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Bike Share: A Synthesis of the Literature

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ABSTRACT *This paper begins by providing an overview of bike share programs, followed by a critical examination of the growing body of literature on these programs. This synthesis of previous works, both peer-reviewed and gray, includes an identification of the current gaps in knowledge related to the impacts of bike sharing programs. This synthesis represents a critically needed evaluation of the current state of global bike share research, in order to better understand, and maximize the effectiveness of current and future programs. Several consistent themes have emerged within the growing body of research on bike share programs. Firstly, the importance bike share members place on convenience and value for money appears paramount in their motivation to sign up and use these programs. Secondly, and somewhat counter intuitively, scheme members are more likely to own and use private bicycles than nonmembers. Thirdly, users demonstrate a greater reluctance to wear helmets than private bicycle riders and helmets have acted as a deterrent in jurisdictions in which helmets are mandatory. Finally, and perhaps most importantly from a sustainable transport perspective, the majority of scheme users are substituting from sustainable modes of transport rather than the car.*

Keywords: public bicycle; bicycle; bike share; transport; sustainable; cities

Introduction

Bike share programs have existed for almost 50 years, although the last decade has seen a sharp increase in both their prevalence and popularity worldwide (Shaheen, Guzman, & Zhang, 2010). Contemporary bike share programs refer to the provision of bicycles to enable short-term rental from one docking station to another. These bicycles usually contain technologies that allow scheme operators to track movements, from one docking station to the next, and for those with

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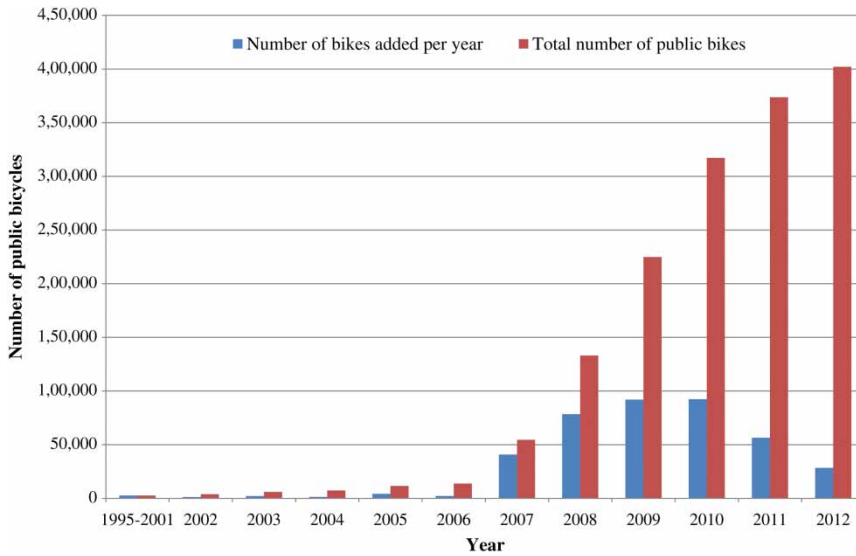


Figure 1. Global growth in bike share programs.

Source: R. Meddin (personal communication, 8 August 2012).

integrated global positioning system (GPS), the bike's movement through the network. Pricing structures generally encourage short-term rental (for example, the first 30 min are usually free), after which, users are charged on a sharply rising scale. Users are generally required to provide credit card details, which act both as a deposit, as well as payment for registration and usage fees.

In 2007, Paris launched Europe's largest scheme, with over 20 000 bicycles. Wuhan and Hangzhou, China currently have the world's largest public bicycle share schemes, with 70 000 and 65 000 bikes, respectively, (China News, 2011; Meddin, 2011a). New York City is due to launch North America's largest bike share program, with 10 000 bicycles in 2013. Figure 1 documents the expansion of bike share programs globally. It should, however, be stressed that figures for 2012 only include the first six months and are expected to rise substantially by the end of the year.

Shaheen et al. (2010) summarize the benefits of bike sharing as flexible mobility, emission reductions, physical activity benefits, reduced congestion and fuel use, individual financial savings and support for multimodal transport connections. These factors have acted as a catalyst for the development of bike sharing globally, yet little research has been conducted to evaluate to what extent these programs accomplish such benefits. Moreover, there is a paucity of research examining the factors constituting barriers and facilitators to bike share usage. The prospect of bike sharing programs acting as a catalyst for the take up of private riding has not been critically examined. These knowledge gaps are currently being investigated as part of a PhD program by the authors.

Review of the Literature

This literature review begins by briefly identifying the policy context to which the bike sharing concept responds, in terms of the need to enhance the sustainability of the transport system, as well as meet public health and urban livability

objectives. This review is followed by a discussion on the limited work directly investigating the impacts of bike share programs. These works were found through a scan of the academic literature on bike share, as well as through the gray literature between April 2011 and September 2012. Google Alerts were also established between these dates for the words “bike share” and “public bike”. Readers are encouraged to refer to the bibliography to determine whether cited works are from the peer-reviewed or gray literature. As with any area of research, but perhaps particularly so with bike share, given the rapid pace of growth, papers can quickly become outdated.

Sustainability Challenges, Bicycling and Its Promotion

As contemporary urban policy seeks to overcome the challenges presented by car dependence, replacing car journeys with bicycles has emerged as an increasingly common response in many cities, as highlighted recently in the new book *City Cycling* (Pucher & Buehler, 2012). This paper does not seek to repeat a discussion of the benefits of bicycling found elsewhere, but simply wishes to highlight that the rise of bike share has come about ostensibly in an attempt to capitalize on the potential benefits associated with an increase in cycling. Finally, the establishment of bike share programs has prominently enabled cities to demonstrate their commitment to addressing climate change, population health issues, traffic congestion, oil dependence and livability.

Public Bicycle Share Schemes

The policy context identified above, combined with improvements to the capability and affordability of tracking, communications, security and payment technology have enabled considerable growth in bike-sharing programs, mostly in Europe and China (and other Asian countries), but also in the US, and to a lesser extent, Australia.

Benefits. Shaheen et al. (2010), in their overview of the bicycle share concept, history and future, outline the benefits of bike share programs, which can be summarized as:

- flexible mobility;
- emission reductions;
- individual financial savings;
- reduced congestion and fuel use;
- health benefits and
- support for multimodal transport connections, by acting as a “last mile” connection to public transport.

Mode substitution and impacts. Implicit in many of the aforementioned benefits is the assumption that a significant proportion of users are transferring to public bicycle from single occupant car use. Yet, a wide range of papers from a number of countries have reported that this is seldom the case. A report on bike share from the United Nations warned about the possibility of exaggerating the benefits of these programs, given that it is quite common for the majority of bike share trips to be substituting for sustainable modes (Midgley, 2011). This United Nations report failed to describe the precise methodology used in its

development, although the author provides comprehensive references. Citing data from the Barcelona, Lyon, Montreal and Paris bike share programs, the author concludes that these programs show “little impact on reducing car use” (p. 16). Similarly, the Dublin, London and Washington, DC schemes have all reported low transfer rates from car journeys to public bike (LDA Consulting, 2012; Murphy, 2010; Transport for London, 2010), as shown in Figure 2. One study, Murphy (2010) sought to determine the influence of the Dublin bike share program specifically measuring trips that would have previously been made by car. The data were collected via surveys at docking stations. Eight randomly selected stations (out of a total of 40) were used as sites for the carrying out of the survey, where bike share users were targeted. Survey times were stratified, in an effort to diversify the sample. In total, 251 surveys were completed, which approximates, according to the author, 8% of Dublin’s bike share users in any average 24-h period. The results are included in Figure 2. Another study, by LDA Consulting (2012) known as the *2012 Capital Bikeshare Customer use and Satisfaction Survey* was carried out with users of *Capital Bikeshare* in Washington, DC. An online survey was distributed to those registered as *Capital Bikeshare* members ($n = 18\,000$). The survey was open for a one-month period, with 5464 completed surveys (response rate of 31%). For their most recent bike share journey, respondents were asked what mode of transport they would have used if *Capital Bikeshare* was not available, with the results showing only 7% shifting from private car. A full set of results to this question is provided in Figure 2. Participants were not offered options for weekday and weekend travel, making the results potentially dependent on what day the survey was completed. Providing such an option would assist in our understanding of mode substitution, and as to how this would vary between weekday and weekend travel.

Transport for London (2010) undertook an online survey of 3500 members of the London bike share program. The authors of the report do not identify how many

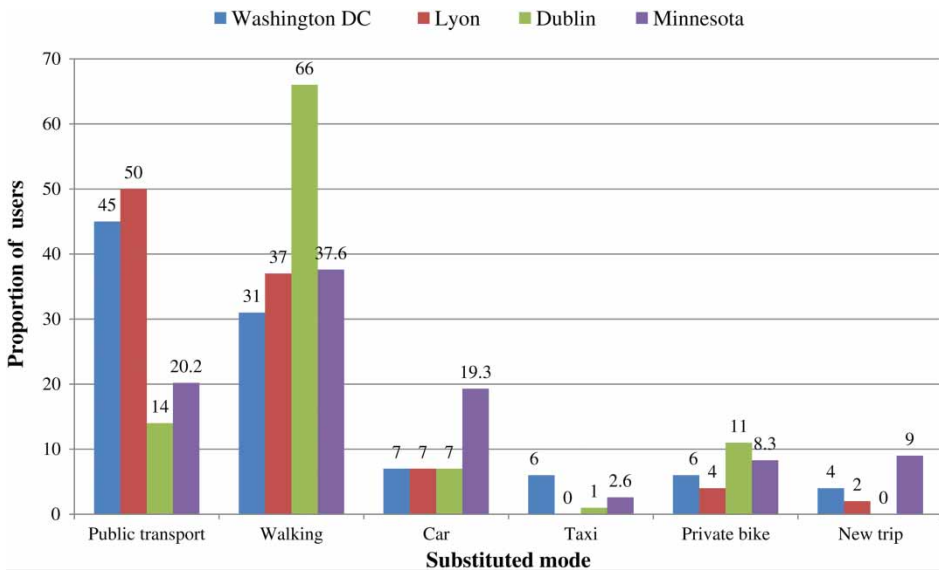


Figure 2. Mode substitution in selected cities.

Source: Buttner et al. (2011), LDA Consulting (2012), Murphy (2010) and Nice Ride Minnesota (2010).

people the survey was sent to, and therefore, it is not possible to determine the response rate, however at the time, the program had over 100 000 members. The survey was conducted shortly after the introduction of the scheme (September–October 2010). The paper did not describe the methodology in detail. According to the authors, only 1% of members were substituting for private car travel. The results suggest, however, that the program is reasonably successful in encouraging cycling, with 60% of respondents reporting their cycling participation only began in the previous six months (presumably due to the program) and over 50% never cycle in London on a bike they own. Clearly many users were substituting for walking and public transport use.

Similarly, new research from China indicates that a large proportion (around 80%) of those using bike share would have walked, used public transport or traveled on their own bicycle if the bike share program was not available (Yang, Haixiao, & Qing, 2010). Yang et al. (2010) investigated the issue of mode substitution in Chinese bike share programs. Given the low proportion of trips in China by private vehicle, it is not surprising that only 5.2%, 0.46% and 4% of bicycle trips were substituting for private car in Beijing, Shanghai and Hangzhou, respectively. The authors conclude that the shift from private motor vehicles has been disappointing. Indeed, the overwhelming substitution came from walking and public transit. The survey design was limited, as it did not collect information on trip distance, including any variation between the trip distance of a public bicycle journey and the mode that would have been used, had the bike share program not been available. Trip distance is a key determinant of congestion, emissions, impact on livability and physical activity (Bauman et al., 2008; Fishman, Ker, Garrard, & Litman, 2011; Ker, Litman, Fishman, & Garrard, 2011). Also missing from the evaluation were the number of trips per day per bicycle, as this would, in combination with average trip distance, provide an aggregate measure of total distance traveled by public bicycle. Moreover, total number of subscribers and the percentage of trips that are “new” (would not have otherwise been taken) were important, but absent components of the study. Despite these limitations, Yang et al. (2010) have made an important contribution to the literature and a useful foundation for further work.

Shaheen, Shaheen, Zhang, Martin, and Guzman (2011) undertook one of the most detailed investigations to date into bike share in China. The authors sought to better understand the travel impacts of the world’s second largest bike share program, in Hangzhou, China. Bicycle modal share in Hangzhou, whilst significantly reduced from two decades ago, still hovers at 33.5% (Yang et al., 2010), which is comparable to the highest bicycle modal share in European cities (Pucher & Buehler, 2008). The researchers conducted intercept surveys with members and nonmembers of the bike share program, all in close proximity to docking stations. A key aim of the study was to determine how the bike share program influenced transport choice. Over 800 surveys were completed, the vast majority of respondents being members of the bike share program. The researchers asked the respondents what mode of transport they would have used had the bicycle scheme not existed. The results reveal the following shifts in mode share as a consequence of the program:

- An overwhelming majority previously walked or used the bus. In fact for noncar owners, 80% shifted from public transport, compared to 50% for car owners.

- 30% shifted from taxi to bike share.
- Almost four out of five (78%) of the car owners said that they used bike share for trips when they would have ordinarily used the car.

Shaheen et al. (2011) discovered "... car ownership does not lead to a reduced propensity to use bike sharing. In fact, members exhibited a higher rate of auto ownership in comparison to non members" (p. 13). This finding may well be a result somewhat unique to China, in which early adopters of bike sharing were also more willing to purchase a motor vehicle. LDA Consulting (2012) asked members of *Capital Bikeshare*, how their riding frequency has changed since joining the scheme. Some 36% of respondents reported riding "much more often", 46% "more often" and 17% "about the same". Younger respondents were found to be more likely to report higher frequency of riding since becoming members. As some respondents may have joined many months or even years ago, it is possible respondents may have trouble accurately recalling their frequency of riding, before becoming members of the scheme. It is also unclear to what extent the increase in cycling was on private or public bicycle. In addition, some respondents may have a tendency to select the perceived socially desirable answer, which in this case would be a tendency to report having cycled more since becoming members.

A landmark study into bike share in North America (Shaheen, Martin, Cohen, & Finson, 2012) provides the most up-to-date, comprehensive assessment of bike share, from both the operator and user perspective. The report sets out to understand, among other things, the impacts of bike share on transport choice, user perceptions and the influence of commute distance on propensity to use bike share. The method used by the authors involved an extensive literature review, interviews with bike share operators and transport stakeholders. The study team also conducted an online survey with 10 661 users of bike share, in Montreal, Toronto, Washington, DC and Minneapolis/St. Paul (response rate 15%). Respondents were asked how their use of other modes of transport has changed due to bike share and the results are shown in Figure 3.

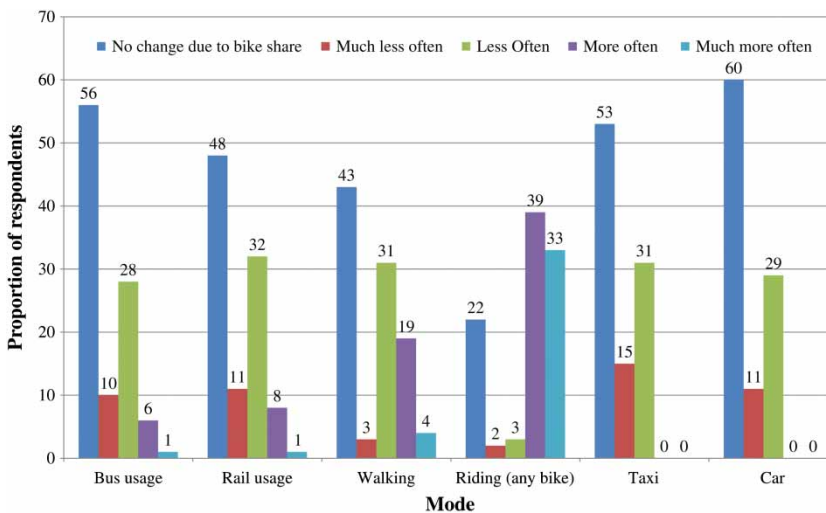


Figure 3. Changes in mode use due to bike share, North America.
Source: Shaheen et al. (2012).

The results shown in Figure 3 are consistent with other studies showing that mode substitution from cars to bike share is low. It would be of further interest to ascertain how these changes in mode choice relate to distance traveled, which is crucial for any meaningful outcome related to vehicle miles traveled and subsequent metrics, such as greenhouse gas emissions.

Usage rates. Substantial differences exist in the usage of bike share programs globally, yet the reasons for this variation have only received limited attention. Globally, usage rates vary from around three to eight trips per bicycle per day (Fishman, 2011; Meddin, 2011a, 2011b; Rojas-Rueda, de Nazelle, Tainio, & Nieuwenhuijsen, 2011). Melbourne and Brisbane (Australia’s only two bike share programs) have usage rates significantly less than other cities (R. Meddin, personal communication, 1 May 2012). These Australian schemes have approximately 0.3–0.4 trips per day per bicycle according to information supplied by the operators to the authors (M. Vincent, personal communication, 20 December 2011; K. Ilott, personal communication, 4 October 2011) although recent months have shown usage growth (J. Hoernel, personal communication, 4 April 2012; Y. Redhead, personal communication, 8 May 2012). Figure 4 illustrates the number of trips per day per bicycle for a small selection of cities. It should be noted that although there are over 300 bike share programs globally, reporting measures vary widely, and it is rare for operators to provide accurate trip frequency data. For this reason, Figure 4 is limited to six systems. For Europe’s largest bike share program, *Velib*, in Paris, six trips per day per bike has been reported in a paper published in the *International Journal of Sustainable Transportation* (Nair, Miller-Hooks, Hampshire, & Busic, 2013), which cites a 2008 article from the *New York Times* (Erlanger, 2008). Nair et al. (2013), later in their paper on *Velib*, using data supplied by the operator, JCDecaux, report 79 945 trips per day, which at 20 000 bicycles, equates to approximately four trips per day per bike. The discrepancy is illustrative of the paucity of reliable, comparable data across different systems. Another well-known French bike share program, *Velo’v*

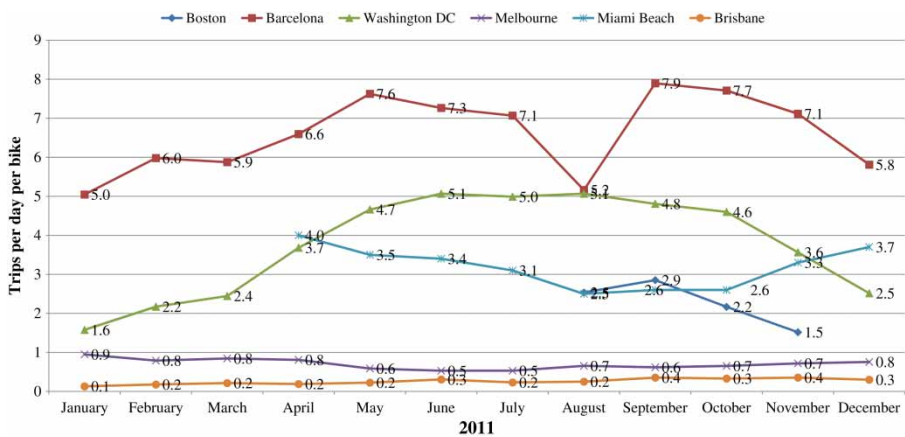


Figure 4. Bike share trips per bicycle per day — selected cities.
Source: Capital Bike Share (2012), R. Meddin (personal communication, 1 May 2012), R. Meddin (personal communication, April 13, 2012), J. Hoernel (personal communication, 4 April 2012), Y. Redhead (personal communication, May 8, 2012) and S. Mullen (personal communication, 6 April 2012).

in Lyon is reported as averaging 16 000 trips per day, and therefore, with a fleet of 4000 bikes, equates to approximately four trips per day (Jensen, Rouquier, Ovtracht, & Robardet, 2010). Reporting average annual usage is of limited use, given the large variation associated with seasonal weather patterns, an effect that is clearly evident in Figure 4. Interestingly, during instances of public transit service disruptions, such as strikes, bike share usage can double, as was the case with *Velo'v* (Jensen et al., 2010), and a similar effect has been identified in London (Fuller, Sahlqvist, Cummins, & Ogilvie, 2011b).

Little in the peer-reviewed literature has appeared to explain reasons for lower usage rates in Australian cities. Research with users and potential users of Brisbane's *CityCycle* program found a lack of accessibility/spontaneity, caused in part by helmet issues (mandatory in Australia), overnight closure of the system and an inability to sign up easily with a credit card swipe, to be significant barriers. Barriers to instant access were thought to stifle the spontaneity typically thought to attract people to bike share. In addition, safety issues (to be discussed in greater detail later) related to a perceived lack of motorist awareness and bicycle infrastructure reduced the attractiveness of the scheme (Fishman, Washington, & Haworth, 2012a).

Only sporadic data have been reported on the duration of bike share journeys and the speed at which riders travel. Jensen et al. (2010) used data obtained by the operator of Lyon's bike share program to better understand the speed and travel characteristics of users. Capturing activity on *Velo'v* between 25 May 2005 and 12 December 2007, the authors were able to report an average trip distance of 2.49 km, with an average duration of just under 15 min. The authors note that the average travel speed varies by time of day and day of week. The top average speed (14.5 km/h) occurs early on weekday mornings, whilst the slowest average speeds are recorded on weekend afternoons (10 km/h). Interestingly, and a first for bike share studies, the authors compared trip distances on *Velo'v* between stations, to the distances that would need to be traveled between those two points if on foot or by car. The results of this analysis indicate that travel patterns of *Velo'v* riders bear closer resemblance to that of pedestrians than car drivers. The authors note that in instances in which a short cut becomes available, 68.2% of trips by *Velo'v* are shorter than by car, with the distance being reduced by an average of 13%. Due to the lack of dedicated bicycle infrastructure in Lyon during the period in which the data was collected, the authors note many of the cyclists must have been using sidewalks, bus/tramways, as well as riding the wrong way up one-way streets. The benefit of conducting an analysis of this type, although not mentioned by the report's authors, is that it can provide an indication of *level of service* in relation to trip distance and travel time. Given the importance of travel time in individuals' transport decision-making (Sener, Eluru, & Bhat, 2009), an analysis of this type provides a practical understanding of how bike share compares to other modes on this crucial parameter. This paper's findings suggest that a city can maximize the attractiveness of its bike share program by creating competitive advantages for bike share route choice, compared to car use. This may help mitigate the problem of low mode substitution rates from private cars reported earlier.

User motivation, preference and purpose. With modern bike share programs currently in their infancy, and a large number set to be introduced over the next few years, it is critically important that an understanding is reached regarding

user motivation and preferences. Currently, research undertaken to establish the determinants of bike share usage is limited (Buck & Buehler, 2011). Confirming a view commonly seen in the literature that does exist, Murphy (2010) found that 55% of those using the Dublin bike share program integrate it as part of a trip chain (multimodal travel). Walking was the most common linking mode, with 42% of the 55% indicating they walked more than 500 m in combination with bicycle share use. The overwhelming majority of users of the Dublin scheme (70%) state their trip purpose to be work or education related (Murphy, 2010).

The proximity of residential addresses to docking stations appears to have a powerful influence over propensity to use a bike share program. Fuller et al. (2011a) investigated the prevalence and correlates of using public bikes among Montreal residents, a city which at the time of publication had the largest bike share program in North America, known as *BIXI*, with 5000 bikes. The investigation involved telephone surveys with 2502 people to compare the prevalence of using the program depending on whether the respondent lived within 250 m of at least one docking station. The authors found that for those living within 250 m of a docking station, 14.3% had used *BIXI*, whereas only 6% had when living greater than 250 m from a docking station. Almost 80% of respondents lived beyond 250 m from a docking station, with 12.8% living within 250 m from one docking station and 7.9% having more than one docking station within 250 m.

Understanding trip purpose is important for the planning of new bike programs and the expansion of existing ones. Insights into trip purpose can be a useful tool for understanding bike flows and distribution issues across a system and can provide an indication of the impacts, in relation to the aforementioned benefits of bike sharing. Yang et al. (2010) compared the bike share programs of Beijing, Shanghai and Hangzhou. The data were collected via a survey of users (154 respondents in Beijing, 218 in Shanghai and 276 in Hangzhou) who were asked a range of questions regarding their transport choice. Significant differences in trip purpose were found across the three cities. In Beijing, almost 45% of respondents reported using the bike share for journeys to work, compared to around 18% for both Shanghai and Hangzhou. Over half the Shanghai respondents reported using bike share for the return from work journey, compared to 29% and 23% for Beijing and Hangzhou, respectively. Hangzhou respondents generally used the bicycles for a broader range of trip purposes than Beijing and Shanghai respondents. Although the researchers made it clear as to what time of year the survey was undertaken, it was unclear what time of day the survey questions were asked, a detail that may have had an impact on responses, given that respondents were only able to select one journey purpose. Moreover, the sample size may not have been sufficient relative to the size of the schemes, and it may therefore, be difficult to generalize the results across the total user base of these programs. A membership survey from Washington, DC found the main trip purposes were registered as *social/entertainment* and *errands/personal appointments* (LDA Consulting, 2012). When asked about their most recent trip using *Capital Bikeshare*, members reported a wide range of purposes, with commuting and social/entertainment the most common as illustrated in Figure 5. This study, as well as others investigating bike share trip purpose for the most recent journey, would benefit from providing respondents with a weekday and weekend option. Without this option, results become dependent to some extent, on the particular

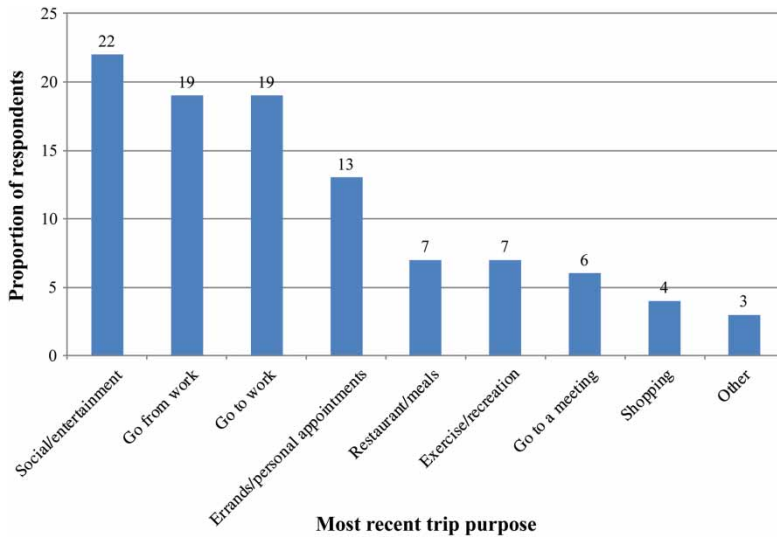


Figure 5. Trip purpose on *Capital Bikeshare*, Washington, DC.
Source: LDA Consulting (2012).

day of the week in which respondents completed the survey. Not surprisingly, respondents without a car used *Capital Bikeshare* for a greater range of trip purposes. Similarly, members without a private bicycle used the program more for exercise/recreation (LDA Consulting, 2012).

Commuting (travel to/from work or school) was the most common trip purpose across a survey of four of North America's largest bike share programs (Shaheen et al., 2012). This study, which also interviewed the operators of 19 bike share programs in North America, reported that annual members were more likely to use bike share for regular, nonrecreational journeys, whereas daily pass holders tended to use the system more for recreational trips.

Interestingly, 60–70% of respondents in a study by Yang et al. (2010) reported that using the bike share program in China was a more convenient option than using private bicycles. Convenience has emerged as a key motivation for the use of bike share, with similar findings in Washington, DC, Minneapolis/St. Paul and Melbourne. In Washington, DC, 85% of respondents cited access and speed as a motivation for using the scheme (LDA Consulting, 2012). "Convenience" was also the top reason cited by those using the *Nice Ride* program in Minneapolis/St. Paul and *Melbourne Bike Share* (Alta Bike Share, 2011; Shaheen et al., 2012). Some studies have found bike share to be used by those seeking to avoid private bike theft (Fuller et al., 2011a).

Bike share and public transit. The integration of cycling and public transit has been shown to strengthen the benefits of both modes (Brons, Givoni, & Rietveld, 2009; Pucher & Buehler, 2012), and in the peer-reviewed, as well as gray literature, strong user demand for integrating bike share with transit is apparent. Yang et al. (2010) found integration to the metro system to be an important function of the bike share program in both Beijing and Shanghai, with 58.4% and 55% of respondents combining these modes, respectively. Hangzhou's metro system is currently under construction, but an extensive bus network services the city.

These bus passengers are provided an extra 30 min on the public bicycles before incurring a fee (90 min free period instead of 60 min). The integration of bike share with public transit does not appear to be restricted to China. Recent research from Melbourne, Australia analyzing activity and trip patterns across their system, found a strong relationship between docking station activity and proximity to train stations, and this trend was most pronounced during peak hour periods (Lansell, 2011). Similarly, over half the respondents to a survey of *Capital Bikeshare* members had used the scheme to access the train system (LDA Consulting, 2012). Both the Melbourne and Washington, DC study, found users making trips from one public transit station to another, suggesting bike share is being used to reduce the journey times associated with backtracking and transfer inefficiencies that can be found in some parts of a public transit network. In London, some 35% of bike share users report substituting the underground rail system for the bike share (Transport for London, 2010). Given the peak hour congestion experienced on many urban public transport systems, bike sharing may act to reduce public transport overcrowding.

Demographics of bike share users. Several bike share papers have found the demographics of members to differ from the general population (LDA Consulting, 2012; Lewis, 2011; Ogilvie & Goodman, 2012; Virginia Tech, 2012). A recent study conducted on the membership of *Capital Bikeshare* in Washington, DC (LDA Consulting, 2012) found that they differed from the general population of the city, with significantly higher employment rates and education levels, lower average age, and more likely to be male. Members were also more likely to be Caucasian and living within the inner urban area. This is at least the second study to reveal large racial differences between the users of *Capital Bikeshare*. Virginia Tech (2012) conducted a study into casual users of *Capital Bikeshare* (one- and five-day memberships). Data were collected via intercept surveys at five popular docking stations, with 340 survey responses. Results showed respondents were disproportionately Caucasian (78% compared to 34% in the Washington, DC Census). Only 5% of respondents were Black/African American, compared to 50% in the Washington, DC Census. When looking specifically at annual members, however, only 2% are Black/African American. The results were similar to those reported by LDA Consulting with regard to the higher education levels. Finally, in the previously cited large scale study by Shaheen et al. (2012), bike share users in North America were found to be more likely, than the general population, to live closer to their work, and this is consistent with known determinants of commuter cycling, on private bikes (Heinen, van Wee, & Maat, 2010).

An analysis of registration data for members of the London bike share program, examining over 100 000 individuals, also found significant differences when compared to the general population (Ogilvie & Goodman, 2012). When compared to others living and working in the areas of London served by the bike share program, members were disproportionately male, lived in pockets of relative affluence and had higher general cycling participation rates. Interestingly, the authors, when adjusting for the fact that deprived areas had lower docking station concentration, “users in the most deprived areas made 0.85 more trips per month than those in the least deprived areas” (p. 3). This suggests the lower rate of bike share adoption among those with less income and education may be, at least to some extent, a consequence of docking station location than an inherent disinterest in bike share from these groups.

The age profile of bike share users is typically younger than the general population average. Fuller et al. (2011a) found members of the *BIXI* program in Montreal to be skewed toward the 18–24 years band. They also found users to be more likely to have a tertiary education and use a private bicycle as a mode of transport for work, potentially conflicting with the primary purpose of bike sharing, that is, to increase the proportion of the population riding bicycles. Interestingly, men and women had the same likelihood of using *BIXI*, in contrast to the higher proportion of males among nonbike share bicycle riders in North America (Pucher & Buehler, 2011), and Australia (Pucher, Greaves, & Garrard, 2010). Whilst an interesting and useful addition to the body of research on bike sharing, this study had several limitations including a failure to ask respondents questions on car ownership, substituted mode and distance traveled. Including such questions would have more effectively captured the full possibilities for new knowledge in this area.

When looking at bicycle ownership characteristics of members and nonmembers, Shaheen et al. (2011) found in their research conducted in Hangzhou (with the world's second largest bike share program), that there were an average 0.55 bicycles per household for members and 0.49 for nonmembers. This finding is somewhat counterintuitive in that, owning a bicycle is associated with greater interest in bike sharing. This finding also confirms a theme throughout the literature — bike share members have a greater propensity to cycle independently of bike share programs (Fishman et al., 2012a; Fuller et al., 2011a).

Safety concerns. Safety concerns are a major barrier to bicycling in Australia, the UK and North America (Fishman, Washington, & Haworth, 2012b; Garrard, 2009; Horton, Rosen, & Cox, 2007), and these concerns appear to hold true for bike share participation (Fishman et al., 2012a; Wiersma, 2010). In focus groups with riders and nonriders in Brisbane, Australia, safety concerns emerged as a major barrier (Fishman et al., 2012b). Lack of rider awareness by motorists was a major issue, particularly for regular riders. Limited bicycle infrastructure and perceived risk of collision with motor vehicles were a major concern for all participants, regardless of bicycle riding experience, as illustrated in the quote from one of the participants:

You know, if you're driving a car and you get in an accident, your car will protect you. But the thing is when it comes to a bike, actually there is nothing protecting you. You are more exposed to getting an injury.
(Fishman et al., 2012a, p. 15)

Study participants with an active membership of the Brisbane's *CityCycle* program reported greater levels of consideration from motorists when riding a public rather than a private bicycle. Possible explanations for this phenomenon include that in Brisbane, a public bike in use is still somewhat of a rarity, as well as assumptions from the motorist regarding the low level of experience and skill of the bike share rider (Fishman et al., 2012a). A study conducted in Plymouth, UK (Wiersma, 2010) that set out to examine the feasibility of establishing a bike share program for Plymouth found that perceptions of fear act to prevent bicycle riding generally, and this includes the propensity for bike share participation (although no bike share program exists in Plymouth at the time of publication). The author concludes that due to the lack of a bicycle friendly

environment in Plymouth and the subsequent safety concerns expressed by study participants, the scheme would suffer from low participation rates. Research conducted by Buck and Buehler (2011) support the importance given by users to a safe riding environment. The authors investigated the relationship between docking station activity within the *Capital Bikeshare* system in Washington, DC and proximity to bicycle lanes. Using multiple regression analysis, Buck and Buehler found a statistically significant relationship between bike share activity and the presence of bike lanes — even when controlling for population and retail opportunities around docking stations. Although there is a strong relationship between the positive effect bicycle lanes have on private bicycle riding (Pucher & Buehler, 2011), this is the first study to find such a relationship with public bicycle riding. Interestingly, the researchers found a negative correlation between docking station activity and the proportion of households without a car. The authors offered a plausible explanation for this counterintuitive result; the areas of Washington, DC with the least car ownership also have the lowest bike lane and population density, as well as the lowest docking station density (Buck & Buehler, 2011).

The issue of safety was also addressed in Shaheen et al.'s (2012) large scale study. Their analysis concludes that bike share accident rates were relatively low across North American systems. Of the operators involved in the study, 14 kept records on accidents, with an average of 1.36 accidents in 2011 (per system). A variety of methods were used by operators to express the accident rate. One operator reported one accident for every 50 000–60 000 rides. Another said they experienced one accident per 100 000 miles of riding. It is not clear what level of injury severity was sustained in these accidents or the precise method used to determine crash rates. The report notes that for systems with more than 1000 bicycles, there is an average of 4.3 accidents per year. As bike share systems mature, it may be beneficial for the industry and government to develop common, well-accepted reporting standards to determine crash rates for bike share users.

Helmets. Helmets have emerged as a contentious issue for bike sharing, particularly in jurisdictions with mandatory helmet legislation (Fishman, 2012; Moore, 2011; Ward, 2011). In Minnesota, where there are no mandatory helmet laws, only 14% of respondents to a survey of their membership said they always wore a helmet (Nice Ride Minnesota, 2010), and this finding is consistent with recent work on the relationship between bike share and helmet use in Washington, DC and Boston (Fischer et al., 2012). Fischer et al. (2012) observed bike share riders and private bike use, documenting whether riders were wearing helmets, their gender and type of bike (public or private). Observing over 3000 people on bikes, the results found just over half were unhelmeted, with significant differences depending on gender and whether on a private or public bike. Slightly over 80% of bike share users were unhelmeted, compared to 48.6% for private bicyclists. Men were 1.6 times more likely to ride unhelmeted (unadjusted analysis). When controlling for sex, time of week and city, the results showed a 4.4-fold greater chance of a bike share rider without a helmet than a private bike rider (Fischer et al., 2012). The authors note that one of the reasons for this substantial difference in helmet use is that helmets are “not provided or easily accessible” (p. 3).

The work of Fischer et al. (2012) is supported by the multisystem, North American analysis conducted by Shaheen et al. (2012), which found that

industry experts generally agreed that helmet use is not conducive to bike share usage. In particular, the requirement to wear a helmet was a significant impediment to short, spontaneous trips. Between 43% and 62% of survey respondents in Shaheen et al. (2012) study reported *never* using a helmet while using bike share.

Conducting focus groups with *CityCycle* members, as well as nonmembers (including both regular and nonriders) in Brisbane, Fishman et al. (2012a) found mandatory helmet regulation acted to reduce the reported spontaneity with which participants could use *CityCycle*, and these views correspond well with research on Melbourne's bike share program, which revealed 36% of people citing difficulty finding a helmet and 25% not wanting to wear a helmet as the key barriers to using the scheme (Alta Bike Share, 2011). On 22 August 2011, Brisbane City Council distributed 400 helmets across the fleet, resulting in approximately one helmet for every three *CityCycle* bikes. These helmets were placed on handlebars, in bike baskets, or secured on the locking mechanism that held the bike to the docking station. In the first two weeks of December, a further 500 helmets were distributed (Y. Redhead, personal communication 19 December 2011). As shown in Figure 6, short-term usage increased dramatically after August 2011, once helmet distribution came into effect — validating the views regarding helmets expressed in the focus groups.

Research from *Capital Bikeshare's* membership reveals 43% of respondents report never wearing a helmet, 21% some of the time, 19% most of the time and only 17% report always wearing a helmet when riding a *Capital Bikeshare* bike (LDA Consulting, 2012). Supporting the findings of the aforementioned Brisbane *CityCycle* research (Fishman et al., 2012a), the *Capital Bikeshare* respondents cited the main reason for not wearing a helmet was that their trip was unplanned and therefore, were not carrying a helmet at the time (LDA Consulting, 2012). The inconvenience associated with carrying a helmet throughout the day on the chance it might be

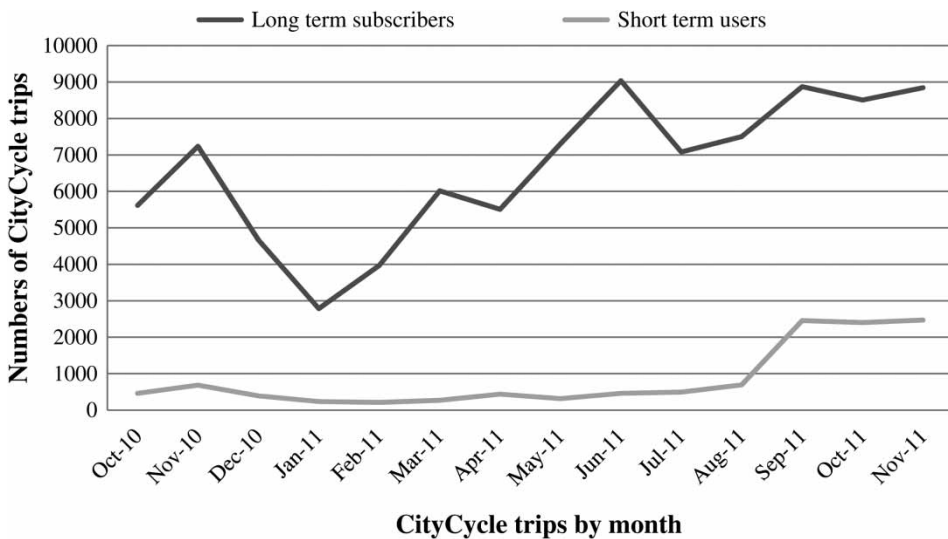


Figure 6. *CityCycle* trips per month.
Source: Fishman et al. (2012a).

required, appears to be a major barrier to their use, and in the case of programs operating under mandatory helmet laws, reduces the attractiveness of using the scheme.

Rebalancing. With a large number of bike share users commuting, the bikes inevitably become concentrated in some areas of the city, whilst other parts have limited fleet availability. Rebalancing involves an operator moving bicycles across the network, to maintain a more even distribution across the network. In their analysis of Chinese systems, Yang et al. (2010) described the rebalancing of bicycles across the system as a major problem. Rebalancing is both a financially demanding responsibility for operators, as well as a practice that can threaten the environmental credibility of bike share, given that the bicycles are often carried by fossil fueled vehicles (Wiersma, 2010). In order to help reduce the extent of this problem, Yang et al. (2010) suggest offering rewards for those that ride bikes against the flow, helping to relocate bicycles to docking stations that are low on bikes. This is a strategy employed by a number of bike share programs, including *Capital Bike Share* in Washington, DC (Capital Bike Share, 2011), although the effectiveness of this strategy is limited (Virginia Tech, 2012). As bike share programs continue to grow in popularity, the prospect of technologically advanced, demand responsive systems will be increasingly required (Shaheen et al., 2012).

Conclusions

Interest in urban cycling is increasing and the number of bike share programs has grown rapidly over the last five years. The peer-reviewed literature on bike share is limited and there are important questions yet to be examined in detail. The ability of bike share to attract trips previously made by private car has emerged as a key challenge for bike share programs, and the literature that does exist on this question has exposed disappointing conversion rates. Whilst bike share programs have undoubtedly enhanced user convenience and reduced travel time, an opportunity exists to enhance bike sharing's performance in reducing car use. Improving the level of service for bike share users, particularly in relation to a competitive advantage over car travel for short trips appears to be a plausible option for bike share programs seeking to maximize mode substitution from private car travel. This taps into a very clear theme in the literature: bike share users are most frequently motivated by *convenience*.

Little research has focused on the perceptions, attitudes and preferences related to bike share for those who *do not* ride a bicycle. Improved understanding of this group, especially those who drive as their primary mode of transport may help shift car journeys to bike share. Finally, Australia is unique in being one of very few countries with mandatory helmet legislation (Haworth, Schramm, King, & Steinhardt, 2010) and it is unclear to what extent this may influence demand for public bicycle use in Melbourne and Brisbane, as well as future programs in jurisdictions with similar legislation, such as Vancouver.

A number of indirect impacts of bike sharing are yet to be addressed in the literature. For instance, the potential for bike share to act as a catalyst for private bike riding has received little attention. Furthermore, the capacity for bike share to legitimize bicycle riding has not been evaluated. Research

conducted for the UK Department of Transport has previously found drivers to be frustrated with cyclists, viewing them as an out-group (Basford, Reid, Lester, Thomson, & Tolmie, 2002), and this may have implications for driver behavior and road safety outcomes. Bike share programs, as a prominent action by government to support bicycle riding, may act to increase the level of legitimacy for bicycle riding. As contemporary bike share programs grow and mature, opportunities for responding to these and other research questions will expand.

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