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Associations of utilitarian cycling with destinations and street connectivity assessed within multiple buffers

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Abstract: In examining neighborhood environmental attributes associated with bicycle use, measuring attributes within a buffer area around home has been a common approach. However, buffer sizes have been determined with limited empirical support. This study investigated associations of cycling for utilitarian purposes with destinations and street connectivity measured within empirically informed multiple buffer zones. Household travel survey data collected in Victoria, Australia (2012–20), were used to calculate the mode share of cycling for home-based utilitarian trips in 1,105 Statistical Area Level 1s (SA1s), which contained 43,965 adult participants. Based on the distribution of home-based utilitarian cycling trip distances, three non-overlapping concentric circular buffers were drawn from the centroid of each SA1: 0–1 km (Zone 1); 1–1.8 km (Zone 2); and 1.8–4 km (Zone 3). Two destination density measures (core and expanded destinations) and two intersection density measures (3-way+ and 4-way+ intersections) were assessed within each zone. Two-part regression models examined the associations of environmental measures with the presence of utilitarian cycling (logistic regression) and with the mode share of cycling (linear regression). Logistic regression found that higher destination density in all zones and intersection density in Zone 3 were associated with higher odds of utilitarian cycling trips. Linear regression found that higher destination and intersection densities in Zone 2 were associated with a higher mode share of cycling. Future research could use a buffer area within 1 to 4 km from home to further understand the relationships between the built environment and cycling for utilitarian purposes.

Keywords: travel survey, bicycle use, physical activity, environment

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1 Introduction

Bicycle use is advocated as an accessible mode of transportation with multiple benefits. Its promotion can contribute to key United Nations Sustainable Development Goals (United Nations, 2015), as increasing participation in cycling can help to reduce

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human health risk, greenhouse gas emissions, and traffic congestion (Brand et al., 2021; Götschi et al., 2016; Lee & March, 2010). Despite the evidence supporting multiple benefits of bicycle use, the prevalence of cycling is low worldwide, except for a few countries such as the Netherlands and Japan (Goel et al., 2022). Since promoting cycling is a priority of many cities and local governments (City of Sydney, 2018; Transport for Victoria, 2017), further evidence is needed to inform the development of relevant policies and strategies.

Neighborhood built environments can play important roles in encouraging or discouraging cycling participation (Christiansen et al., 2016; Koohsari et al., 2020; Mertens et al., 2017). There has been an increasing interest in identifying environmental correlates of bicycle use to inform urban planning and design initiatives to promote cycling (Adam et al., 2020; Hagen & Rynning, 2021). A literature review on built environment correlates of cycling (Yang et al., 2019) identified 39 empirical studies (published between 2007 and 2017) and found that environmental correlates of cycling differed by cycling purposes: for transport (travel from one place to another in general), for commuting (travel specifically between home and workplace or school), and for recreation (cycling for leisure or exercise). Availability of destinations to cycle to and greater street connectivity were identified as correlates of cycling for transport, while the presence of bike paths was found to be relevant to cycling for commuting, but it did not find any environmental attributes consistently associated with cycling for recreation (Yang et al., 2019).

Given the purpose-specific nature of environmental attributes related to cycling, it can be argued that environmental strategies for cycling promotion are likely to be more effective if they focus on cycling for a particular purpose. Since cycling for transport is generic and can include commuting, there is a case for focusing on cycling for utilitarian purposes, which is to access local destinations for practical purposes such as shopping and errands. Utilitarian cycling can be a more suitable target for promotion, since it is generally shorter in distance than cycling for commuting (Schneider et al., 2022), with potential for ease of uptake. Availability of destinations for daily needs and a well-connected street network, which have been identified as fundamental local environmental attributes relevant to walking (Sugiyama et al., 2012), are potential environmental attributes that may help to promote utilitarian cycling (Yang et al., 2019).

In examining whether and to what extent local environmental attributes are related to cycling, it is necessary to identify an area within which the potentially relevant environmental attributes are measured. One approach to do so is to draw a "buffer" around a point of interest such as a home address (Chen et al., 2017; Porter et al., 2020). Using such a buffer is widely used in research that aims to identify environmental correlates of walking (Adams et al., 2014; Holliday et al., 2017). Buffers can be considered to represent an area within which walking to get to local destinations from home takes place. Studies examining how far people walk from home found that the buffer sizes used to examine environmental attributes relevant to walking are generally consistent with the walking distances identified (Millward et al., 2013; Morency et al., 2014; Sugiyama et al., 2019).

Varying buffer sizes have been used in studies investigating environmental correlates of cycling (Beenackers et al., 2012; Ma et al., 2014; Nielsen et al., 2013; Porter et al., 2020), but there is limited empirical support for the choice of buffer sizes. For instance, Porter et al. (2020) used 1.5 km and 3 km buffers to examine environmental attributes associated with cycling for transport and for recreation. They noted that these distances corresponded to 5-min and 10-min cycling distances respectively, but no justification for these durations was given. Nielsen et al. (2013) also used a 1.5 km buffer based on cycling duration. Beenackers et al. (2012) and Ma et al. (2014) used a 1.6 km buffer around residences, which has been used to define a neighborhood in research on the built environment and walking (Smith et al., 2010). Other cycling studies also employed buffer sizes used to examine environmental correlates of walking, such as 500 m, 800 m, and 1 km (Christiansen et al., 2016; Hino et al., 2014; Ma & Dill, 2015). However, since it is possible to travel a much longer distance by cycling than by walking, it may not be adequate to use buffer sizes employed in environment-walking studies.

We investigated the cross-sectional associations of two key environmental attributes—local destinations and street connectivity—with cycling for utilitarian purposes, using multiple buffer sizes determined from an empirical analysis of the distribution of cycling distances. It should be noted that this study is underpinned by the ecological model of health behaviors, in which behaviors related to health are conceptualized to be shaped by broad contextual factors (Sallis & Owen, 2015). Thus, the basis upon which this study was built is different from the framework of transport modelling, which aims to predict travel demands by understanding how various conditions (in transport and other relevant domains) impact them. Our aim was to expand the knowledge on environmental correlates of cycling, with a view toward informing relevant environmental and planning policies, by focusing on cycling for utilitarian purposes and applying empirically derived cycling distances to define buffer sizes.

2 Methods

2.1 Data sources

Cycling data for this study were obtained from the Victorian Integrated Survey of Travel Activities (VISTA), conducted between 2012 and 2020, prior to the enforcement of COVID-19 movement restrictions in the state. Participants were recruited from the Melbourne Statistical Division and surrounding regional cities (Geelong, Ballarat, Bendigo, Shepparton, and Traralgon). The total population of these municipalities was 4.6 million in 2016. The survey used a multi-stage random sampling method: mesh blocks, the smallest geographic area in the Australian Statistical Geography Standard (Australian Bureau of Statistics, 2016a), were sampled first, then private households were sampled within the selected mesh blocks. A 24-hour travel diary was used to collect details of travel (mode of transport, origin, start time, destination, arrival time, and purpose of trips) made by all members of the selected households. Self-administered questionnaires were used to collect demographic details such as age, gender, and employment status. Over the 9-year period, a total of 78,978 participants responded to the survey with a response rate of approximately 50%. Further details of the survey procedures were reported elsewhere (Ipsos Social Research Institute, 2017). The current study targeted adult participants aged 18 to 74 years old (N= 57,125). Those aged 75+ were excluded, as they may experience potential age-related functional difficulties (Peeters et al., 2013). All the ethical standards outlined in government statutes and regulations were followed. The approval to use VISTA data for this study was granted by the Swinburne University Human Research Ethics Committee (Ref: 20237362-16509).

2.2 Outcome: Mode share of cycling

The outcome variable was the area-level mode share of cycling for home-based utilitarian trips, i.e., trips starting or ending at a participant's residence and undertaken for daily necessities, such as local shopping or running errands. Cycling trips to get to/from work or school were not included, as cycling for commuting is known to have different environmental correlates from utilitarian cycling (Yang et al., 2019). The mode share value was calculated by dividing the count of home-based utilitarian cycling trips by home-based utilitarian trips made by all modes of transportation (multiplied by 100 to express this value as a percentage). This was treated as both a binary categorical measure (zero or non-zero mode share) and a continuous measure (non-zero mode share percentage values). We used the area-level measure due to the unavailability of participant's home address in the VISTA.

The area unit within which the mode share of cycling was calculated was the Statistical Area Level 1 (SA1). This is the smallest unit for the release of census data, with an average population size of approximately 400 people (Australian Bureau of Statistics, 2016c). Of the SA1s where the VISTA collected data, we used those with 30 or more home-based utilitarian trips (N=1,123) to ensure a sufficiently large number of observations for calculating a robust area-level measure (Hogg et al., 2020). SA1s larger than 3.1 km^2 (N=18) were excluded due to a reason explained in Section 2.3.1. The number of SA1s remained for analysis was 1,105. The median size of those selected SA1s was 0.16 km^2. Of these, 896 SA1s (81%) had no utilitarian cycling trips, while 209 SA1s (19%) had non-zero cycling mode share values. The total number of travel survey participants included in the selected SA1s was 43,965.

2.3 Exposure: Environmental attributes

Two types of environmental attributes (destinations and intersections) were examined. We measured these attributes within multiple, non-overlapping buffer areas. In the following sections, we first explain how the buffer areas were defined, then describe the environmental measures and potential confounding variables.

2.3.1 Buffers within which environmental attributes were measured

For each SA1, environmental attributes were assessed in three non-overlapping zones (Figure 1). These zones were delineated using three concentric circular buffers around the centroid (i.e., gravity center) of each SA1, with buffer distances derived from a previous Australian study that examined cycling distance distributions for specific purposes (Mohamed et al., 2024). The study reported that the 20th, 50th and 80th percentile distances of utilitarian cycling trips were 1 km, 1.8 km, and 4 km, respectively. The 80th percentile distance was considered as the upper limit for how far most people would cycle, consistent with previous research on walking that employed a similar approach (Cole et al., 2017; Morency et al., 2014; Sugiyama et al., 2019). By the same token, the 20th percentile distance was regarded as the lower limit of cycling distance (i.e., the distance shorter than this would be covered by walking). These distance thresholds were used to define the three zones. Zone 1 is the area within 1 km from the centroid (20th percentile), which is the immediate area adjacent to the center of the SA1. Zone 2 is the area within 1 to 1.8 km from the center, which corresponds to relatively shorter cycling trips for utilitarian purposes (20th to 50th percentile). Zone 3 is the area within 1.8 to 4 km from the centroid. This outer-most zone represents an area that can be reached by longer cycling trip distances (50th to 80th percentile). The geographic areas of Zones 1, 2 and 3 were 3.1 km^2, 7 km^2 and 40 km^2, respectively. As noted above, 18 SA1s larger than 3.1 km^2 were excluded from the current analyses since their boundaries can extend beyond Zone 1. Spatial analyses were carried out using ArcGIS Pro 3.2.

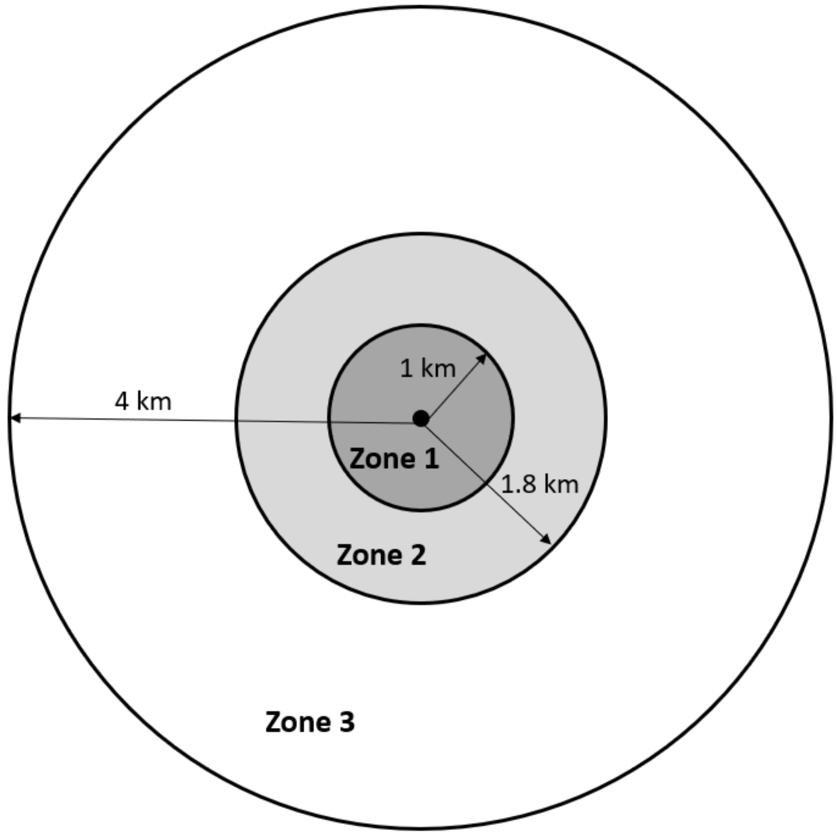

Figure 1. Three zones within which the environmental measures (destination density, intersection density) were calculated

2.3.2 Destination density

As the destination measure, we used the density of two sets of destinations that may be accessed by bicycle for utilitarian purposes. One is the "core" set with a few typical destinations for daily needs, while the other is the "expanded" set with additional destinations. The list of these destinations and data sources are provided in Table 1. These destinations were selected based on previous studies, considering their data availability and suitability for cycling in the context of Australia (Higgs et al., 2023; Ma et al., 2014; McNeil, 2011). Of these, supermarkets, convenience stores, and train stations were regarded as the core destinations, since they are the type of places people would visit on a regular basis (Mavoa et al., 2018). The destination density was calculated as the number of destinations within each zone divided by the area of the zone in square kilometers. In total, there were six destination measures examined: two types (core and expanded destinations) in three zones.

Table 1. List of core and expanded destinations used to calculate destination density

Destination	Data source	Core set	Expanded set
Supermarkets	Supermarkets, Pitney Bowes Ltd [a]	✓	✓
Convenience stores and news agents	Axiom Business Points, Pitney Bowes Ltd [a]	✓	✓
Train stations	PSMA Australia Transport & Topography (the 2012 release)	✓	✓
Grocery stores	Axiom Business Points, Pitney Bowes Ltd [a]		✓
GP - health clinics	National Health Services Directory (2017)		✓
Pharmacies	National Health Services Directory (2017)		✓
Libraries	State-specific library location layer from the Australian national liveability datasets (2016-2018)		✓
Post offices	Axiom Business Points, Pitney Bowes Ltd [a]		✓

[a] The 2014 release, sourced in 2012-2013.

2.3.3 Intersection density

Intersection density was used as a measure of street connectivity and calculated as the number of street intersections in each zone divided by the area of the zone. Two types of intersection densities, corresponding to 3-way-or-more (3-way+) and 4-way-or-more (4-way+) intersections, were examined. The locations of street intersections were identified using the road network data from the PSMA Australia's 2012 Transport & Topography dataset. In total, there were six intersection density measures examined: two types (3-way+ and 4-way+ intersections) in three zones.

2.3.4 Potential confounders

SA1-level sociodemographic characteristics were considered as potential confounders in regression modelling. For each SA1, mean age, percentage of older adults (≥ 60 years), and percentage of men were calculated using self-reported data in the VISTA. The percentage of older adults was included to account specifically for the presence of older adults in SA1s. We also used the Index of Relative Socioeconomic Disadvantage (IRSD) as a potential confounder. The IRSD is an area-level indicator of disadvantage, derived from multiple census-based measures of individuals and households, such as employment status, income, education, and car ownership (Australian Bureau of Statistics, 2016b).

2.4 Statistical analyses

Descriptive statistics were calculated for all SA1s and separately for SA1s with zero and non-zero cycling mode share. Pearson's correlation coefficients between key variables (cycling mode share and environmental attributes) were calculated. The outcome variable, the mode share of cycling for utilitarian trips, was a non-negative skewed continuous variable with a high proportion of zero values. A two-part regression modelling approach is a recommended method for modelling this type of variable (Boulton & Williford, 2018; Buntin & Zaslavsky, 2004). The first part was logistic regression models, which examined the associations of environmental attributes with the odds of having utilitarian cycling trips across all SA1s (N=1,105). The second part was linear regression models that examined the associations of environmental attributes with cycling mode share (%) using only those SA1s with non-zero mode share values (N=209). In each modelling part, two types of models (Models 1 and 2) were fitted. Model 1 assessed the associations of the outcome measures with each environmental attribute in a specific zone separately (3 models for each density measure). Model 2 assessed the associations by examining density values from three zones simultaneously. Model 2 was used to isolate the association of each type of attribute in different zones. Namely, a positive association for one attribute from one zone (e.g., core destination density in Zone 1) observed in Model 1 may be partly due to its correlation with the same attribute from the other zones (e.g., core destination density in Zone 2 or 3). All models were adjusted for the potential confounders. As a sensitivity analysis, we tested for sample selection bias in our data (i.e., whether areas with cycling mode share values are selective rather than random, potentially violating the assumptions of the second-part linear regression models) by fitting Heckman selection models using the sampleSelection package in R (Toomet & Henningsen, 2008). The results, presented in Supplementary Table 1, showed no significant sample selection bias in this data. This supports the use of two-part regression models as a suitable technique for our modelling purposes. All statistical analyses were carried out using R version 4.2.0.

3 Results

Table 2 shows the characteristics of the 1,105 SA1s included. Cycling mode share for home-based utilitarian trips ranged from 0 to 26%, with the overall mean of 1%. Most SA1s were much smaller than Zone 1 (3.1 km^2), with the median size of 0.16 km^2. SA1s with non-zero cycling mode share were slightly smaller in size than those with zero cycling mode share. These two SA1 groups did not differ markedly in their mean age, proportion of older adults, proportion of men, and area-level disadvantage.

Table 2. Characteristics of the SA1s

	SA1s without HB utilitarian cycling trips	SA1s with HB utilitarian cycling trips	All SA1s
Number of SA1s	896	209	1,105
Median size [min, max], km^2	0.17 [0.02, 3.00]	0.13 [0.04, 2.25]	0.16 [0.02, 3.00]
Total number of travel survey participants [a]	35,615	8,350	43,965
Mean number of HB utilitarian trips (SD)	45.0 (14.7)	49.7 (19.3)	45.9 (15.8)
Cycling mode share of HB utilitarian trips, %			
Mean (SD)	0 (0)	5.9 (4.1)	1.1 (2.9)
Median [min, max]	0 [0, 0]	4.8 [0.7, 25.9]	0 [0, 25.9]
Demographic characteristics			
Mean age (SD)	39.2 (6.3)	39.4 (5.7)	39.3 (6.2)
Mean % of adults ≥ 60 years (SD)	21.5 (12.6)	20.7 (12.5)	21.4 (12.6)
Mean % of men (SD)	48.6 (6.1)	48.2 (6.4)	48.5 (6.1)
Mean IRSD (SD)	1,040 (67.6)	1,060 (55.2)	1,050 (65.8)

[a] aged 18 to 74 years

HB: home-based; IRSD: Index of Relative Socioeconomic Disadvantage

Figure 2 presents boxplots that show the distributions of the four environmental measures (core destination density, expanded destination density, 3-way+ intersection density, and 4-way+ intersection density) in three zones for the SA1 groups with zero and non-zero cycling mode share. The means and standard deviations of these variables are presented in Supplementary Table 2. These plots clearly illustrate the gradient of the destination and intersection densities across the SA1 groups: SA1s with non-zero cycling mode share had a higher destination and intersection density than those with zero cycling mode share.

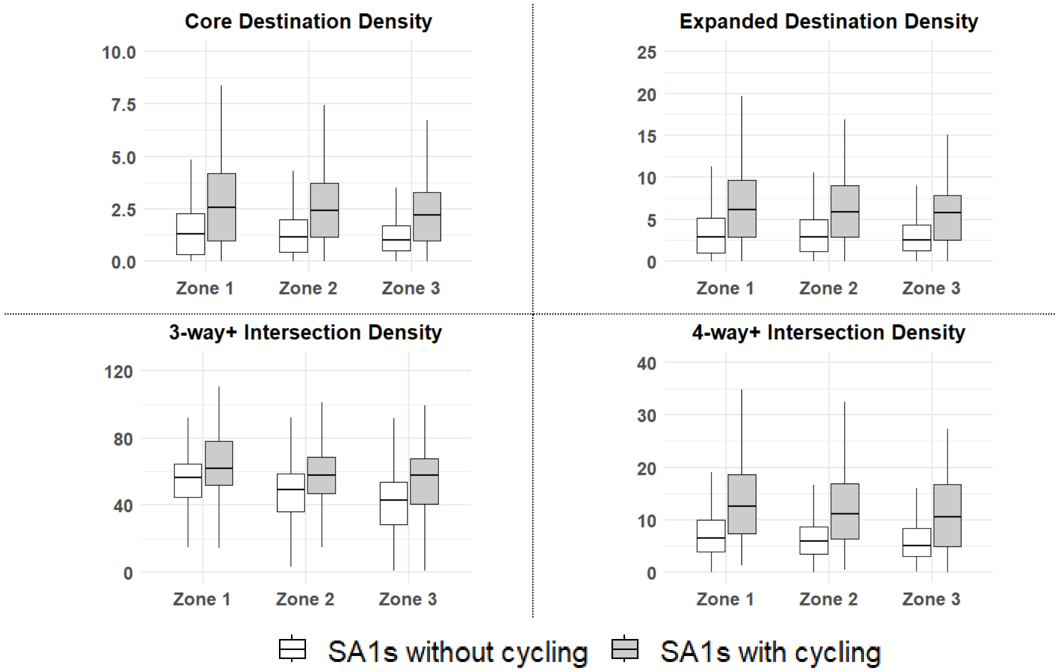

Figure 2. Boxplots displaying the distributions of destination and intersection densities (in counts/km²) calculated within three mutually exclusive zones, shown for SA1 groups stratified by the presence of utilitarian cycling trips
Zone 1: 0–1.0 km; Zone 2: 1.0–1.8 km; Zone 3: 1.8–4.0 km

Supplementary Table 3 shows Pearson's correlation coefficients between cycling mode share and environmental attributes calculated in three zones. All environmental measures were significantly positively correlated with cycling mode share, with the coefficients ranging from 0.2 to 0.4. We used this matrix to assess to what extent core destination density and expanded destination density were correlated in different zones: the correlation coefficients were 0.96 for Zone 1, 0.97 for Zone 2, and 0.99 for Zone 3. This means that these destination measures are almost fully correlated, suggesting that it is not necessary to examine both to investigate how destination density is related to cycling. Similarly, 3-way+ and 4-way+ intersection densities were strongly correlated: $r = 0.80$ for Zone 1, 0.83 for Zone 2, and 0.89 for Zone 3. Again, high correlation coefficients between the two types of intersection density suggest that examining only one would be sufficient in analysis.

Given the high correlation coefficients between core and expanded destination density and between 3-way+ and 4-way+ intersection density, we used only one measure for each attribute to present results in a concise manner: core destination density and 4-way+ intersection density. Core destination density was selected as it is easier to collect data and can serve as a proxy measure of other destinations, i.e., a place with a supermarket, convenience store, or train station is likely to have other shops and services. We chose 4-way+ intersection density since its correlation coefficients with cycling mode share (0.34 to 0.40) were slightly higher than those of 3-way+ intersection density (0.23 to 0.28).

Table 3 shows the results of the logistic and linear regression models. In Model 1, where density measures were examined separately, destination and intersection densities in all zones were significantly associated with the odds of having utilitarian cycling or with cycling mode share. However, different patterns emerged in Model 2, in which density values from three zones were examined simultaneously. The logistic regression model for destination density indicated that higher densities in all three zones were associated with greater odds of having utilitarian cyclists. However, the logistic regression model for intersection density found a significant association only in Zone 3. The linear regression models for destination and intersection densities found that a higher density in Zone 2 was associated with a higher percentage of cycling mode share. For intersection density, it was also found that a greater density in Zone 1 was associated with a lower percentage of cycling mode share.

Table 3. Results of two-part regression models examining the associations of utilitarian cycling with destination and intersection densities

	Zone	Logistic regression		Linear regression	
		Model 1	Model 2	Model 1	Model 2
		OR (95% CI)	OR (95% CI)	β (95% CI)	β (95% CI)
Core destination density	1	**2.1 (1.8, 2.4)** ***	**1.5 (1.2, 1.8)** **	**1.0 (0.5, 1.4)** ***	0.4 (-0.2, 0.9)
	2	**2.1 (1.8, 2.4)** ***	**1.3 (1.1, 1.7)** *	**1.1 (0.7, 1.6)** ***	**0.7 (0.1, 1.3)** *
	3	**2.1 (1.8, 2.4)** ***	**1.4 (1.1, 1.7)** **	**1.0 (0.6, 1.5)** ***	0.4 (-0.2, 1.0)
4-way+ intersection density	1	**2.0 (1.7, 2.4)** ***	1.2 (0.9, 1.6)	**0.6 (0.2, 1.1)** **	**-0.8 (-1.6, -0.0)** *
	2	**2.2 (1.9, 2.6)** ***	1.2 (0.8, 1.8)	**1.1 (0.7, 1.5)** ***	**1.4 (0.3, 2.5)** *
	3	**2.3 (1.9, 2.7)** ***	**1.7 (1.3, 2.3)** **	**1.1 (0.7, 1.6)** ***	0.4 (-0.5, 1.3)

*$p < .05$. **$p < .01$. ***$p < .001$

In the two-part regression models, the first part was logistic regression examining the association of explanatory variables with the odds of having utilitarian cycling across all SA1 units (N=1,105). The second part was linear regression assessing the association of explanatory variables with cycling mode share (%) using only those SA1s with non-zero mode shares (N=209). Model 1 examined the association of the cycling outcome with each environmental attribute in the relevant zone separately (6 models). Model 2 examined the association of the cycling outcome with two sets of environmental attributes (destination or intersection densities) from three zones simultaneously (2 models). All models were adjusted for the potential confounders. Bold coefficients indicate statistical significance. ORs represent the odd ratios of having utilitarian cycling trips in an SA1 and correspond to each one SD unit higher value in environmental attribute. βs represent the difference in utilitarian cycling mode share (in SA1s with non-zero mode shares) in % and correspond to each one SD unit higher value in environmental attribute.

4 Discussion

Using travel survey data from Victoria, Australia, we examined the area-level associations of utilitarian cycling with destination and street connectivity attributes measured in three buffer zones that were based on an empirical examination of cycling distances. Overall, we found the majority of SA1s (81%) did not have any home-based cycling trips for utilitarian purposes. Even in SA1s with non-zero cycling mode share, cycling was used only for a small portion of home-based utilitarian trips (about 6% on average).

In general, we observed that areas with higher destination density and intersection density were more likely to support cycling for utilitarian purposes, which is consistent with the research synthesis reported in the review by Yang et al (2019). However, our analyses also found that the relationships between utilitarian cycling and these environmental attributes varied between the categorical (presence of utilitarian cycling trips) and continuous outcome (mode share of cycling) and across the three zones.

For destination density, higher density values in all zones were related to the presence of utilitarian cycling, but they were associated with a higher mode share of cycling only in Zone 2, after adjusting for the same attribute from the other zones. The non-significant finding for cycling mode share for Zone 1 (0–1 km) in Model 2 may be partly due to destinations in such an area being accessible by walking. This interpretation is supported by an Australian study on walking, which found frequent walking to be associated with utilitarian destinations within 0.8 km from home but not with those within 0.8 to 1.2 km (Gunn et al., 2017). Assuming 4.5 km/h as the typical walking speed (Bohannon & Andrews, 2011), it takes 13 minutes to walk 1 km and 24 minutes to walk 1.8 km. It is possible that Zone 2, which can be reached by 4–7 minutes of cycling with the average speed of 15 km/h (Eriksson et al., 2019), may represent an area that is easy to access by cycling but extend beyond a convenient walking distance. Destination density in Zone 3 (1.8 to 4 km from the center) was associated with the odds of utilitarian cycling but not with cycling mode share. Destinations in this distant zone may encourage bicycle use for utilitarian trips for certain individuals, but they may be too far for many adults to reach (or more convenient to reach by car), thus may not be conducive to higher levels of utilitarian cycling.

For intersection density, logistic and linear regression analyses produced distinct findings in Model 2. For Zone 1, intersection density was not significantly related to the odds of utilitarian cycling but significantly and negatively associated with cycling mode share. For Zone 2, it was unrelated to the presence of utilitarian cycling but positively related to mode share. For Zone 3, a higher intersection density was associated with greater odds of utilitarian cycling but not with the mode share of cycling. It is difficult to interpret these findings. It was anticipated that higher street connectivity in all zones from home to destinations would be relevant to cycling, as well-connected streets can provide a more direct route from the origin (home) to destination. One potential reason for the unexpected findings for Zone 1 can be that street connectivity at the destination area may be more relevant to cycling than connectivity near home, since most cycling begins from residential areas where intersection density is unlikely to be high in Australia. It is also possible that residential areas with high street connectivity may be more conducive to walking, which may end up discouraging bicycle use. Further research is needed to understand how well-connected street network contributes to cycling in what areas.

It can be argued based on the findings (and the consideration that destinations within 1 km from home can be accessed by walking) that the availability of core destinations (supermarkets, convenience stores, train stations) and 4-way+ intersections within 1 to 4 km from home may facilitate bicycle use for utilitarian purposes in Australia. This buffer area and the environmental attributes may be used in future research to assess how bicycle-friendly neighborhoods are and whether it is worth providing additional infrastructure for cycling to further promote bicycle use.

Our findings contribute to the identification of a parsimonious set of environmental measures relevant to utilitarian cycling. We found very strong correlations between the core and expanded sets of utilitarian destinations, suggesting that future studies can rely on a few destinations in assessing environment-cycling associations. It was also found that the densities of 3-way+ and 4-way+ intersections were strongly correlated, but the latter was slightly more closely correlated with cycling mode share. These findings, along with the knowledge of buffer sizes in which the associations with cycling were significant, could help to inform the construction of a bikeability index, which would be of interest to research and practice.

There are some limitations that need to be recognized. Data on cycling trips were collected from participants using a 24-hour travel diary. Due to a short time span of the travel diary, it may not capture cycling trips by non-regular cyclists. Although survey participants were recruited using a multi-stage random sampling method, the response rate was around 50%. In particular, men, older adults, and those residing in rented, multi-unit housing (flats and apartments) were potentially underrepresented in the sample, according to the technical report of the travel survey (Urban Transport Institute and I-view Pty Ltd., 2011). Thus, the sample may not be representative of the population of the study area, and this may have implications on the generalizability of the findings to the study region. The three zones were derived from an empirical investigation of cycling trip distances. The thresholds applied to define the zones (20th percentile, median, and 80th percentile) were chosen based on existing transport studies that investigated walking distances (Cole et al., 2017; Morency et al, 2014; Sugiyama et al., 2019). Different thresholds may perform better in identifying associations with environmental measures. Another limitation is that we used the gravity center of each SA1 to draw buffers in the absence of participants' residential locations. However, this may not be a critical issue, as most of the selected SA1s were much smaller than the smallest buffer (3.1 km^2). We focused on the densities of destinations and street intersections, which are previously identified as fundamental environmental factors in research on walking (Sugiyama et al., 2012) and consistent correlates of cycling for transport in the literature review (Yang et al., 2019). Future studies can investigate other environmental attributes such as bike paths, traffic volumes, and slope within multiple buffers. We examined the ecological association between environmental factors and cycling mode share, adjusting for potential area-level confounders. However, these area-level factors may not fully capture individual-level variations in cycling behavior, which are also influenced by individual-level demographic and socioeconomic characteristics (Mohamed et al., 2024). Further research examining individual-level relationships is needed to confirm the findings of the ecological associations in this study. Finally, the buffer sizes and associations were identified using data from Australia, a country with low cycling rates. Our findings may be applicable only to countries with low prevalences of cycling such as the United States and Brazil (Goel et al., 2022). For countries with high cycling prevalences, such as the Netherlands and Japan, cycling distances may be shorter since there are greater diversities in cycling participation (e.g., more women and older adults). Future studies examining environmental correlates of cycling in such countries may have to first identify suitable buffer sizes by investigating how far they cycle.

5 Conclusions

We examined area-level associations of cycling for utilitarian purposes with destination and intersection attributes measured in multiple zones. The study contributes to future research investigating environmental correlates of cycling in two ways. First, we tested to what extent environmental attributes (known to be related to the broader category of cycling for transport) measured in multiple buffers were associated with utilitarian cycling. Based on the findings, we propose that a buffer area within 1 to 4 km from home may be employed in future research investigating environmental correlates of bicycle use in Australia and potentially in similar contexts with a low prevalence of cycling. Second, we identified a parsimonious set of environmental measures related to cycling for utilitarian purposes (core destination and 4-way+ intersection density). This knowledge on buffer sizes and relevant environmental attributes can be useful for future studies aiming to advance the understanding of the relationship between the built environment and cycling, e.g., to assess how bicycle-friendly neighborhoods are, and how other environmental factors (bicycle infrastructure, safety) can contribute to cycling in the presence (or absence) of these fundamental environmental attributes.

An important goal for society is not just to increase bicycle use but also to reduce car use by making the built environment more conducive to cycling and active travel in general. Although some European cities were successful in initiating such a modal shift through implementing various initiatives including building infrastructure for cycling (Ferretto et al., 2021), one study conducted in the UK found that providing active travel infrastructure alone was not sufficient to promote the modal shift (Song et al., 2017). It can be argued that distinct strategies may be needed to discourage people from driving. Future research needs to investigate how car trips, in particular trips that are short enough to be cycled, are distributed within society and whether cycling promotion strategies can reduce such short car trips.

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Data availability

The original data presented in the study are publicly available at https://discover.data.vic.gov.au/dataset/victorian-integrated-survey-of-travel-and-activity-vista.

Author contribution

Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing—original draft preparation, visualization, project administration: F. Mohamed; conceptualization, methodology, writing—review and editing, supervision: M. Chandrabose; conceptualization, writing—review and editing, supervision: N. Owen; conceptualization, methodology, resources, writing—review and editing, supervision: T. Sugiyama.

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