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Users and non-users of bikesharing: How do they differ?

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Abstract

What makes some people eschew bikesharing? What distinguishes users from non-users? The present study examines the transport priorities and socio-demographic characteristics of both users and non-users of bikesharing in the context of Adelaide, an Australian metropolis of 1.3 million people. We apply statistical techniques, including Principal Component Analysis (PCA) and two-level Nested Logit (NL) modelling, to original survey data collected in 2018. We find that younger age, digital literacy, full-time work status, household size, and certain transport priority dimensions which we term Safekeeping, Ease, and Fitness, are key factors associated with the likelihood of choosing or shunning bikesharing as a mode of transport.

Note

Accompanying tables and figures are at the end of this paper.

Introduction

Bikesharing represents an attractive travel alternative for many urbanites as demonstrated by a rapid uptake of this mode over the past few decades (Julsrud and Farstad 2020; Fishman 2016). While the bikesharing concept dates back to the 1960s, the number of cities that offer bikesharing services has grown from just a handful in the late 1990s to over 1,000 worldwide (Wu and Kim 2020; Fishman 2016). Bikesharing has competitive advantages over other modes, including affordability, convenience, flexibility, opportunity for physical exercise, and environmental-friendliness (Wang et al. 2020; Bauman et al. 2017; Faghih-Imani and Eluru 2016; Götschi et al., 2016). Its users can purchase the service (cycling) by the hour without having the own the vehicle (the bicycle).

Bikesharing has been in existence long enough to have attracted considerable attention from transportation researchers. Many studies have extensively investigated bikesharing benefits, usage patterns, the characteristics of bikesharing users and the factors that may encourage the use of bikesharing service (Eren and Uz 2020; Si et al. 2019; Wang and Zhou 2017; de Chardon et al., 2017; Götschi et al., 2016; Ogilvie and Goodman 2012; Shaheen et al., 2010). Some studies gone a step further by also examining the traits of non-users of bikesharing, as well as the major barriers to bikesharing (see Fishman and von Wyss 2017; Fishman 2016; Ricci 2015; Fishman et al., 2012, 2013). However, so far, the emphasis has been on users rather than non-users.

The present study aims to fill a gap in the literature by focusing more closely on non-users of bikesharing. We seek to answer two research questions: What makes some people eschew bikesharing? What distinguishes users from non-users? To do so, we examine the individual transport priorities and socio-demographic characteristics of non-users of bikesharing in Adelaide, an Australian metropolis of 1.4 million people, and the state capital of South Australia. This is the first large-scale empirical study on bikesharing in Adelaide, as well as the first study to employ survey data collected from actual users. To analyse the data, we apply two statistical techniques, including Principal Component Analysis (PCA) and two-level Nested Logit (NL) modelling, to original survey data collected in 2018.

Beyond the specific context of Adelaide, research into active transport modes and micromobility is paramount in Australia - a country with a strong car culture (Butterworth and Pojani 2018; Kenworthy and Laube 1999). Nationwide, there are 20 million motor vehicles registered – for a population of 25 million (ABS 2020). In South Australia, the rate of cycling to work is under 3%, and only 14% of residents ride a bicycle in a typical week (ABS 2017). As people are gradually shunning suburbs and reclaiming the inner cities, traffic congestion is growing while parking is become scarcer. Car dependency comes with other socio-economic costs, including consumption of non-renewable energy resources, segregation, accidents, pollution, and climate change (Meyer and Shaheen 2017; Soltani et al. 2006). The situation has already become unsustainable in larger Australian state capitals.

This study contributes to the scholarly literature on sustainable transport by providing a more comprehensive understanding of the transport priorities and the socio-demographic characteristics of *non-users* of bikesharing in relation of particular built environment attributes. Unlike previous studies that simply compare users to non-users, we provide more nuance by segmenting survey respondents into three groups: (1) bikesharing users, (2) non-users of bikesharing who are interested in trying this mode in the future, and (3) non-users of bikesharing who do not want to try this mode. This helps us to investigate the determinants of people's behaviours and preferences in more detail. Moreover, we differentiate between CBD residents and suburban residents. Another novelty in this study is the coining of 'transport priorities', i.e., constructs that help explain people's transport behaviours and preferences. Our

hope is that this study will help the formulation of policies to support bikesharing and cycling in Australian cities and further afield.

Background: Bikesharing in Australia and around the world

Before proceeding to the empirical portion, we present an overview of the history of bikesharing, focusing more closely on Australia and Adelaide.

Public bikesharing systems have evolved through five generations (Galatoulas et al., 2020; Parkes et al. 2013). The first generation, born in 1965, included just Amsterdam's Witte Fiets. It was pioneered by Provo, an anarchic group of Dutch activists. As the name suggests, the fleet included regular white bicycles docked around the city, which were free to use. While the concept attracted much fanfare, it was short-lived. The second generation emerged in 1995 in Copenhagen. The system, called Bicyklen, was docked, coin-based, and featured 1000 bicycles. This still exists today, in an updated form. ICT technology was introduced in the third bikesharing generation, launched in the late 1990s in various cities. While bicycles remained conventional and the systems docked, magnetic user cards were now used. Vélo à la Carte in Rennes, France, is an example of a third-generation system - still in existence. The fourth generation, which appeared in 2005, was much more digitally sophisticated. A typical example is MOL-Bubi, Budapest (Mátrai and Tóth 2016).

The fifth and current generation, born in 2017, involves smartphone applications and dockless fleets in addition to the regular fleets docked at stations. Electric bikes are also being introduced in larger and/or hilly cities in which use of conventional push bicycles is impractical. High processing power, data-handling capacity, and geo-positioning capability allow current providers to manage a bulk of user transactions in real-time (Allan and Soltani 2019). On the negative side, dockless bikesharing is generally considered as a failure. Not only does it have higher capital and operational costs, but it is also prone to public vandalism and, as such, has been met with community hostility and high fines by local councils (Poiani et al. 2020; Heymes 2019).

European cities have better performing bikesharing systems relative to Asian, North American, and Australian cities. Barcelona, Dublin, and Turin are the top three bikesharing cities, with 8.4, 8.0, and 7.9 trips/day/bicycle respectively (Allan and Soltani 2019). This is probably due to their longer cycling history and stronger cycling culture (Poiani et al. 2017). London and Washington, D.C. are also high performers (de Chardon et al., 2016). Worldwide, bikesharing users tend to be younger, white-collar men who do not own a car (Eren and Uz 2020; Soltani et al. 2019; Wang and Akar 2019; Wang et al., 2018; Mattson and Godavarthy 2017; Molina-García et al., 2013; Buck et al. 2013).

Australia has lagged behind other countries in terms of bikesharing adoption. The first large-scale systems here, Melbourne's Bike Share and Brisbane's CityCycle, were not introduced until 2010 (Fishman, Washington, and Haworth 2012). These docked systems offered 600 and 2,000 bicycles in the respective inner cities; no attempt was made to extend bikesharing to car-dominated suburbia (Soltani et al. 2019; Mateo-Babiano et al. 2016).

In addition to docked schemes, by 2018 five major dockless bikesharing companies were operational in Sydney and some other state capitals: ofo, oBike, Mobike, ReddyGo, and LimeBike. The provision of bikesharing services has boosted cycling rates in some cities, especially for shorter trips (Fishman et al., 2014). But overall, the frequency of trips/day/bike is still low. Melbourne and Brisbane only reach a meagre 0.7 and 0.3 trips/day/bike respectively (Fishman 2016).¹ Here, bikesharing is considered more as an occasional or adjunct mode, while the car continues to reign supreme. In Adelaide two newer, dockless systems, ofo and oBike,

entered the market in 2018. Since dockless bikes joined Adelaide Free Bikes, the fleet increased to a total of 550 bicycles (250 docked and 300 dockless).

Theoretical framework

Upon reviewing the existing literature on bikesharing, we constructed a theoretical framework which rests upon three sets of interrelated factors, including: (1) transport priorities; (2) socio-economic characteristics; and (3) built environment characteristics. These are listed in Figure 1 and detailed below.

Transport priorities

Research shows that comfort, convenience, safety, security, speed, time, health, and exercise are among the key transport priorities that affect modal choice (Soltani et al. 2021; Egset and Nordfjærn 2019; Rundmo et al., 2011). People who are less concerned about safety (from traffic) or security (from crime) are more likely to adopt bikesharing. However, access to designated cycling paths and bicycle parking racks is highly desirable as it increases perceptions of comfort, convenience, and safety (Shen et al., 2018; Shaheen et al., 2010). Well-lit streets make shift workers feel more secure when using bikesharing at night (Chandra et al., 2017).

Beyond safety and security, people who value independence, status, athleticism, and the environment are more often bikesharing users (Rérat 2019; Leister et al. 2018; Namgung and Jun 2018; Prabhakar and Rixey 2017; Pucher and Buehler 2017; Martin et al. 2016; Heinen et al., 2013; Akar et al., 2013; Nkurunziza et al., 2012; Pucher et al., 2011; Gatersleben and Appleton 2007; Scheiner and Holz-Rau 2007; Wardman et al., 2007).

Bikesharing is mainly used in shorter trips where driving, walking, or riding a bus is less convenient or potentially slower (Eren and Uz 2020; Jensen et al. 2010). Systems with simple sign-up displays and credit card readers invite more customers (Fishman 2016). At the same time, systems must guarantee user data privacy in order to be attractive. Also, bicycles must be easy to ride and park (Qian et al., 2020; Ma et al. 2020; Chen et al., 2020; Leister et al. 2018; Campbell et al. 2016). The bikesharing network coverage must be broad and stations must stay open during most of the day or possibly 24/7 – in order to increase the perception of convenience.

Socio-economic characteristics

Research has established that the “typical bikesharer” tends to be male, white, wealthier, and younger than average; he tends to be employed (full-time or part-time), live and work closer to the inner city and bikesharing catchment areas, and own a car (Eren and Uz 2020; Fishman 2016; Ricci 2015; Fishman et al., 2014; Shaheen et al., 2012; Steinbach et al., 2011).

Women are socialised to be more risk-averse and therefore tend to use bikesharing less than men; also, they often cycle at a slower speed and take shorter trips (Fishman 2016; Zhao, Wang, and Deng 2015). Helmet use is more widespread among women too (Eren and Uz 2020; Kaplan et al., 2015; Bonyun et al., 2012). However, in countries with a very strong cycling culture, such as the Netherlands, Denmark, and Germany, women are more likely to adopt bikesharing than men (Harms et al., 2013; Steinbach et al., 2011; Garrard, 2003).

Parents are less likely to use bikesharing as this is less convenient for child transport than cars (Barbour et al., 2019; Nikitas 2018; Nikitas et al., 2015). People with access to a smartphone and those who are more technologically literate are more likely to take up bikesharing; youth

are advantaged over the elderly in this respect (Tao and Pender 2020; Chen et al., 2020; Shen et al., 2018). In this study, we look at socio-economic characteristics including: age, gender, ethnicity, job status, employment type, income, car ownership, household size, and smartphone access.

Built environment attributes

Those who are attracted to bikesharing believe that this mode will save them time, money, and effort. This tends to be the case in dense urban cores, which concentrate residences and jobs and feature a mix of other land-uses (Dällenbach 2020; Hamilton and Wichman 2018; Xie and Wang 2018; Prabhakar and Rixey 2017; Campbell et al. 2016; Madhuwanthi et al. 2015; Bachand-Marleau, Lee, and El-Geneidy 2012). Bikesharing uptake is also higher near recreational centres, schools, and transit nodes – where these include bikesharing docks (Eren and Uz 2020; Mateo-Babiano et al. 2016; Wang and Akar 2019; El-Assi et al., 2017; Noland, Smart, and Guo 2016; Faghih-Imani et al. 2014).

As expected, the presence of specialised cycling infrastructure, in the form of an interconnected network of dedicated paths, possibly tree-lined, increases the likelihood of bikesharing (Eren and Uz 2020; El-Assi et al., 2017; Faghih-Imani et al. 2014; Winters et al., 2010). Some studies have also found that housing type and location can affect the uptake of bikesharing (Fishman 2016; Guo and He 2020; Shen et al., 2018). For example, people living in exurban areas with lower population densities, wide roads with frequent intersections, and inadequate public transit and cycling infrastructure coverage may be less likely to adopt bikesharing (Guo and He 2020). In this study, we look at the following indicators: population density; employment density; intersection density; distance to CBD; land use mix; and housing value (as a proxy for neighbourhood quality).

Method and analysis

The case study setting and the data collection and analysis procedures, along with the key findings, are reported below.

Case study setting

Adelaide is the capital of South Australia and Australia's fifth-most populated city. It was founded in the mid-19th century as the planned capital of the only freely-settled British province in Australia. As such, Adelaide's inner city features a colonial, gridiron street pattern, good public transport services, and a higher population density than the rest of the metropolitan region, which is sprawling and car-oriented city (Nguyen et al., 2018). The CBD area is relatively compact and comprises many middle-income families, students, and singles. Recently, the inner city has been attracting a younger and more educated cohort of residents. Moreover, employment opportunities are concentrated in the urban core (Allan and Soltani 2019; Soltani et al. 2019). Hence the potential for cycling and bikesharing uptake is high.

Generally, the Adelaide City Council has been supportive of bikesharing, as well as other progressive planning tools such as infill development (Nguyen, Soltani, and Allan 2018; Government of South Australia 2017). The local bikesharing scheme (Adelaide Free Bikes or AFB) was introduced as early as 2005, although in a rudimentary form (Soltani et al. 2019). Adelaide's network of cycling routes (BikeDirect) spans over 2,100 km. However, many of these are simple shared lane markings, known as 'sharrows', rather than dedicated paths, fully protected from cars (DTEI, 2006). Cycling is popular for recreation, with a third of individuals cycling at least once a year. Meanwhile, the share of cycling as a commute mode is minuscule

(Table 1), with most cyclists concentrated in the inner city and a few master-planned suburbs (Figure 2).

Data collection

This study employed both primary and secondary data. The primary data consisted of population surveys, collected in February-March 2018.² Respondents were recruited at six major destinations within the City of Adelaide boundary. These included: the Adelaide Oval, Royal Adelaide Hospital, Adelaide Railway Station, the University of Adelaide, Rundle Mall, and the Adelaide Central Market. All are considered as key trip attractors in the city.

In total, 422 complete questionnaires were received (at least 70 at each trip attractor). Respondents who lived more than 60 km from the CBD were considered as outliers and eliminated, thus reducing the dataset to 408 questionnaires. As this study targeted younger and working individuals (who are more likely to use bikesharing, based on the literature), people over the age of 65 were removed from the dataset, resulting in 365 questionnaires. After cleaning the dataset and deleting incomplete responses, 353 questionnaires were retained in total. As Figure 3 shows, respondents were well-distributed throughout Adelaide. Overall, the study sample was representative and reflected the characteristics of the population in metropolitan Adelaide, South Australia, and Australia. Hence, we are confident that the findings are applicable beyond the case study setting.

The survey included 36 questions. Of these, 13 questions were designed to measure the participants' transport priorities in relation to bikesharing, including: comfort, convenience, safety, security, health, exercise, time, speed, status/image, distance, environmental concern, cost (value) and independence. A slightly revised version of a validated survey instrument was used for this purpose (Mehdizadeh et al., 2019; Nordfjærn and Rundmo 2015; Şimşekoğlu et al., 2015; Nordfjærn and Rundmo 2015). Respondents were asked to rate on a five-point Likert scale each transport priority when deciding whether to adopt or shun bikesharing.

In the second part of the survey, we asked a few open-ended questions to find out more about people's personal experiences with bikesharing schemes in Adelaide, including AFB, ofo, and oBike. Then the participants were asked to report their frequency of bikesharing usage within the last year (daily, fortnightly, monthly, yearly, never). The remaining questions collected socio-economic characteristics (age, gender, ethnicity, job status, employment type, income, car ownership, household size, and smartphone access) and residential built environment attributes such as housing type (a proxy for residential density) and residential addresses (a proxy for accessibility).

The data on built environment attributes (population density; employment density; intersection density; distance to CBD; land use mix, and housing value) were retrieved from secondary sources, including the Australian Bureau of Statistics website, the Open-source Street Map website, and Data.SA.gov.au (an open-source data portal provided by the South Australia state government). The study did not consider non-CBD-bound trips, as in Adelaide, the inner city tends to dominate the labour market. However, in the future, trips directed to suburban employment centres (or intra-suburban trips) should be included as well.

Descriptive statistics

A summary of the descriptive statistics (for the variables ultimately modelled) is presented in Table 2. The surveys revealed that respondents utilise bikesharing infrequently. More than half (52%) only used bikesharing a few times a year; a mere 10% and 5% used bikesharing weekly and daily respectively. This finding is consistent with Fishman's (2016) data for other

Australian cities. The key reasons for bikesharing included socialising (62%), shopping (25%), going to work (20%), returning home from work (23%), sightseeing (12%), and accessing public transport (8%) or educational sites (5%). These reasons are different from those provided in other studies - a finding which highlights the importance of context in transportation planning studies (LDA Consulting 2013).

Data reduction

Based on the survey responses, current and potential bikesharing customers were segmented into three groups: users (U); interested non-users (I); and uninterested non-users (H). The definitions that we adopted for each group are below.

1. Users (U): people who had used at least one form of bikesharing in Adelaide at least once and enjoyed it.
2. Interested non-users (I): people who did not use bikesharing at the time of the survey but were willing to consider using it in the future.
3. Uninterested non-users (H): people who did not use bikesharing nor were considering using it in the future.

The distribution of participants among the three groups was the following: U = 15%; I = 33%; H = 52%. The fact that more than half of the respondents fell in the H group is problematic from a transport sustainability perspective but also highlights the need for a study such as this, which investigates the behaviours and preferences of non-users. At the same time, given a car-oriented context, it is encouraging to see that nearly a third of the respondents are interested to try bikesharing in the future.

The 13 transport priorities of the groups of participants (U, I, and H) are displayed in a radar graph (Figure 4). This shows that priorities varied by group. For example, group H prioritized safety and security whereas group U cared more about the environment, health, and exercise.

The original transport priorities were reduced through Principal Component Analysis (PCA).³ Out of the 13 transport priorities, 5 (cost, independence, status, environment, and distance) failed to consistently load to a dimension.⁴ Therefore, only 8 transport priorities (speed, time, health exercise, safety, security, comfort, and convenience) were retained. These resulted into the following 4 dimensions:

1. Punctuality, accounting for speed and time;
2. Fitness, accounting for health and exercise;
3. Safekeeping, accounting for safety and security; and
4. Ease, accounting for comfort and convenience.

These dimensions, which accounted for 73% of the variability in the data (Table 3), were then modelled in conjunction with the socio-economic characteristics and the built environment attributes to determine the behaviours and preferences of users and non-users of bikesharing in Adelaide.⁵

Data modelling

Following the data description and reduction, a two-level Nested Logit (NL) model was applied in NLOGIT 6.0. By way of explanation, a two-level NL model is a discrete choice model, which allows groups of similar alternatives to be grouped into 'branches' and 'nests'. In this case, as shown in Figure 5, groups H and I (both non-users) are combined into one branch with two nests, whereas group U (users) constitutes a separate branch with a single nest.⁶ In the interest of readability, the mathematical details of the model are provided in a note.⁷ The model script and output are presented in the Appendix. The results follow below.

We found that only some socio-economic characteristics of the participants were influential in choice to adopt or shun bikesharing. Both use of, and interest in, bikesharing decline with age. Older people are more likely to fall within group H (uninterested non-users). Other studies have revealed a similar trend (Eren and Uz 2020; Ricci 2015; Fishman et al., 2014; Shaheen et al., 2012). However, among older cohorts, where people have access to a smartphone, they are more likely to choose bikesharing than their peers. The access to smartphones moderates the effect of advancing age on bikesharing (see Wang et al., 2018). This means that, as younger cohorts with high levels of digital literacy enter middle age, the effect of age on bikesharing may disappear altogether.

The model showed that the larger the household size, the lower the likelihood of belonging in group H (uninterested non-users). This finding is inconsistent with the literature. The understanding to date has been that larger households (e.g., families with multiple children) are less likely they use bikesharing. The discrepancy may be a function of local culture, with Australian parents cycling alongside their children during recreational outings. Or it may be due to a bias in the sample: larger households may have been composed of flatting students or recent graduates rather than families. Or, it may have been the case that individuals in smaller households were older empty-nesters and advancing age is negatively associated with bikesharing, as noted earlier.

Respondents who lived in single-family houses - in other words, in lower density suburbs - were more likely to fall within group I (interested non-users). Meanwhile, the literature maintains that living in higher residential densities increases the likelihood of bikesharing. While modifying residential densities takes time, bikesharing could be enabled in suburbs where interest in this mode is high by providing dedicated connected cycling paths that connect homes to transit stations, schools, and other key destinations. It is crucial to provide the suitable conditions and help people in group I take a first step in trying bikesharing, at least on a casual basis. That experience may lead to a longer-term commitment and possibly regular membership in a bikesharing scheme.

Individuals who were employed full-time were less likely to be interested in bikesharing – possibly because of their more rigid schedules and time poverty compared to casual workers. It may also be the case that, owing to their reasonable incomes full-time can afford their own bicycles (and have sufficient space to store them at home) and therefore are not interested in bicycle rentals. Notably, these findings contrast to some previous studies, which have found that full-time workers are more likely to take up bikesharing (see Fishman 2016; Woodcock et al., 2014). While bikesharing may never become a viable commuting mode for this group in Adelaide, it can still be promoted by highlighting its recreational potential on a casual basis.

Other socio-economic factors such as car ownership, ethnic background, gender, and personal income, were not associated with bikesharing behaviour or interest. This finding contrasts with previous studies which have suggested that female gender and lower incomes lead to less bikesharing (Wang et al., 2018; Fishman 2016).

The modelling of the four key dimensions (*Ease*, *Safekeeping*, *Fitness*, and *Punctuality*) resulted in some interesting findings. Two dimensions (*Ease* and *Safekeeping*) had a negative and statistically significant association with bikesharing. Those who valued *Ease* and *Safekeeping* were more likely to fall within group H (uninterested non-users). To them, other modes such as private car or public transport may feel safer, more convenient, and more accessible. This was as expected based on the literature (AAA 2018; BicycleNetwork 2018; Pucher and Dijkstra 2003). On the other hand, the *Fitness* dimension had a positive and statistically significant association with bikesharing. Those who valued *Fitness* were more likely to fall within groups U and I, meaning that they either used bikesharing already or were

interested in trying it in the future. As noted, other studies have reached similar conclusions (see Götschi et al., 2016). This shows that at least one portion of the public is aware of the health benefits conferred by cycling. One dimension, *Punctuality*, was not statistically significant. Built environment attributes such as population density, employment density, intersection density, distance to CBD, land use mix, and housing value were less significant in this study. This may be due to the study design: the data was collected at six major destinations in the inner city, whose built environment attributes are somewhat similar.

Conclusion and policy recommendations

Adelaide's bikesharing market is driven by casually employed youth, possibly students. Bikesharing is hardly commonplace, but it is attracting increasing support and interest. Nearly a third of survey respondents are not current users but would like to try bikesharing in the future. This is promising. Those uninterested in using or even trying bikesharing tend to be older people with less access to smartphones. Gender is irrelevant here.

Retaining the youth and/or student market is crucial. Bikesharing companies need to ensure that these groups remain loyal bikesharing customers as they enter the regular workforce and move to suburban housing (see Kutela and Teng 2019). Policies should target bikesharing more specifically - for example by ensuring that (a) stations are placed in strategic spots near trip generators and transit stops, (b) the system is balanced so that bicycles and parking spots are available at all stations at all times, (c) digital user data is protected, (d) shared bicycles are comfortable, and (e) apps are easy to use (van Waes et al., 2020; Piatkowski et al., 2015; Martin and Shaheen 2014).

Importantly, policies should also focus on urban cycling more broadly. A wealth of experience from European and Asian cities is available on how to make cycling "irresistible" and could be harnessed in Australia (Lee, 2020; Schepers et al., 2017; Audikana et al., 2017; Weinberg et al., 2015; Pucher et al., 2011; Martens 2004; Lee and Pojani 2019). To guarantee success, cycling policies should not be applied in isolation. Policy packages are necessary, which strengthen the position of alternative modes (including other micro-mobility options such as e-scooters) while curtailing car use (Stead and Pojani 2017).

Much of the existing research in the bikesharing space has been quantitative and has targeted users. Future research should be qualitative, finer grained, and target non-users more directly. The use of qualitative approaches such as semi-structured interviews is encouraged for a more in-depth understanding of the impact of transport priorities, socio-economic characteristics, and built environment attributes on bikesharing. While surveys and secondary census data paint a broad picture of the behaviours and preferences of user and non-users, the reasons for shunning bikesharing need to be investigated via in-depth interviews as well. The opinions of policy makers, cycling lobbyists, service providers, and professional planners need to be gathered too, as these groups are expected to have a wealth of information on opportunities and barriers to bikesharing.

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Notes

¹ Brisbane's CityCycle scheme recently folded.

² A limitation of a survey-based approach is a lack of detailed travel data for participants (such as a weekly travel diary) or big data obtained from bikesharing providers (such as Chicago's DIVVY open-source data).

³ PCA with varimax rotation and iteration was applied to test the dimensional structure of the transport priorities. A factor loading above 0.40 was considered as the cut-off for retaining a dimension (Hair et al. 1998). The Scree plot and Kaiser criterion were used to determine the number of extracted components. An eigenvalue above 1.00 was regarded as significant.

⁴ In other words, the factor loadings were less than 0.4.

⁵ To check for collinearity between pairs of variables, the Variance Inflation Factor (VIF) test was performed:

$$VIF_j = \frac{1}{1 - R_j^2}$$

R_j is the multiple correlation coefficient between a variable (j) and the other independent variables. Values over 10.0 indicate a collinearity problem. In this case, the results suggested no collinearity: Age = 1.334; Smart = 1.117; HHsize = 1.399; SepHouse = 1.277; FullTime = 1.082; *Ease* dimension = 1.043; *Safekeeping* dimension = 1.014; *Punctuality* dimension = 1.034; *Fitness* dimension = 1.020.

⁶ We considered applying a MultiNomial Logistic (MNL) model instead of a two-level NL model. But when we compared the revealed behavioural responses, the goodness-of-fit, and the Inclusive Value (IV) criteria, the tree structure presented in Figure 2 was found to be superior over a MNL regression. In a two-level NL model, the IV parameters should fall between 0 and 1 to satisfy the global utility maximisation theory. The IV parameter for Users (U) was fixed to one as it has only one alternative in its nest. The IV parameter of Non-users, however, was estimated in the modelling process. As shown in Table 4, the IV parameter of the Non-user branch is 0.608, which is statistically positive and less than 1 (according to a Wald test). This means that in this case, a MNL model would cause misspecification and misrepresent the impact of explanatory variables.

⁷ The utility that an individual n perceives from alternative j in nest B_k is defined as:

$$U_{nj} = V_{nj} + \varepsilon_{nj}$$

where:

V_{nj} is the observable part

ε_{nj} is the random component of utility

In an NL model, V_{nj} can be split into two components: (1) component W which is constant for all alternatives within a nest, and (2) component Y which varies across alternatives within a nest (Train 2009). The utility is then expressed as:

$$U_{nj} = W_{nk} + Y_{nj} + \varepsilon_{nj}$$

for $j \in B_k$, where:

W_{nk} depends only on variables that describe nest k . These variables differ over nests but not over alternatives within each nest.

Y_{nj} depends on variables that describe alternative j . These variables vary over alternatives within nest k .

The probability that an alternative within nest B_k is chosen and the probability that the alternative i is chosen given that an alternative in B_k is chosen are expressed as:

$$P_{ni} = P_{ni|B_k} P_{nB_k},$$

where:

$P_{ni|B_k}$ is the conditional probability of choosing alternative i given that an alternative in nest B_k is chosen

P_{nB_k} is the marginal probability of choosing an alternative in nest B_k

The marginal and conditional probabilities are expressed as:

$$P_{nB_k} = \frac{e^{W_{nk} + \lambda_k I_{nk}}}{\sum_{l=1}^K e^{W_{nl} + \lambda_l I_{nl}}},$$

$$P_{ni|B_k} = \frac{e^{Y_{ni}/\lambda_k}}{\sum_{j \in B_k} e^{Y_{nj}/\lambda_k}},$$

where:

$$I_{nk} = \ln \sum_{j \in B_k} e^{Y_{nj}/\lambda_k}.$$

The parameter λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest k . The quantity I_{nk} (Inclusive Value) connects the upper and lower models (Train, 2009).

The ‘Full Information Maximum Likelihood’ (FIML) method was employed to estimate the NL model (Hensher, Rose, and Greene 2005). We included only variables that were significant at the 90% confidence interval according to the student’s t-test statistic. The model had a McFadden pseudo-rho-squared of 44%, which is considered as an acceptable explanation power. The model specifications are listed below.

The utility function of choice I consisted of following parameters:

$$I = I_0 + I_1 * SEPHOUSE + I_2 * FULLTIME + I_3 * EASE$$

The utility function of choice H consisted of following parameters included:

$$H = H_0 + H_1 * AGE + H_2 * AGE * SMART + H_3 * HHSIZE + H_4 * EASE + H_5 * SAFEKEEPING + H_6 * FITNESS$$

U was considered as the reference.

Two alternative-specific constants for I and H were considered.

Tables

Table 1. Cycling to work in Adelaide.

	Number of people cycling to work			Number of employed people			Percentage of people cycling to work		
	male	female	total	male	female	total	male	female	total
Greater Adelaide	4,368	1,144	5,512	334,036	222,691	556,727	1.31	0.51	0.99

Source: ABS (2016).

Table 3. Data reduction.

Dimension	Loading
1. Ease ($\alpha = .87$, explained variance = 28.39%)	
Convenience	.95
Comfort	.88
2. Fitness ($\alpha = .82$, explained variance = 21.95%)	
Exercise	.86
Health	.76
3. Safekeeping ($\alpha = .79$, explained variance = 12.82%)	
Safety	.80
Security	.72
4. Punctuality ($\alpha = .83$, explained variance = 9.84%)	
Time	.77
Speed	.63
Notes: Extraction method: Principal Component Analysis (PCA). Rotation method: Varimax with Kaiser normalization. Rotation converged in five iterations. The scree plot and Kaiser criterion were used to determine the number of extracted dimensions. An eigenvalue above 1.00 was considered as significant. Factor loading above 0.40 was used to retain dimensions.	

Table 4. Modelling results.

Variables	Groups	NL model			
		Coefficient	SE	t-value	p-value
Constant	H	-0.151	0.207	-0.730	0.466
Age		0.141***	0.037	3.760	0.000
Age*Smart		-0.063**	0.029	-2.180	0.029
HHsize		-0.103**	0.052	-1.970	0.049
Ease		0.123*	0.064	1.920	0.055
Safekeeping		0.276***	0.078	3.510	0.000
Fitness		-0.147**	0.063	-2.330	0.020
Constant	I	-0.277	0.390	-0.710	0.479
SepHouse		0.359**	0.156	2.300	0.021
FullTime		-0.132*	0.068	-1.941	0.053
Ease		0.294***	0.092	3.210	0.001
Inclusive value parameters					
Users		1.000		1.0 (fixed)	
Non-users		0.608***	0.182	3.340	0.001
Log-likelihood at zero				-262.518	
Log-likelihood at convergence				-469.954	
McFadden Pseudo-R-squared				0.441	
Sample size				353	
Number of iterations				36	
Chi-square				414.872	0.000
K				12	
Notes:					
*** significant at 1%					
** significant at 5%					
* significant at 10%					

Figures

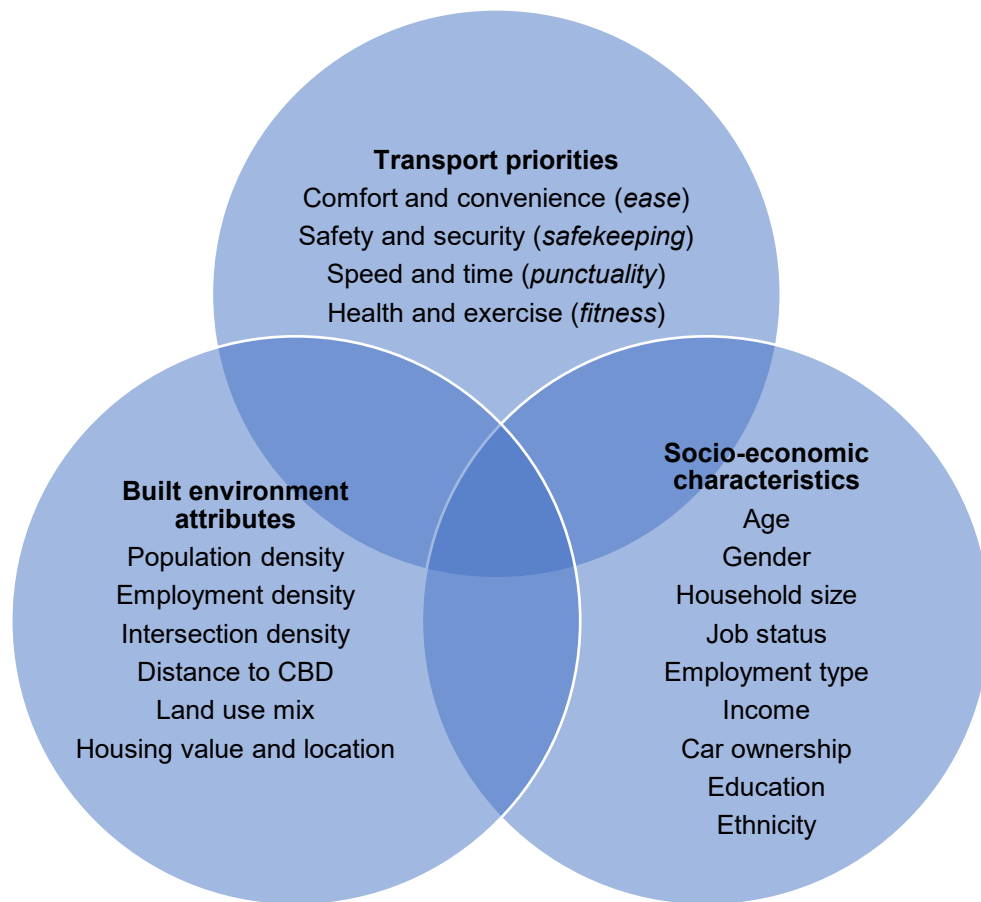


Figure 1. Theoretical framework. Diagram by authors.

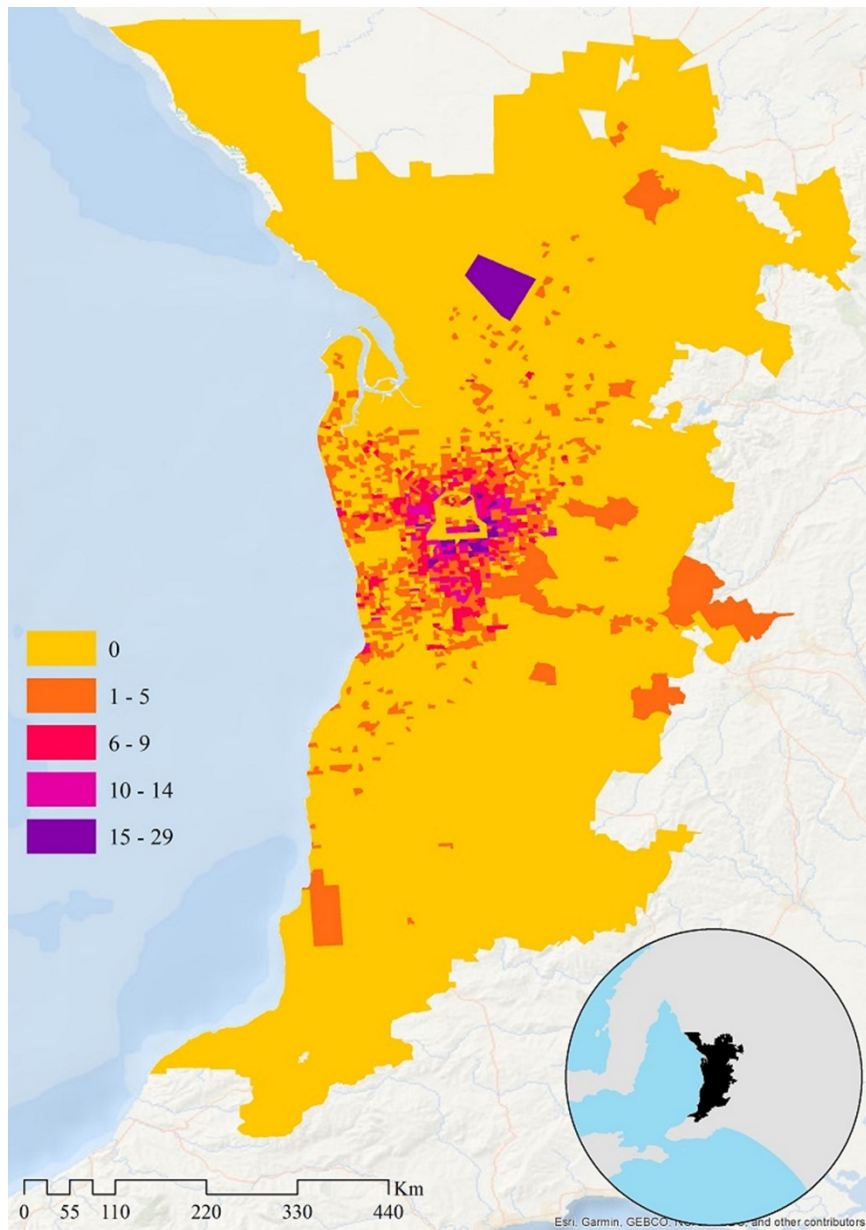


Figure 2. Distribution of cycling commuters in Adelaide. Map by authors based on ABS (2016) data.

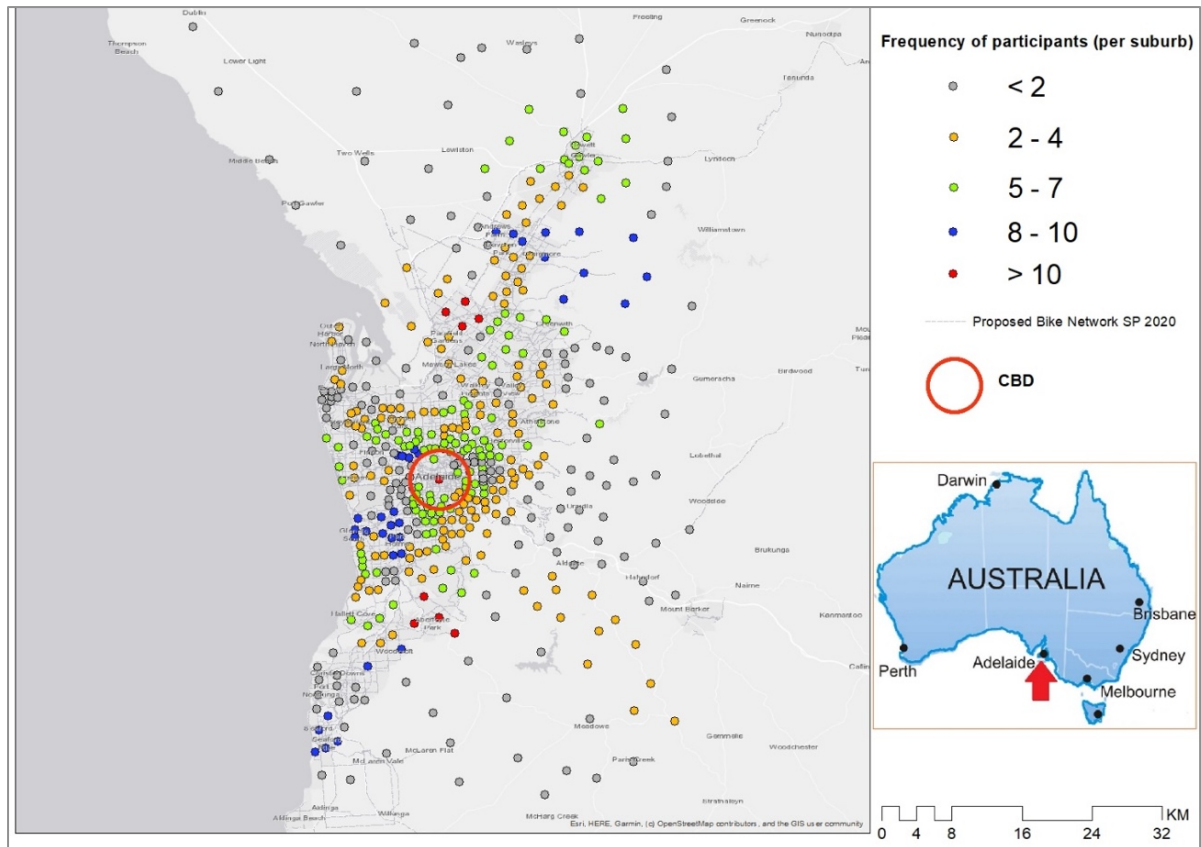
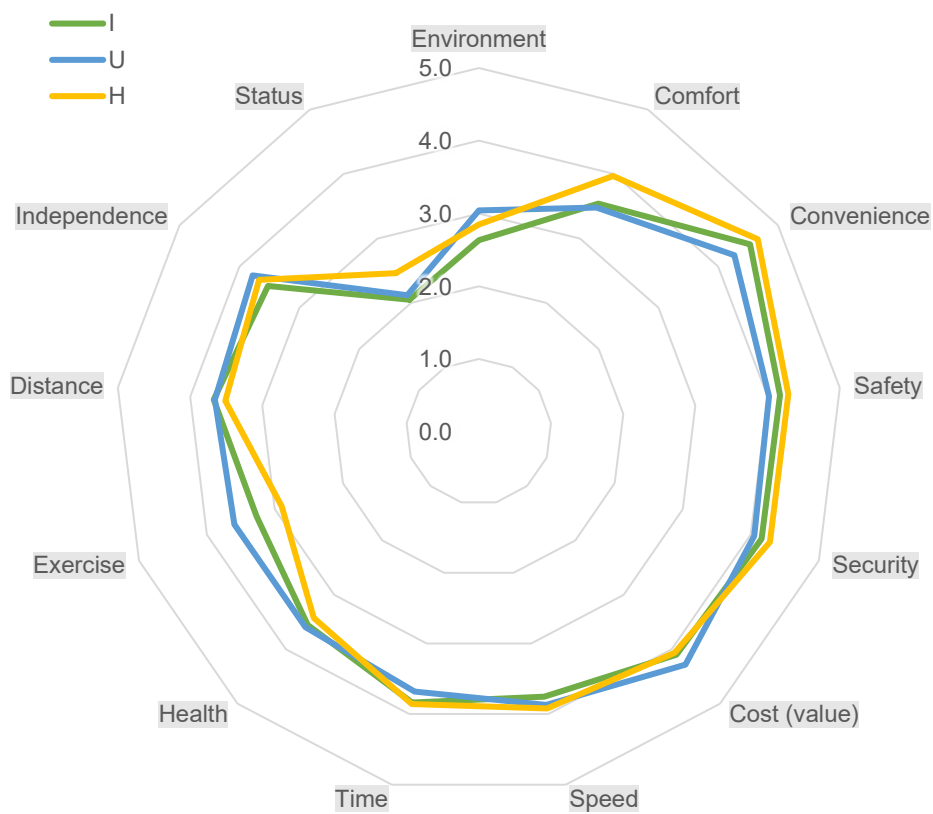


Figure 3. Distribution of survey respondents. The location of proposed cycling infrastructure is based on Adelaide's Cycling Strategic Plan (2017). Map by authors.



Legend

- 1=not important
- 2=slightly important
- 3=neutral
- 4=moderately important
- 5=very important

Figure 4. Ranking of the 13 transport priorities by group (I, U, H).

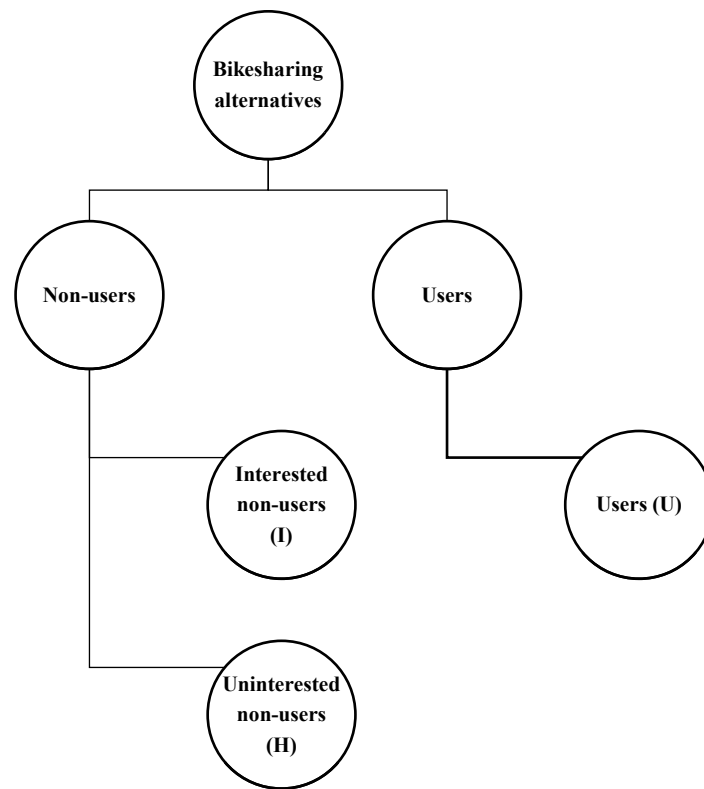


Figure 5. Two-level Nested Logit (NL) model structure of bikesharing alternatives.

Appendix: Model script and output

```

|-> nlogit
;lhs=choice
;choices=HATE,INTEREST,USERS
;effects:SAFETY(*)/HHSIZE(*)/AGE(*)
;pwt
;tree=NU(HATE,INTEREST),US(USERS)
;ivset:(US)=[1.0]
;maxit=100
;model:
U(HATE)=H0+H3*FAC3_1+H4*FAC4_1+H6*HHSIZE+H5*FAC5_1+H1*AGE+H2*AGE*SMART/
U(INTEREST)=I0+I4*FAC4_1+I6*SEPHOUSE+I3*SAFETY
$

```

Iterative procedure has converged

Normal exit: 36 iterations. Status=0, F= .2625179D+03

FIML Nested Multinomial Logit Model

Dependent variable CHOICE

Log likelihood function -262.51793

Restricted log likelihood -469.95379

Chi squared [12](P= .000) 414.87172

Significance level .00000

McFadden Pseudo R-squared .4413963

Estimation based on N = 353, K = 12

Inf.Cr.AIC = 549.0 AIC/N = 1.555

Log likelihood R-sqrd R2Adj

No coefficients -469.9538 .4414 .4317

Constants only -301.5509 .1294 .1144

At start values -272.9663 .0383 .0216

Note: R-sqrd = 1 - logL/Logl(constants)

Response data is given as ind. choices

The model has 2 levels. Model form: RU1

Number of obs.= 353, skipped 0 obs

	Standard	Prob.	95% Confidence	
CHOICE Coefficient	Error	z	z >Z* Interval	
Attributes in the Utility Functions (beta).....				
H0	-.15109	.20735	-.73 .4662	-.55749 .25530
H3	.12285*	.06396	1.92 .0548	-.00252 .24822
H4	.27577***	.07846	3.51 .0004	.12200 .42954
H6	-.10268**	.05206	-1.97 .0486	-.20473 -.00064
H5	-.14747**	.06316	-2.33 .0196	-.27127 -.02368
H1	.14092***	.03746	3.76 .0002	.06750 .21433
H2	-.06337**	.02906	-2.18 .0292	-.12033 -.00641
I0	-.27675	.39046	-.71 .4785	-1.04205 .48854
I4	.29427***	.09165	3.21 .0013	.11465 .47390
I6	.35941**	.15617	2.30 .0214	.05332 .66551
I3	-.13206*	.06876	-1.94 .1319	-.30385 .03973
IV parameters (RU1), tau(b l,r),sigma(l r),phi(r).....				
NU	.60874***	.18247	3.34 .0008	.51098 9.66377
US	1.0		(Fixed Parameter).....	

***, **, * ==> Significance at 1%, 5%, 10% level.

Fixed parameter ... is constrained to equal the value or had a nonpositive st.error because of an earlier problem.

Model was estimated on Jul 22, 2020 at 02:24:24 PM

Nested logit random utility normalization

No normalization was imposed a priori. (Default form is RU1)

IV parameters for RU1 model are Tau(Br|Lmb), Sigma(Lmb|Trnk)

Prob(alt=j|br=B,lmb=L,trnk=T) = exp[bX_j|BLT]/Sum (MNL)

Prob(br=b |lmb=L,trnk=T) = exp[aY_b|LT+taub|LR*IVB|LT)]/Sum