Australasian Transport Research Forum 2021 Proceedings
8-10 December, Brisbane, Australia
Publication website: http://www.atrf.info

Network Assessment for Cycling, the Inner Adelaide Case

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Abstract

Cycling is a fantastic method to get about while also being environmentally friendly. It improves urban mobility, liveability, and public health while reducing traffic congestion and pollution at the same time. Hillier's (1984) research of spatial syntax is suggested for going beyond the street network and looking at how network layout influences travel behaviour choices. The goal of this study is to see if there's a link between street network morphology and commuters' desire to ride their bikes to work in Adelaide's inner suburbs. To obtain a better understanding of the implications that street network geometry may have on the estimation of cycling to work, two ordinary least square (OLS) models including both base socio-economic factors and street network variables are developed. The analysis showed that adding space syntax measure variables to the equation enhances the goodness of fit for cycling to work. When it comes to explaining variations in cycling to work, the model that incorporates spatial syntax features has a greater (about 10%) explanatory power. The findings may be seen as an evidence-based statement that planners and policymakers can use to help them make decisions about how to improve the design of bicycle networks in suburban areas.

Key words: Space Syntax; Street Network Configuration; Cycling; Travel Behaviour; Adelaide.

1.Introduction

1.1. The big picture

Cycling, is an essential mode of transportation at various times, serving as both an exercise and a kind of pleasure (Law & Karnilowicz 2015). Although cycling is popular in many countries(John Parkin 2013a) . It is still a niche mode of transportation in much of the industrialised, technologically sophisticated, and rich globe(Pucher & Buehler 2008). The exceptions are some European countries such as Denmark, Germany, and the Netherlands, where population cycling rates are significantly higher than in countries such as the United States, the United Kingdom, and, in particular, Australia, in terms of overall percentage of total travels by bicycle versus other modes of transportation(Pucher & Buehler 2008).

In comparison to the early movement of English immigrants and the population consisting mostly of individuals of British nationality, contemporary Australian culture is on the verge of witnessing a higher proportionate number of people born in East Asia, South Asia, and Arab Africa. The relationship between cycling and 'location' becomes more complex when home prices rise in most Australian cities(Pucher & Buehler 2008).

As the country's population grew, so did the need for cheap housing, forcing many newly arrived migrants and refugees to relocate outside of the city limits. This resulted in a significant increase in the distance between popular locations, resulting in a significant shift in riding behaviour and a stronger sensation of displacement. This type of 'locational disadvantage and spatial disparities' has an impact on mobility, social commitment, psychological well-being, and wellbeing. The location-based disadvantages in these societies make cycling more difficult because people believe that many of the generic healthy living services and activities (such as active cycling participation with related social-cultural, fitness, and environmental benefits) are extremely limited and confined to dominant and elitist white Australians(Pucher & Buehler 2008; Nguyen, Soltani, & Allan 2018; Soltani, Allan, & Pojani 2021).

1.2. The current scholarship

Lengthier journeys and longer delays may arise from efforts to make riding safer or more pleasurable for cyclists and motorists (Forester 1996). More importantly, if bicycle-specific facilities are only provided in a few locations or segments of networks, at least some cyclists will have to go out of their way to utilise them. As a result, understanding how cyclists feel about trade-offs between directness and pleasantness might help with the design and evaluation of cycling infrastructure. Nonetheless, it is worth noting that, in certain cases where travel time has been considered, it has not shown to be a significant or important factor (Aultman-Hall 1996). The amount of physical effort required to pedal, contacts with motor vehicles, and the quality of the environment all have an effect on the cyclist (Dalton, Peponis, & Conroy-Dalton 2003). Based on this knowledge, it is possible to design a bicycle network that fits users' wishes by picking routes with the most enticing qualities. The usual knowledge of route selection is insufficient to handle this issue since the characteristics of a bicycle differ considerably from those of a motor vehicle.

To describe the spatial structure of roadway networks, a computer language called Space Syntax (Hillier & Hanson 1988)was created. In space syntax, the spatial pattern or arrangement is thought to have a significant influence on human social interactions. Configurational models quantify the pattern features of the highway network by creating an axial map (Dalton, Peponis, & Conroy-Dalton 2003). The shortest set of axial lines that goes through each convex space and links all axial points is an axial map of the settlement's open space structure (Kazerani 2010). Meanwhile, the pattern of how people travel around a city may be anticipated by examining how areas within an urban zone are connected or integrated.

To better understand the relationship between urban structure and human movement, space syntax is an effective tool. Pedestrian behaviour modelling, bicycle route mapping, and wayfinding are all common applications for spatial syntax in urban environments(Xia 2013). By analysing street network layout, transportation planners may acquire a better understanding of traffic flow patterns, allowing them to provide a more efficient and practical solution. It's possible that cycling offers greater freedom of route selection than driving (Creutzig et al. 2020), on the other hand, it is constrained by factors such as the directness of the route, the infrastructure of the route, sense of safety, and the purpose and duration of the trip. The spatial syntax is capable of analyzing some of these constraints and is therefore very useful for studies of cycling route selection.

By using space syntax analysis, the calculation of segment angular shift is extremely well connected to bicycle traffic (Raford, Chiaradia, & Gil 2007). Stability in terms of angular reduction or the least amount of angular change is critical for making cycling lanes appealing. Cyclists are well aware of this; when riding a bike, you must exert effort to "smooth" sharp curves in the path in order to maintain speed. Cyclists in the real world follow a complicated dynamic that must balance the various features of the routes. A common example of this is taking a detour to pass through a more enjoyable area (Creutzig et al. 2020).

To examine the factors that influence biking to work, Ashley and Banister used UK census data and built a model that took into account human characteristics, trip distances, the availability of cycling infrastructure in urban areas, and car ownership among other things (Raford, Chiaradia, & Gil 2007). On the other hand, any major modification to the layout of the road network, such as changing the size or shape of urban blocks, is costly and therefore less practical (Cooper 2017). Nelson and Allen (1997) used census data from 18 locations in the United States to estimate work trip cycle mode splits based on weather, topography, the number of college students, and the number of per capita miles of bikeway infrastructure. They observed that providing good bikeway facilities resulted in a higher percentage of persons riding their bikes to work. Nathalie Noël & Lee-gosselin (2004) used surveys to generate travel diaries in Quebec City, Canada, however they didn't look into the relationship between claimed preferences and actual route choice. In an Edmonton, Canada, stated preference research (Hunt & Abraham 2007), cyclists were asked to choose between two hypothetical route choices to a "all day conference." According to their survey, cyclists preferred routes with specialised cycling facilities and those that provided destination-based amenities such as parking and showers.

1.3. What remains less evident

In most current transportation modelling practices, variables like transportation demand, distance measurements, and route capacities are all included, but variables like cognitive ease of route finding, route directness, and smoothness, which have been shown to be critical for built-environment bikeability, are rarely included [8]. Rather, more refined and user-friendly methods for projecting bicycle route selection based on urban street architecture would be beneficial from both a traffic planning and a user perspective (Manum et al. 2017).

There are limited studies on the measures that are most likely to succeed in encouraging people to cycle instead of driving and the true impact of such efforts on public health in South Australia. In order to increase the number of people who use active transportation, safety measures such as bike lanes and proper signaling must be improved (Carnall, McGrath, Lingwood, & Ogilvie 2004). In South Australia, efforts to promote active transport should focus on making it simple for individuals to walk or cycle to work. Most importantly, additional methodologically sound studies to establish the influence of interference on cycling should be conducted (John Parkin 2013b). The research on street design features that affect cycling behavior in South Australia is particularly scarce, and only a handful of these studies have used space syntax research techniques. The few studies on cycling have tended to focus on travel patterns (or why people prefer cycling to other modes of transportation) or issues with cycling infrastructure design (cycle lanes, parking facilities at the destination, etc.).

1.4. Research objective/questions

This research could aid in the understanding of the influence of road network design on the choice of bike route for commuting in Australia's cities and towns. This research makes use of a spatial syntax approach to determine the relationship between street network design and data on commutes to work. Inner suburbs in different directions around Adelaide's metropolitan area were selected because they had a higher percentage of cyclists because of the quality of the built environment and proximity to workplaces.

Street network design and geometry will be examined, as well as how urban form can aid in improving cycling conditions. One issue is the street network's configurational qualities, or, more precisely, the bicycle route network's accessibility properties, which include all highways, lanes, and paths where riding is permitted, authorised, and generally secure. A mix of GIS and Space Syntax is one such tool for navigating bike lanes and paths in urban areas. Consequently, the key research questions are as follows:

• Research question 1: What would be the benefit of using street network geometry in the prediction model in terms of improving bicycle share estimation?

• Research question 2: What are the most important factors to consider when modelling bicycle work trips in Adelaide's inner suburbs?

The paper's contribution is to provide a methodology for better understanding the patterns of work trip cycling based on a mix of metrics drawn from space syntax theory on a fine-scale, city-wide scale. Results contribute to theories and understanding of how street networks designed as a result of behavioural activities and how street network layout as a generator of power in relation to cycling activities are a result of. In addition, this is the first time that a large-scale morphological analysis of Adelaide's street network has been done as part of a study on cycling travel behaviour. This research has the benefit of being worked on a fine-grained small geography (SA1 level) in order to have as homogenous a sample for investigation in a large part of the Adelaide metropolitan region.

The rest of article is structured as follows. Section 2 describes the methods and materials, by giving a brief explanation of space syntax, how we applied space syntax measures to measure connectivity, depth and other configuration attributes of the street network, then the case study area is introduced, and then the collection of secondary data and its processing is described. Next, Section 3 presents the analysis of data, i.e., the outcomes of applying space syntax to numericize the street network geometry, and the results of regression models on cycling behaviour of workers and its associated factors. Finally, in Section 4, we discuss the results of our modelling and describe how the findings are consistent with previous studies. We also discuss the implications for both theory and practice and present some directions for future research on cycling network.

2. Materials and Methods

2.1. Space Syntax

The spatial syntax (Hillier & Hanson 1988) is in fact a collection of techniques to study the patterns of spatial configuration, particularly where the spatial configuration sounds to be a significant dimension of human behaviour, either on an urban scale or a building scale. According to Hillier and Hanson (1988), space syntax is a methodology for describing human behaviour and social activities in the perspective of space configuration.

The space syntax analysis is conducted on a segment graph or an axial graph (Lebendiger & Lerman 2019). Using a linear network to represent the road system, an axial graph can be constructed to show the road network's open spaces in detail. The segment graph shows a finer granularity, which takes into account each part between the nodes, and in addition to the topological distance with the same weight for each turn, it can also calculate the minimum angular distance (Lebendiger & Lerman 2019; Turner 2007). It's important to remember that the terms "shortest path" and "shortest distance" refer to graph-based concepts, not geometric network equivalents. In this case, the topological distance is represented by the number of edges between two different nodes (Kazerani 2010).

The relative importance of each street segment can be calculated using the "Graph theory" and the space syntax technique. As it turns out, centrality refers to the systemic hierarchy of accessibility (Nes & Yamu 2017). To measure centrality, it is suggested to measure detailed features included: Connectivity; Integration, and Choice (Figure 1).

The Connectivity of a line is determined by the number of other lines that are immediately connected to it. So, a node's degree is the number of edges that pass through it. Choice measures the shortest routes between all of the network's edges (ABS 2016; Roosta, Javadpoor, & Ebadi 2021). Choice illustrates how many ways lines in a network can cross each other. It refers to the level of ease with which a travelling wishes to move from one location within a region to another. Higher numbers indicate a greater potential for through-movement throughout the network, while lower numbers indicate a reduced potential for through-movement within the network. Using Integration, you can find the distance between any two elements using only the axial measurements, selection, and length of the shortest path between them. For this function, an angular change parameter was created in conjunction with segment analysis (Turner 2007).

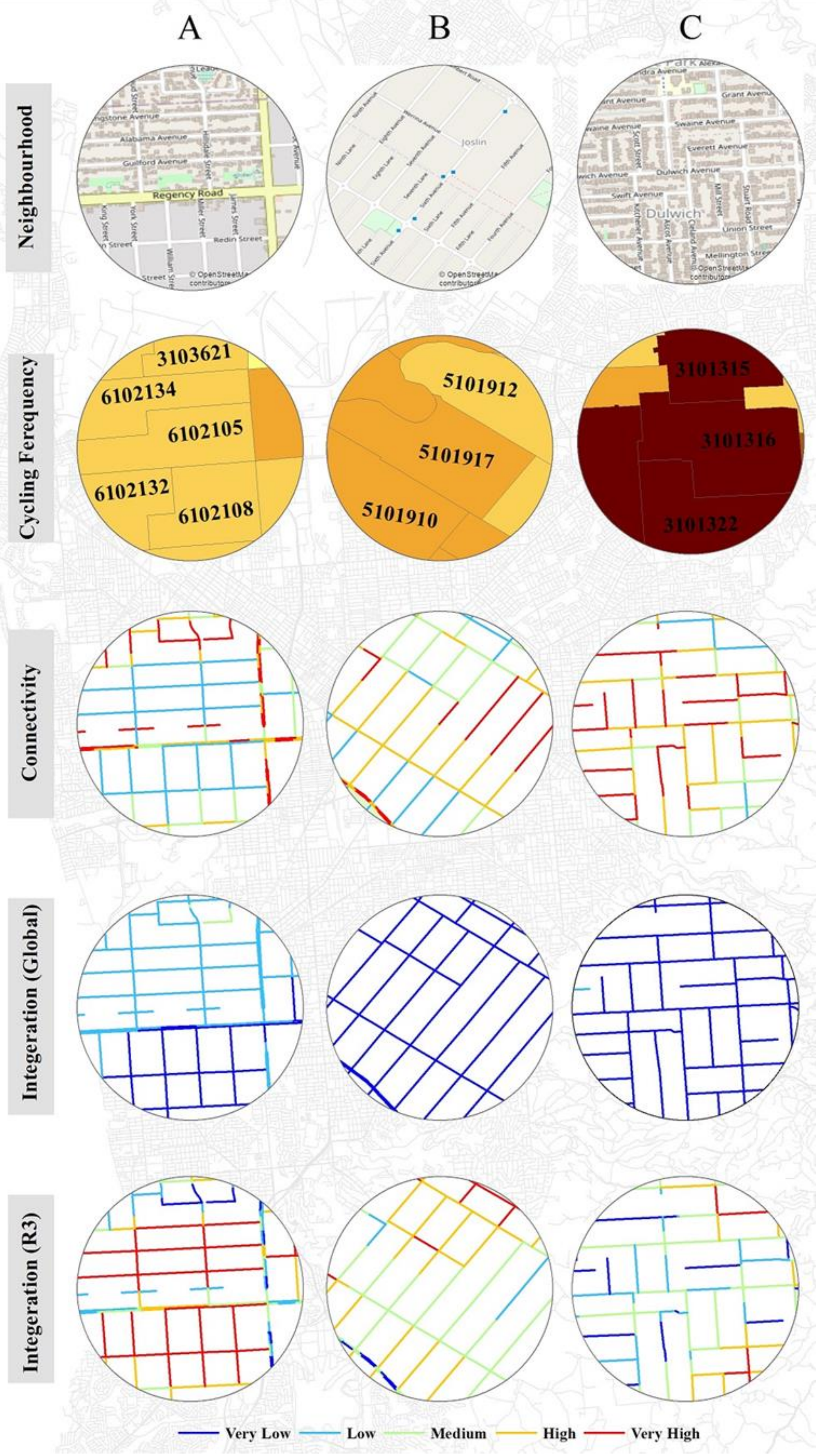
A
B
C
Neighbourhood
Cycling Ferequency
Connectivity
Integeration (Global)
Integeration (R3)
3103621
6102134
6102105
6102132
6102108
5101912
5101917
5101910
3101315
3101316
3101322
Very Low
Low
Medium
High
Very High

Figure 1. Integration, and Connectivity measures for Inner Suburbs of Adelaide (three samples), and its correlation with cycling frequency at census tract level (SA1). Source: Author

2.2. Study area

Adelaide is the capital of South Australia and Australia's fifth-most populated city (with population of over 1.4 million people) with a land area of 3,259.8 km2 (Nguyen, Soltani, & Allan 2018). The Strategic Plan for South Australia has set a number of ambitious goals for the state's future prosperity. Cycling, according to the State Government, is critical to achieving several goals outlined in the Strategic Plan. In South Australia, cycling has risen to the fourth spot among leisure activities, with over a third of people saying they do it at least once yearly. International cycling events, such as the Tour Down Under, have brought a large number of tourists to the state, causing tourism to rebound. More than 2,100 km of bicycle routes have been planned and marked as part of the Bikedirect network in metropolitan Adelaide, which covers 3,259.8 km2. The government's Bike Ed project has taught over 30,000 primary school students how to ride a bicycle safely. This, combined with South Australia's ideal climate and geography, has led to a revival in the state's vibrant cycling culture

Despite the above-mentioned strategic goals and initiatives, the percentage of people who cycle to work (for the first or entire route) is relatively low, with female commuters accounting for around one-third of male commuters (Table 1). The inner suburban area of Adelaide metropolitan region (radius of 10km from CBD) was chosen for this study because it has a comparatively larger percentage of people cycling to work, as seen in Figure 1. This region, which is made up of 1388 SA3 census tracts and has a population of 620,769 people (2016). The selected area has a population density of 2,622 people per km2. In addition, the average price of a home in this region is $3918.5 per square metres as of 2016. However, for modelling purposes, only 822 tracts with non-zero cyclists were chosen. We've also weeded out outliers like tracts of Adelaide's CBD where a disproportionate number of people commute to work by bicycle.

Table 1. Percentage of people using bike, Journey to work(ABS 2016)

Region	**No. of people using bike**			**No. of employed people**			**share of people using bike to work (percent)**		
	Male	**Female**	**Total**	**male**	**female**	**total**	**men**	**women**	**total**
Greater Adelaide Metropolitan	4368	1144	5512	334036	222691	556727	1.31	0.51	0.99

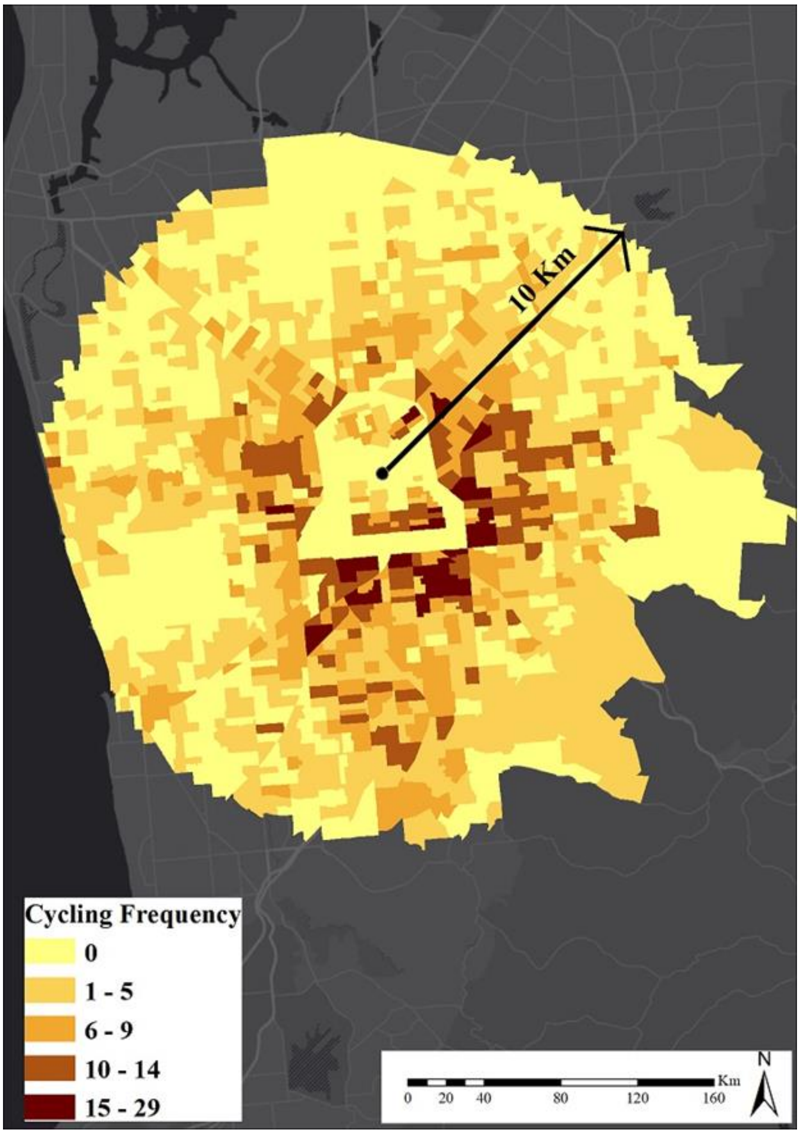

Figure 2. Location of selected suburbs

A set of socio-demographic and physical data are collected from secondary sources. The GIS-data is taken from the government: "Data.sa.gov.au", and open street map (OSM). The data on housing price originates from the South Australian cadastral database called the Integrated Land Information System (SAILIS). Based on the cleaned GIS-map, a detailed axial map of path and cycle network is made using the GitHub DepthmapX. Then, we have captured different measures of space syntax; at both global and local (in different directions as named R3, R5, and R7) scales. The goal of the combined space syntax and GIS is to analyse parameters that, should be important for people deciding the mode of transport. The 'Journey to work' data is collected from ABS (2016) which is combined with socio-economic profile data. The best unit of analysis is the geographic level of SA1 with an average population of 447. Larger regions such as SA2 have a lower resolution, and the selection of smaller units such as mesh blocks makes the calculation very complicated and tedious.

SEIFA measures IER, IRSAD, and IRSD are used, all defined by the ABS as SEIFA (socio-economic indexes for areas). The IER index measures a country's overall access to economic resources, and a high IER score indicates this. There may be many high-income households or many owned properties in a neighbourhood with high IER amounts, for example (ABS 2016). When it comes to a community's economic and social profile, IRSAD compiles statistics on both the community's advantages and disadvantages. A higher IRSAD score indicates a lower level of deprivation and a greater overall advantage (Lovric 2011). The IRSD (Indicator of Relative Socio-economic Disadvantage) is a socio-economic index that measures the average economic and social circumstances of families in a neighbourhood. Unlike the others, this metric only takes into account indicators of a person's relative disadvantage. A higher score indicates that an area has fewer disadvantaged families. For example, a neighbourhood with a high IRSD may have fewer low-income families, educated people, and/or residents working in low-skilled jobs (ABS 2016). Datasets used to build the exclusive bike network database for this study are shown in Figure 3.

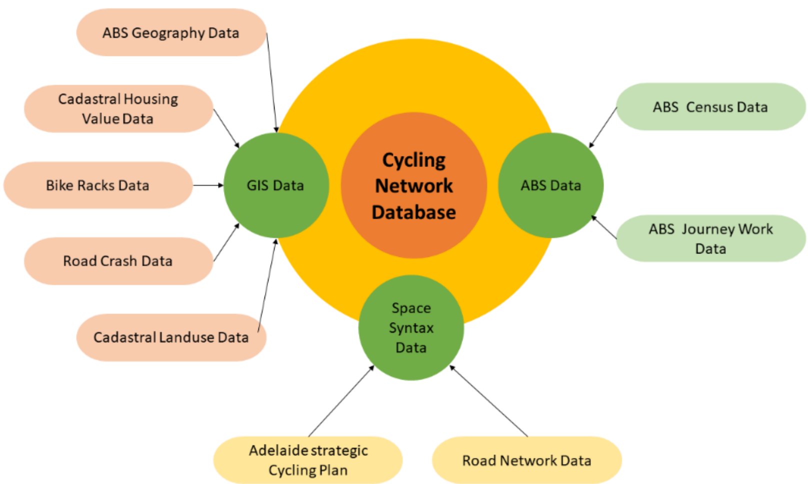

Figure 3. Cycling network database.

3. Results

The dependent variable in all the regression analysis is the share of employees taken a cycle to get to work. The explanatory variables are a combination of socio-economic and street network geometry in continuous fashion that each are expected to influence the share of trips by cycle. The space syntax measures including Connectivity, Integration, and Choice, are measured and as shown in Figure 1 before. The hot colour in the map represents higher connectivity and the cold colour represents less connectivity. The variables are entred in two stages:

- An OLS estimation for a simple model which includes only basic socio-economic variables;
- A more inclusive model that considers the role of space syntax factors included: in addition to including socio-economic variables;

The aim was to compare the power of each set of variables that each are expected to influence these trip rates. The descriptive statistics of those variables extracted from our manipulated database is provided in Table 2.

According to Table 3, all of the characteristics included in the above models have been shown to be statistically significant (CI=95%), making them crucial in calculating bicycle trips for work commuting. The addition of street geometry parameters in type of space syntax measurements increased the explanatory power and overall quality. The goodness of fit measurements of the final model (0.297) are compared to the simple socio-economic model (0.252) to demonstrate how these physical features contribute to the model's improvement by 20 percent. In fact, the addition of space syntax measures has significantly increased model power. These indicators, as part of the cycling network evaluation, give a more inclusive view and, when their behaviour is considered in the journey prediction model, are more accurate. The remaining socioeconomic and space syntax factors that did not make it into Table 3 are those for which no statistically significant association was found. It is also characterized by other significant features, such as the high relative quality, given the lowest values for the Akaike's Information Criterion (AIC) (Lovric 2011). The further details are shown in Appendix (the output of Python coding).

Table 2. Descriptive Statistics of explanatory variables

definition	mean	std	min	25%	50%	75%	max

POPdensity	Population divided by area (pp/ha)	2727.697	1025.172	19.7	2184.975	2681.15	3134.725	10329
ZPOPdensity	Z-score for population density	-0.000	1.001	-2.6	-0.5	0	0.4	7.4
popch	Change rate in population for ten years (percent)	1.078	7.037	-4.8	-0.4	0.5	1.5	177.1
Ave_PriceP	Average housing value	4117.703	839.615	2132	3511.85	3996.15	4655.875	9556
percent_desity_COMMERCIAL	Area of commercial divided by total area	2.975	5.831	0	0	0.5	3.075	43.4
Bike	Number of workers cycled	5.953771	3.676	3	3	4	8	22
IER_INDEX	SEIFA advantage	4.727	2.473	1	3	4	7	10
IEO_INDEX	SEIFA advantage	7.510	2.168	1	6	8	9	10
ZIRSAD	SEIFA index: disadvantage	0.000	1.008	-2.3	-0.6	0.2	0.7	1.5
ZDensity_Crash	Number of traffic accidents divided by area	0.043	0.994	-0.1	-0.1	-0.1	-0.1	17.7
Dist_CBD	Distance to CBD (metre)	5663.440	2278.570	735.090	3991.698	5414.097	7364.592	10506.016
Dist_CBD_Ln	Distance to CBD (Ln)	8.544	0.475	6.600	8.292	8.597	8.904	9.259
ZMEAN_Integration_HH	Space Syntax: Integration global	-0.000	0.998	-9.7	-0.6	0.2	0.8	2.2
ZMEAN_Integrn_HH_R3	Space Syntax: Integration local	-0.001	1.002	-3.8	-0.6	0.1	0.7	2.8
ZMEAN_Contvty_CN	Space Syntax: Connectivity	-0.002	1.000	-3.7	-0.6	0.1	0.7	2.6
Z_Mean_Depth_R5	Space Syntax: Depth local	-0.000	0.999	-6.4	-0.5	0.2	0.7	1.7

N= 822

Table 3. Model with and without Space Syntax measures

Variable	coeff	std err	t	P>|t|	[0.025	0.975]
const	2.163	1.54	1.405	0.16	-0.858	5.185

IER_INDEX	0.512	0.107	4.789	0	0.303	0.723
IEO_INDEX	0.314	0.141	2.229	0.026	0.038	0.592
ZIRSAD	-1.127	0.44	-2.56	0.011	-1.992	-0.263
Ave_PriceP	0.000	0	4.78	0	0.001	0.001
percent_desity_COMMERCIAL	0.097	0.021	4.551	0	0.055	0.139
ZDensity_Crash	-0.386	0.121	-3.189	0.001	-0.624	-0.148
Omnibus	166.297					
AIC	4193					
R-squared	0.257					
Adj. R-squared	0.252					
Log-Likelihood	-2114					
const	11.776	0.612	19.247	0	10.576	12.978
IER_INDEX	-0.355	0.097	-3.675	0	-0.545	-0.165
ZIRSAD	1.363	0.244	5.595	0	0.885	1.841
percent_desity_COMMERCIAL	0.065	0.021	3.085	0.002	0.024	0.107
ZDensity_Crash	-0.436	0.118	-3.688	0	-0.669	-0.204
Dist_CBD	-0.000	9.66E-05	-7.894	0	-0.001	-0.001
ZMEAN_Integration_HH	-0.580	0.198	-2.925	0.004	-0.97	-0.191
ZMEAN_Integrn_HH_R3	-1.4675	0.872	-1.682	0.093	-3.18	0.245
ZMEAN_Contivity_CN	1.5287	0.885	1.728	0.084	-0.208	3.265
Omnibus	131.471					
AIC	4242					
R-squared	0.303					
Adj. R-squared	0.297					
Log-Likelihood	-2087.5					

Some more interesting findings are as follows:

The first model had three types of variables: socio-economics (represented by SEIFA and housing value); safety (represented by crash density); and density of land use (represented by density of commercial activities). Workers who cycle are less likely to live in areas with high traffic crash rates than those who do. This finding confirms the significance of bicycle safety on the road. Commuters are more likely to ride their bikes to work if the population commercial activity density is higher in their area. The average residential property price in a neighbourhood appears to have a major role in explaining variations in work-related cycling. This variable is thought to be a proxy for some neighbourhood quality characteristics. The higher the median property value in the neighbourhood, the higher the share of bike-to-work. A study by (Liu & Shi 2017) in the United States showed that the distance between home and bicycle facilities/networks has a significant positive impact on the average property value, confirming the preference of households for a high-quality bicycle infrastructure. Conversely, proximity to cycling infrastructure can reduce privacy and sense of security from crime, leading to a decrease in home values (Krizek 2006). A Canadian study reported that changes in home values due to the deployment of bicycle lanes vary widely depending on the location and type of cycling facilities. However, this result requires further study when considering the potential non-linear relationship between cycling and housing value. The model also showed that the greater the distance the CBD, the lower the likelihood of using bikes to work.

Commuters in inner Adelaide areas with a better socio-economic profile, as measured by the IER and IEO indices for advantage, take a greater percentage of work trips on bicycles, demonstrating the favorable effects of increased cycling. On the other hand, neighbourhoods with higher IRSAD (index for disadvantage), are associated with lower share of cycling to work. This data might show that riding to work in Adelaide is more about respecting the environment or caring for one's own health than it is about affordability to drive a car.

Examining two metrics of space syntax, Connectivity, and Integration, identifies important contributions. The results show that connectivity of the street network at neighbourhood scale has positive effect on the percentage of people who cycled. On contrast, the integration (local) and integration (global) have the opposite effect on cycling. This finding shows that the use of bicycles mainly concerns the impedance of the movement; simply expressed, the distance performs a significant influence on the use of bicycles.

In response to research question 1, this study added to the literature by utilising the axial-based street connectivity metrics of Connectivity and Integration. Rather than using traditional simple measures such as intersection or road density, the study focused on topological distance inside a space. In reality, the technique is successful in capturing network spatial and hierarchical structural properties (Koohsari, Oka, Owen, & Sugiyama 2019). The inclusive model with street network geometry attributes is proved to have approximately 20 percent improvement in explanatory power in describing the variations in cycling to work. Overall, the findings of this study indicate that street network design and layout should be considered for behavioural models targeting bicycle journeys since active transportation patterns are mostly influenced by geographies smaller than the zonal scale in traditional traffic engineering models (Cooper 2017).

In response to research question 2, this study found a mixture of physical, street network and socio-economic factors influences the choice of cycling to work. The findings on street network morphology support some similar literature, such as the study by (Rybarczyk, et al., (2020), which assessed the impact of local integration. In addition, the studies by Schepers, et al., (2018) and Ozbil, et al (2016), investigated the impacts of Integration (global) on active transport. According to our study, employees who live in high-integrated neighbourhoods (local R3) are less likely to choose cycling as a means of transportation to and from work. This is consistent with the findings of (Schepers, et al. (2018), who discovered that (local) integration within a 100-meter radius of the trip-maker's neighbourhood between origin and destination had a negative relationship with the active trip-maker's travel. This finding confirms the role of space in the urban spatial hierarchy and rigidity, which can lead to increased car movement and the presence of strangers in space, thereby increasing the safety of cyclists on the way to work.

Other findings, such as the favourable effects of commercial activities density and home value (as a proxy for neighbourhood quality) on cycling share, are consistent with previous studies. According to Ewing, et al. (2014), there is a substantial link between cycling preference and urban density (included land use density). In a similar study, Parkin et al. (2007) discovered that urban density (as measured by proximity to work sites) was associated to the percentage of people who cycled. This study may give evidence that cycling to work in Adelaide is less related to the affordability of driving a car; rather, it is a decision made by middle- and upper-income groups, most likely owing to respect for the environment or caring of personal heath.

This research has limitations that should be considered in future study. As previously stated, this study solely evaluated the inner suburbs, which are believed to constitute one-third of the Adelaide metropolitan region's network. A further study may cover the whole Adelaide metropolitan region (particularly the bike-friendly outlying districts such as Mawson Lakes on the North edge) and run the regression model again. Similarly, this study solely looked at data from the commute to work. Considering non-work excursions (shopping, socializing, sports) in an area as well as journeys for other activities might improve and provide additional insight into the true influence of network architecture on travel behaviour(Raford, Chiaradia, & Gil 2007). The conclusions of this study are based on the 2016 ABS household census survey; however, additional research is needed to discover whether there is any support from more recent independent studies on cycling behaviour and its significant variables. It should be emphasised that only work commuting trips for employees and non-workers (students, retirees, etc.) are simulated; hence, no weekly working excursions, which might include numerous journeys performed by cycling and, of course, are quite different in type and pattern from work trips, are ignored. The proposed model can be improved by including more variables on individual perceptions that reflect the perceptual barriers of different social groups to cycling, similar to the work undertaken by Dill and McNeil (2013) in the United States. More comprehensive segmentation of commuters by gender, age, job status, occupation, and education level can be examined to evaluate their influence on improving bicycle trip estimates.

References

Aultman-Hall, L, 1996, *Commuter bicycle route choice: analysis of major determinants and safety implications*, *Open Dissertations and Theses*, Viewed September 16, 2021, http://digitalcommons.mcmaster.ca/opendissertations/1035/.

Australian Bureau of Statistics, (ABS), 2016, “2016 Census QuickStats.”

Carnall, DJ, McGrath, MJ, Lingwood, P, & Ogilvie, D, 2004, “Promoting walking and cycling as an alternative to using cars [1] (multiple letters),” *British Medical Journal*.

Cooper, CHV, 2017, “Using spatial network analysis to model pedal cycle flows, risk and mode choice,” *Journal of Transport Geography*, vol. 58, pp. 157–165, doi: 10.1016/j.jtrangeo.2016.12.003.

Creutzig, F, Javaid, A, Soomauroo, Z, Lohrey, S, Milojevic-Dupont, N, Ramakrishnan, A, Sethi, M, Liu, L, Niamir, L, Bren d’Amour, C, Weddige, U, Lenzi, D, Kowarsch, M, Arndt, L, Baumann, L, Betzien, J, Fonkwa, L, Huber, B, Mendez, E, Misiou, A, Pearce, C, Radman, P, Skaloud, P, & Zausch, JM, 2020, “Fair street space allocation: ethical principles and empirical insights,” *Transport Reviews*, vol. 40, no. 6, pp. 711–733, doi: 10.1080/01441647.2020.1762795.

Dalton, N, Peponis, J, & Conroy-Dalton, R, 2003, "To tame a TIGER one has to know its nature: extending weighted angular integration analysis to the descriptionof GIS road-centerline data for large scale urban."

Dill, J & McNeil, N, 2013, "Four Types of Cyclists?: Examination of Typology for Better Understanding of Bicycling Behavior and Potential," *Https://Doi.Org/10.3141/2387-15*, no. 2387, pp. 129–138, doi: 10.3141/2387-15.

Ewing, R, Meakins, G, Hamidi, S, & Nelson, AC, 2014, "Relationship between urban sprawl and physical activity, obesity, and morbidity – Update and refinement," *Health & Place*, vol. 26, pp. 118–126, doi: 10.1016/J.HEALTHPLACE.2013.12.008.

Forester, J, 1996, *How to make biking a real alternative ? Should we encourage cyclists by separating them from motor traffic or by giving them freedom of the roads ?*

Hillier, B & Hanson, J, 1988, "The social logic of space," *The Social Logic of Space*, doi: 10.4324/9780429450174-9/SOCIAL-LOGIC-SPACE-CLAES-CALDENBY-PERNILLA-HAGBERT-CATHRIN-WASSHEDE.

Hunt, JD & Abraham, JE, 2007, "Influences on bicycle use," *Transportation*, vol. 34, no. 4, pp. 453–470, doi: 10.1007/s11116-006-9109-1.

Kazerani, A, 2010, "Characterization of the Urban Street Network and its Emerged Phenomena," no. January.

Koohsari, MJ, Oka, K, Owen, N, & Sugiyama, T, 2019, "Natural movement: A space syntax theory linking urban form and function with walking for transport," *Health and Place*, vol. 58, doi: 10.1016/j.healthplace.2019.01.002.

Krizek, KJ, 2006, "Two approaches to valuing some of bicycle facilities' presumed benefits," *Journal of the American Planning Association*, vol. 72, no. 3, pp. 309–320, doi: 10.1080/01944360608976753.

Law, SF & Karnilowicz, W, 2015, "'In Our Country it's Just Poor People who Ride a Bike': Place, Displacement and Cycling in Australia," *Journal of Community and Applied Social Psychology*, vol. 25, no. 4, pp. 296–309, doi: 10.1002/CASP.2215.

Lebendiger, Y & Lerman, Y, 2019, "Applying space syntax for surface rapid transit planning," *Transportation Research Part A: Policy and Practice*, vol. 128, pp. 59–72, doi: 10.1016/j.tra.2019.07.016.

Liu, JH & Shi, W, 2017, "Impact of Bike Facilities on Residential Property Prices," *Transportation Research Record*, vol. 2662, no. 1, pp. 50–58, doi: 10.3141/2662-06.

Lovric, Miodrag, 2011, "International encyclopedia of statistical science," p. 1673.

Manum, B, Nordström, T, Gil, J, Nilsson, L, & Marcus, L, 2017, "Modelling bikeability," in *Proceedings of the 11th Space Syntax Symposium*, pp. 89.1-89.16.

Nelson, AC & Allen, D, 1997, "If you build them, commuters will use them: Association between bicycle facilities and bicycle commuting," *Transportation Research Record*, no. 1578, pp. 79–83, doi: 10.3141/1578-10.

Nes, A van & Yamu, C, 2017, "Space Syntax : A method to measure urban space related to social, economic and cognitive factors," *The Virtual and the Real in Planning and Urban Design*, pp. 136–150, doi: 10.4324/9781315270241-10.

Nguyen, HA, Soltani, A, & Allan, A, 2018, "Adelaide's East End tramline: Effects on modal shift and carbon reduction," *Travel Behaviour and Society*, vol. 11, pp. 21–30, doi: 10.1016/j.tbs.2017.12.002.

Noël, Nathalie & Lee-gosselin, MEH, 2004, "Urban forms , road network design and bicycle use," *Laval University, Centre de Recherche En Aménagement et Développement*, no. Cervero 1996.

Ozbil, A, Argin, G, & Yesiltepe, D, 2016, "Pedestrian route choice by elementary school students: The role of street network configuration and pedestrian quality attributes in walking to school," *International Journal of Design Creativity and Innovation*, vol. 4, no. 2, pp. 67–84, doi: 10.1080/21650349.2015.1123120.

Parkin, J, Wardman, M, Prevention, MP-AA&, & 2007, U, n.d., "Models of perceived cycling risk and route acceptability," *Elsevier*, doi: 10.1016/j.aap.2006.08.007.

Parkin, John, 2013a, "City cycling," *Http://Dx.Doi.Org/10.1080/01441647.2013.782592*, vol. 33, no. 2, pp. 239–240, doi: 10.1080/01441647.2013.782592.

Parkin, John, 2013b, "City cycling," *Transport Reviews*, vol. 33, no. 2, pp. 239–240, doi: 10.1080/01441647.2013.782592.

Pucher, J & Buehler, R, 2008, "Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany," *Transport Reviews*, vol. 28, no. 4, pp. 495–528, doi: 10.1080/01441640701806612.

Raford, N, Chiaradia, A, & Gil, J, 2007, "Space syntax: The role of urban form in cyclist route choice in Central London."

Roosta, M, Javadpoor, M, & Ebadi, M, 2021, "A study on street network resilience in urban areas by urban network analysis: comparative study of old, new and middle fabrics in shiraz," *Https://Doi.Org/10.1080/12265934.2021.1911676*, doi: 10.1080/12265934.2021.1911676.

Rybarczyk, G, Ozbil, A, Andresen, E, & Hayes, Z, 2020, "Physiological responses to urban design during bicycling: A naturalistic investigation," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 68, pp. 79–93, doi: 10.1016/j.trf.2019.12.001.

Schepers, P, Lovegrove, G, & Helbich, M, 2018, "Urban form and road safety: Public and active transport enable high levels of road safety," *Integrating Human Health into Urban and Transport Planning: A Framework*, pp. 383–408, doi: 10.1007/978-3-319-74983-9_19.

Soltani, A, Allan, A, & Pojani, D, 2021, "Ridesharing in Adelaide: Segmentation of users," *Elsevier*, doi: 10.1016/j.jtrangeo.2021.103030.

Turner, A, 2007, “From axial to road-centre lines: A new representation for space syntax and a new model of route choice for transport network analysis,” *Environment and Planning B: Planning and Design*, vol. 34, no. 3, pp. 539–555, doi: 10.1068/B32067.

Xia, X, 2013, “A comparison study on a set of space syntax based methods: Applying metric, topological and angular analysis to natural streets, axial lines and axial segments.”