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The public bicycle-sharing scheme in Brisbane, Australia: evaluating the influence of its introduction on changes in time spent cycling amongst a middle- and older-age population

Eva Heinen
University of Leeds
Institute for Transport Studies
Faculty of the Environment
Leeds LS2 9JT
United Kingdom
+44-(0)1132431790
e.heinen@leeds.ac.uk

Md. Kamruzzaman
Monash University
Monash Art Design & Architecture
900 Dandenong Road, Caulfield East, VIC 3145
Australia
+61 (0)44 9746 912
md.kamruzzaman@monash.edu

Gavin Turrell
School of Public Health and Social Work
Queensland University of Technology
Victoria Park Road, Kelvin Grove, Brisbane, Queensland, Australia, 4059
+61 0408 843 271
g.turrell@qut.edu.au

Abstract

Background: Active travel may improve individual health as it contributes to higher levels of physical activity, particularly in an aging society. Bicycle-sharing schemes may contribute to public health by encouraging active travel.

Aim: To investigate whether exposure to a bicycle-sharing scheme—measured as residential proximity to a bicycle station—was associated with the propensity to use it. Second, we aimed to study the extent to which exposure to the scheme was associated with a change in time spent cycling.

Method: In this natural-experimental study, we analysed a large panel of residents in Brisbane, Australia, who were surveyed before and after the introduction of a bicycle-sharing scheme in 2010. Data were collected as part of the HABITAT study, a multilevel longitudinal investigation of physical activity and health among 'baby boomers' (persons aged 40-65). Data were collected in 2009 (n=7,866), 2011 (n=6,900), and 2013 (n=6520). Two self-reported outcome variables were examined: (1) a stages-of-change variable measuring the likelihood of using the scheme and the intention to use it in the future, and (2) change in time spent cycling between 2009 and 2013.

Results: In the unadjusted model, proximity was significantly associated with stages of change, but became non-significant after adjustment. Moreover, higher levels of exposure to the intervention did not predict a change in time spent cycling. Younger respondents and respondents with a higher education level were more likely to consider using the bicycle-sharing scheme. Individuals who had a college degree were more likely to have used this scheme.

Conclusion: Residential proximity to a bicycle-sharing station was not found to be associated with the use of the bicycle-sharing scheme nor did its introduction significantly predict an increase in time spent cycling. Other interventions may be more supportive of increasing cycling in the baby boomer cohort, and, thereby, improving their overall health.

Highlights

- We assessed of the impacts of a bicycle-sharing scheme (BSS) on cycling behaviour.
- We analysed a large cohort of baby boomers before and after the BSS introduction.
- Residential proximity to the BSS did not predict its use.
- Residential proximity did not predict a change in time spent cycling.

Keywords:

Bicycle-sharing schemes, cycling, physical activity, built environment, natural experiment

1. Introduction

Physical inactivity is a major cause of morbidity and mortality (Lee et al., 2012). The World Health Organization (WHO) recommends spending at least 150 minutes of moderate-intensity aerobic activity, or at least 75 minutes of vigorous-intensity aerobic activity, or an equivalent combination a week (WHO, 2010). Older adults in particular do not achieve this recommended level of physical activity (Taylor, 2013; Sun et al., 2013), even though physical activity has been shown to result in improved health in older age groups (Wen et al., 2011; Landi et al., 2004; Guell et al., 2016). Increases in active travel time are associated with increases in total physical activity (Shalqvist et al., 2013; Foley et al., 2016), and offer levels sufficient to improve individual health (Chief Medical Officers, 2011). Therefore, encouraging active travel amongst an aging population may result in improved individual and public health.

Bicycle-sharing schemes (BSS) may contribute to public health by encouraging active travel. Over the last 15 years, BSS have been launched in more than 800 cities, including many ‘world cities’ such as London, Paris, and New York. For the purposes of this study, we define BSS as schemes that provide time-restricted rental of bicycles to anyone, which sometimes require registration or subscription. The limited research on the health impacts of BSS concluded that the benefits of the schemes are indeed greater than the risks to health for most users (Woodcock et al., 2014; Rojas-Rueda, 2011). The contribution of BSS to public health depends, amongst other things, on changes in travel behaviour. In this respect, both the level of use of the scheme as well as the extent to which public bicycle schemes generate new trips or substitute another mode of transport are important, as physical activity benefits are achieved by an increase in time spent cycling, either from new trips or a change in the mode choice of existing trips.

In addition to health effects modelling, research on BSS is diverse. One strand focusses on the technical aspects, such as the optimal location for stations and the optimisation of continuous bicycle distribution over the city (e.g. Ahillen et al., 2016; Benarbia et al., 2013; Kadri et al., 2015). A second focus has been on the economic modelling of bicycle schemes, such as the cost effectiveness and willingness to pay (e.g. Wuerzer & Mason, 2016; Dell'Olio et al., 2011). The main research focus has been spatial differences in use of docking stations and the characteristics of individuals who use these schemes (e.g. Wang et al., 2016, Clark & Curl, 2016; El-Assi et al., 2017; Medard de Chardon & Curuso, 2015; Bernatchex et al., 2015; Fishman et al, 2014a, b). These studies indicate that the proximity of residential housing, train stations, shops, or employment sites to a docking station increases ridership (e.g. Fishman et al., 2015; 2014a; Bachand-Marleau et al., 2012; Buck and Buehler, 2012, Daddio, 2012; Wang et al., 2016; Rixey, 2013; Nair et al., 2013; Hampshire and Marla, 2012; Fuller et al., 2011). BSS stations located in the city centre and on the university campus generally have high ridership (Mattson and Godavarthy, 2017; Zhang et al., 2016). Docking station density and population size are positively associated with the use of BSS (Médard de Chardon et al., 2017). The presence of a helmet law was associated with lower levels of use (Médard de Chardon et al., 2017). Several socio-economic characteristics are also associated with higher levels of membership and use: users appear to be younger adults, have higher incomes than average, male and are more likely to own a bicycle (Fishman et al., 2015; Fishman et al., 2013; Ji et al., 2017). Ogilvie and Goodman (2012) reported that registered users of the London scheme were more likely to be male and living in socioeconomically advantaged areas and areas with high cycling levels. However, amongst registered users, individuals living in more deprived areas made more trips than individuals in less deprived areas.

These studies provide useful insights about the characteristics of the users of bicycle-sharing schemes, and show, to a certain extent, the determinants of use (e.g. Fuller et al., 2011; Fishman et al., 2014a; Fishman et al., 2015). They also suggest that bicycle-sharing schemes appear to have the potential to alter travel behaviour away from the car towards active travel (Fishman et al., 2014b). However, most existing studies share two limitations. First, the majority of studies only collect data from users/members (e.g. Ogilvie and Goodman, 2012). Although user data allows us to determine user profiles, it does not enable us to investigate the correlates of usage or predictors of changes in travel behaviour on a population level (i.e. including non-users). Moreover, study findings involving only users are subject to self-selection bias (i.e. individuals who prefer cycling become a member of a scheme). Second, the majority of the studies on bicycle-sharing schemes rely on cross-sectional data (i.e. collected at one moment in time) (e.g. Fuller et al., 2011; Fishman et al., 2014a). The nature of cross-sectional data (irrespective of the collection from users and/or non-users) prevents causal inference of the bicycle-sharing scheme. As a result, changes in behaviour cannot be attributed to the introduction of such schemes.

The aim of this quasi-experimental study was twofold. First, we investigated whether exposure to a bicycle-sharing scheme—measured as residential proximity to a bicycle station—was associated with the propensity to use this scheme amongst a middle- and older-age population. We used a stages-of-change model to differentiate between (1) individuals who had never used the BSS and who did not intend to use it in the future, (2) individuals who had never used the BSS, but who intended to use the scheme in the future, and (3) individuals who had used the scheme. Second, this study investigated the extent to which exposure to this bicycle-sharing scheme has influenced individual travel behaviour amongst a middle- and older-age population, particularly whether its introduction was associated with changes in time spent cycling. We used residential proximity as our exposure measure, as the most frequently used BSS station is the one closest to home (Shaheen, Zhang, Martin, & Guzman, 2011). It is therefore conceivable that the likelihood of using the BSS or changing one's travel behaviour may be influenced by residential proximity to a BSS station.

We analysed data from a large panel of residents in Brisbane, Australia, followed before and after the introduction of a large-scale BSS in 2010. The cohort consisted of adults aged between 40 and 65 years at baseline (2007). Whereas older individuals are less likely to cycle (e.g. Heinen et al., 2011), the benefits of cycling for older individuals are much greater than for younger individuals (Woodcock et al., 2014). Thus, it is important to understand the determinants of use and predictors of change in the active travel behaviour of this population.

2. Method

2.1 Setting

Brisbane is the capital city of Queensland, Australia, and had over two million inhabitants in 2016. It is a rapidly growing city: its population increased by about

10% between 2011 and 2016 (Australian Bureau of Statistics, 2016). Of its commuting population, 75.3% travel to work by car as a driver, 10.5% commute by public transport, and 4.9% commute by active transport (Australian Bureau of Statistics, 2016).

Cycling infrastructure was limited, but has expanded in Brisbane over the past decade. In 2006, there were only 75 km of cycling infrastructure (Queensland Government, 2011; Ahillen et al., 2015). By 2016, its network had expanded to over 1,300 km of bikeways and shared pathways (Brisbane City Council, 2016). Previous research using data from the HABITAT study (**H**ow **A**reas in **B**risbane **I**nfluence Heal**t**h and **A**c**t**ivity) revealed that in a baby boomer cohort, a higher income was positively associated with utilitarian and recreational cycling. Furthermore, vehicle access and working part-time were positively associated with higher levels of utilitarian cycling. Closer proximity to the central business district increased the likelihood of cycling for transport (Heesch et al., 2014, 2015).

2.2 Intervention: Brisbane public bicycle scheme—CityCycle

In 2010, a BSS was introduced in Brisbane. At first, this comprised 50 stations and 500 bicycles (Ahillen et al., 2015) and has grown to 150 CityCycle bike stations with up to 2,000 bicycles in 2015 (Brisbane City Council, 2016). Membership is compulsory for usage, but possible for various durations with costs ranging from 2 Australian dollars (AUD) for one day (1 AUD=0.76 USD (as of 13 February 2017)) to 60.5 AUD for a year. The first 30 minutes of use are free of charge.

2.3 Study Sample

Data were collected as part of a larger cohort study, the HABITAT study, in four phases: 2007, 2009, 2011, and 2013. The HABITAT study aims (1) to assess the patterns of changes in physical activity, (2) to examine the contributions of psychological, social, environmental, area level, and sociodemographic factors to change in physical activity, and (3) to examine the associations of psychological, social, environmental, area level, and sociodemographic factors with different types of activity, including cycling (Burton et al., 2009). All data were collected between the months of May and August (winter) in respective years. The winter months are suitable for cycling, as Brisbane has a sub-tropical climate, which means that summers are hot and wet, and winters are dry and moderately warm. The cohort consisted of adults aged between 40 and 65 years at baseline (2007), living in 200 Census collection districts (CCDs) in Brisbane. In this paper, we analysed data from the years 2009, 2011, and 2013, in which 7,866, 6,900, and 6,520 individuals participated in the survey, with response rates of 72.6%, 67.3%, and 67.1%, respectively.

3. Data & analyses

3.1 Analyses

In this paper we perform two analyses:

Analysis 1: The use of CityCycle

The first analysis focusses on the correlates of CityCycle use. This analysis allows us to reveal whether exposure to CityCycle is associated with the propensity to use this scheme in 2011.

Analysis 2: Changes in travel behaviour

The second analysis investigates the extent to which exposure to CityCycle predicts a change in time spent cycling. For this analysis, we investigated the change in travel behaviour, using data from our cohort in 2009 and 2013.

3.2 Outcomes

3.2.1 Analysis 1: The use of CityCycle

The first analysis addresses the likelihood of using Brisbane's CityCycle and the intention to use the scheme in the future. The dependent variable follows the stages-of-change model from Prochaska & DiClemente (1983), which differentiates between five stages: Pre-Contemplation, Contemplation, Preparation, Action, and Maintenance. Stages-of-change models are well established both in public health and travel behaviour research (Friman et al., 2017), but have been criticised (e.g. Adams and White, 2005; Littell and Girvin, 2002) and their suitability as the basis for developing or evaluating interventions has been questioned. In this study, this model was not used to develop an intervention (as this study was a natural experiment), but to provide a framework for examining how people progress towards adopting the BSS in Brisbane.

In the 2011 survey, respondents were first asked if they were aware of the CityCycle scheme. If they were aware, they were then directed to answer whether they had used the CityCycle: 'Have you used Brisbane City Council's Bike Hire Scheme?' (yes/no). If the respondent answered yes, a follow-up question was asked: 'Do you plan to use the Bike Hire Scheme again?' (yes regularly/yes occasionally/no). If the respondents answered no to the first question, a similar follow-up question was asked: 'Do you plan to use the Bike Hire Scheme?' (yes regularly/yes occasionally/no).[1]

Given the limited reported use of CityCycle amongst our respondents, we adjusted the Prochaska and DiClemente stages of change and considered three stages of change:

1. Pre-Contemplation: Individuals who had never used the BSS and who did not intend to use it in the future.
2. Contemplation & Preparation: Individuals who had never used CityCycle, but who intended to use the scheme in the future, either occasionally or regularly.
3. Action & Maintenance: Individuals who had used CityCycle (irrespective of future intentions).

3.2.2 Analysis 2: Changes in travel behaviour

The second part of our analyses focussed on changes in travel behaviour. For this, we analysed the self-reported time spent cycling for all activities, a sum of the self-reported time spent cycling for transport and time spent cycling for recreation. Respondents were asked to estimate their time spent cycling with the following questions: 'What do you estimate was the total time that you spent cycling for recreation, leisure, or exercise in the last week?' and 'What do you estimate was the total time that you spent cycling for transport in the last week?' These questions were adapted from the Active Australian Survey, which has been shown to yield reliable and valid data (Brown et al., 2008).

[1] These questions were not included in the 2013 questionnaire.

The change in time spent cycling was determined between 2009 and 2013 for both transport and recreational activities as well as the total change in time spent cycling. We excluded individuals who had missing data in either year and individuals who in total reported more than 35 hours of cycling a week (i.e. more than 5 hours on average a day, in either year).

The changes in time spent cycling were not normally distributed with a preponderance of zero values, which made the log transformation (which can be used to make highly skewed data less skewed) of the data difficult. Therefore, we transformed these variables into three groups for the analyses: a decrease in time spent cycling of more than 35 minutes; no change in time spent cycling (i.e. less than 35 minutes decrease or increase per week); and an increase in time spent cycling of more than 35 minutes per week. We considered any change as a cut-off, and the smallest daily change that individuals were likely to remember, i.e. 5 minutes a day, resulting in 35 minutes per week. We selected the cut-off of 35 minutes for our main analyses as it was the more conservative measure, but conducted a sensitivity test with the other measure (see Section 3.5.3).

3.3 Exposure to the intervention

Several studies amongst (registered) users of BSS have shown that proximity to bicycle-sharing station corresponds with an increased likelihood of using a BSS (e.g. Fishman et al., 2015; Bernatchez et al., 2015; Fuller et al., 2011). In the literature, a cut-off distance is often chosen for including individuals in a study. Fishman et al. (2015), for example, used a cut-off of 250 m. The finding that the working location was a stronger predictor than the residential area may be explained by the short cut-off—very few individuals lived within a 250-m radius of a bicycle rental station. This also implies that users may actually travel further to access a shared bicycle (e.g. in combination with public transport). Thus, we chose not to select a firm cut-off; rather, we decided in favour of a continuous measure of exposure. We expected that the likelihood of using CityCycle and the likelihood of increasing the level of cycling decline with any increment in distance. We derived an objective, ego-centred (Perchoux et al, 2013) measure of exposure to the intervention for each individual, based on the proximity of their baseline home location to the closest bicycle-sharing station over the street network. We defined exposure as the natural log value of the network distance from home to the nearest bicycle-sharing station. This would result in limited increases in exposure measure after 5 km. We used the negative value of the log transformation, and as a result, the measure of exposure was a measure of proximity (instead of distance).

Proximity to CityCycle stations represents the network distance to the nearest station available in 2011 when the stages of change were analysed (Analysis 1). However, given that more CityCycle stations were added recently, the proximity values for the assessment of changes in cycling (2009-2013) represent distance to the nearest CityCycle station available in 2013 (Analysis 2). We excluded individuals who moved between 2009 and 2011 for the stage-of-change analysis and between 2009 and 2013 for the assessment of changes in time spent cycling. However, movers were included to perform a sensitivity analysis (see Section 3.5.3)

3.4 Covariates

3.4.1 Analysis 1: The use of CityCycle

For the first analysis, we considered the following covariates (Table 1): gender (male/female), car availability (yes/no), education level (high school or less/diploma or certificate/bachelor or higher), employment status (yes/no), country of birth (Australia/other), age, and health status (poor/fair to excellent) all derived from the 2011 questionnaire. In addition, we considered several characteristics of the residential built environment as continuous indicators: density, land use diversity, street connectivity, hilliness, total length of bicycle network, and distance to the central business district (CBD), which were all measured for the 2011 conditions and within a 1-km network buffer of respondents' home locations (except distance to the CBD). Distance to the CBD was eventually dropped given the high correlation with the exposure measure. The land-use mix was calculated using the five classifications of land use (commercial, industrial, leisure/recreation, residential, and other) using the formula from Leslie et al. (2007). Hilliness was measured as the standard deviation of elevation above sea level. Density was calculated by dividing the number of residential dwellings by the total size of residential land within the buffer.

Table 1: Overview of characteristics of the participants

			Sample used in Analysis 1: use of the BSS			Sample used in Analysis 2: change in time spent cycling			All individuals participating in 2007 (first wave of data collection)		
			Proportion	Mean (st. dev.)	n	Proportion	Mean (st. dev.)	n	Proportion	Mean (st. dev.)	n
Exposure	Residential proximity to bicycle station (km)			-2.13 (0.78)	4635		-1.98 (0.86)	4031		-2.13 (0.80)	11029
Outcomes	Change in cycle time						-1.99 (107.89)	4118			
	Change in total cycle time	Decrease				9.7%		400			
		No change				81.5%		3356			
		Increase				8.8%		362			
	Stages of change	Pre-Contemplation	92.3%		4279						
		Contemplation/ Preparation	6.9%		318						
		Action/Maintenance	0.9%		40						
Covariates	Gender	Female	57.7%		2670	57.8%		2381	56.1%		6187

	Male	42.4%		1961	42.2%		1737	43.9%		4848
Age			56.0 (7.1)	4630		54.1 (7.1)	4115		51.2 (7.1)	11035
Employment status	Non-working	31.3%		1441	27.3%		1048	24.0%		2644
	Part-time working	22.4%		1031	22.9%		881	22.9%		2520
	Full-time working	46.3%		2129	49.8%		1917	53.1%		5846
Country of birth	Australia	78.9%		3568	77.0%		3097	75.2%		8245
	Other	21.1%		954	23.0%		927	24.8%		2719
Education	Up to year 12	36.8%		1667	36.2		1459	39.2		4311
	Diploma/certificate	28.8%		1303	28.7%		1158	29.3		3220
	Graduate or higher	34.4%		1557	35.1%		1412	31.5		3457
Being in poor health	No	97.1%		4462	97.7%		3936	3.4		375
	Yes	2.9%		135	2.3%		94	96.6		10556
Vehicle possession	Yes, always	89.9%		4007	89.1%		3657	89.5		9783
	Yes, sometime	5.2%		230	6.0%		246	5.2		563
	No/do not drive	5.0%		225	4.9%		203	5.3		581
Income	1st Quintile	20.1%		910	21.2%		862	20.6		2232
	2nd Quintile	20.0%		906	21.1%		859	22.5		2438
	3rd Quintile	25.5%		1151	26.7%		1084	26.3		2845
	4th Quintile	22.0%		995	19.5%		792	17.5		1889
	Don't know/Don't want to answer	12.4%		561	11.5%		467	13.1		1417
Connectivity			123.1 (40.6)	4637		118.5 (40.2)	4031	117.5 (40.6)		11035
Land use diversity			.57 (.1)	4637		0.6 (.1)	4031	0.6 (0.1)		11035
Residential density			17.1 (9.4)	4637		16.3 (9.2)	4031	16.3 (8.4)		11035
Hilliness			11.8 (6.3)	4637		11.6 (6.1)	4031	11.5 (6.1)		11035
Length bike lanes (km)			3.1 (2.5)	4637		2.9 (2.5)	4031	2.6 (2.3)		11035
Distance to CBD (km)			10.1 (4.5)	4637		10.2 (4.5)	4031	10.2 (4.5)		11035
Increased hours at work	No				71.6%		2863			
	Yes				28.4%		1137			
Increased care responsibility for child	No				93.2%		3728			
	Yes				6.8%		273			
Increased financial difficulty 2009--2013	No				61.4%		2478			
	Yes				38.6%		1559			
Reduced hours of working	No				84.2%		3388			
	Yes				15.8%		634			
Increased care responsibility for adults	No				76.3%		3080			
	Yes				23.7%		957			
Increased working hours	No				71.6%		2863			
	Yes				28.4%		1137			
Retired from work	No				77.0%		3103			
2009-2013	Yes				23.0%		927			
Became unemployed	No				92.5		3711			
	Yes				7.5%		299			

3.4.2 Analysis 2: Changes in cycling behaviour

We considered three types of covariates: (1) socio-economic characteristics; (2) built environment characteristics, similar to the analyses of correlates of use of CityCycle; and (3) other changes.

We considered the same socio-economic and built environment characteristics as in Analysis 1 (Table 1), but in this analysis, these characteristics were all derived from the 2009 questionnaire. Moreover, we considered other changes that an individual may have experienced between 2009 and 2013: increased financial difficulty, increased care responsibilities, changes in working hours, retirement, and becoming unemployed.

3.5 Statistical approach

3.5.1 Analysis 1: The use of CityCycle

For the first analyses, we excluded movers from our main analyses, individuals who indicated not being aware of the Brisbane City Council's Bike Hire Scheme and individuals who did not report a valid answer on existing use and intention to use, resulting in a total sample of 4,637 individuals. We estimated a multinomial logit model and stepwise analysed the association between exposure to the intervention and stages of change, taking Pre-Contemplation as the reference category. We first estimated the unadjusted model, with just the outcome and exposure. We then investigated all variables separately on the outcome. Only covariates associated with the outcome at $p<0.25$ in unadjusted models were included in the adjusted models. Finally, we estimated the maximally adjusted model. We tested for multicollinearity using variance inflation factor (VIF) scores in the maximally adjusted model.

3.5.2 Analysis 2: Changes in travel behaviour

For the second analyses, we excluded movers from our main analyses, individuals who had not answered the questions regarding cycling time in 2009 or in 2013, as well as individuals who had reported more than 35 hours cycling per week in either wave, resulting in 4,118 respondents.

The predictors of change in time spent cycling were tested with multivariable multinomial logistic regression models, progressively adjusted as follows: (1) unadjusted—only exposure to the intervention, (2) adjusted for socio-economic characteristics, (3) adjusted for other built environment characteristics, (4) adjusted for other changes, and (5) maximally adjusted model. Only covariates associated with the outcome at $p<0.25$ in unadjusted models were included in the adjusted models. We tested for multicollinearity using variance inflation factor (VIF) scores in the maximally adjusted model. The model estimating ‘changes in total time spent cycling’ was our main model. Given that previous research showed that cycling for transport and cycling for recreation were associated with different covariates (Heesch 2014, 2015), we repeated the analyses on changes in ‘time spent cycling for recreation’ and ‘time spent cycling for transport’, controlling for the same covariates.

3.5.3 Sensitivity tests

We conducted several sensitivity tests, including (1) the maximally adjusted model incorporating individuals who moved between 2009 and 2011 (Analysis 1) or between 2009 and 2013 (Analysis 2); (2) the maximally adjusted model with only those individuals included who lived within 5 km of a bicycle-sharing station; (3) the maximally adjusted model with additional control for income, which was not included in the maximally adjusted model due to the relatively large number of individuals indicating not knowing or not wanting to answer; (4) the maximally adjusted model taking into account the potential clustering effect of the participants in CCDs (Analysis 2); and (5) the maximally adjusted model with a different cut-off for change in time spent cycling a change at 1 minute (instead of 35) (Analysis 2).

4. Results

4.1 Analysis 1: The use of CityCycle

4.1.1 Descriptive analyses

Of the 4,637 respondents included in analysis 1, 4,279 (92.3%) reported not having used CityCycle and not intending to use it in the future (i.e. Pre-Contemplation) in 2011. Four hundred five respondents (6.9%) belonged to the Contemplation & Preparation group (i.e. not having used the scheme, but planning to use it in the future). A small proportion of our respondents (n=40, 0.98%) belonged to the Action & Maintenance group (i.e. individuals who had used the CityCycle).

4.1.2 Multivariate analyses

Residential proximity to a bicycle-sharing station was significantly associated with a higher likelihood to be in the Contemplation & Preparation and Action & Maintenance groups in the unadjusted models (relative risk ratio (RRR)=1.18 and RRR=1.55, respectively), but after adjustment, this association became non-significant (Table 2 and Appendix A). The association between proximity and belonging to the Action & Maintenance stage became non-significant after adjusting for density, land use, and hilliness. The association between proximity and being in the Action & Maintenance stage only became non-significant after maximal adjustment.

Although the variance and uncertainty of the effect size were large (and the results were therefore non-significant), individuals who lived 1 km away compared to individuals who lived 2.72 km from a bicycle-sharing station (or any other one-point difference on a log transformation) were approximately 10%-20% more likely to be in the Contemplation & Preparation stage than in the Pre-Contemplation stage and approximately 40% more likely to be in the Action & Maintenance stage (RRR: 1.22, 95% Confidence Interval (CI): 0.95-1.57; RRR: 1.43, 95% CI: 0.81-2.51).

In addition, as age increased, individuals were less likely to be in the Contemplation & Preparation stage instead of the Pre-Contemplation stage. In contrast, having a diploma or being a graduate from university, compared to only having received education up to school year 12, increased the likelihood of belonging in the contemplating & preparing stage and belonging to the Action & Maintenance stage by 60% and 140%, respectively. The results in the sensitivity test were comparable to the maximally adjusted model.

Table 2: Correlates of stages of change of using the Brisbane bicycle-sharing scheme

	Variable	**Category**	Maximally adjusted model	
			RRR	95% CI
Contemplation & Preparation	Proximity to bicycle station		1.22	[0.95-1.57]
	Gender (ref: male)	Female	1.14	[0.88-1.47]
	Age		**0.97*** **	[0.95-0.99]
	Employment status (ref: full-time working)	Part-time working	0.83	[0.60-1.13]
		Non-working	0.83	[0.59-1.16]
	Education (ref: up to year 12)	Diploma/certificate	**1.64****	[1.16-2.30]
		Graduate or higher	**2.39*****	[1.75-3.27]

	Density		1.00	[0.97-1.02]
	Land use		0.55	[0.22-1.39]
	Hilliness		1.02	[1.00-1.03]
Action & Maintenance	Proximity to bicycle station		1.43	[0.81-2.51]
	Gender (ref: male)	Female	0.99	[0.49-1.99]
	Age		0.98	[0.93-1.04]
	Employment status (ref: full-time working)	Part-time working	1.42	[0.64-3.11]
		Non-working	0.65	[0.23-1.81]
	Education (ref: up to year 12)	Diploma/certificate	1.81	[0.64-5.16]
		Graduate or higher	**3.34***	[1.31-8.52]
	Density		1.00	[0.95-1.05]
	Land use		2.79	[0.23-33.70]
	Hilliness		1.04	[1.00-1.09]
	n=4493			

Reference=Pre-Contemplation
***=p<0.001; **=p<0.01; * p<0.05
RRR=Relative Risk Ratio; 95% CI=95% Confidence Interval

4.2 Analysis 2: Changes in travel behaviour

4.2.1 Descriptive analyses

Valid data were obtained from 4,118 non-moving respondents for the self-reported total time spent cycling in 2009 and 2013. On average, the respondents decreased the total time spent cycling by 1.98 minutes a week. The average time spent cycling for transport decreased by 2.34 minutes per week, whereas the average time spent cycling for recreation increased by 0.35 minutes.

Between 2009 and 2013, 81.5% of the respondents (n=3,356) had less than a 35-minute change in either direction in their total time spent cycling. 9.7% (n=400) decreased their total time cycling by 35 minutes or more, whereas 8.8% (n=362) increased their total time cycling by 35 minutes or more in a week.

4.2.2 Multivariate analyses

The associations between proximity to a bicycle-sharing station and changes in time spent cycling were not found to be statistically significant (Table 3, Appendix B). This finding appears to suggest that the residential proximity to a bicycle-sharing station had no consequence on the level of one form of physical activity—the time spent cycling.

Several covariates were significantly associated with changes in time spent cycling. Women, when compared to men, were less likely to increase or decrease the time spent cycling (i.e. their levels of cycling were stable over the period). Similarly, with an increase in age, individuals were less likely to either increase or decrease their time spent cycling. These findings may be a consequence of the fact that women and older individuals were less likely to cycle in the first place and therefore less likely to change.

Individuals with a university degree were more likely to decrease their time spent cycling. Individuals who had experienced financial difficulty were less likely to have a decrease and an increase in time spent cycling. In contrast, individuals with limited access to a car and individuals who were born outside of Australia were more likely to change their level of cycling (in both directions). Individuals who resided in an area with more hills were less likely to decrease time spent cycling.

The results in the sensitivity test were comparable to the maximally adjusted model. However, unlike the total cycling model as discussed above, some of the estimated coefficients were found to have non-significant effects when the models were estimated separately for cycling for transport and cycling for recreation (Appendix B), which may be due to smaller sample sizes. For example, the level of education and the country of birth were not statistically significant associated with cycling for transport, but there was a relationship with cycling for recreation.

Table 3: Predictors and correlates of changes in time spent cycling

	Variable	**Category**	Maximally adjusted model	
			RRR	95%CI
Decrease in time spent cycling	Proximity to bicycle station		1.06	[0.85-1.34]
	Gender (ref: male)	Female	**0.50*** **	**[0.39-0.64]**
	Age		**0.96*** **	**[0.95-0.98]**
	Employment status (ref: full-time working)	Part-time working	1.19	[0.88-1.62]
		Non-working	0.89	[0.64-1.25]
	Being in poor health (ref: no)	Yes	0.29	[0.07-1.21]
	Education (ref: up to year 12)	Diploma/certificate	**1.35***	**[1.01-1.85]**
		Graduate or higher	**1.47***	**[1.09-1.98]**
	Country of birth (ref: Australia)	Other	**1.36***	**[1.05-1.77]**
	Vehicle possession (ref: yes, always)	Yes, sometimes	**1.66***	**[1.09-2.53]**
		No/do not drive	0.87	[0.47-1.63]
	Connectivity		1.00	[1.00-1.01]
	Land use diversity		1.68	[0.61-4.63]
	Residential density		1.00	[0.98-1.02]
	Hilliness		**0.97***	**[0.94-0.99]**
	Length bike lanes		1.00	[1.00-1.00]
	Increased financial difficulty (ref: no)	Yes	**0.72***	**[0.57-0.93]**
Increase in time spent cycling	Proximity to bicycle station		1.09	[0.85-1.40]
	Gender (ref: male)	Female	**0.56*** **	**[0.43-0.73]**
	Age		**0.96*** **	**[0.94-0.97]**
	Employment status (ref: full-time working)	Part-time working	0.86	[0.61-1.21]
		Non-working	1.07	[0.77-1.49]
	Being in poor health (ref: no)	Yes	1.07	[0.48-2.40]
	Education (ref: up to year 12)	Diploma/certificate	0.93	[0.68-1.27]
		Graduate or higher	1.06	[0.79-1.43]
	Country of birth (ref: Australia)	Other	**1.34***	**[1.02-1.76]**
	Vehicle possession (ref: yes, always)	Yes, sometimes	**1.86****	**[1.23-2.83]**
		No/do not drive	0.82	[0.43-1.56]
	Connectivity		1.00	[1.00-1.00]
	Land use diversity		1.37	[0.48-3.90]
	Residential density		1.00	[0.96-1.01]
	Hilliness		1.99	[0.98-1.02]
	Length bike lanes		1.00	[1.00-1.00]
	Increased financial difficulty (ref: no)	Yes	**0.75***	**[0.58-0.97]**
	N		3513	

Reference=no change in time spent cycling
***=p<0.001; **=p<0.01; *=p<0.05
RRR=Relative Risk Ratio; 95% CI=95% Confidence Interval

5. Discussion

Residential proximity to a bicycle-sharing station was not found to be associated with the use of CityCycle in Brisbane amongst a baby boomer cohort. Although individuals on higher stages of change based on the Prochaska and DiClemente model were on average living closer to bicycle stations, the association between proximity and the stages of change became non-significant after adjustment for socioeconomic and built environmental characteristics. Although non-significant, proximity had a stronger association with the Action & Maintenance stage compared to the Pre-Contemplation stage, which is an indication that higher levels of involvement with the activity of using CityCycle may to some extent be related to residential proximity to this scheme. Residential proximity to a CityCycle station was also not significantly associated with changes in total time spent cycling. The link between proximity to a bicycle-sharing station and its use has been made in several studies (e.g. Fishman et al., 2015; Bernatchez et al., 2015; Fuller et al., 2011). Our study did not corroborate these findings amongst residents in the wider Brisbane area aged between 40 and 70 years. Several reasons may explain these findings. First, existing studies did not control for built environment characteristics. Some of our associations became insignificant only after controlling for these characteristics. This could imply that the relationship between proximity and stages of change was explained by the control variables. Second, the focus on older adults may have reduced the number of individuals in our sample that used CityCycle and consequently changed their travel behaviour. Both existing studies and our own analyses showed that with an increase in age, individuals are less likely to cycle. However, it is important to note, that this does not automatically mean that interventions such as these will not have an effect. Third, residential proximity may not be the key determinant for this population to use the bicycle scheme, and the proximity of workplace for example (as suggested by Fishman et al., 2015) may be equally important. However, several studies have shown that residential proximity to other interventions such as new infrastructure may increase cycling (e.g. Heinen et al., 2015; Panter et al., 2016; Goodman et al., 2014a&b), whereas other studies found no evidence of a significant relationship between proximity to the installation of bicycle boulevards and an increase in physical activity or active transportation amongst adults with children (Dill et al., 2014). Fourth, Australian BSS, including CityCycle, have not been as successful as their American and European counterparts (Fishman et al., 2013). Over time, a few of their deterrents have been reduced, including widening the operational time to 24 hours, and the provision of some bicycle helmets at the bicycle station locations (wearing a helmet is compulsory in Australia). However, the slow uptake may have resulted in few users in general and in our sample. Fifth, the BSS in Brisbane required registration and membership for a certain period (e.g. for a day). Some studies have argued that memberships may reduce ridership, and using a smart card for public transport has been recommended for Brisbane (Fishman et al., 2012). Nevertheless, most if not all BSS require some sort of registration or direct payment, and research is inconclusive which payment system will result in the highest level of ridership.

Socio-economic characteristics were found to be associated with stages of change. Younger respondents and respondents with a higher education level were more likely to consider using CityCycle and the latter group was also more likely to have used CityCycle. Both age and education level have previously been acknowledged as an important predictor of using a BSS (e.g. Fuller, 2011; Fishman et al., 2013; Campbell et al., 2016). However, several other predictors that have been found to be important in previous studies, such as gender (Ogilvie & Goodman, 2012; Ji et al., 2017) did not have a significant relationship with the use of BSS. Many of the significant socio-economic characteristics that predicted changes in travel behaviour, including gender, age, and country of birth, predicted both an increase as well as a decrease in time spent cycling. An explanation for this finding is that these characteristics are often associated with the likelihood of cycling, and individuals who cycle in the first wave of data collection have more opportunity to change their time spent cycling. For example, individuals who did not cycle in 2009 need to alter their mode choice in order to change their minutes spent cycling. Individuals who cycled in 2009 ‘only’ needed to change their frequency or duration in order to change their time spent cycling. As a result, the lower likelihood of women and older adults changing their time spent cycling (either increasing or decreasing) may be due to the fact that these groups are less likely to cycle in the first wave of data collection.

The key strengths of this study included the use of panel data, which allowed us to calculate changes in travel behaviour in contrast to self-reported changes and allowed the intervention to precede the measured change. Another strength was that data were collected on inhabitants as opposed to only users, which therefore allowed for an exploration of the correlates of use and predictors of change in the general population. A limitation was that the use of the scheme as well as individual cycling behaviour was self-reported, which may threaten the validity of the outcome measures by intentional or unintentional misreporting. However, the question on cycling time has been validated in previous studies (Brown et al, 2008). A second limitation is that we did not control for all potential covariates due to data limitations. For example, we did not have information about (changes in) bicycle ownership. A third limitation is that our analyses are based on a specific age group (40-65 at baseline). Although it is important to understand the determinants of use and predictors of change in the active travel behaviour of this population, given the lower likelihood of cycling in this age group and the larger benefits compared to younger individuals, the conclusions of this study are only based on this age group. A final limitation is that our analyses focussed on the use of the BSS and changes in time spent cycling, independent of whether this use or this change was due to cycling the entire distance or using the bicycle in combination with other modes. Some studies have shown that BSS stations close to rail stations have higher levels of usage (Ricci, 2015). This may indicate that BSS are often used in combination with public transport, although other studies suggest that BSS mostly substitute public transport use (Fishman 2015). Our study did not separate these two kinds of usage.

It is important to emphasise that our study was focussed on only one scheme and analysed only one cohort. There are large differences between schemes, including the differences in registration method, price, size of the fleet and the geographical coverage, and our findings can consequently not be generalised to all schemes or cities. Our findings may be best transferable to schemes that operate in countries that also have a mandatory helmet law, to schemes that are similar in size, and to cities with a similar urban layout and transport network.

This study has clear relevance to policymakers and practitioners. The introduction of BSS may offer many benefits to cities and wider society. However, this study revealed that residential proximity does not necessary predict the likelihood of using a BSS or changes in time spent cycling. This might suggest that the placement of BSS docking stations may not result in inequalities in health benefits due to changes in time spent cycling as a result of residential proximity to these stations. We discussed possible explanations of these findings, but these may imply that the location of BSS relative to individuals' residential locations is not the most dominant factor of using bicycle-sharing schemes and individual changes in time spent cycling. It may also mean that other conditions are currently not being satisfied for individuals to use the BSS.

This paper examined population level impacts of the bicycle-sharing scheme in Brisbane in terms of whether the introduction of the scheme resulted in an increase in cycling behaviour. Additional research is necessary to further differentiate the changes in cycling between new and matured cyclists in order to inform group specific policy effectiveness.

6. Conclusion

This study aimed to investigate the correlates of the use of a public bicycle scheme and to investigate the extent to which exposure to the introduced bicycle scheme has influenced individual travel behaviour, in particular whether it has increased the time spent cycling. For this, we analysed a large panel of residents in Brisbane, Australia between 2009 and 2013, Australia, followed before and after the introduction of a large-scale bicycle-sharing scheme in 2010. Our results indicate that residential proximity to a bicycle-sharing station was not significantly associated with a higher level of (intention to) use nor with a larger propensity to have increased the total time spent cycling—perhaps due to our sample's older age cohort. Studies have indicated that older people are less susceptible to adjust travel behaviour compared to younger aged cohort. As a result, this study leaves room for further investigation using a younger cohort to more widely validate the models presented in this research. However, several socio-economic covariates were significant. Younger respondents and respondents with a higher education level were more likely to consider using the bicycle-sharing scheme and the latter group was also more likely to have used the bicycle scheme. We did not find evidence that the introduction of bicycle schemes by themselves may improve the health of an aging population by increasing their physical activity levels as a result of spending more time cycling.

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808 Appendix A: Correlates of stages of change of using the Brisbane bicycle-sharing scheme

	Variable	**Category**	**Maximally adjusted**		**Unadjusted**		**Sensitivity 1: including movers**		**Sensitivity 2: within 5 km**		**Sensitivity 3: with income included**		**Sensitivity 4: with vehicle possession included^**	
			RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI
Contemplation & Preparation	Proximity to bicycle station		1.221	[0.948-1.572]	**1.177***	**[1.036-1.338]**	1.081	[0.896-1.306]	0.996	[0.606-1.637]	1.238	[0.955-1.604]	1.236	[0.954-1.600]
	Gender (ref: male)	Female	1.139	[0.884-1.468]	0.981	[0.779-1.235]	1.195	[0.941-1.519]	1.405	[0.763-2.589]	1.14	[0.881-1.476]	1.151	[0.889-1.491]
	Age		**0.967*** **	[0.948-0.985]	**0.956*** **	**[0.940-0.972]**	0.970***	[0.952-0.987]	0.992	[0.947-1.039]	**0.970****	**[0.951-0.989]**	**0.967*** **	**[0.948-0.986]**
	Employment status (ref: full-time working)	Part-time working	0.825	[0.602-1.130]	0.859	[0.646-1.141]	0.795	[0.587-1.076]	0.943	[0.467-1.905]	0.894	[0.647-1.235]	0.845	[0.614-1.163]
		Non-working	0.828	[0.593-1.157]	**0.562*** **	**[0.422-0.749]**	0.88	[0.645-1.203]	0.467	[0.189-1.153]	0.838	[0.583-1.206]	0.843	[0.598-1.188]
	Education (ref: up to year 12)	Diploma/certificate	**1.635****	[1.164-2.296]	**1.734****	**[1.242-2.420]**	1.720**	[1.243-2.379]	1.209	[0.478-3.056]	**1.606****	**[1.139-2.265]**	**1.617****	**[1.141-2.291]**
		Graduate or higher	**2.391*** **	[1.747-3.274]	**2.867*** **	**[2.126-3.868]**	2.584***	[1.916-3.485]	1.966	[0.895-4.319]	**2.206*** **	**[1.591-3.058]**	**2.417*** **	**[1.755-3.329]**
	Residential density		0.995	[0.972-1.018]	1.002	[0.990-1.014]	1.007	[0.993-1.022]	0.994	[0.958-1.030]	0.994	[0.971-1.018]	0.995	[0.972-1.019]
	Land use diversity		0.552	[0.218-1.394]	**0.415***	**[0.181-0.952]**	0.607	[0.256-1.437]	1.415	[0.163-12.29]	0.671	[0.261-1.724]	0.582	[0.226-1.495]
	Hilliness		1.015	[0.995-1.034]	**1.022****	**[1.006-1.038]**	1.018*	[1.001-1.035]	1.008	[0.940-1.080]	1.014	[0.994-1.033]	1.013	[0.993-1.033]
	Being in poor health (ref: no)	Yes			0.968	[0.487-1.922]								
	Vehicle possession (ref: yes, always)	Yes, sometimes			1.141	[0.694-1.875]							1.227	[0.741-2.033]
		No/do not drive			**0.488***	**[0.239-0.999]**							0.654	[0.315-1.359]
	Income	2nd Quintile			**1.768****	**[1.165-2.682}]**					1.49	[0.960-2.313]		
	(ref: 1st Quintile)	3rd Quintile			**1.796****	**[1.205-2.678]**					1.103	[0.704-1.729]		
		4th Quintile			**2.705*** **	**[1.835-3.988]**					1.466	[0.932-2.306]		
		Don't know/Don't want to answer			1.192	[0.717-1.980]					0.945	[0.556-1.607]		
Action & Maintenance	Proximity to bicycle station		1.425	[0.810-2.508]	**1.545****	**[1.191-2.003]**	1.525	[0.995-2.339]	1.344	[0.520-3.474]	1.4	[0.779-2.514]	1.56	[0.875-2.783]
	Gender (ref: male)	Female	0.985	[0.487-1.994]	0.896	[0.479-1.675]	0.823	[0.424-1.597]	1.487	[0.376-5.875]	1.073	[0.524-2.198]	1.003	[0.487-2.066]
	Age		0.983	[0.933-1.036]	0.973	[0.931-1.017]	0.975	[0.928-1.024]	0.966	[0.865-1.078]	0.992	[0.939-1.048]	0.992	[0.939-1.047]
	Employment status (ref: full-time working)	Part-time working	1.415	[0.644-3.112]	1.293	[0.625-2.674]	1.614	[0.772-3.376]	0.886	[0.195-4.032]	1.667	[0.741-3.750]	1.394	[0.617-3.150]
		Non-working	0.648	[0.232-1.813]	0.448	[0.178-1.124]	0.662	[0.243-1.800]	0.37	[0.036-3.820]	0.803	[0.271-2.376]	0.609	[0.213-1.740]
	Education (ref: up to year 12)	Diploma/certificate	1.809	[0.635-5.157]	2.202	[0.798-6.074]	2.306	[0.855-6.220]	0.763	[0.046-12.78]	1.641	[0.572-4.708]	1.416	[0.466-4.304]
		Graduate or higher	**3.340***	[1.309-8.520]	**4.646*** **	**[1.894-11.40]**	**3.462****	**[1.376-8.709]**	3.512	[0.413-29.88]	**2.615***	**[1.003-6.823]**	**3.324***	**[1.292-8.551]**
	Residential density		1	[0.952-1.050]	**1.031*** **	**[1.013-1.049]**	0.989	[0.950-1.030]	0.967	[0.884-1.057]	1.001	[0.952-1.051]	0.995	[0.945-1.046]
	Land use diversity		2.785	[0.230-33.70]	3.567	[0.383-33.22]	2.4	[0.232-24.88]	9.309	[0.051-1705.6]	3.096	[0.248-38.71]	2.352	[0.171-32.27]
	Hilliness		1.041	[0.998-1.087]	1.031	[0.991-1.072]	1.026	[0.984-1.070]	0.839	[0.679-1.036]	1.039	[0.996-1.085]	**1.047***	**[1.004-1.092]**

Being in poor health (ref: no)	Yes			<0.001	[0-.]								
Vehicle possession (ref: yes, always)	Yes, sometimes			**3.711****	**[1.524-9.038]**							**4.137****	**[1.666-10.270]**
	No/do not drive			1.786	[0.540-5.910]							1.741	[0.392-7.724]
Income (ref: 1st Quintile)	2nd Quintile			1.557	[0.438-5.538]					1.415	[0.386-5.187]		
	3rd Quintile			2.257	[0.716-7.112]					1.653	[0.475-5.749]		
	4th Quintile			**4.211****	**[1.411-12.570]**					2.236	[0.640-7.809]		
	Don't know/Don't want to answer			0.817	[0.149-4.474]					0.356	[0.039-3.265]		

Reference=Pre-Contemplation

***=p<0.001; **=p<0.01; * p<0.05

RRR=Relative Risk Ratio; 95% CI=95% Confidence Interval

^Vehicle possession was left out of the maximally adjusted model. If included the model yielded counterintuitive results for hilliness.

Appendix B: Predictors and correlates of changes in time spent cycling

		Maximally Adjusted		**Unadjusted**		**Sensitivity 1: including movers**		**Sensitivity 2: within 5 km**		**Sensitivity 3: with income included**		**Sensitivity 4: considering spatial clustering**		**Sensitivity 5: threshold for change is 1 minute**		**Cycling for transport**		**Cycling for recreation**	
Decrease in time spent cycling		RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI	RRR	95%CI
Proximity to bicycle station		1.064	[0.846-1.338]	**1.161****	**[1.041-1.296]**	1.045	[0.876-1.247]	1.009	[0.623-1.633]	1.021	[0.809-1.290]	1.040	[0.815-1.327]	1.051	[0.852-1.296]	1.560	[0.921-2.642]	0.982	[0.762-1.267]
Gender (ref: male)	Female	**0.497*****	**[0.386-0.640]**	**0.522*****	**[0.424-0.644]**	**0.481*****	**[0.381-0.607]**	**0.471****	**[0.290-0.765]**	**0.486*****	**[0.376-0.628]**	**0.496*****	**[0.390-0.630]**	**0.564*****	**[0.449-0.708]**	**0.224*****	**[0.123-0.411]**	**0.557*****	**[0.422-0.737]**
Age		**0.962*****	**[0.945-0.980]**	**0.961*****	**[0.947-0.976]**	**0.957*****	**[0.942-0.973]**	**0.949****	**[0.916-0.983]**	**0.967*****	**[0.949-0.985]**	**0.961*****	**[0.945-0.978]**	**0.959*****	**[0.944-0.975]**	**0.960***	**[0.924-0.998]**	**0.963*****	**[0.944-0.982]**
Employment status (ref: full-time working)	Part-time working	1.193	[0.879-1.620]	0.839	[0.644-1.092]	1.220	[0.919-1.618]	0.978	[0.542-1.764]	1.275	[0.930-1.748]	1.184	[0.864-1.623]	1.118	[0.845-1.478]	1.266	[0.636-2.517]	1.045	[0.735-1.484]
	Non-working	0.891	[0.636-1.248]	**0.542*****	**[0.408-0.720]**	0.933	[0.683-1.275]	1.064	[0.553-2.046]	0.895	[0.626-1.280]	0.908	[0.648-1.274]	0.963	[0.715-1.298]	0.856	[0.406-1.805]	1.063	[0.741-1.525]
Being in poor health (ref: no)	Yes	0.292	[0.0703-1.209]	**0.297***	**[0.094-0.945]**	0.381	[0.118-1.234]	<0.001	[0-.]	0.294	[0.071-1.223]	0.292	[0.071-1.207]	0.866	[0.387-1.939]	<0.001	[0-.]	0.556	[0.171-1.805]
Education (ref: up to year 12)	Diploma/certificate	**1.354***	**[1.001-1.832]**	**1.414***	**[1.078-1.856]**	**1.336***	**[1.010-1.767]**	1.584	[0.801-3.134]	1.327	[0.979-1.799]	**1.372***	**[1.028-1.830]**	**1.371***	**[1.044-1.798]**	1.206	[0.624-2.333]	**1.468***	**[1.048-2.057]**
	Graduate or higher	**1.473***	**[1.093-1.984]**	**1.603*****	**[1.242-2.068]**	**1.510****	**[1.148-1.988]**	**1.874***	**[1.018-3.451]**	1.332	[0.979-1.813]	**1.466***	**[1.085-1.980]**	**1.439****	**[1.099-1.883]**	1.490	[0.783-2.836]	**1.485***	**[1.063-2.075]**
Country of birth (ref: Australia)	Other	**1.360***	**[1.048-1.765]**	**1.349***	**[1.065-1.709]**	**1.325***	**[1.042-1.685]**	0.929	[0.521-1.654]	**1.386***	**[1.067-1.802]**	**1.380***	**[1.037-1.836]**	1.281	[1.009-1.628]	0.910	[0.506-1.639]	**1.613*****	**[1.217-2.136]**
Vehicle possession (ref: yes, always)	Yes, sometime	**1.661***	**[1.093-2.525]**	**1.679****	**[1.150-2.452]**	**1.659***	**[1.112-2.475]**	1.875	[0.907-3.874]	**1.694***	**[1.112-2.581]**	**1.626***	**[1.069-2.474]**	**1.510***	**[1.020-2.235]**	1.514	[0.635-3.607]	1.484	[0.933-2.361]
	No/do not drive	0.872	[0.467-1.630]	0.803	[0.476-1.357]	0.826	[0.454-1.503]	1.105	[0.429-2.843]	0.904	[0.482-1.696]	0.876	[0.478-1.607]	0.694	[0.382-1.263]	2.564	[0.955-6.880]	0.827	[0.404-1.691]
Connectivity		1.001	[0.998-1.005]	1.003	[1.000-1.005]	1.001	[0.997-1.004]	1.002	[0.995-1.009]	1.001	[0.998-1.005]	1.001	[0.997-1.006]	1.000	[0.997-1.003]	1.000	[0.992-1.009]	1.001	[0.997-1.005]
Land use diversity		1.676	[0.607-4.627]	1.660	[0.759-3.628]	1.429	[0.562-3.632]	1.202	[0.181-7.977]	1.915	[0.684-5.360]	1.724	[0.602-4.937]	1.776	[0.712-4.430]	2.576	[0.291-22.84]	1.584	[0.517-4.856]

Residential density		0.996	[0.975-1.018]	**1.013****	**[1.004-1.023]**	0.998	[0.980-1.016]	0.999	[0.971-1.028]	0.998	[0.977-1.020]	0.999	[0.977-1.021]	1.000	[0.981-1.020]	0.955	[0.893-1.021]	1.006	[0.984-1.029]
Hilliness		**0.968***	**[0.944-0.993]**	**0.976***	**[0.956-0.995]**	**0.975***	**[0.954-0.997]**	0.983	[0.934-1.036]	**0.966****	**[0.942-0.991]**	**0.969***	**[0.944-0.994]**	**0.973***	**[0.952-0.995]**	0.954	[0.904-1.006]	0.995	[0.970-1.020]
Length bike lanes		1.000	[1.000-1.000]	**1.000***	**[1.000-1.000]**	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]
Increased financial difficulty (ref: yes)	No	**0.724***	**[0.566-0.927]**	**0.770***	**[0.617-0.960]**	**0.694****	**[0.554-0.870]**	0.723	[0.448-1.168]	**0.760***	**[0.592-0.977]**	**0.724****	**[0.574-0.912]**	**0.777***	**[0.662-0.969]**	0.692	[0.404-1.185]	**0.721***	**[0.547-0.951]**
Income	2nd Quintile			1.104	[0.776-1.571]					0.932	[0.617-1.407]								
(ref: 1st Quintile)	3rd Quintile			1.374	[0.993-1.899]					1.061	[0.712-1.581]								
	4th Quintile			**2.074*****	**[1.497-2.872]**					**1.523***	**[1.000-2.318]**								
	Don't know/Don't want to answer			1.362	[0.915-2.026]					1.356	[0.860-2.138]								
Increase in time spent cycling																			
Proximity to bicycle station		1.094	[0.853-1.403]	1.066	[0.943-1.206]	1.114	[0.925-1.343]	1.291	[0.736-2.264]	1.063	[0.826-1.368]	1.054	[0.803-1.382]	1.063	[0.846-1.337]	1.352	[0.837-2.184]	1.198	[0.923-1.554]
Gender (ref: male)	Female	**0.562*****	**[0.433-0.730]**	**0.583*****	**[0.469-0.725]**	**0.526*****	**[0.413-0.671]**	**0.403****	**[0.232-0.702]**	**0.566*****	**[0.435-0.737]**	**0.562*****	**[0.437-0.723]**	**0.606*****	**[0.477-0.769]**	**0.212*****	**[0.111-0.406]**	**0.641****	**[0.490-0.838]**
Age		**0.955*****	**[0.937-0.973]**	**0.962*****	**[0.947-0.977]**	**0.955*****	**[0.939-0.972]**	**0.932*****	**[0.896-0.971]**	**0.960*****	**[0.941-0.978]**	**0.955*****	**[0.936-0.973]**	**0.962*****	**[0.946-0.979]**	**0.927*****	**[0.888-0.967]**	0.983	[0.964-1.002]
Employment status (ref: full-time working)	Part-time working	0.860	[0.611-1.211]	**0.663****	**[0.491-0.894]**	0.871	[0.633-1.200]	0.863	[0.430-1.734]	0.897	[0.631-1.276]	0.819	[0.574-1.169]	0.925	[0.683-1.254]	1.160	[0.539-2.496]	0.895	[0.636-1.260]
	Non-working	1.070	[0.770-1.487]	**0.706***	**[0.537-0.927]**	1.084	[0.797-1.475]	1.083	[0.519-2.261]	1.128	[0.797-1.597]	1.078	[0.810-1.435]	0.975	[0.720-1.322]	1.231	[0.565-2.685]	0.850	[0.600-1.205]
Being in poor health (ref: no)	Yes	1.073	[0.479-2.404]	0.889	[0.427-1.852]	1.064	[0.498-2.270]	0.827	[0.096-7.134]	0.924	[0.389-2.192]	0.918	[0.370-2.278]	1.084	[0.506-2.323]	<0.001	[0-.]	0.657	[0.235-1.840]
Education (ref: up to year 12)	Diploma/certificate	0.933	[0.684-1.272]	1.085	[0.818-1.438]	0.926	[0.692-1.239]	1.693	[0.806-3.557]	0.917	[0.671-1.254]	0.936	[0.694-1.262]	0.927	[0.697-1.233]	1.233	[0.572-2.658]	1.076	[0.775-1.493]
	Graduate or higher	1.059	[0.786-1.428]	1.294	[0.998-1.678]	1.136	[0.860-1.500]	1.344	[0.673-2.685]	0.989	[0.727-1.347]	1.065	[0.786-1.444]	1.093	[0.832-1.436]	**2.050***	**[1.014-4.146]**	1.333	[0.976-1.821]
Country of birth (ref: Australia)	Other	**1.338***	**[1.018-1.757]**	1.270	[0.988-1.632]	1.230	[0.951-1.590]	1.486	[0.827-2.673]	**1.327***	**[1.007-1.749]**	**1.316***	**[1.018-1.702]**	1.212	[0.940-1.562]	0.656	[0.328-1.314]	**1.532****	**[1.164-2.016]**
Vehicle possession (ref: yes, always)	Yes, sometime	**1.862****	**[1.227-2.828]**	**1.723****	**[1.162-2.554]**	**1.721***	**[1.138-2.603]**	**2.964****	**[1.432-6.135]**	**1.879****	**[1.236-2.857]**	**1.895****	**[1.248-2.879]**	**1.581***	**[1.055-2.371]**	**2.797****	**[1.365-5.731]**	1.223	[0.751-1.991]
	No/do not drive	0.819	[0.429-1.564]	0.902	[0.533-1.525]	0.922	[0.517-1.644]	0.767	[0.220-2.676]	0.875	[0.457-1.676]	0.761	[0.376-1.540]	0.857	[0.480-1.531]	0.985	[0.222-4.364]	1.296	[0.720-2.333]
Connectivity		1.001	[0.997-1.004]	1.000	[0.997-1.003]	1.001	[0.997-1.005]	**0.991***	**[0.983-0.999]**	1.001	[0.997-1.005]	1.000	[0.996-1.004]	0.999	[0.996-1.003]	0.996	[0.989-1.004]	1.002	[0.998-1.007]
Land use diversity		1.365	[0.478-3.899]	1.200	[0.530-2.717]	1.135	[0.427-3.020]	0.504	[0.055-4.656]	1.431	[0.494-4.149]	1.279	[0.430-3.804]	1.018	[0.393-2.638]	2.274	[0.264-19.59]	2.462	[0.817-7.421]
Residential density		0.988	[0.963-1.014]	1.002	[0.991-1.014]	0.990	[0.969-1.011]	1.003	[0.970-1.037]	0.990	[0.965-1.015]	0.991	[0.965-1.018]	0.990	[0.967-1.014]	0.997	[0.960-1.035]	0.975	[0.947-1.004]
Hilliness		0.999	[0.977-1.021]	0.998	[0.980-1.016]	1.000	[0.981-1.021]	0.993	[0.951-1.037]	1.000	[0.978-1.022]	1.001	[0.977-1.025]	1.006	[0.987-1.026]	0.993	[0.950-1.038]	1.006	[0.984-1.029]
Length bike lanes		1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]	1.000	[1.000-1.000]

Increased financial difficulty (ref: yes)	No	**0.748***	**[0.578-0.966]**	0.844	[0.672-1.059]	0.836	[0.661-1.056]	**0.492***	**[0.279-0.866]**	0.772	[0.595-1.002]	**0.770***	**[0.597-0.994]**	**0.770***	**[0.609-0.973]**	0.788	[0.450-1.378]	0.871	[0.669-1.133]
Income	2nd Quintile			1.196	[0.834-1.714]					1.061	[0.700-1.608]								
(ref: 1st Quintile)	3rd Quintile			**1.446***	**[1.036-2.017]**					1.122	[0.746-1.687]								
	4th Quintile			**1.793*****	**[1.268-2.535]**					1.360	[0.876-2.112]								
	Don't know/Don't want to answer			1.219	[0.797-1.864]					0.933	[0.562-1.551]								

Reference=no change in time spent cycling
***=p<0.001; **=p<0.01; *=p<0.05
RRR=Relative Risk Ratio; 95% CI=95% Confidence Interval