Exploring Variation in Built Environment Predictors of Ridership by Transit Mode

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Study Context

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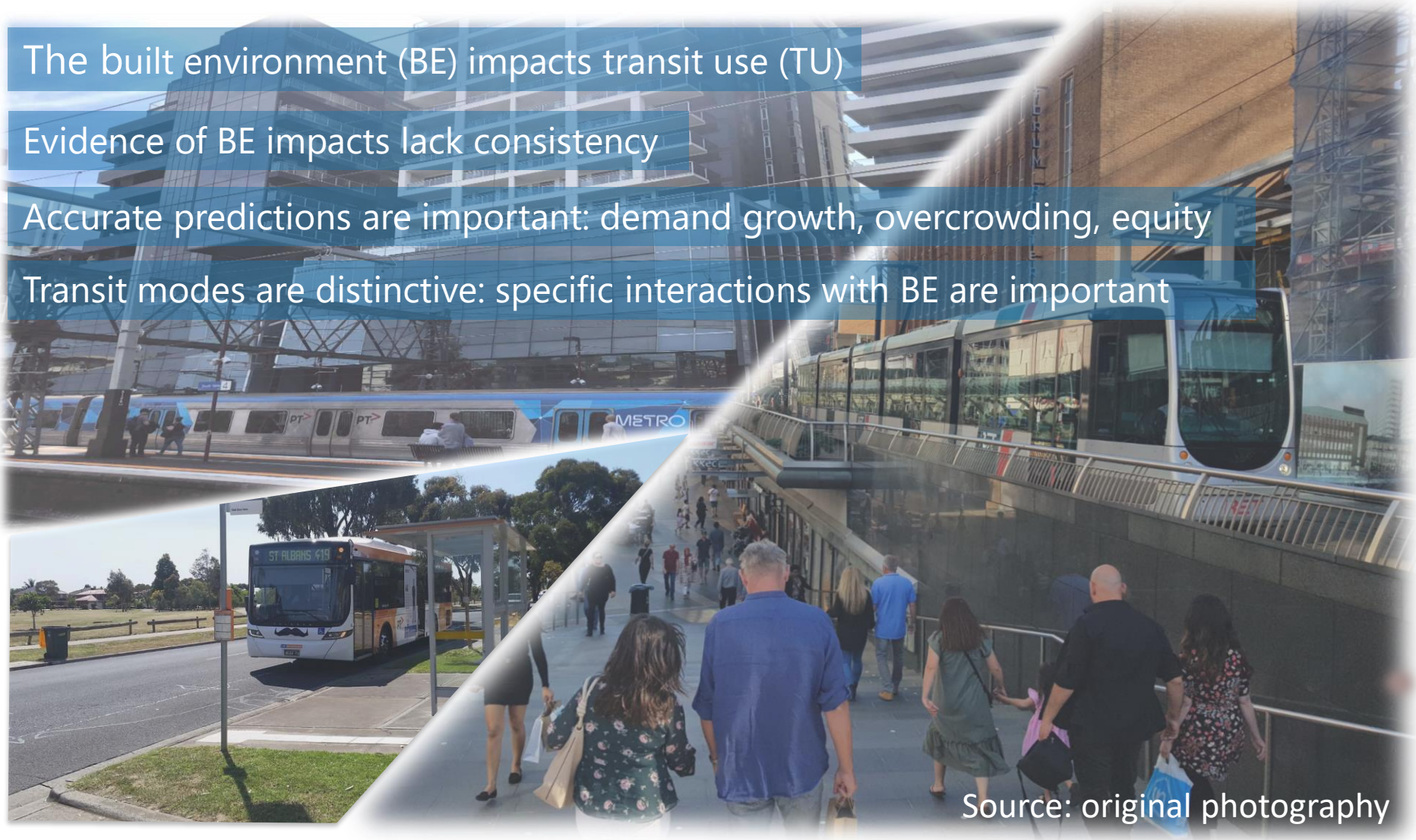
The built environment (BE) impacts transit use (TU)

Evidence of BE impacts lack consistency

Accurate predictions are important: demand growth, overcrowding, equity

Transit modes are distinctive: specific interactions with BE are important



Source: original photography

Study Aim and Approach

Aim 1

Identify the built environment attributes that significantly relate to ridership of different transit modes that are co-located.

Aim 2

Determine whether the built environment predictors of transit use differ between modes, given a controlled built environment setting.

Research Setting: Greater Metropolitan Melbourne

Sample: Co-located transit modes ('clusters') comprising:

- Bus and train (n = 135)
- Bus and tram (n = 339)

Method: Aggregate multivariate multiple regression of built environment and relevant external variables on average daily ridership

Methodology

Developing an unbiased sampling strategy

Problem: Modes serve different functions and are competitive in different urban environments.

- The BE characteristics of station access/egress and transfer catchments in Melbourne differ by mode (Table below).
- This causes bias in the sample

	Ref	Tram	Train	Bus
Walk radius of catchment (m)		400	800	600
Employment density (employees/ km²)	2	897	2,448	7,401
Population density (persons/ km²)	3	2,443	3,020	4,977
Retail density (retail employees/ km²)	4	94	200	480
Attraction-generation balance	5	0.082	0.098	0.146
Pedestrian Connectivity (Intersection density)*	7	82	108	153
Distance to CDB		23	17	6.3
Local accessibility (destination score)	9	4.0	5.4	6.0

*** Intersection density reported for 800m catchment area for all modes for comparability**

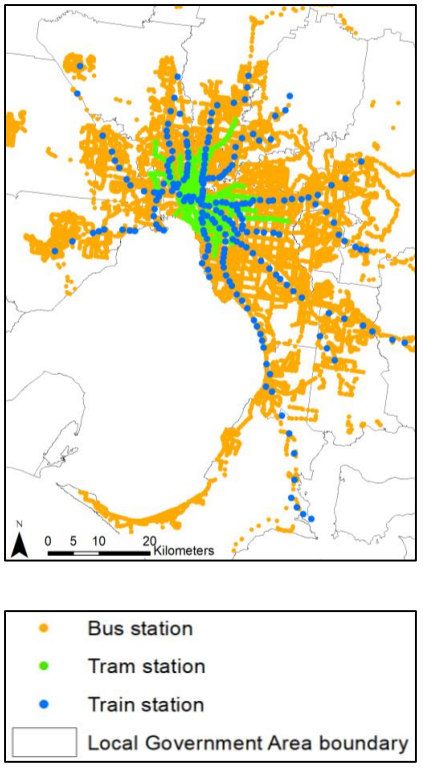
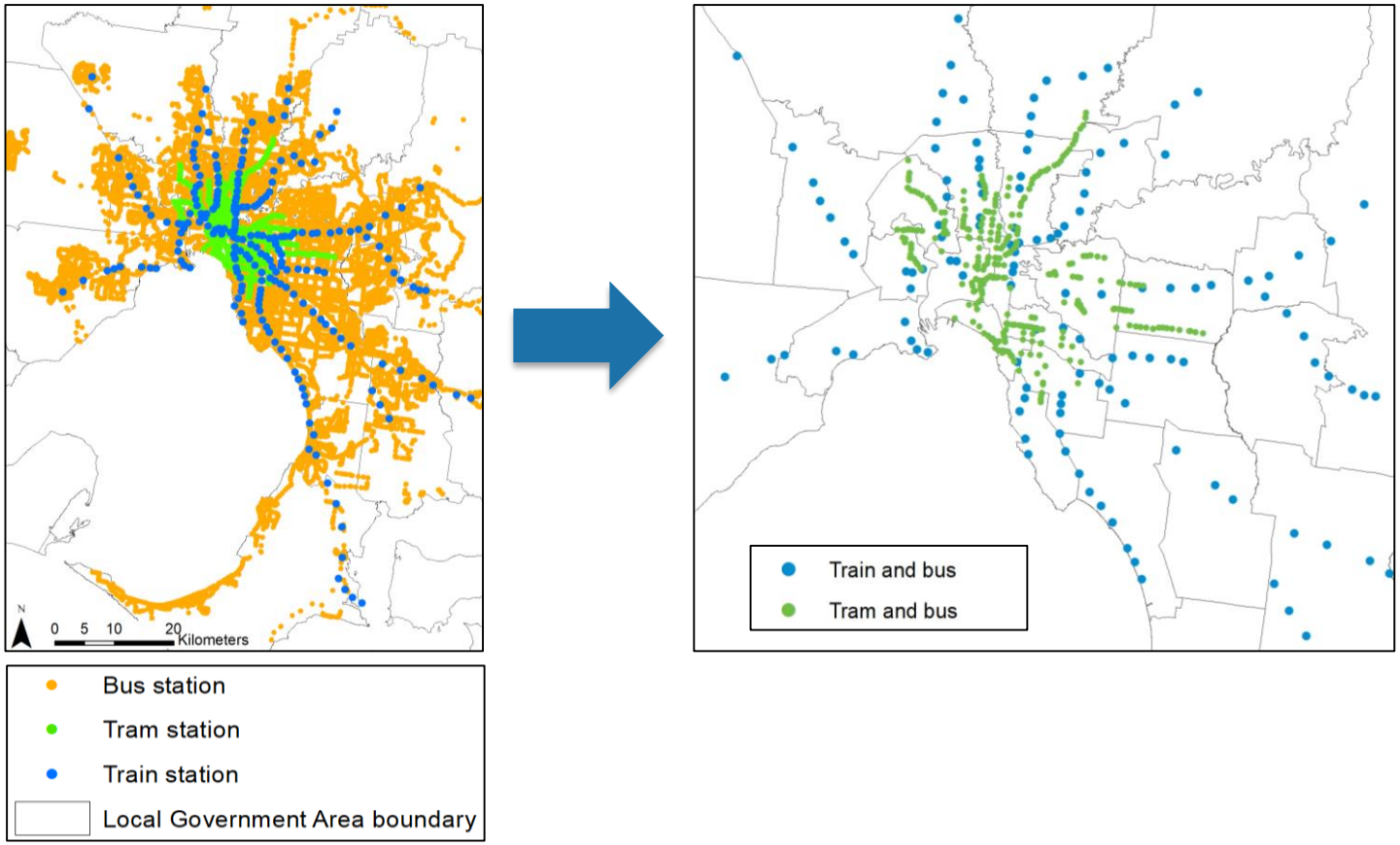


Figure: Distribution of transit stops by mode in Greater Metropolitan Melbourne

Methodology

Step 1: Develop an unbiased sampling strategy



Figures: (left) Distribution of transit stops by mode in Greater Metropolitan Melbourne and (right) location of sample sites for co-located train and bus (n = 135) and co-located tram and bus (n = 339).

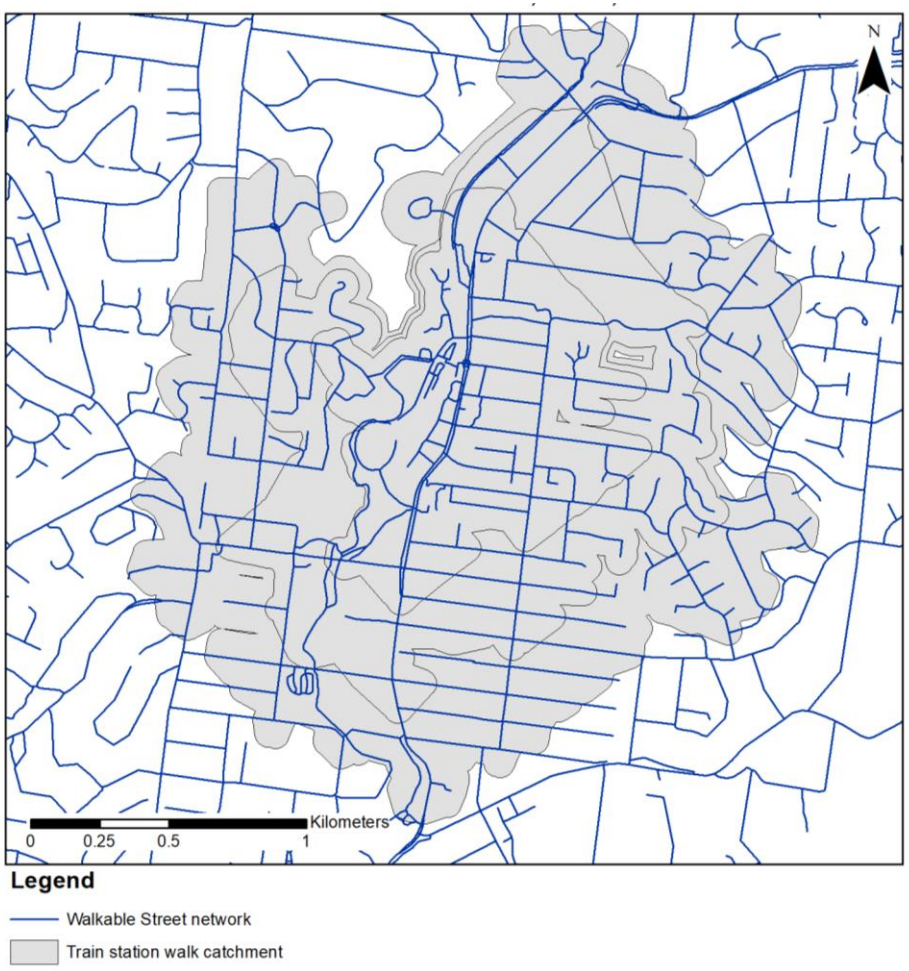
Step 2: Collect and aggregate data

Travel behaviour:
Annual average (weekday) ridership (measured as station entries)

Built environment:
- Employed persons
- Employment density
- Population
- Population density
- Dwelling density
- Activity density
- Commercial density
- Retail worker density
- Population density
- Attraction-generation balance
- Land use diversity
- Housing diversity
- Intersections
- Cycle path length
- Destination score
- Destination count
- Distance to CBD
- Count of Activity Centres
- Proportion urban land

Other variables:
- Level of service (departures/hour)
- Proportion full time employed
- Household income
- Household size

Figure: Walkable train station catchments (unit of analysis)



Descriptive Results

	Ref	Train-Bus	Tram-Bus*
Sample size (Clusters)		135	339
Total ridership (average weekday boardings)	1	3,041	616
Built Environment Variables			
Centroid walkable buffer distance (m)		800	600
Employment density	2	512	1,290
Population^	3	3,350	3,470
Population density		2,570	4,240
Retail worker density	4	117	221
Attraction – generation balance	5	0.90	0.91
Housing diversity	6	5.9	6.6
Intersections^ (600/800m)	7	150/230	190/300
Cycle path length (km)	8	52	71
Destination count	9	50	44
Distance to CBD (km)		18	7.7
Explanatory Variables			
Level of service (average weekday departures/hour)	10	180	120
Proportion full time employed	11	0.58	0.58

**excludes tram-bus sites within Melbourne's free [fare] tram zone*
^Population and intersection counts expressed in absolute terms

Results

Rank and direction of significant predictors of transit use

Tram ridership	Bus ridership
1. Level of service (+)	1. Level of service (+)
2. Land use diversity (+)	2. Pedestrian connectivity (+)
3. Average density (+)	3. Proximity to CBD (+)
4. Commercial density (+)	4. Proportion 'urbanised' (+)

Tram-bus sample

- Different predictors and relative magnitudes
- Unexpected association between bus ridership and proximity to CBD. In comparison proximity to CBD positively impacted bus ridership in the bus-train sample → suggests different functions served by bus near tram compared to train

Train ridership	Bus ridership
1. Proximity to CBD (+)	1. Level of service (+)
2. Dist to Activity center	2. Activity centers (+)
3. Level of service (+)	3. Average density (-)
4. Proportion FTE (+)	4. Mean income (-)
5. Proportion 'urban' (+)	5. Proportion FTE (+)
6. Mean income (-)	6. Dist. To CBD (+)
7. Average density (-)	7. Land use balance (-)
8. Land Use balance (-)	

Train-bus sample

- Only one significant built environment association with ridership for train-bus sample
- Unexpected associations of ridership with density and land use diversity for train-bus sample (negative; although both insignificant)

Discussion

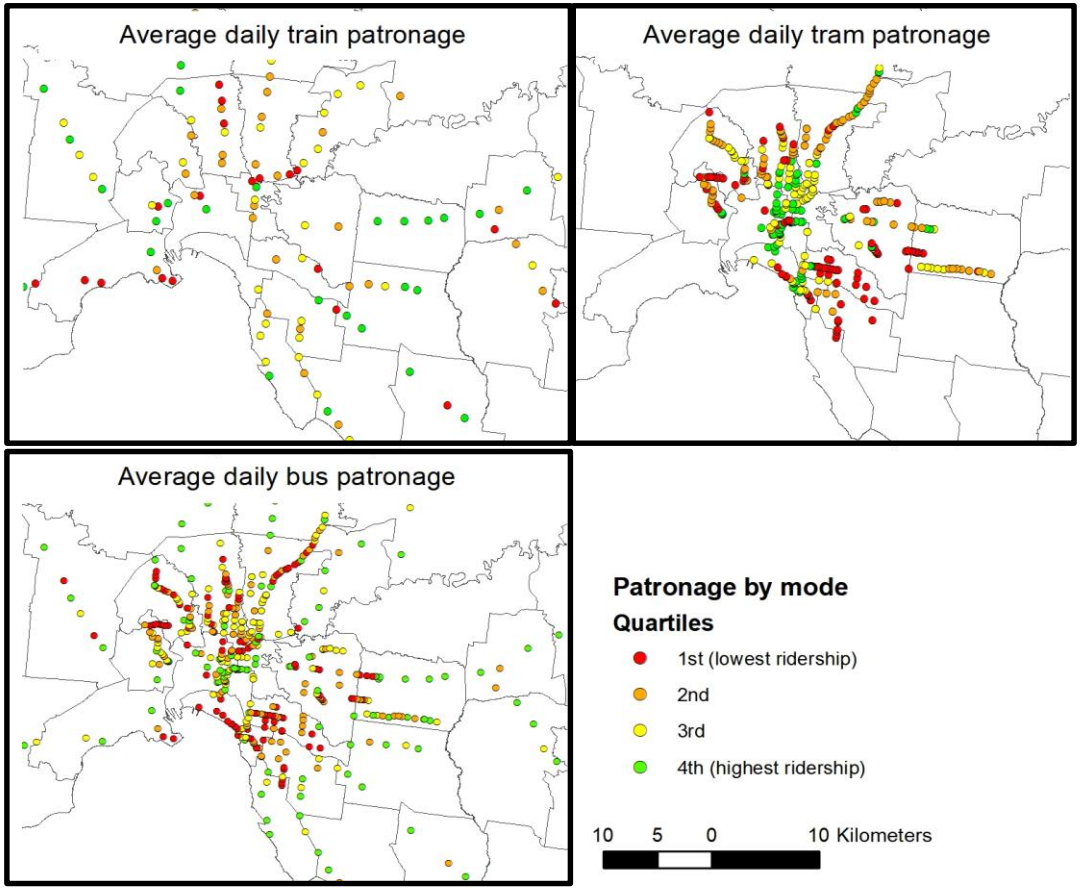
Probing unexpected results for Density and Diversity

Unexpected negative associations of bus and train ridership with Density and Diversity hint at possible competition between modes in inner areas, where trams are most readily available.

Limitations

- The requirement of the study sites to be co-located may be causing unwanted interaction
- Future analysis should control overlapping service level and explore alternate sampling approaches

Figure: Distribution of patronage (average daily touch-ons) by quartiles for sample, by mode



Discussion

The finding that bus transit is not impacted by land use intensity but is impacted by walkability warrants further exploration to determine if bus ridership - associated with lower frequencies and legibility – is impacted more strongly by connectivity and design than other modes.

Source: original photography

Conclusions

- Tram and bus ridership shared no BE predictors.
- Bus ridership was not positively associated with typical neighbourhood-level latent demand factors.
- Unexpected negative impacts of Density and Diversity for bus and train ridership may be due to interaction effects.
- Ridership models could provide more accurate forecasts if predictions are differentiated by mode.
- Further investigation, which explores attitudes and perceptions linked to built environment features by mode, will help make these findings generalizable for planning.

Data sources

Transit stop points		Public Transport Victoria, Public Transport Points in Public Transport: A collection of PTV datasets, State of Victoria, Editor. 2018.
Total ridership (average weekday boardings)	1	Department of Transport, Data Request Metropolitan Patronage - Stop Level (2018), State of Victoria, Editor. 2019.
Employment density	2	Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 2) 2016 Working Person Profile: Table W01 Labour Force Status by Age by Sex, in 2016 Census of Population and Housing. 2017: Canberra.
Population, Population density	3	Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 1) 2016 General Community Profile: Table G01: Selected Person Characteristics by Sex, in 2016 Census of Population and Housing, Commonwealth Government of Australia, Editor. 2017: Canberra.
Retail worker density	4	Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 2) 2016 Working Person Profile: Table W09 Industry of Employment by Sex, in 2016 Census of Population and Housing. 2017: Canberra
Attraction – generation balance	5	• Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 1) 2016 General Community Profile: Table G01: Selected Person Characteristics by Sex, in 2016 Census of Population and Housing, Commonwealth Government of Australia, Editor. 2017: Canberra. • Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 2) 2016 Working Person Profile: Table W09 Industry of Employment by Sex, in 2016 Census of Population and Housing. 2017: Canberra
Housing diversity	6	Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 1) 2016 General Community Profile: Table G38: Dwelling Structure by Household Composition and Family Composition, in 2016 Census of Population and Housing, Commonwealth Government of Australia, Editor. 2017: Canberra.
Intersections^ (600/800m)	7	State Government of Victoria, Vicmap Transport, Department of Environment Land Water and Planning, Editor. 2017, data.vic.gov.au.
Cycle path length (km)	8	VicRoads, Principal Bicycle Network, State of Victoria, Editor. 2017.
Destination count	9	• GeoFabrik downloads, GIS OSM pois free 1: Australia, Open Street Map, Editor. 2019. • PSMA Australia Limited, PSMA Australia Limited, PSMA Features of Interest (Polygon) (August 2018); accessed from AURIN on 1/3/2019, PSMA Australia Limited, Editor. 2018.
Level of service (average weekday departures/hour)	10	Public Transport Victoria. PTV Google Transit Feed Specification. 2018 27 July 2018; Available from: https://transitfeeds.com/p/ptv/497.
Proportion full time employed	11	Australian Bureau of Statistics, Victoria (STE) (Statistical Area Level 1) 2016 General Community Profile: Table G43B: Dwelling Structure by Household Composition and Family Composition, in 2016 Census of Population and Housing. 2017: Canberra.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Laura Aston, Graham Currie, Md. Kamruzzaman, Alexa Delbosc and David Teller; data collection: Laura Aston and Nicholas Fournier; analysis and interpretation of results: Laura Aston and Md Kamruzzaman; draft manuscript preparation: Laura Aston. All authors reviewed the results and approved the final version of the manuscript.

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