 67% reside in the Greater Melbourne area.[13] The Australian Bureau of Statistics (ABS) define seven hierarchical classifications of functional areas in Australia, from mesh blocks (the smallest unit) to the country level (the largest unit). Within these is a functional area known as Statistical Areas Level 2 (SA2), which are medium-sized general-purpose areas, reflecting a community that interacts together socially and economically. SA2s generally have a population range of 3,000 to 25,000 persons, with an average of approximately 10,000 persons. For this study, analyses were restricted to the 309 SA2 areas within Greater Melbourne, reflecting an area of 9,986 km^2 (Figure 1).

Travel survey data

Travel survey data were captured through the Victorian Integrated Survey of Travel & Activity (VISTA), coordinated by the Victorian Department of Transport. We used data from three waves (2012-14, 2014-16, 2016-18) of the VISTA. VISTA is a survey of day-to-day travel conducted in the

Greater Melbourne area and in a single regional centre in Victoria. Since 2012, 16,000 households and 66,000 people have contributed to the VISTA survey. VISTA randomly selects households to complete the VISTA travel diary for a single specified day. VISTA employs a stratified, clustered sampling methodology, with stratification based on ABS Statistical Areas Level 3 (SA3), which are geographical areas built from whole SA2s. The survey and resulting data are weighted to generate population-representative data at the SA3 level. In this study, we employed a set of combined weights that use the full data set from 2012-2018 to produce statistics weighted to the 2017-18 population. As robust weights for bicycling were not available at a SA2 level, SA3 weights were applied to SA2 level. Weights were applied to the SA2 in which the trip originated, and therefore, data reflect where trips commenced and not trip routes or destinations. Unless otherwise specified, data reflect trips made within Greater Melbourne on an average day across the study period. Eligibility for inclusion in this study were participants aged 18 years and older, and trips that had trip origins and destinations within the Greater Melbourne region.

Bicycle infrastructure data

In the absence of government data sets of bicycle infrastructure in Victoria, we used Open Street Map (OSM) data to characterise bicycling infrastructure in the study region. We captured infrastructure at a single time-point, which was the final year of the study period (2018). 2018 OSM data was downloaded for the Greater Melbourne region from Geofrabrik.[14] Bicycle infrastructure was coded by OSM contributors according to the OSM Wiki[15] and stratified into: on-road bike lanes, protected on-road bike lanes, and off-road paths (off-road dedicated bike path, off-road shared path (shared with pedestrians), and footways where bicycling is legal). Further information on this method is described previously.[16] In some cases, the border lines of SA2 areas fell along roads and paths. When classifying network characteristics for each SA2, a road or path that fell along an SA2 border was included in the analysis for both adjacent SA2s. Therefore, in some situations, roads or paths have been double counted as a result of their inclusion in multiple SA2s.

Network characteristics

To explore characteristics of the network, we calculated seven network metrics that have previous been demonstrated to be associated with bicycle ridership. [9, 11, 12] These were measures of bicycle network length, network centrality (betweenness and degree centrality), connectivity and coverage (network density, network coverage, and intersection density), and topography (average weighted slope). These are described in detail below.

Bicycle network length

The length of the bicycle network was calculated for each SA2. This was stratified by bicycle infrastructure that was off-road (off-road dedicated bike path and off-road shared path) and on-road (on-road bike lanes and protected on-road bike lanes).

Network centrality

Two measures of centrality were calculated for the bicycle network (combined for both on-road and off-road infrastructure): betweenness centrality and degree centrality. Betweenness centrality quantifies the number of times a node acts as a bridge along the shortest path between two other nodes, and is based on the idea that a node is central if it lies between many other nodes. Betweenness centrality, C^B, is calculated as:

$$C^B = \frac{1}{(n-1)(n-2)}\sum_{j}^{n}\sum_{k}^{n}\frac{g_{jk(i)}}{g_{jk}} \quad i \neq j \ \neq k$$

Where $g_{jk(i)}$represents the number of node pairs j and k that contain point i on the shortest path connecting them and g_{jk} represents the number of node pairs j and k.

Degree centrality measures to what extent a node is connected directly to other nodes, and is based on the idea that important nodes have the largest number of ties to other nodes in the graph. Degree centrality, C^D, is calculated as:

$$C^D = \frac{1}{(n-1)}\sum_{j=1}^{n} a_{ij}$$

Where $a_{ij} = 1$ only if node i and node j are connected by a link or more, and is equal to zero otherwise, and n is the number of nodes in the network.

Because the aim of this study was to explore the association between network characteristics and bicycle trips at an SA2 level, betweenness centrality and degree centrality were aggregated to SA2s, as per Zhang *et al.*[17] 'Network centrality' is defined as "the average difference between the relative centrality of the most central point and that of all other points".[18] Therefore, higher values of network centrality reflect a network that has a greater number of greater number of streets/paths that serve as the only connection to other streets/paths.[17] Conversely, a gridded network tends to have a lower value of network centrality because all streets/paths in such a network are equally important and have the same possibility of connecting to others. The following equation is used to calculate these aggregate measures of centrality (C^X):

$$C^X = \frac{\sum_{i=1}^{n}[C_{i*}^X - C_i^X]}{\max\sum_{i=1}^{n}[C_{i*}^X - C_i^X]}$$

Where C_i^X is the centrality of SA2 i and C_{i*}^X is the largest possible value of C_i^X for the SA2.

Coverage

Three measures of connectivity and coverage were implemented in this study: network coverage, network density and intersection density. [12, 19] Network coverage was calculated as the ratio of the number of bicycle network links to the number of street network links in the SA2. Network density was calculated as the ratio of the total length of bicycle network links in the SA2 to the SA2 area. Intersection density was calculated as the ratio of the number of intersections to the area of the SA2, including intersections between bicycle network links, and between bicycle network and street network links.

Topography

Topography was measured using the average weighted slope of the bicycle network within the SA2. Elevation data was sourced from the Victorian Government 'Vicmap Elevation' product, which includes a Digital Elevation Model (DEM) at 10m grid resolution.[20] The elevation data was applied to the OSM network using the 'slopes' package in R.[21] The average weighted slope was then calculated by computing the bicycle network link slopes (s_i), multiplying the slope by the length of the link (l_i), and then applying the following formula:

$$Average\ weighted\ slope\ in\ SA2 = \frac{l_1 \times s_1 + l_2 \times s_2 + \ldots + l_n \times s_n}{l_1 + l_2 + \ldots + l_n}$$

Process

The first step in calculating network metrics is to characterise the bicycle network as a graph. The links represent the bicycle network infrastructure (e.g. off-road path or on-road bike lane) and the nodes represent the intersections between network links (e.g. street and bicycle network links). Street and path networks, such as those represented in OSM data, are commonly represented by points which are effectively arbitrarily located, such as scenarios in which a curved path between two intersections is represented by a series of intermediate points.[22] In these scenarios, it is necessary to 'contract' the network and remove these artefacts such that the network contains only edges that directly connect junctions. Following the guidance of Gilardi *et al.*,[22] we used the R package 'dodgr' to contract the OSM network and employed the 'igraph' package to calculate the aforementioned network metrics.

Data were prepared using the statistical software package R v4.0.3 (R Core Team, 2021) and the integrated development environment RStudio (RStudio 2020, Boston, MA, USA), using the 'srvyr', 'tmap', 'survey', 'srvyr', 'dodgr', 'igraph' and 'slopes' libraries.

Statistical analyses

We employed Bayesian spatial models to explore the association between network characteristics and bicycle ridership. We modelled two outcomes: counts of the number of trips, and the proportion of all trips that were made by bike. These outcomes were spatially modelled according to Besag-York-Mollie,[23] as described elsewhere.[24, 25]

Counts of the number of trips made by bike (y_i) were modelled as Poisson distributed with mean λ_i:

$$y_i \sim Poisson(\lambda_i)$$

Then, the logarithmic transform of λ_i is modelled as:

$$\log(\lambda_i) = \beta_0 + \beta_1 x_i + \mu_i + \upsilon_i$$

Where β_0 is the main effect, $\beta_1 x_i$ is a vector of area-level covariates, μ_i is the spatially structured effect, and υ_i is the spatially unstructured effect.

The proportion of trips that were made by bike were modelled as Binomial distributed (accounting for the ratio of the number of trips made by bike y_i over the total number of trips n_i). Then, the logistic transformation of π_i is modelled as:

$$\text{logit}(\pi_i) = \beta_0 + \beta_1 x_i + \mu_i + \upsilon_i$$

Where β_0 is the main effect, $\beta_1 x_i$ is a vector of area-level covariates, μ_i is the spatially structured effect, and υ_i is the spatially unstructured effect.

Similar to prior studies,[17] to inform the selection of covariates in the models, we firstly used correlation analyses to examine whether variables were highly correlated with each other. If two variables were found to be substantially correlated (defined as a Pearson's product moment correlation coefficient greater than 0.5), they were not used in the same model. This left a total of 33 combinations of eight covariates. All 33 models were run and evaluated and model fit was evaluated using the Deviance Information Criterion (DIC). The model with the lowest DIC was considered to have the best fit and selected as the final model.

Models were fitted using the INLA library[26] through the statistical software package R v4.0.3 (R Core Team, 2021) and the integrated development environment Rstudio (Rstudio 2020, Boston, MA, USA). The default prior distributions in INLA were employed.

Sensitivity analysis

To explore the impact of the size of the study area on model covariates, we conducted sensitivity analyses by classifying Greater Melbourne into three sub-regions and running the aforementioned analyses in each of these sub-regions. Three sub-regions were defined based on ABS Statistical Areas Level 4 (SA4) areas. Specifically, 'Inner Melbourne' was defined as the SA4 areas of 'Melbourne – Inner', 'Melbourne – Inner East' and 'Melbourne – Inner South', 'North and West Melbourne' was defined as the SA4 areas of 'Melbourne – West', 'Melbourne – North West' and 'Melbourne – North East', and 'South and East Melbourne' was defined as the SA4 areas of 'Melbourne – Outer East', 'Melbourne – South East' and 'Mornington Peninsula'. These areas are shown in Figure 2.

Ethical approval

Ethical approval for this study was provided by the Monash University Human Research Ethics Committee (Project ID: 29210).

RESULTS

On an average day in Greater Melbourne, there were 180,393 trips made by bike, reflecting 1.7% of all trips. The median number of bike trips across SA2s in Greater Melbourne was 222 trips (Q1: 64, Q3: 505) and the median proportion of trips made by bike was 0.8% (Q1: 0.3%, Q3: 1.6%) (Table 1). Spatial variation in the number of bike trips is shown in Figure 3 and spatial variation in the proportion of bike trips is shown in Figure 4. The median length of off-road bicycle infrastructure per SA2 was 6.06 km (Q1: 2.50, Q3: 10.47) and the median length of on-road bicycle infrastructure per SA2 was 2.34 km (Q1: 0.22, Q3: 5.82). A map of bicycle infrastructure is shown in Figure 5 and further summary statistics of network characteristics are provided in Table 1. Spatial variation in network characteristics is shown in Figure 6 and Figure 7. In general, on-road bicycle network length, network density, and intersection density were higher in the inner regions of Greater Melbourne, while off-road bicycle network length, degree centrality and average weighted slope were higher in the outer regions of Greater Melbourne.

For the number of trips made by bike, the model with the lowest DIC included measures of degree centrality, off-road bicycle network length, on-road bicycle network length, and network density (Table 2). Off-road bicycle network length (mean: 0.08; 95% credible interval: 0.04, 0,12) and on-road bicycle network length (mean: 0.14; 95% credible interval: 0.07, 0.22) were positively associated with the number of trips made by bike. Degree centrality (mean: 0.86; 95% credible interval: -3.29, 5.00) and network density (mean: -0.26, 95% credible interval: =0.54, 0.03) were not statistically credible at the 5% level.

For the proportion of trips made by bike, the model with the lowest DIC included measures of intersection density and averaged weighted slope (Table 3). Neither of these measures were statistically credible at the 5% level.

Model fit parameters for all models are provided in Supplementary Material.

Sensitivity analysis

We conducted sensitivity analyses to explore the impact of the study area on model selection and model covariates. Comparisons of bicycle ridership and network characteristics between the overall study area of Greater Melbourne and the three sub-regions of Inner Melbourne, North and West Melbourne, and South and East Melbourne are presented in Table 1. In summary, median values of the count of the number of trips made by bike, the proportion of trips made by bike, the length of on-road bicycling infrastructure, network density and intersection density were higher in Inner Melbourne relative to North and West Melbourne and South and East Melbourne, while the length of off-road bicycling infrastructure was higher in North and West Melbourne and South and East Melbourne.

For the number of trips made by bike, variation was observed in model covariates, as well as the strength and direction of associations, between the overall study region and the three sub-regions (Table 4). For example, differences were observed in the inclusion of measures of bicycle network length, centrality and network coverage across all models. Where covariates were included in multiple models, there was some variation in the direction and strength of associations. For example, degree centrality was included in modes for both Inner Melbourne and North and West Melbourne. However, degree centrality was negatively associated with the number of trips made by bike in Inner Melbourne (mean: -12.34; 95% credible interval: -18.39, -7.04), but positively associated with the number of trips made by bike in North and West Melbourne (mean: 22.14; 95% credible interval: 8.27, 36.49). Additionally, off-road bicycle network length was positively associated with the number of trips made by bike for Greater Melbourne overall (mean: 0.08; 95% credible interval: 0.04, 0.12) and for North and West Melbourne (mean: 0.11; 95% credible interval: 0.05, 0.17), but was not associated with the number of trips made by bike in South and East Melbourne (mean: 0.06; 95% credible interval: -0.02, 0.14) and was not included as a covariate in the Inner Melbourne model.

For the proportion of trips made by bike, variation was observed in model covariates, as well as the strength and direction of associations, between the overall study region and the three sub-regions (Table 5). For example, while measures of off-road bicycle network length and on-road bicycle network length were included in the models for North and West Melbourne and South and East Melbourne, they were not included in the overall model nor the Inner Melbourne model. Further, as an example of differences in the strength and direction of associations, on-road bicycle network length was positively associated with the proportion of trips made by bike in North and West Melbourne (mean: 0.17; 95% credible interval: 0.06, 0.28)), but was not associated with the proportion of trips made by bike in South and East Melbourne (mean: -0.01, 95% credible interval: -0.16, 0.14).

Model fit parameters for all models are provided in Supplementary Material.

DISCUSSION

In this study of the bicycle network characteristics and bicycle ridership, we demonstrated that bicycling rates were associated with several network characteristics, and that these characteristics varied according to the outcome (count of the number of trips made by bike or the proportion of trips made by bike) and the size and characteristics of the study region. Given the sensitivity of these models to model inputs, these findings challenge the utility of approaches based on spatially modelling network characteristics and bicycle ridership when informing the monitoring and evaluation of bicycle networks. There is a need to progress the science of measuring safe and connected bicycle networks for people of all ages and abilities.

Consistent with prior research, we demonstrated that the length of the bicycle network was positively associated with various measures of bicycle ridership.[11, 12, 27] A surprising finding was variation in the direction of association between degree centrality and bicycle ridership. In the inner-city region of Inner Melbourne, the finding of centrality being negatively associated with bicycle ridership is logical; high network centrality indicates low inter-connectivity and accessibility of the network.[17] However, degree centrality was strongly positively associated with bicycle ridership in the North and West Melbourne region. The association between low connectivity and bicycle ridership may be an artefact of a focus on off-road bicycle infrastructure (particularly rail trails; shared-use paths recycled from abandoned railway corridors) in these regions that, while they are not considered as connected and accessible using graph theory approaches, are supportive of recreational bicycling.

It is also important to consider the size and composition of the spatial area when modelling bicycle ridership. In this study, we modelled two outcomes: the count of the number of trips by bike, and the proportion of all trips made by bike. As depicted in Figure 1, there is variation in both population density and the total population of each SA2. Modelling the count of the number of trips or the number of bicycle kilometres travelled, both of which are common approaches in the literature,[11, 12, 19] is potentially confounded by the underlying population of the spatial area. Therefore, normalising these measures, either as a proportion of the population or as a proportion of all trips (as we have done), is needed to account for this confounding. Additionally, and similar to prior research,[9, 11, 12] we explored the association between bicycle network length and bicycle ridership. Measures of bicycle length suffer from similar issues in that they may be related to the underlying size of the spatial area. To address this limitation, we explored normalised measures of bicycle infrastructure (network density and coverage), but further research is required to combine measures of both network coverage and network connectivity. We discuss this in detail below.

An interesting finding of this study was the impact of the size and characteristics of the study area had on model and covariate selection. Specifically, our sensitivity analyses on three sub-regions of the Greater Melbourne metropolitan region demonstrated inconsistencies in model selection and the strength and direction of associations between network characteristics and bicycle ridership. This is, perhaps, unsurprising as bicycle ridership and network characteristics vary vastly across large geographical regions, as we have demonstrated. This issue has been highlighted previously; Gil (2017) demonstrated the impact of varying sizes of study areas on measures of street network centrality.[28] Given that the vast majority of prior research has focused on inner city areas,[8, 11, 12] the generalisability of such findings, particularly to metropolitan areas outside of the inner city, must be questioned. It also raises the question of how robust such approaches are to defining important characteristics of bicycle networks.

It is well established that connected networks of safe and comfortable bicycling infrastructure, known as 'All Ages and Abilities (AAA) bicycle networks', are needed to enhance bike riding participation and safety, and thereby realise the potential for substantial gains in population health, equity and sustainability. Reflecting this, engineering guidance has focussed on providing tools to measure bicycling infrastructure on individual street segments, intersections or corridors. However, the absence of standardised definitions and supporting metrics to measure AAA bicycle networks has hindered the implementation of connected, safe and comfortable bicycle networks that enable people of all ages and abilities to get where they want to go. Certainly, the development of measures of 'bicycle level of service' (similar to 'level of traffic stress') has enhanced our understanding of how the actual and perceived environment is conducive and safe for bicycling.[29, 30] These measures include such factors as the presence, type and quality of bicycle infrastructure, topography, exposure to and speed of traffic, bicycle volumes, lighting, perceived and objective safety, and end of trip facilities.[29, 30] However, as previously described, these measures are often applied to individual street/path segments and challenges exist as to how to utilise these measures to defined AAA bicycle networks. Where the connectivity of networks has been considered, the measurement of connectivity has often been limited to the use of graph theory approaches, such as that employed in this study. The challenge with such approaches is that they don't consider the myriad of aforementioned factors that relate to comfort and safety. Our study is an example of this. Measures of connectivity used in this study included on-road bicycling infrastructure; the vast majority of which was on-road painted lanes. During the study period, only 8 km of the 1173 km (0.7%) of the on-road infrastructure were protected bike lanes,[16] and it is acknowledged that marked on-road bicycle lanes are inadequate in creating safe spaces for people on bikes and are likely only supportive of bicycling for the most confident riders.[4, 31] This also reflects current ridership in our region in which the vast majority of people who ride bikes are considered 'Strong and fearless' (people who are comfortable riding with traffic in any road environment) and 'Enthused and confident' (people who are comfortable riding in traffic, but prefer bike lanes and like using segregated facilities).[4] There has been some progress towards better characterising bicycle networks, such as the use of multi-objective methodologies to assess bikeability between origin-destination locations over an entire network.[32] However, it is evident that we need to advance the science of measuring AAA bicycle networks to support the implementation of such networks for health, sustainability and equity benefits.

The strengths of this study include the use of population-weighted travel survey data that enables robust evaluation of bike riding across small spatial areas in Greater Melbourne, and the evaluation of the association between network characteristics and bicycling across a large metropolitan area. However, there are a number of limitations to note. Firstly, due to a low number of bicycle trips, robust survey weights were only available at the SA3 level, and these were applied to SA2 areas. As a result, there may be some errors in the weightings applied the travel survey data. Further, survey weights were applied to the SA2 in which the trip originated, and the data presented do not reflect trips that occurred across multiple SA2s. Additionally, due to the relatively low number of trips made by bike, we were unable to stratify by trip purpose; it is likely that network characteristics that are supportive of bicycling may differ between recreational and transport trips. In the absence of government data sets of bicycling infrastructure in Victoria, we were reliant on Open Street Map (OSM) data to characterise bicycling infrastructure. There is variability in the accuracy of OSM data in international settings,[33] and the accuracy of OSM data is unknown in our region. Additionally, as described above, network characteristics may not reflect how connected and comfortable a network is for all ages and abilities. Further, we did not consider land use and other parameters shown to be associated with bicycle ridership,[7, 34] as the primary focus of this study was on the association between network characteristics and bicycle ridership.

CONCLUSION

We have demonstrated that the association between network characteristics and bicycle ridership varies according to the measure of bicycle ridership and the size and characteristics of the study area. When considering the development of models of bicycle ridership, consideration must be given to the impact of the study area and the generalisability of findings. While we employed robust measures of network connectivity, these measures not to consider comfort and safety. There is a need to advance how we characterise the connectivity and comfort of bicycling networks for all ages and abilities.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance provided by the Victorian Department of Transport, and in particular, Geoffrey Simmons.

FUNDING

BB was supported by an Australian Research Council Future Fellowship (FT210100183). The CYCLED (CitY-wide biCycLing Exposure modelling) Study is funded by an Australian Research Council Discovery Project (DP210102089). KN and SS were supported by a National Health and Medical Research Council (NHMRC) and United Kingdom Research and Innovation (UKRI) grant (#1194959).

DISCLOSURE STATEMENT

There are no conflicts of interest to declare.

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TABLES

Table 1: Summary statistics of bicycle ridership and network data across SA2s. Data presented for Greater Melbourne and for Inner Melbourne.

Measure	Greater Melbourne [median (Q1, Q3)]	Inner Melbourne [median (Q1, Q3)]	North and West Melbourne [median (Q1, Q3)]	South and East Melbourne [median (Q1, Q3)]
Bicycling data				
Count of the number of trips made by bike	222 (64, 505)	576 (283, 2219)	184 (10, 353)	165 (39, 299)
Proportion of trips made by bike (%)	0.8 (0.3, 1.6)	1.7 (0.8, 3.6)	0.6 (0.0, 1.4)	0.5 (0.1, 0.9)
Network data				
Off-road bicycle network length (km)	6.06 (2.50, 10.47)	4.21 (1.83, 7.16)	8.23 (4.53, 13.48)	7.20 (2.06, 12.07)
On-road bicycle network length (km)	2.34 (0.22, 5.82)	3.35 (1.46, 6.23)	2.91 (0.61, 7.23)	0.64 (0.00, 3.63)
Betweenness centrality	0.04 (0.02, 0.08)	0.05 (0.02, 0.09)	0.04 (0.01, 0.08)	0.04 (0.02, 0.08)
Degree centrality	0.04 (0.02, 0.07)	0.04 (0.02, 0.08)	0.03 (0.02, 0.05)	0.04 (0.02, 0.08)
Network density	1.19 (0.50, 1.97)	1.69 (1.03, 2.95)	1.38 (0.41, 2.02)	0.64 (0.22, 1.19)
Network coverage	4.16 (1.99, 6.31)	5.13 (2.54, 7.03)	4.88 (2.90, 7.50)	2.90 (1.14, 4.51)
Intersection density	6.16 (2.49, 11.57)	9.98 (4.63, 18.72)	7.36 (2.62, 11.99)	3.48 (0.70, 6.45)
Average weighted slope (%)	1.85 (1.15, 2.84)	1.70 (1.13, 2.51)	1.51 (1.06, 2.77)	2.23 (1.36, 3.38)

Note: Q1 = quartile 1; Q3 = quartile 3.

Table 2: Summary statistics for the model of the count of the number of trips take by bike: posterior mean, posterior standard deviation (SD), and posterior 95% credible interval for the fixed effects of the covariates. This model relates to the Greater Melbourne region.

			Credible Interval	
	Mean	**SD**	**2.5%**	**97.5%**
Degree centrality	0.86	2.11	-3.29	5.00
Off-road bicycle network length	0.08	0.02	0.04	0.12
On-road bicycle network length	0.14	0.04	0.07	0.22
Network density	-0.26	0.14	-0.54	0.03
Intercept	3.67	0.30	3.07	4.26

Table 3: Summary statistics for the model of the proportion of trips taken by bike: posterior mean, posterior standard deviation (SD), and posterior 95% credible interval for the fixed effects of the covariates. This model relates to the Greater Melbourne region.

			Credible Interval	
	Mean	**SD**	**2.5%**	**97.5%**
Intersection density	0.02	0.02	-0.02	0.05
Averaged weighted slope	0.02	0.09	-0.15	0.19
Intercept	-5.90	0.28	-5.89	-5.33

Table 4: Summary statistics for the model of the count of the number of trips take by bike: posterior mean, posterior standard deviation (SD), and posterior 95% credible interval for the fixed effects of the covariates. Three separate models are presented for Inner Melbourne, North and West Melbourne, and South and East Melbourne.

			Credible Interval	
	Mean	**SD**	**2.5%**	**97.5%**
INNER MELBOURNE				
Degree centrality	-12.34	2.88	-18.39	-7.04
Network coverage	0.06	0.06	-0.04	0.17
Intercept	6.71	0.46	0.582	7.62
NORTH AND WEST MELBOURNE				
Degree centrality	22.14	7.17	8.27	36.49
Off-road bicycle network length	0.11	0.03	0.05	0.17
On-road bicycle network length	0.26	0.07	0.14	0.39
Network density	-0.35	0.26	-0.86	0.15
Average weighted slope	0.37	0.15	0.08	0.68
Intercept	0.33	0.76	-1.23	1.78
SOUTH AND EAST MELBOURNE				
Betweenness centrality	0.25	2.98	-5.62	6.11
Off-road bicycle network length	0.06	0.04	-0.02	0.14
On-road bicycle network length	0.09	0.10	-0.12	0.29
Network coverage	-0.02	0.17	-0.36	0.32
Intercept	2.98	0.69	1.61	4.32

Table 5: Summary statistics for the model of the proportion of trips taken by bike: posterior mean, posterior standard deviation (SD), and posterior 95% credible interval for the fixed effects of the covariates. Three separate models are presented for Inner Melbourne, North and West Melbourne, and South and East Melbourne.

			Credible Interval	
	Mean	**SD**	**2.5%**	**97.5%**
INNER MELBOURNE				
Degree centrality	-7.61	2.25	-12.26	-3.41
Network coverage	0.09	0.04	0.01	0.18
Intercept	-4.26	0.36	-4.96	-3.54
NORTH AND WEST MELBOURNE				
Degree centrality	19.52	6.63	6.71	32.84
Off-road bicycle network length	0.07	0.03	0.02	0.13
On-road bicycle network length	0.17	0.06	0.06	0.28
Intersection density	-0.03	0.03	-0.09	0.02
Average weighted slope	0.43	0.14	0.15	0.71
Intercept	-9.06	0.72	-10.52	-7.69
SOUTH AND EAST MELBOURNE				
Off-road bicycle network length	0.10	0.04	0.03	0.18
On-road bicycle network length	-0.01	0.08	-0.16	0.14
Network density	-1.21	0.54	-2.32	-0.17
Intercept	-6.39	0.44	-7.29	-5.54

FIGURES

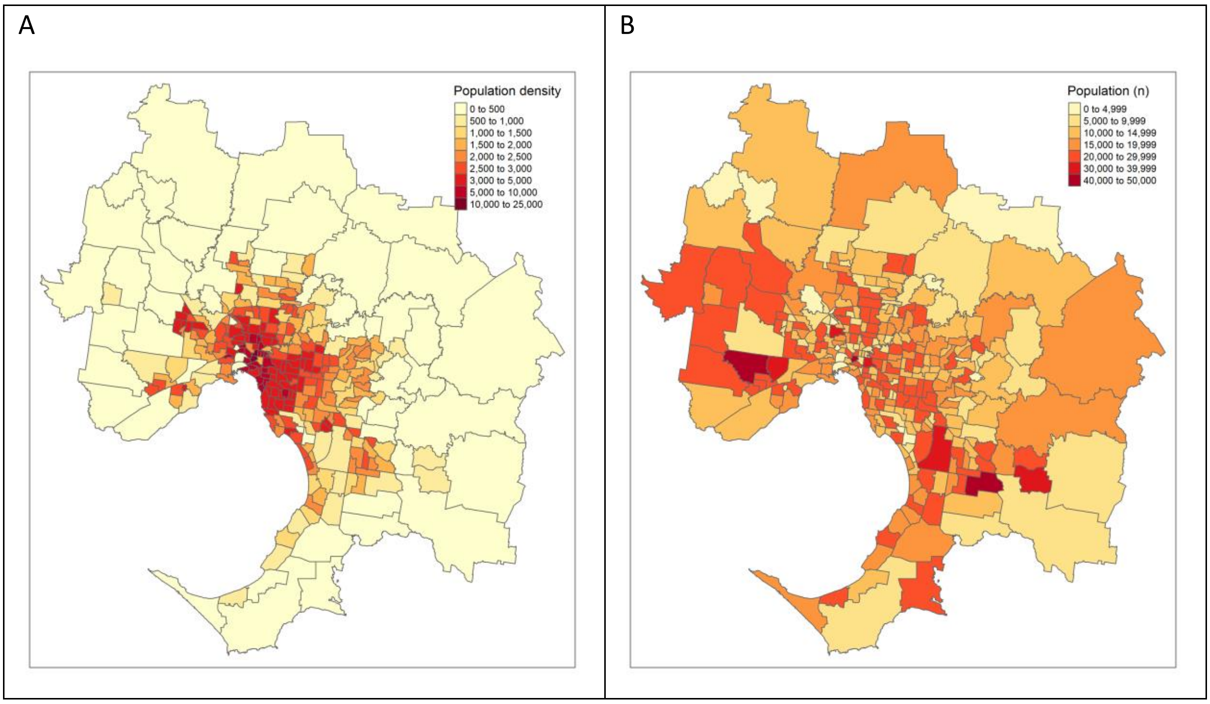

Figure 1: Map of: A) population density (persons per square kilometre); and B) total population per SA2. The borders represent SA2 boundaries in the Greater Melbourne region.

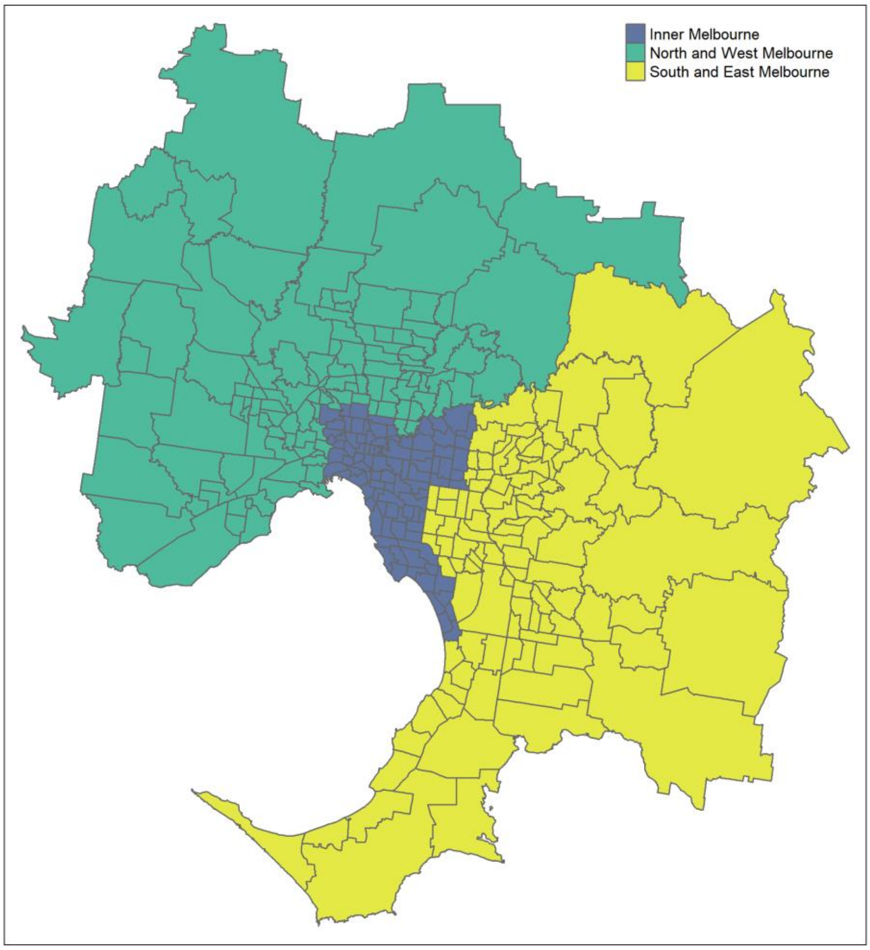

Figure 2: Map of Greater Melbourne region with black borders depicting SA2 boundaries and the coloured regions depicting the three sub-regions of Inner Melbourne, North and West Melbourne, and South and East Melbourne.

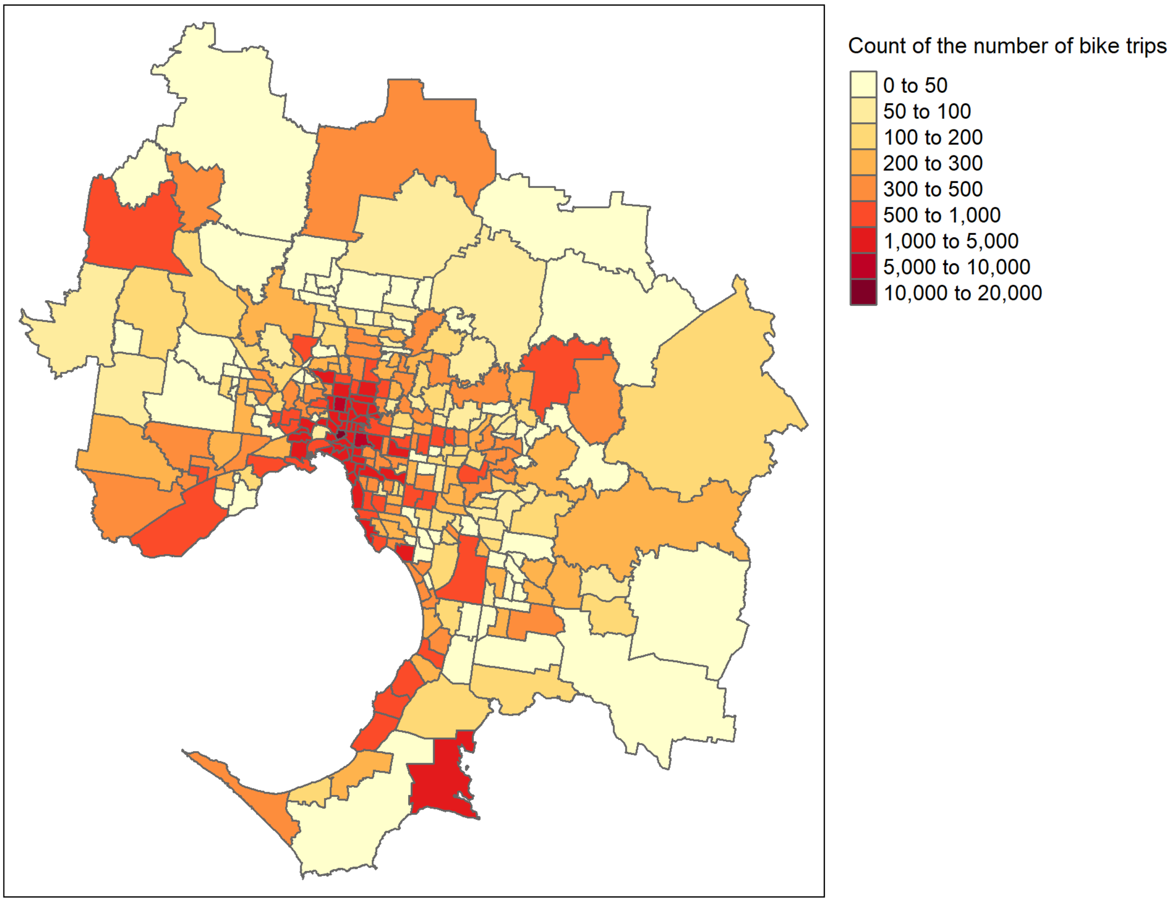

Figure 3: Count of the number of bicycle trips (per SA2 area).

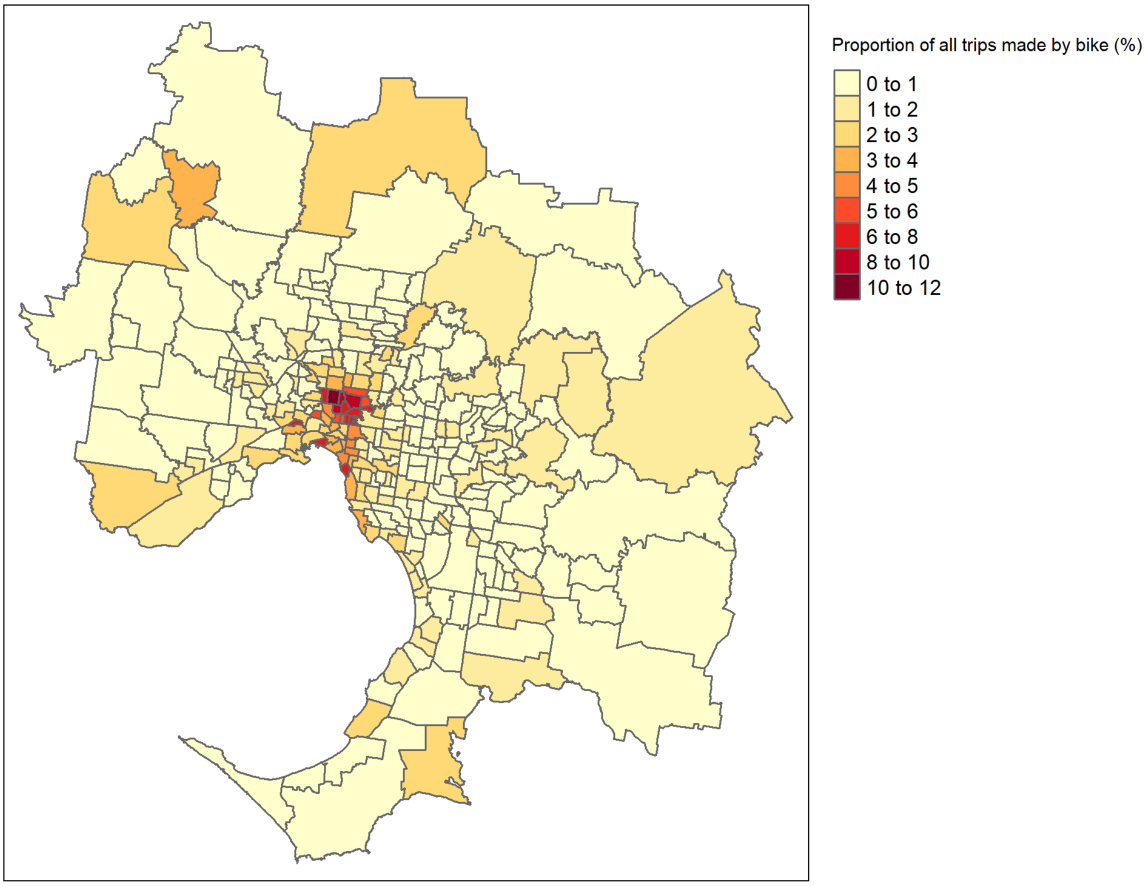

Figure 4: Proportion of all trips that were made by bike (per SA2).

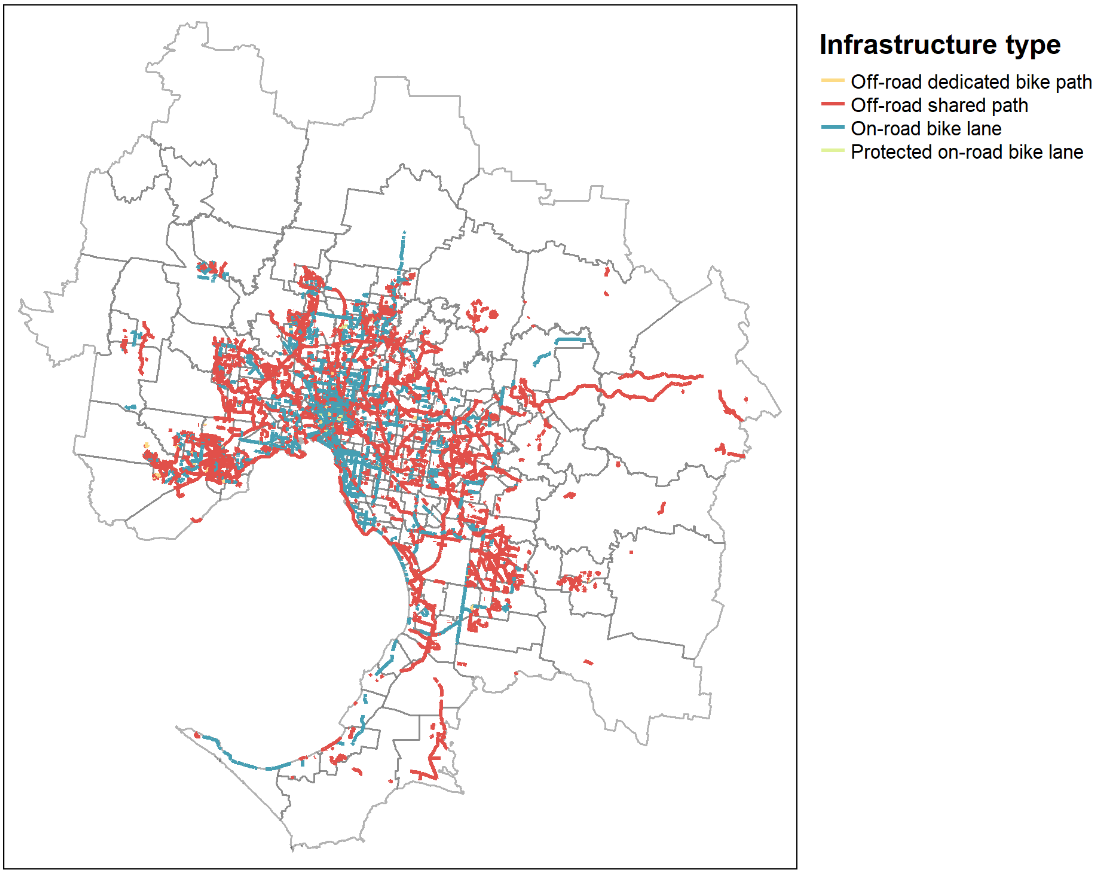

Figure 5: Map of bicycling infrastructure, stratified by infrastructure type. The grey borders reflect SA2 boundaries.

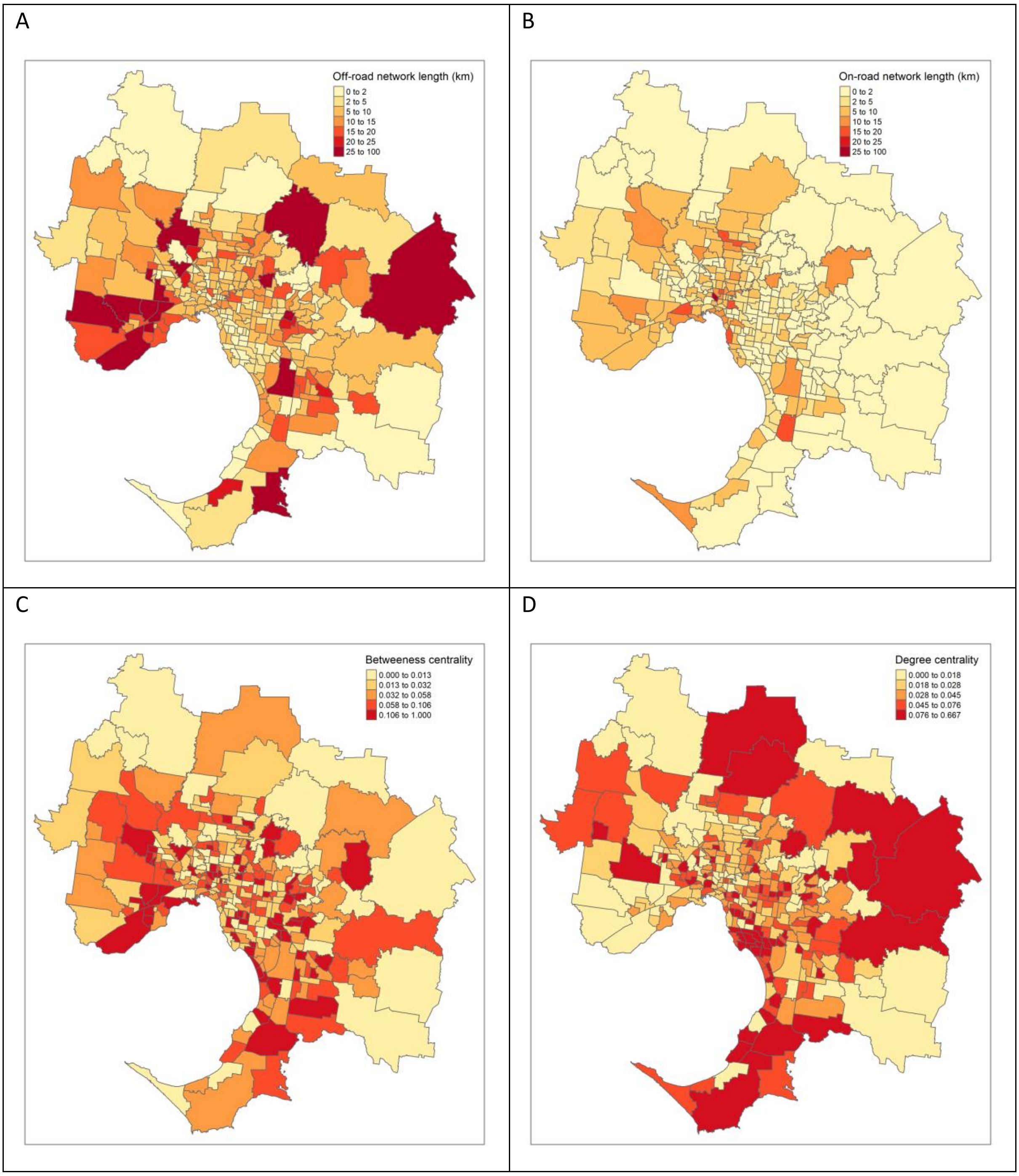

Figure 6: Network characteristics (per SA2). A) Off-road bicycle network length; B) On-road bicycle network length; C) Betweenness centrality; D) Degree centrality.

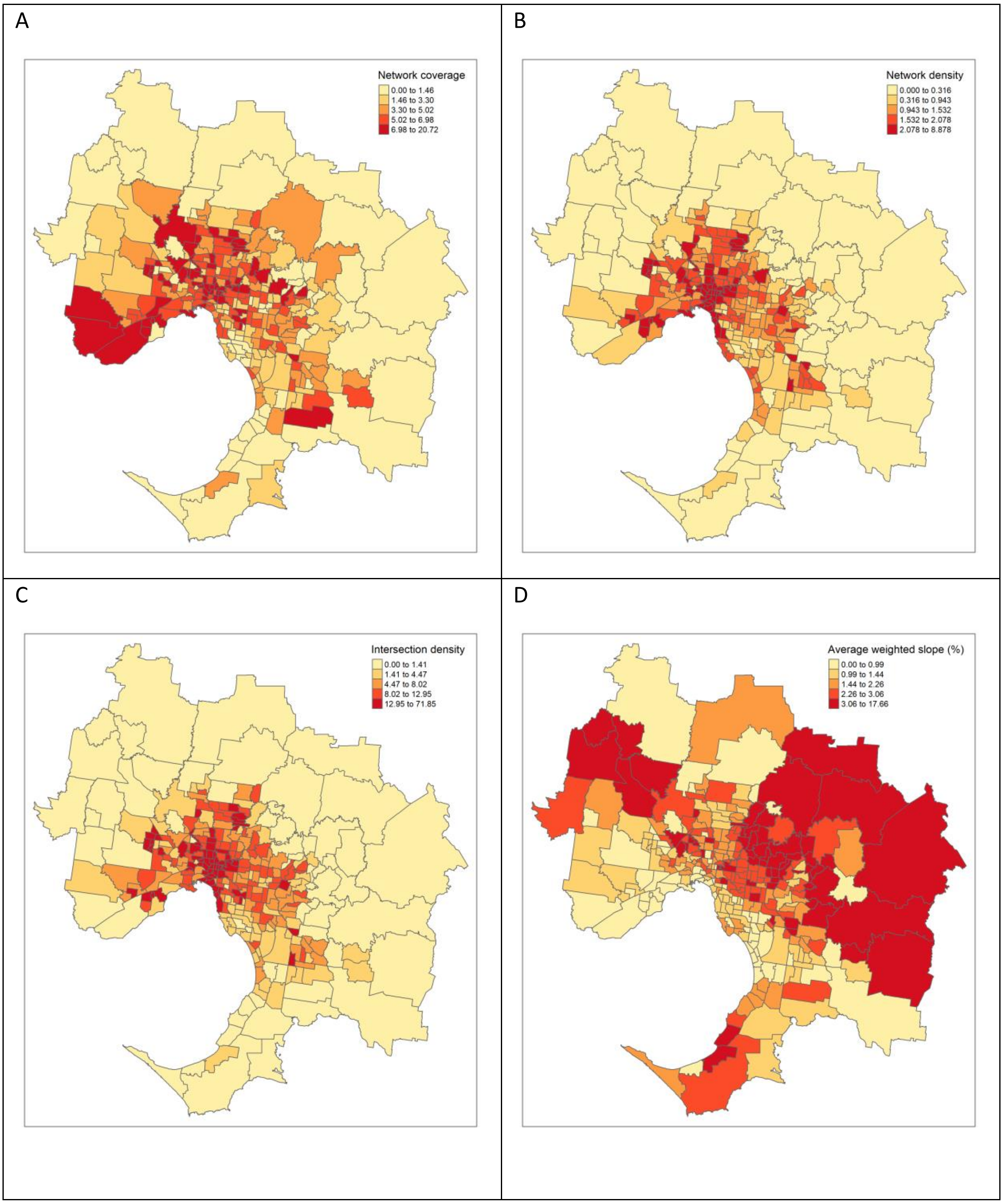

Figure 7: Network characteristics (per SA2). A) Network coverage; B) Network density; C) Intersection density; D) Average weighted slope.

SUPPLEMENTARY MATERIAL

Covariates: correlation matrix

Highlighted cells reflect Pearson correlation coefficients greater than 0.5.

	Betweenness centrality	Degree centrality	Bicycle network length – off-road	Bicycle network length – on-road	Network density	Network coverage	Intersection density	Average weighted slope
Betweenness centrality	1	0.6	0.11	-0.05	0.12	0.1	0.04	-0.17
Degree centrality		1	-0.24	-0.25	-0.23	-0.32	-0.24	-0.06
Bicycle network length – off-road			1	0.17	0.13	0.29	0.05	-0.03
Bicycle network length – on-road				1	0.48	0.38	0.41	-0.23
Network density					1	0.67	0.92	-0.21
Network coverage						1	0.73	-0.14
Intersection density							1	-0.16
Average weighted slope								1

Modelling counts of the number of bicycle trips: covariates and model fit parameters (Greater Melbourne)

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2582.34	296.587
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	2582.221	296.4258
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2581.538	296.4862
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	2581.468	296.3515
5	Betweenness centrality + network coverage + average weighted slope	2584.66	298.2385
6	Betweenness centrality + network coverage	2584.639	298.0784
7	Betweenness centrality + network density + average weighted slope	2585.231	298.2907
8	Betweenness centrality + network density	2585.208	298.1399
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2582.24	296.7281
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	2582.175	296.552
11	Betweenness centrality + intersection density + average weighted slope	2584.93	298.2501
12	Betweenness centrality + intersection density	2584.851	298.0878
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2582.342	296.5809
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	2582.267	296.4333
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2581.478	296.4333
16	**Degree centrality + Bicycle length off-road + Bicycle length on-road + network density**	**2581.391**	**296.2776**
17	Degree centrality + network coverage + average weighted slope	2584.944	298.3277
18	Degree centrality + network coverage	2584.919	298.1654
19	Degree centrality + network density + average weighted slope	2585.228	298.2983
20	Degree centrality + network density	2585.204	298.1457
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2581.982	296.6878
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	2582.112	296.5138

23	Degree centrality + intersection density + average weighted slope	2585.22	298.3159
24	Degree centrality + intersection density	2585.096	298.1719
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2582.605	296.5113
26	Bicycle length off-road + Bicycle length on-road + network coverage	2582.514	296.3559
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2581.511	296.4125
28	Bicycle length off-road + Bicycle length on-road + network density	2581.412	296.2248
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2582.441	296.694
30	Bicycle length off-road + Bicycle length on-road + intersection density	2582.336	296.441
31	Network density + average weighted slope	2585.19	298.1326
32	Network coverage + average weighted slope	2584.811	298.1483
33	Intersection density + average weighted slope	2585.01	298.1797

Modelling the proportion of trips made by bicycle: covariates and model fit parameters (Greater Melbourne)

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2592.214	297.8813
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	2591.445	297.4911
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2590.634	297.4894
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	2591.253	297.3336
5	Betweenness centrality + network coverage + average weighted slope	2594.671	298.2679
6	Betweenness centrality + network coverage	2595.062	298.2668
7	Betweenness centrality + network density + average weighted slope	2595.358	298.5736
8	Betweenness centrality + network density	2594.813	298.1853
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2589.708	296.9658
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	2591.107	297.4425
11	Betweenness centrality + intersection density + average weighted slope	2594.692	298.3134
12	Betweenness centrality + intersection density	2595.351	298.4502
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2591.772	297.8121
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	2590.56	297.2419
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2589.759	297.145
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	2590.5	297.2548
17	Degree centrality + network coverage + average weighted slope	2595.018	298.41
18	Degree centrality + network coverage	2594.897	298.2747
19	Degree centrality + network density + average weighted slope	2595.648	298.5982
20	Degree centrality + network density	2594.932	298.1735
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2591.542	297.6344
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	2590.252	297.0733

23	Degree centrality + intersection density + average weighted slope	2587.596	301.7865
24	Degree centrality + intersection density	2595.58	298.5183
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	2592.025	297.6023
26	Bicycle length off-road + Bicycle length on-road + network coverage	2590.829	297.1427
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	2591.607	297.582
28	Bicycle length off-road + Bicycle length on-road + network density	2591.009	297.2637
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	2591.399	297.3353
30	Bicycle length off-road + Bicycle length on-road + intersection density	2592.185	297.6946
31	Network density + average weighted slope	2584.696	301.8204
32	Network coverage + average weighted slope	2595.021	298.1743
33	**Intersection density + average weighted slope**	**2583.404**	**301.5073**

Modelling counts of the number of bicycle trips: covariates and model fit parameters

Inner Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	938.5053	92.14977
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	938.3852	92.14072
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	939.1291	92.17102
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	939.152	92.13594
5	Betweenness centrality + network coverage + average weighted slope	937.5864	92.20227
6	Betweenness centrality + network coverage	937.0141	92.20504
7	Betweenness centrality + network density + average weighted slope	939.4461	92.15936
8	Betweenness centrality + network density	939.2781	92.08382
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	939.6071	92.16326
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	939.3879	92.10681
11	Betweenness centrality + intersection density + average weighted slope	939.7624	92.17568
12	Betweenness centrality + intersection density	939.4616	92.17072
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	937.7516	91.94054
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	937.6217	91.92354
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	938.169	91.92123
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	938.1713	91.91918
17	Degree centrality + network coverage + average weighted slope	936.6586	91.94916
18	**Degree centrality + network coverage**	**935.0777**	**92.05474**
19	Degree centrality + network density + average weighted slope	938.1691	91.95818
20	Degree centrality + network density	937.9556	91.98682
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	938.602	91.91471
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	938.4169	91.96588

23	Degree centrality + intersection density + average weighted slope	938.5874	91.94692
24	Degree centrality + intersection density	938.0953	91.97694
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	938.7449	92.15606
26	Bicycle length off-road + Bicycle length on-road + network coverage	938.8692	92.11084
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	939.2167	92.14041
28	Bicycle length off-road + Bicycle length on-road + network density	939.4209	92.15563
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	939.6858	92.17184
30	Bicycle length off-road + Bicycle length on-road + intersection density	939.7974	92.13599
31	Network density + average weighted slope	939.3555	92.16915
32	Network coverage + average weighted slope	937.7688	92.24352
33	Intersection density + average weighted slope	939.8281	92.2071

Modelling the proportion of trips made by bicycle: covariates and model fit parameters

Inner Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	941.4414	92.00321
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	940.4013	91.92084
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	941.4271	91.94921
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	940.9627	91.95268
5	Betweenness centrality + network coverage + average weighted slope	941.1734	91.94699
6	Betweenness centrality + network coverage	938.9721	91.94015
7	Betweenness centrality + network density + average weighted slope	942.0239	91.94289
8	Betweenness centrality + network density	941.042	91.90629
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	941.697	91.91388
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	940.8401	91.9339
11	Betweenness centrality + intersection density + average weighted slope	942.4255	91.89803
12	Betweenness centrality + intersection density	941.0562	91.9187
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	940.3456	91.72
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	939.2749	91.7107
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	940.5987	91.73071
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	939.8039	91.69685
17	Degree centrality + network coverage + average weighted slope	939.7673	91.75912
18	**Degree centrality + network coverage**	936.9489	91.8644
19	Degree centrality + network density + average weighted slope	940.7913	91.76218
20	Degree centrality + network density	939.8014	91.68179
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	940.9296	91.74893
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	939.683	91.69434

23	Degree centrality + intersection density + average weighted slope	941.4187	91.81084
24	Degree centrality + intersection density	939.6452	91.77997
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	941.9773	91.98294
26	Bicycle length off-road + Bicycle length on-road + network coverage	941.3685	91.93038
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	942.046	91.92751
28	Bicycle length off-road + Bicycle length on-road + network density	941.873	91.91036
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	942.5701	91.9782
30	Bicycle length off-road + Bicycle length on-road + intersection density	941.866	91.87461
31	Network density + average weighted slope	942.7169	91.96252
32	Network coverage + average weighted slope	941.5986	91.98187
33	Intersection density + average weighted slope	943.1707	92.00523

Modelling counts of the number of bicycle trips: covariates and model fit parameters

North and West Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	868.21	108.6734
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	868.8677	108.8489
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	867.8078	108.434
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	868.3809	108.6293
5	Betweenness centrality + network coverage + average weighted slope	872.0314	110.0899
6	Betweenness centrality + network coverage	872.0517	110.2027
7	Betweenness centrality + network density + average weighted slope	871.1004	110.149
8	Betweenness centrality + network density	871.6482	110.1572
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	868.0154	108.371
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	868.436	108.5429
11	Betweenness centrality + intersection density + average weighted slope	871.6662	109.956
12	Betweenness centrality + intersection density	872.0128	110.0596
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	865.8591	107.3496
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	866.8227	107.9829
15	**Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope**	**865.4029**	**107.226**
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	866.4752	107.7298
17	Degree centrality + network coverage + average weighted slope	871.1078	109.9805
18	Degree centrality + network coverage	872.0249	110.0727
19	Degree centrality + network density + average weighted slope	871.1479	109.858
20	Degree centrality + network density	871.4645	110.0146
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	865.5369	107.2167
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	866.5996	107.7891

23	Degree centrality + intersection density + average weighted slope	871.3005	109.7595
24	Degree centrality + intersection density	871.5734	109.7934
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	868.1924	108.4782
26	Bicycle length off-road + Bicycle length on-road + network coverage	868.9149	108.7245
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	867.8106	108.2878
28	Bicycle length off-road + Bicycle length on-road + network density	868.4159	108.4653
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	867.8548	108.1824
30	Bicycle length off-road + Bicycle length on-road + intersection density	868.4527	108.4093
31	Network density + average weighted slope	871.5173	109.856
32	Network coverage + average weighted slope	871.6308	109.9932
33	Intersection density + average weighted slope	870.8585	109.7745

Modelling the proportion of trips made by bicycle: covariates and model fit parameters

North and West Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	875.2749	110.7585
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	877.0256	111.9731
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	872.9782	109.7948
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	876.5978	111.2933
5	Betweenness centrality + network coverage + average weighted slope	879.6224	111.5463
6	Betweenness centrality + network coverage	877.5424	111.2088
7	Betweenness centrality + network density + average weighted slope	879.0183	111.537
8	Betweenness centrality + network density	878.1704	111.3961
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	875.0341	110.4822
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	875.8455	111.27
11	Betweenness centrality + intersection density + average weighted slope	874.1603	112.8899
12	Betweenness centrality + intersection density	879.11	111.6487
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	873.6623	109.7352
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	873.98	110.5571
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	872.0168	109.1296
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	874.6884	110.8202
17	Degree centrality + network coverage + average weighted slope	876.5377	110.2628
18	Degree centrality + network coverage	875.2819	110.6284
19	Degree centrality + network density + average weighted slope	877.0736	110.4706
20	Degree centrality + network density	877.2589	111.1718
21	**Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope**	**871.7408**	**109.0401**
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	873.9005	110.4718

23	Degree centrality + intersection density + average weighted slope	876.6781	113.073
24	Degree centrality + intersection density	878.3381	111.4113
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	875.6317	110.61
26	Bicycle length off-road + Bicycle length on-road + network coverage	877.5099	111.7725
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	877.1678	111.3342
28	Bicycle length off-road + Bicycle length on-road + network density	876.4904	111.4692
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	876.7325	110.9251
30	Bicycle length off-road + Bicycle length on-road + intersection density	872.6613	109.8041
31	Network density + average weighted slope	878.8011	111.3913
32	Network coverage + average weighted slope	879.4976	111.614
33	Intersection density + average weighted slope	878.8523	112.9248

Modelling counts of the number of bicycle trips: covariates and model fit parameters

South and East Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	772.0071	99.66835
2	**Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage**	**770.9272**	**99.67434**
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	771.266	99.7766
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	771.9555	98.41639
5	Betweenness centrality + network coverage + average weighted slope	773.9007	99.16665
6	Betweenness centrality + network coverage	773.5655	98.96252
7	Betweenness centrality + network density + average weighted slope	773.9132	99.22891
8	Betweenness centrality + network density	773.6458	98.96909
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	773.5344	99.26658
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	771.4019	99.11838
11	Betweenness centrality + intersection density + average weighted slope	773.6176	99.16443
12	Betweenness centrality + intersection density	773.3959	98.85498
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	772.307	98.81081
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	771.5327	99.13104
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	771.3416	99.51609
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	771.2795	97.93796
17	Degree centrality + network coverage + average weighted slope	773.7706	99.18969
18	Degree centrality + network coverage	773.4604	98.91919
19	Degree centrality + network density + average weighted slope	773.9028	99.2446
20	Degree centrality + network density	773.5966	98.93267
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	771.8742	99.28412
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	772.9734	98.78456

23	Degree centrality + intersection density + average weighted slope	773.6187	99.10113
24	Degree centrality + intersection density	773.3375	98.84517
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	773.6363	99.16157
26	Bicycle length off-road + Bicycle length on-road + network coverage	771.5514	99.29818
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	772.2925	98.19422
28	Bicycle length off-road + Bicycle length on-road + network density	773.2802	98.80227
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	771.7209	99.72491
30	Bicycle length off-road + Bicycle length on-road + intersection density	771.0809	99.28344
31	Network density + average weighted slope	774.0771	99.14003
32	Network coverage + average weighted slope	774.0039	99.18049
33	Intersection density + average weighted slope	774.0145	99.14583

Modelling the proportion of trips made by bicycle: covariates and model fit parameters

South and East Melbourne

The model with the lowest DIC is highlighted in bold.

Model	Covariates	DIC	Effective number of parameters
1	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	780.7368	101.6839
2	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network coverage	780.9822	101.5806
3	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	780.1573	102.0705
4	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + network density	779.7459	100.7279
5	Betweenness centrality + network coverage + average weighted slope	781.0385	101.4823
6	Betweenness centrality + network coverage	780.0207	100.7756
7	Betweenness centrality + network density + average weighted slope	780.2953	101.0924
8	Betweenness centrality + network density	779.67	101.0775
9	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	780.593	101.5677
10	Betweenness centrality + Bicycle length off-road + Bicycle length on-road + intersection density	778.9679	100.727
11	Betweenness centrality + intersection density + average weighted slope	780.8195	101.4399
12	Betweenness centrality + intersection density	779.94	100.7531
13	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	780.7624	102.1617
14	Degree centrality + Bicycle length off-road + Bicycle length on-road + network coverage	779.7164	100.9467
15	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	778.9937	100.9955
16	Degree centrality + Bicycle length off-road + Bicycle length on-road + network density	779.0555	101.4264
17	Degree centrality + network coverage + average weighted slope	781.0754	101.443
18	Degree centrality + network coverage	779.3304	100.4006
19	Degree centrality + network density + average weighted slope	781.1107	101.4689
20	Degree centrality + network density	780.0071	100.7008
21	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	779.5743	101.5367
22	Degree centrality + Bicycle length off-road + Bicycle length on-road + intersection density	779.0882	100.7162

23	Degree centrality + intersection density + average weighted slope	781.2366	101.9255
24	Degree centrality + intersection density	778.3228	99.96271
25	Bicycle length off-road + Bicycle length on-road + network coverage + average weighted slope	780.7624	101.4653
26	Bicycle length off-road + Bicycle length on-road + network coverage	780.331	100.9373
27	Bicycle length off-road + Bicycle length on-road + network density + average weighted slope	780.0156	101.2182
28	**Bicycle length off-road + Bicycle length on-road + network density**	**777.3564**	**100.5806**
29	Bicycle length off-road + Bicycle length on-road + intersection density + average weighted slope	780.5249	101.3422
30	Bicycle length off-road + Bicycle length on-road + intersection density	779.5533	100.7835
31	Network density + average weighted slope	781.5287	101.392
32	Network coverage + average weighted slope	780.6814	101.057
33	Intersection density + average weighted slope	779.7604	100.6717