BIKE SHARE'S IMPACT ON CAR USE: EVIDENCE FROM THE UNITED STATES, GREAT BRITAIN, AND AUSTRALIA

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ABSTRACT

There are currently more than 400 cities operating bike share programs. Purported benefits of bike share programs include flexible mobility, physical activity, reduced congestion, emissions and fuel use. Implicit or explicit in the calculation of program benefits are assumptions regarding the modes of travel replaced by bike share journeys. This paper examines the degree to which car trips are replaced by bike share, through an examination of survey and trip data from bike share programs in Melbourne, Brisbane, Washington, D.C., London, and Minneapolis/St. Paul.

A secondary and unique component of this analysis examines motor vehicle support services required for bike share fleet rebalancing and maintenance. These two components are then combined to estimate bike share's overall contribution to changes in vehicle kilometers traveled.

The results indicate that the estimated mean reduction in car use due to bike share is at least twice the distance covered by operator support vehicles, with the exception of London, in which the relationship is reversed, largely due to a low car mode substitution rate. As bike share programs mature, evaluation of their effectiveness in reducing car use may become increasingly important. This paper reveals that by increasing the convenience of bike share relative to car use and by improving perceptions of safety, the capacity of bike share programs to reduce vehicle trips and yield overall net benefits will be enhanced. Researchers can adapt the analytical approach proposed in this paper to assist in the evaluation of current and future bike share programs.

INTRODUCTION

As cities seek to improve sustainable transport options, bike share programs have emerged as an innovative approach in a growing number of cities in Europe, China and North America. These programs also serve to showcase and market eco-friendly mobility aspects of these cities, and may serve the stated mobility targets concerning health and fossil fuel dependence *[1]*. Although bike share programs have existed for almost half a century, the most recent decade has seen a sharp increase in both their prevalence and popularity worldwide *[2]*, with over 400 cities currently operating bike share programs *[3]*.

In 2007, Paris launched Europe's largest scheme, with over 20,000 bicycles. Wuhan and Hangzhou in China currently have the world's largest bike share programs, with 90,000 and 70,000 bikes respectively *[4]*. New York City launched North America's largest bike share program, with 6,000 bikes in May, 2013, and is set to grow to 10,000 bikes in the near future. Figure 1 provides a snapshot of the globe's largest bike share programs. China is clearly the dominant country, holding the majority of the world's largest bike share programs (eight of the top ten). The Chinese cities are shown in blue diagonal columns.

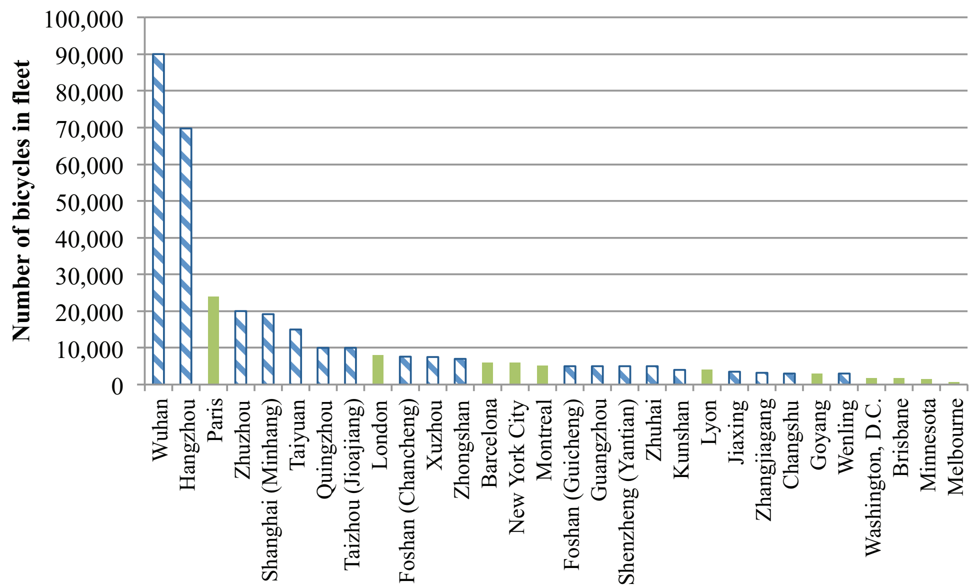

FIGURE 1 Largest bike share systems.
Source: Earth Policy Institute *[4],* using information supplied by Russell Meddin and Paul DeMaio of *The Bike-sharing Blog*, as well as Tang, Pan, & Lu *[5]*. Green bars indicate non-Chinese cities. Brisbane and Melbourne figures supplied by Fishman *[6]*.
NB: The number of bikes can change rapidly and many of these figures are likely to be outdated within months. There is some uncertainty regarding the precise figures for each city, as there are often bikes in the fleet that are not in operation.

Several researchers have examined the motivating factors associated with bike share use. Bachand-Marleau et al. *[1]* found convenience and the avoidance of private bike theft and maintenance to be key facilitators to the use of the *BIXI* program in Montreal. These findings are generally supportive of an earlier study by Fuller et al. *[7]* of the same program. Convenience consistently emerges as the main motivating factor for bike share use, and this has been found in various programs in North America *[8-10]*, China *[11]*, London *[12]* and Australia *[*3, *13-15]*. The distance between home and closest docking station is a factor directly associated with convenience and this has been found to be a reliable predictor of bike share usage. Bachand-Marleau et al. *[1]* found that living within 500m of a docking station resulted in a three-fold increase in the odds of *BIXI* use.

In 2010, Brisbane and Melbourne introduced bike share programs in their city centers and some of the local surrounding inner suburbs, known as *CityCycle* and *Melbourne Bike Share* (*MBS*) respectively. These Australian schemes have been included in Figure 1, although they are considerably smaller than many of the other cities, at 1,800 and 600 bikes respectively. Bike share usage in Australia is considerably lower than other countries *[3, 6, 14]* and there are currently no commitments from other Australian cities to introduce bike share programs.

Shaheen et al. *[2]* summarize the benefits of bike share as flexible mobility, emission reductions, physical activity benefits, reduced congestion and fuel use, individual financial savings and support for multimodal transport connections. Underlying many of the benefits attributed to bike share is an assumption that a significant proportion of bike share journeys are replacing trips previously made by car. International evidence suggests this is seldom the case *[3, 6, 16]*. This paper seeks to examine net changes to car use as a consequence of bike share. It does this by examining estimated distance traveled and the degree to which bike share programs substitute for car use. A secondary component of this analysis examines motor vehicle support services used for fleet rebalancing and maintenance. Rebalancing refers to the manual transfer of bikes by the operator to reduce the likelihood of docking stations being completely full or empty. Rebalancing requires fuel use and is not insignificant, and therefore this aspect of the ongoing operation of bike share programs must be considered. Rebalancing is not unique to bike share. Public transit vehicles run relatively empty/out of service, in order to meet imbalances in demand across the network.

These two components are then combined to provide a picture of bike share's overall contribution to changes in vehicle kilometers traveled (VKT). Whilst bike share's impact on car use is the focus of this paper, the authors do not wish to imply this is the only benefit of bike share. It is proposed that the analytical approach of this paper may be able to be adapted for future research evaluating bike share impacts. The cities included in this analysis are Melbourne, Brisbane, Washington, D.C., London, and Minneapolis/St. Paul (referred to in this paper as Minnesota, as the program is called *Nice Ride Minnesota*). With many programs operating in the United States, the Washington, D.C. and Minnesota programs may not be representative of United States based bike share programs in general. The bike share programs included in this analysis have all been established in the past five years and are considered I.T based systems, relying on electronic payment and tracking technology, enabling automated rental and returns. The user can return the bike to any docking station within the system and it is this feature that creates the rebalancing responsibility for program operators.

METHODOLOGY

The authors have obtained the data log for each of the bike share programs included in this analysis. This log contains information on each trip taken throughout 2012. Each system runs 365 days per year, with the exception of Minnesota, which was open from April 8th to November 7th, 2012. Each trip has a start and end date and time, as well as the origin and destination docking station. Trips of less than two minutes or greater than three hours have been omitted from our analysis. This decision was made on an assumption that such trips are unlikely to represent genuine bicycle riding time but rather a result of operator or technical error (e.g. a bicycle not removed or docked correctly).

Trip duration was determined by subtracting trip end time from trip start time. Distance traveled was estimated by combining trip duration with a travel speed estimate of

12km/h, which is broadly consistent with a study on bike share travel velocity *[17]*. Only the proportion of trips substituting for car use has been included in the final analysis.

Motor vehicle fleet characteristics and usage for 2012 were obtained directly from bike share operators in Melbourne, Washington, D.C., London, and Minnesota. Brisbane bike share operator *JCDecaux* declined to provide data on this component of the analysis. Fuel consumed, type of fuel and fuel efficiency of vehicles allowed for the total distance traveled to be calculated for each system.

RESULTS AND DISCUSSION

Mode substitution

The members of the bike share programs included in this study were asked to participate in separate online surveys. These surveys were wide-ranging but contained a common question - "*Thinking about your last journey on bike share, which mode of transport would you have taken had it not existed?"*[1] These surveys were conducted as independent activities and carried out or commissioned by the operators of each program. *Nice Ride Minnesota* conducted a survey sent out to subscribers in 2010 *[10]*. *Capital Bikeshare* in Washington, D.C. commissioned a study of members in 2012 carried out by LDA Consulting *[9]*. In 2011 Transport for London ran a survey for members of *Barclays Cycle Hire [12]*. The authors of the current study included a mode substitution question in an online survey sent to *MBS* and *CityCycle* members. Figure 2 documents the results to this question, across the aforementioned bike share programs.

A substantial proportion of trips currently taken on bike share in the cities included in this study are substituting for public transit and walking. London has the lowest level of car substitution, which is broadly in line with the lower proportion of trips undertaken by car, relative to the other cities included in this analysis. The substantial share of bike share trips substituting for public transit, particularly in London, may be helping to relieve public transit overcrowding.

[1] The wording of this question varied slightly; In Melbourne (n = 372) and Brisbane (n = 443) it was presented as shown. In Washington, D.C: *"If Capital Bikeshare had not been available, how would you have made your most recent trip"* (n = 5,287). In Minnesota: *"Please recall the most recent trip you took using a Nice Ride bicycle"* (n = 685). In London: *"Before the Barclays Cycle Hire Scheme was introduced last July, how would you have typically made this trip?"* (n = 2,177).

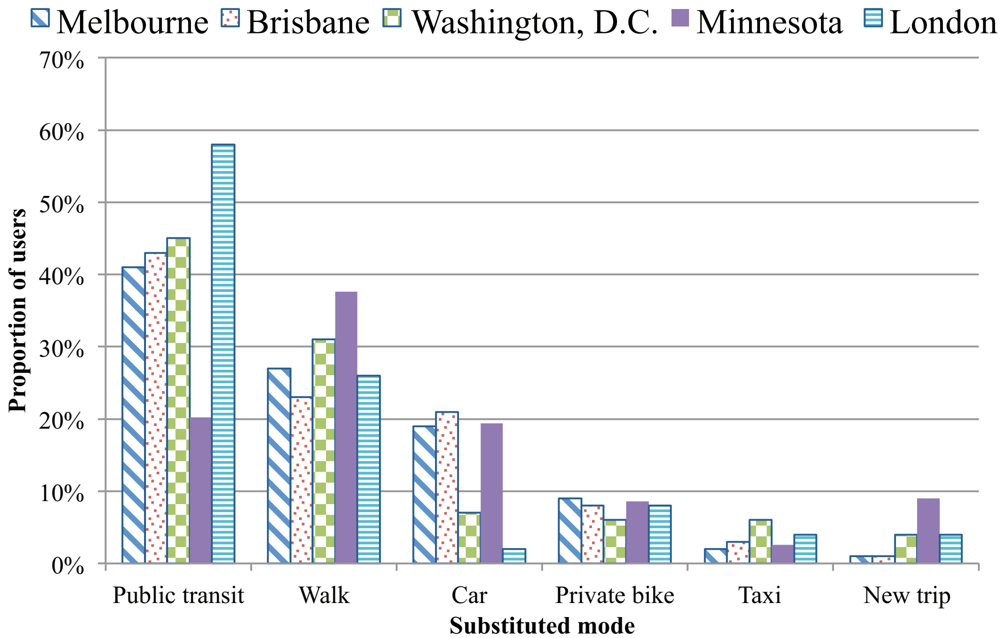

FIGURE 2 Mode substitution in selected cities.
Source: Melbourne and Brisbane *[18]*, Washington, D.C. *[9]* Minnesota *[10]* London *[12]*

Bike share fleet size, usage and car travel reduction

Table 1 presents the key metrics used to estimate the reduction in car travel as a consequence of the bike share programs. The number of trips per day per bike provides an opportunity to compare different systems usage levels, controlling for fleet size. This metric does however mask seasonal differences in usage, which can often be considerable *[3]*, although these differences do not impact on the current analysis. Melbourne was found to have an average trip duration of 22 minutes, considerably longer than other cities. It is not clear why this might be, as the system's catchment is smaller than each of the other cities. One possible explanation may be that visitors are using the *MBS* program for longer, touristic purposes. This is supported by ride data from Minnesota, which showed an average ride time for casual users of 38 minutes, compared to 11 minutes for members.[2] Previous analysis has found some 13% of trips end at the same docking station as they started in Melbourne, rising to 40% in key tourist precincts *[19]*.

[2] The *MBS* data log did not differentiate between casual users and members, which is why Minnesota data was used. These calculations include all rides, regardless of duration, for each day the Minnesota program was operational in 2012.

TABLE 1 Bike share size, usage and car travel reduction

	Melbourne	Brisbane	Washington, D.C.	Minnesota	London*
Bikes^	600	1,800	1,800	1,325	8,000
Trips# (2012)	138,548	209,232	2,008,079	268,151	9,040,580
Trips per day per bike	0.6	0.3	3.0	0.9	3.1
Regional population[3]	3,999,980	2,065,998	5,860,342	3,759,978	7,170,000
Mean trip duration#	22.0	16.2	15.8	17.5	17.5
Est. travel speed (km/h)	12	12	12	12	12
Est. distance traveled per trip (KM)	4.4	3.2	3.1	3.5	3.5
Est. distance traveled per system 2012 (KM)	609,611	677,912	6,345,530	940,152	31,642,029
Car substitution	19%	21%	7%	19%	2%
Est. car travel reduction (KM)	115,826	142,361	444,187	182,390	632,841
Est. car travel reduction per bike (KM)	193	79	247	135	79
Annual members	921	1,926	18,000	3500	76,283

Source: Regional population: Brisbane and Melbourne *[20]*, London *[21],* Minnesota (Minneapolis/St. Paul Combined Statistical Area) *[22]* and Washington,Metropolitan Area.*[23].* Trips and duration: Melbourne (Hoernel, Unpublished data), Brisbane (Lundberg, Unpublished data), Minnesota (Vars, Unpublished data), London (Stanhope, Unpublished data), Washington, D.C. *[24],* Estimated travel speed *[17].* Car substitution *[3]*
^Fleet total, which may not reflect actual number of bicycles in circulation.
#Trips < 2 minutes and > 3 hours excluded from analysis.
*In March 2012, London's bike share fleet rose from approximately 6,000 bikes to 8,000 bikes. Serco (bike share operator) experienced data loss between 1st January – 3rd January and 5th February – 28th February 2012. Estimates used for missing trip data during these dates based on activity either side of data loss period. Trips less than 4 minutes duration removed by Serco between 29th April – 18th August 2012 (unrecoverable).

Table 1 demonstrates the impact *car substitution* has on *estimated car travel reduction*. Car travel reduction has been estimated by multiplying the estimated distance traveled by the car substitution rate. Our analysis shows that for 2012, bike share usage was responsible for 115,826km less car driving in Melbourne, through to 632,841km in London. Washington, D.C. despite having almost ten times greater bike share travel than Brisbane, only has approx. 3.5 times the car use reduction impact. This difference is due to a *car substitution* rate of 21% for Brisbane, compared to only 7% for Washington, D.C.

Bike share operator motor vehicle usage

A challenge for many bike share operators has been the rebalancing of bicycles, to reduce the likelihood of docking stations being either completely empty or full *[16].* Fleet rebalancing is typically achieved through the use of trucks and trailers, and these are associated with many of the very impacts bike share aims to reduce (e.g. congestion, pollution). Table 2 provides an indication of the fuel used and distance traveled for the cities included in this analysis.

[3] Method of demarcating regional boundaries differs and those interested are encouraged to examine cited sources.

TABLE 2 Fuel consumption of bike share operators' vehicles, 2012

City	Annual distance traveled (KM)	Diesel consumed (liters)	Unleaded petrol consumed (liters)	CO_2 emissions (Tons)^
London	1,399,182	116,605	391	316
Minnesota	88,000	-	11436	26
Melbourne	27,851	2,952	-	8
Washington, D.C.	200,896	23,765	-	64

Source: London (Stanhope, Unpublished data), Minnesota (Vars, Unpublished data), Melbourne (Hoernel, Unpublished data), Washington, D.C. (Fisk, Unpublished data).
^2.3kg and 2.7kg of CO_2 for each liter of petrol and diesel consumed respectively *[25]*.
NB: Washington, D.C. fuel use is for the period September 2011 to September 2012. An additional vehicle was added to the fleet in October 2012 and this has been included in the calculations. London data for fourth quarter fuel usage not available. Third quarter data was substituted.

Bike share impacts on vehicle kilometers traveled

By comparing estimates of car travel reduction as a consequence of bike share (Table 1) with motor vehicle use associated with the operation of bike share (Table 2), it is possible to estimate the net effect of bike share on VKT. Figure 3 indicates that for each kilometer traveled by motorized vehicles associated with the operation of bike share programs, there are between two and four kilometers of private car use avoided, with the exception of London, in which the relationship is reversed.

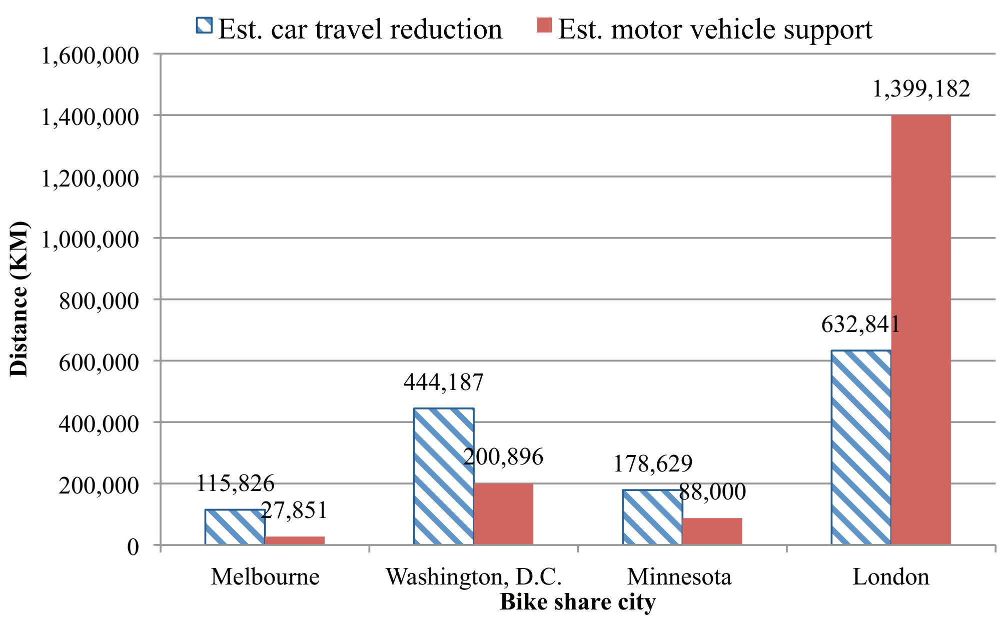

FIGURE 3 Comparing car use reduction to motor vehicle support, selected cities, 2012.

London, owing to its car mode substitution rate of only 2%, coupled with heavy demand for fleet redistribution is estimated to have approximately 2.2 kilometers in motor vehicle support travel for each kilometer of private car use avoided. To illustrate the influence of mode substitution, should the percentage of bike share trips substituting for car increase to 10% in London, estimated car travel reduction would rise to 3.1 million km, approximately 2.2 times greater than the distance travelled by motor vehicle support services.

Optimizing car use reduction

The impact of bike share on car use reduction is determined to a large degree by the rate of car substitution. The greater the proportion of trips substituting for trips previously made by car, the greater the program's impact on reducing car use and all of the associated benefits. Understanding barriers to bike share from those who predominantly drive may assist efforts to increase the rate at which bike share substitutes for car use.

In November 2012 the authors undertook a survey of non-bike share users in Brisbane, Australia to better understand current barriers to bike share. The survey was sent to a research panel managed by the Centre for Accident Research and Road Safety – Queensland. Of the 311 emails received by respondents, 60 fully completed surveys were returned *[19]*. Car use was the predominant mode of transport in this sample, with very little use of walking, cycling or public transport over the previous month.

Respondents were asked if they were to consider joining the bike share program *CityCycle*, to what degree would the reasons shown in Figure 4 act as a barrier. Respondents were provided with a 0 – 4 Likert scale in which 0 was *"Not at all"* and 4 was '*A lot'*. For simplicity of presentation, the mean scores only are reported, as illustrated in Figure 4.

Barriers to bike share can broadly be divided into two categories; those acting as barriers to bike use generally, such as safety concerns or distance, and secondly, those relating specifically to bike share, such as docking station location. The results presented in Figure 4 indicate that both categories are acting as barriers to bike share use in Brisbane. Convenience emerges as a key theme, with *Driving is more convenient, docking stations are not close enough to my house & work* and *I don't want to carry a helmet with me* each receiving the strongest responses. Safety concerns whilst riding in traffic also received among the highest mean score. These results are consistent with research showing convenience factors to be one of the most important motivators for bike share use *[8, 9]*. Moreover, safety concerns have been shown to be a key barrier to biking in both the UK, US *[26]* and Australia *[27]*.

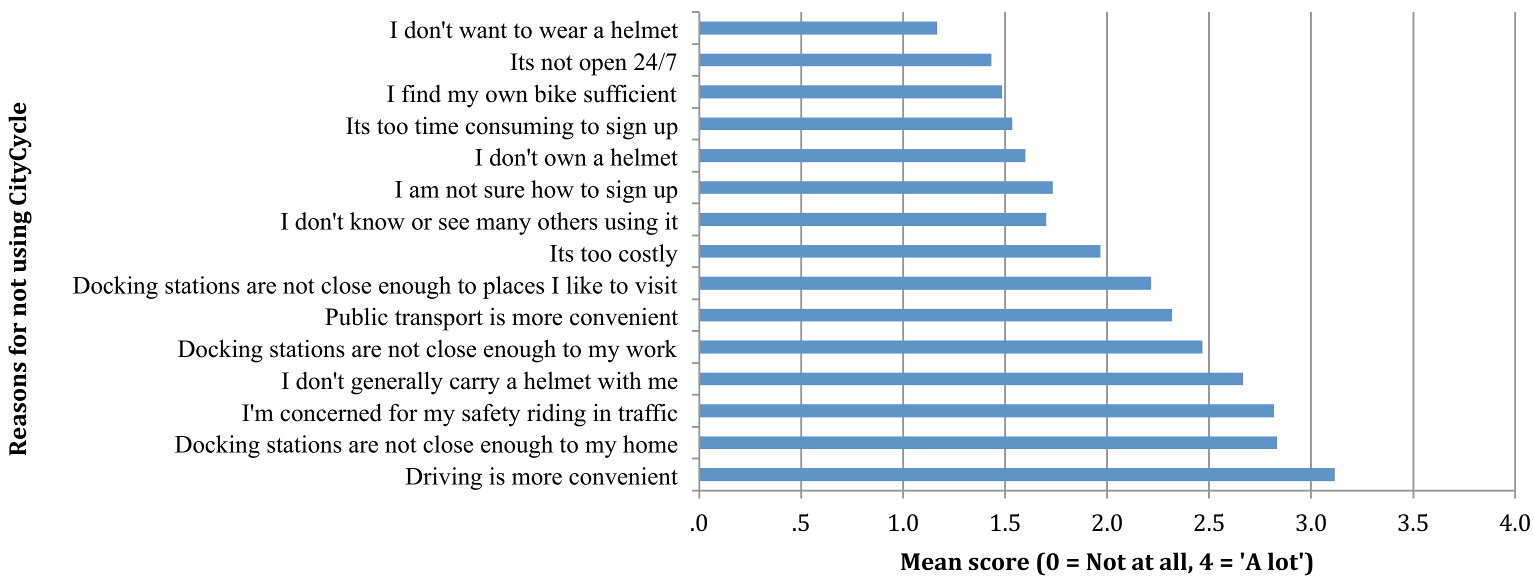

FIGURE 4 If you were considering joining *CityCycle*, to what extent would these factors discourage you?
NB: Mandatory helmet legislation exists in Brisbane, where the survey was undertaken. Brisbane's bike share program (*CityCycle*) opens at 5am and closes at 10pm each day.

CONCLUSIONS

Bike share has emerged as an initiative to expand sustainable transport opportunities in predominately urban settings. The number of bike share programs has grown dramatically over the past 10 years, particularly in North America, Europe and China. An implicit assumption that equates bike share use with car use reduction has emerged, despite evidence showing that only a minority of bike share journeys are replacing car trips (ranging from 2% in London to 21% in Brisbane).

This paper has used ridership and mode substitution data from bike share programs in Melbourne, Brisbane, Washington, D.C., London, and Minnesota to better understand the magnitude of changes to car use as a consequence of bike share programs. This type of analysis revealed the critical importance of car substitution rates to bike share's car use reduction impacts.

Pressure on bike share operators to maintain a reasonably balanced system requires a reliance on motorized trucks and vans to re-distribute bicycles to different docking stations throughout the day. This paper compares the reduction in car use as a consequence of bike share with the VKT of program operators for fleet redistribution and maintenance. According to the findings, the reduction in VKT due to bike share use is at least twice the VKT from operational and maintenance vehicles. The exception is London, where VKT from operational and maintenance vehicles is estimated to be 2.2 times greater than the reduction in VKT due to bike share. Should London's car mode substitution rate increase from its current 2% to 10%, it is estimated the reduction in VKT to be approximately twice the distance travelled by operational and maintenance vehicles. Future research focused on innovative techniques to minimize manual redistribution by conventional motorized vehicles will improve the efficiency and sustainability credentials of bike share operators.

The results of this paper demonstrate that in order for bike share programs to optimize their impact on reducing car use, it is necessary to implement measures focused on encouraging those currently making trips by car to use bike share. Results from a survey of non-bike share users from Brisbane suggest that this may be best achieved via policy changes that seek to increase the competitive advantage of bike share over the convenience of car use, improving perceptions of rider safety, and providing docking stations in close proximity to home and work.

Finally, this paper has provided the foundational elements for evaluating the impacts of bike share on travel patterns and outcomes related to fuel use, emissions, congestion and physical activity. Researchers can adapt the analytical approach proposed in this paper to assist in the evaluation of current and future bike share programs.

LIMITATIONS

Although every reasonable action has been taken to ensure the validity of the results, several limitations have been identified. Trip usage data may contain technical errors, although this has been mitigated by omitting all journeys recorded as being below two minutes or greater than 180 minutes duration. Such trips are likely to be the result of user or technical error rather than a genuine trip. An assumption has been made that bike share trip length is the same as a substituted car trip. Data from Lyon suggests bike share trips may be shorter than the same trip by car *[17],* however this may not be true of the cities included in this study.

The sample group in all cities included in Figure 2 are annual bike share members, as distinct from casual users. It is plausible casual members may differ in their mode substitution pattern and previous research from Washington, D.C. *[28]* and Montreal *[29]* has identified differences between annual and casual users. Future research on mode substitution may benefit from differentiating the question by weekday/weekend, as well as whether car trips substituted were single-occupancy or higher.

Motorized vehicle fleet data were provided by the bike share operators and have not been independently audited, although there is little reason to suspect gross inaccuracies. It should be noted that the mileage of vehicles (fuel used per unit of distance traveled) used by bike share operators is likely to be significantly more than the typical private car and therefore caution should be exercised when comparing the two. The survey findings on barriers to bike share rely on a sample of 60 adults in the Brisbane area and although the results are broadly consistent with previous research, the findings cannot be generalized.

Finally, this paper focuses on changes to car use as a consequence of bike share. The authors do not wish to imply that reductions in car use are the sole benefit of bike share and acknowledge the numerous potential benefits such as greater transport choice, travel time savings and reductions in transport costs.

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