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Author
Shaheen, Susan

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HANGZHOU PUBLIC BICYCLE: UNDERSTANDING EARLY ADOPTION AND BEHAVIORAL RESPONSE TO BIKESHARING IN HANGZHOU, CHINA

Susan A. Shaheen, Ph.D.
Honda Distinguished Scholar in Transportation, University of California, Davis, &
Co-Director, Transportation Sustainability Research Center (TSRC)
University of California, Berkeley
1301 S. 46th Street, Bldg. 190; Richmond, CA 94804-4648
510-665-3483 (O); 510-665-2183 (F); sashaheen@tsrc.berkeley.edu; sashaheen@ucdavis.edu

Hua Zhang
Visiting Doctoral Student, Transportation Sustainability Research Center (TSRC)
University of California, Berkeley
PhD Candidate of Lanzhou University, China
1301 S. 46th Street. Bldg 190; Richmond, CA 94804-4648
510-665-3545 (O); 510-665-2183 (F); angelazhang@berkeley.edu

Elliot Martin, Ph.D.
Post-Doctoral Research Engineer, Transportation Sustainability Research Center (TSRC)
University of California, Berkeley
1301 S. 46th Street. Bldg 190; Richmond, CA 94804-4648
510-665-3575 (O); 510-665-2183 (F); elliot@tsrc.berkeley.edu

Stacey Guzman
Research Assistant, Transportation Sustainability Research Center (TSRC)
University of California, Berkeley
1301 S. 46th Street. Bldg 190; Richmond, CA 94804-4648
510-665-3646 (O); 510-665-2183 (F); staceyguzman@berkeley.edu

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Susan A. Shaheen, Ph.D.; Hua Zhang; Elliot Martin, Ph.D.; and Stacey Guzman

ABSTRACT

Over the past 20 years, China has experienced a steady decline in bicycle use. To address this trend, China's central and local government for urban transportation created the "Public Transit Priority" to encourage public transport initiatives. As part of this effort, the Hangzhou government launched "Hangzhou Public Bicycle" in 2008. This service allows members to access a shared fleet of bicycles. As of March 2011, it operated 60,600 bicycles with 2,416 fixed stations in eight core districts.

To understand factors leading to bikesharing adoption and barriers to adoption, the authors conducted an intercept survey in Hangzhou between January and March 2010. Two separate questionnaires were issued to bikesharing members and non-members to identify key differences and similarities between these groups. In total, 806 surveys were completed, including 666 members and 140 non-members. The authors found that bikesharing is capturing modal share from bus transit, walking, autos, and taxis. Approximately 30% of members had incorporated bikesharing into their most common commute. Members indicated that they most frequently used a bikesharing station closest to either home (40%) or work (40%). These modal shifts suggest that bikesharing acts as both a competitor and a complement to existing public transit. Members exhibited a higher rate of auto ownership in comparison to non-members, suggesting that bikesharing is attractive to car owners. Recommendations for improving bikesharing in Hangzhou include: adding stations and real-time bike/parking availability technologies, improving bike maintenance and locking mechanisms, and extending operational hours.

KEY WORDS: Bikesharing, Hangzhou, China, innovation, adoption, behavioral change

WORD COUNT: 7,500 words, including 3 tables

INTRODUCTION

In the 1970s, China was named the "Kingdom of Bicycles" due to the nation's heavy reliance on cycling for mobility given the relatively low income of its citizens, compact urban development, and short trip distances. Over the past 20 years, however, bicycle use has steadily declined due to economic growth, rapid motorization, longer trip distances, and a gradually deteriorating cycling environment. For instance, average bicycle ownership in Chinese cities declined from 197 bikes/hundred households in 1993 to 113 bikes/hundred households in 2007 (1). Even some traditional cycling cities, in which the topography and weather is suitable for biking, also experienced decline. In Hangzhou, with a flat topography and an annual average temperature of 17.5°C, bicycle modal share has decreased from 60.78% in 1997 to 33.5% in 2007 (2, 3).

In light of growing traffic congestion and environmental concerns, the Chinese Ministry of Housing and Urban-Rural Development recently opposed bicycle use restrictions and supported tackling cycling barriers. Bikesharing (or short-term public use of a shared bicycle fleet) is one governmental initiative that supports this goal. On May 1, 2008, the Hangzhou city government launched the first information technology-based public bikesharing program in mainland China.

The goal of the "Hangzhou Public Bicycle" service is providing a free and convenient public bike system for residents and tourists, so that bikesharing can act as a seamless feeder service to public transit throughout the city (4). To facilitate use, the Hangzhou bikesharing system employs advanced technologies and management strategies, which have been used by other bikesharing programs around the world (5). For instance, the Hangzhou bikesharing system uses touch-screen kiosks and smart cards for bicycle check-in/checkout, and radio frequency identification to track bicycle information. These technologies enable automated self-service for users. At the end of 2009, there were 2,000 bikesharing stations with 50,000 bikes in five core districts. By far, the highest daily use was 320,000 times, with an average turnover rate of five times per bicycle per day (Xuejun Tao, unpublished data).

Two key features characterize Hangzhou bikesharing. First, it was initiated and backed by the local government and is operated by a state-owned corporation. Second, users can employ their public transit cards for bikesharing and receive a transit discount—since the program's principal aim is to enhance and link to transit (6, 7). Additional program features include 24-hour service centers and one full hour of free bikesharing, followed by incremental pricing. The Hangzhou system uses fixed bicycle docking stations. Upon its launch, the program initially relied upon 31 mobile docking stations that could be relocated for program optimization. Once usage patterns were determined, the mobile stations were modified to fixed stations. To limit financial loss due to bike theft and vandalism, the program employs inexpensive, one-speed bicycles.

While the bikesharing service has spread rapidly, it is critical to understand behavioral adoption trends. Has public transport and bicycle use increased due to this service? What distinguishes members from non-members? How might this understanding increase use? In this paper, the authors explore results of an intercept survey—conducted from January to March 2010—in the five districts in Hangzhou with bikesharing.

This paper is organized into four main sections. First, the authors provide background information on worldwide bikesharing, the City of Hangzhou, the Hangzhou Public Bicycle system, and relevant adoption literature. Next is a methodological discussion. Third, key findings are described. Finally, the authors conclude with a summary of key findings, including recommendations.

BACKGROUND

In this section, the authors provide an overview of worldwide bikesharing, including the social and environmental impacts and lessons learned. It also includes a brief discussion on the city of Hangzhou and its bikesharing service. Finally, the authors provide a review of the innovation adoption literature.

Bikesharing Worldwide

Bikesharing was first launched in Europe in 1965. Since then, bikesharing programs have grown exponentially across the globe. At present, bikesharing exists in Europe, Asia, and North and South America. As of March 2011, there were more than 135 bikesharing programs operating in an estimated 160 cities around the world, with over 235,000 shared bicycles.

Since bikesharing's inception, program successes and failures have led to operational and logistical developments that can be categorized into four generations. First generation bikesharing, known as “White Bikes” (or Free Bike Systems), consisted of bicycles haphazardly placed throughout a city center. These bicycles were unlocked and free for public use. However, bicycles in first generation systems, such as White Bikes in Amsterdam, were either damaged or stolen.

Second generation systems, also known as “Coin Deposit Systems,” improved upon first generation systems by incorporating a bicycle lock that required users to insert a refundable deposit to unlock and use a bicycle. While bicycle locks and user deposits provided theft protection, they were not enough. In addition, this system did not limit bike-usage times. Thus, users often kept bicycles for extended time periods.

To deter theft and encourage bicycle return, third generation systems, known as “IT-Based Systems,” employ designated docking stations and smart technology (i.e., smart cards or mobile phones) for bicycle check-in/checkout. Third-generation systems also implemented additional theft deterrents, such as high deposits. The most well known third-generation system, Vélib’, was launched in Paris, France; it currently operates with 20,600 bicycles (8).

Lessons from first, second, and third generation bikesharing systems have prompted the rise of fourth-generation systems, known as: “Demand Responsive, Multi-Modal Systems.” Integration with larger public transport systems via smart cards is a key feature (5). At present, many cities are exploring ways to seamlessly link bikesharing programs with citywide transportation. For instance, the city of Guangzhou in China is operating a bikesharing program that is integrated with the city’s transportation system. The Guangzhou Public Bike Initiative launched on June 22, 2010, and operates with 5,000 bicycles and 113 stations. This program—also an initiative under China’s “Public Transit Priority” policy—seamlessly links its bikesharing program with the city’s bus rapid transit (BRT) and Metro system. Despite limited research, bikesharing is often viewed as a way to curb the negative social and environmental impacts of global motorization. Compared to personal vehicle use, the bicycle provides a virtually emission-free transportation alternative.

Cities with successful bikesharing programs also have documented an increase in the number of cycling trips made. For instance, surveys of SmartBike (Washington, D.C.), Velo’v (Lyon, France), and Vélib’ have found that many program users are employing bikesharing to make trips they would have otherwise made with private vehicles (9, 10, 11). Furthermore, a high street presence of bicycles has increased public awareness of cycling as a viable and convenient transportation mode (9, 11). Some cities have also noted an increase in cycling following the launch of a bikesharing program. For example, during the first year of Velo’v, Lyon experienced a 44% increase in bicycle use (10).

Despite the benefits of bikesharing, obstacles such as limited supportive infrastructure (i.e., docking stations, bike lanes), theft, high technology costs, funding, and safety issues, remain. In addition, bicycle redistribution is another issue that many programs are starting to tackle. Technology has frequently been deployed to estimate and monitor demand and to help redistribute bicycles to alternate docking stations. Vélib’ employs custom-designed buses to move bicycles. BIXI has augmented this approach by equipping its buses with real-time bike station information. However, both programs employ carbon-emitting vehicles to redistribute bicycles. In the future, cleaner redistribution strategies could be employed. In the next sections, the authors provide an overview of the city of Hangzhou and Hangzhou Public Bicycle.

City of Hangzhou: An Overview

The city of Hangzhou is located on the east coast of China and is the capital of the Zhejiang Province. With a total area of 16,596 square kilometers, the city houses a population of 6.78 million, with 4.24 million in the urban area (eight urban districts) (2). Hangzhou is one of the richest cities in China. In 2009, Hangzhou's gross domestic product reached US$36.2 billion—a 10% increase from the previous year, despite the global financial crisis (2).

Hangzhou's economic development also has impacted the city's transportation system by spurring rapid motorization. For instance, in 1997, 60.8% of Hangzhou's personal trips were made by bicycle, 21.5% by walking, 8.7% by public transit, 6.7% by auto and motorbike, and 2.3% by other modes. The city experienced decreasing bicycle trends in 2000 with only 42.8% of trips made by bike. Walking (27.6%), public transit (22.2%), and auto (7.4%) comprised the balance. Beyond 2000, the city's cycling modal share continued to decline and in 2007 biking accounted for 33.5% of trips in the entire Hangzhou region. In the urban core, the relative proportion of cycling is even lower than that of greater Hangzhou (4, 12, 13).

Despite the auto's comfort and convenience, its growth is coupled with negative effects on land use, energy/environment, congestion, and traffic safety. To counter the growing auto use trend, the Hangzhou Municipal Government adopted the "Public Transit Priority" in 2004 as the top priority for transportation funding to encourage greater public transport use (14). This venture includes a number of existing initiatives, such as the creation of BRT Line 1 and Line 2 in 2006 and 2008, respectively.

As part of this effort, the Hangzhou government also initiated bikesharing as a way to encourage seamless public transportation among bus, metro, and cycling modes. At present, 84% of the secondary and main roads in Hangzhou are physically separated between motorized and non-motorized vehicles (3), providing a safer riding environment than most other Chinese cities. However, additional bicycle infrastructure, such as parking facilities and storage, is still needed.

Hangzhou Public Bicycle

On May 1, 2008, the Hangzhou Public Transport Corporation—a state-owned enterprise—launched bikesharing. This system consisted of 2,800 bicycles, 30 fixed stations, and 31 mobile stations (i.e., a station that can be moved, as needed, to meet demand). The Hangzhou government invested 180 million yuan Renminbi (RMB) (US$26.35 million) to launch this program and also provided 270 million yuan RMB (US$39.53 million) discounted governmental loans to the enterprise (Yang Tang, unpublished data).

The Hangzhou Public Bicycle service is classified as a third-generation bikesharing program, as it uses smart cards, automated check-in/check-out, and distinguishable bicycles and docking stations (5). In the future, this system could be classified as a fourth-generation service, as it is integrated with other public transport modes. In its current state, however, it lacks real-time information and a clean bicycle redistribution strategy. In addition, the current smart card guidelines require a 200 yuan RMB ($30) deposit for bikesharing use. For more information on bikesharing's evolution, see 5, 15. The first hour of use is free; this is followed by incremental pricing where users pay an additional 1 yuan RMB (US$0.15) for the second hour, 2 yuan RMB (US$0.30) for the third hour, and 3 yuan RMB (US$.44) after that (7). The smart card is also integrated with Hangzhou's public transit system and offers users a 10% discount for taking BRT or the bus (6).

As of March 2011, the service operated 60,600 bicycles and 2,416 fixed stations in eight core districts. They include: Shangchen, Xiacheng, Jianggan, Gongsu, Xihu, Binjiang, Xiaoshan, and Yuhan. The average distance between two stations was about 300 meters. In 2011, the bikesharing program will expand from 6,000 shared bicycles to 15,000 shared bicycles in the Binjiang, Xiaoshan, and Yuhan districts (Xuejun Tao, unpublished data).

In contrast to other large-scale bikesharing programs, Hangzhou has experienced minimal bike theft or vandalism as a result of cameras at each docking station and low-cost bikes (16). Due to its lower costs, the service is less expensive than other programs. This has enabled 90% of total trips to be made free of charge (17). Eighty-eight percent of bikesharing users are residents (the remainder are tourists), and more than 25% of trips are made during peak workday hours (16). Residents use bikesharing instead of their own bicycles primarily due to bike theft and maintenance concerns. In addition, bikesharing supports one-way trips and inter-modal transfers, which private bicycles cannot. Due to high use, the service operates 35 stations, 24-hours a day, while the majority operate from 6:00 a.m. to 9:30 p.m. to allow for bicycle redistribution and maintenance. By February 2011, five more 24-hour service stations were added, bringing the total to 40, 24-hour stations. During open hours, program workers at the 100 busiest stations use handheld devices to check-in/checkout bikes in the event that parking spaces are no longer available (18).

In the future, station billboards and bicycle advertisements will be the main revenue source. Annual revenue for 50,000 bikes is expected to be 10 million yuan RMB (US$1.46 million) or more; station billboard revenue is expected to be much higher (19). In the next section, the authors provide a review of the innovation adoption literature.

Innovation Adoption Literature

To understand bikesharing behavioral adoption trends, it is important to identify factors that influence bikesharing adoption and rejection. In the *Diffusion of Innovations*, Rogers identifies four variables that influence the adoption process: 1) prior conditions (i.e., previous practice, felt needs, innovativeness, and social norms); 2) characteristics of the decision maker (i.e., socioeconomics, personality variables, and communication behavior); 3) perceived innovation characteristics (i.e., relative advantages, comparability, complexity, trialability, and observability); and 4) communication channels (i.e., interpersonal information and mass media) (21).

Many researchers have applied Rogers' model in examining adopter and non-adopter behavior. These studies have explored many innovative products and services ranging from personal computers to residential heating systems (22, 23, 24). In this section, the authors review the adoption literature of a few environmentally beneficial innovations, including low-emission vehicles (LEVs), low carbon products, and carsharing (i.e., short-term auto use).

Based on a study of electric vehicle (EV) adoption, Gärling and Thøgersen suggest that early adopters are best understood in terms of a specific product's "innovativeness"—a preference to learn about and adopt innovations in a particular area. Using Rogers' model, Gärling and Thøgersen note that product specific innovativeness arises from a favorable innovation perception. In their study, early adopters were generally more educated and exhibited higher experimentation levels, knowledge, and competence. Since they were heavy users of similar products, this facilitated their understanding of EV advantages (25). Product specific innovativeness had a greater influence on early adopters than demographic and personal characteristics because EVs are "high involvement" products (i.e., high cost and visibility). Gärling's research suggests that EV producers should advertise EVs in terms of their advantages (e.g., environmental friendliness) to encourage adoption and a favorable perception of EVs among consumers.

Roy (2007) designed a model to examine factors that influence the adoption and use of low and zero carbon (LZC) products and technologies. This model includes four variables that influence the adoption process: 1) socio-economic context (e.g., government promotion, fuel prices); 2) communication sources (e.g., government, inter-personal); 3) consumer variables (e.g., income, energy use, education); and 4) product/system properties (e.g., performance, ease of use, safety). He found that LZC adoption is complex, and influencing factors differ for specific products. He also identified "hotspots" (e.g., utility, symbolism, price) or common factors that can influence a wide range of people and products/services at different stages of the adoption/rejection process. Hotspots may be susceptible to change by introducing technical/design improvements, regulation, consumer information, or financial measures (26).

In addition, Lane (2007) studied Roy's approach and defined several key factors influencing LEV consumer adoption/rejection: 1) high purchase price and long payback time; 2) ease and convenience of use; 3) lack of integration between products/systems; and 4) a desire to advertise "green" credentials (27). Caird et al. (2008) identified variables that influence consumer adoption decisions and LZC use in the United Kingdom. They found that adopters generally share similar "drivers" (e.g., cost savings), but there were often different adoption barriers (e.g., high up front costs and limited information).

Since the 1990s, carsharing has spread rapidly throughout the world. This has prompted several empirical studies on behavioral adoption. Shaheen (1999) conducted a longitudinal survey of individuals interested in joining a carsharing program and found that sociodemographic (e.g., age, gender, income, auto ownership) and psychographic characteristics (i.e., attitudes toward current modes, vehicles, congestion, environment, and experimentation) impact an individual's decision to participate (28).

Meijkamp (2000) categorized the possible determinants of carsharing adoption as: 1) personal (e.g., car ownership, auto use frequency); 2) service oriented (e.g., carsharing availability near home); and 3) context oriented (e.g., rising vehicle costs, fuel price). He compared adopters and non-adopters across two aspects: individual characteristics and carsharing perception. Using a telephone survey, Meijkamp tested differences between adopters and non-adopters. The results showed that some individual characteristics correlate significantly with adoption. They include (listed by importance): 1) perception of car costs, 2) involvement with car costs, 3) familiarity with and frequency of car rental, 4) comparison of the private vehicle to public transit, 5) prior car ownership, 6) consideration of public transit use, 7) technology use, 8) education, 9) private vehicle use in commuting, and 10) frequency of car use. Results also showed that carsharing perception (e.g., cost, quality) contributes to carsharing adoption (29).

In 2005, Millard-Ball et al. authored a meta-analysis of previous carsharing studies. The study also included an Internet-based survey to understand participant behavioral characteristics (e.g., trip purpose, trip frequency) and environmental and attitudinal concerns. The authors found that gender, age, and income levels were associated with different motives for adopting carsharing. Members were typically between the ages of 25 and 45, from small households, and were more likely to be male (30). In a study of nearly 6,300 North American carsharing members, Martin and Shaheen (2010) found that users were generally between the ages of 30 to 50, have a bachelor's or master's degree, and are more likely to be female (31).

Overall, the above studies identified several common factors to behavioral adoption, including demographics, attitudes, and innovation perception. Building upon this understanding, the authors employ five key variables to explore bikesharing adoption: 1) before and after travel behavior, 2) sociodemographics, 3) psychographics, 4) bikesharing perception, and 5) bikesharing conditions. Unlike Rogers and Roy, the authors do not examine communication channels in this paper. While bikesharing is associated with a number of social and environmental benefits, it is important to note that it has lower learning requirements and innovation costs than carsharing and LEVs. These differences are notable and can affect the adoption process. This study provides a case study of a transportation innovation with low user adoption costs (i.e., limited training and inexpensive). Further, the widespread availability and use of bikesharing over 1.5 years in Hangzhou provides a unique opportunity for researchers to understand early adoption and behavioral trends, including program perception and recommendations.

METHODOLOGICAL DISCUSSION

Due to the institutional and logistical difficulty in conducting random household surveys in China, researchers designed and conducted an intercept survey in five core districts of Hangzhou with bikesharing. The survey was conducted from January 14, 2010 to March 14, 2010. The authors employed three researchers to implement the survey who were familiar with the Hangzhou bikesharing system and lived there. The surveyors received a strict protocol for engaging respondents. The survey was administered on both workdays and weekends to collect as broad a range of respondent types. The response rate was approximately 20%, with 806 completed surveys: 666 members and 140 non-members.

Survey Design and Administration

To gain a subgroup comparison of bikesharing members and non-members, the authors designed two separate questionnaires. The two questionnaires included the same questions for the respondent's household transport activities, views on several environmental issues, and demographic information. These questions were administered to both members and non-members to identify any differences between their demographic characteristics, travel behaviors, and attitudes.

Both instruments also included a variety of questions exploring bikesharing perception. While non-members have not used bikesharing, the service is widely distributed in five districts. Thus, non-members were able to comment on their program perceptions even as non-users. Non-members were asked to rate on a scale of one to five, their agreement or disagreement with a series of statements about the bikesharing service. For example, "Although I have not used bikesharing personally, from my existing knowledge and observations of others' experience of bikesharing use, I think that...."

In addition, the member questionnaire explored reasons for adoption, bikesharing use, and behavioral change. In contrast, the non-member survey queried reasons for not adopting bikesharing. Before the survey was launched, a pre-test of 10 members and 10 non-members was administered in Hangzhou to identify potential problems with the questionnaires and to prevent biases. Some questions were found to be confusing, and they were corrected.

The three surveyors conducted the intercept survey at bus stations, bikesharing stations, shopping centers, and busy street corners. Researchers screened potential participants for inclusion based on whether they had heard about the bikesharing program and were older than 18. Researchers remained nearby to answer any questions during survey completion. The surveyors were instructed to collect approximately 650 member and 150 non-member surveys. Bikesharing members were intentionally over sampled to understand bikesharing use and behavioral changes.

Study Limitations

With any survey, there is a self-selection bias. In particular, the refusal rate of older adults was higher in this study. Indeed, two to three younger adults (18 to 45) out of 10 refused to take the survey, in contrast to six to seven out of 10 older adults (45+). Survey refusal among this subgroup has received special attention (32). This has been explained by less willingness to participate, a greater tendency to regard questions as sensitive or threatening, and a susceptibility to a wider range of health problems (32, 33).

As our research seeks to understand the effects of bikesharing on mobility behavior, a longitudinal study would have been more appropriate in capturing change in attitudes and behaviors over time. However, this was not feasible due to the study's restricted time and financial budget. Thus, the authors relied upon the members' self-reported behavior and estimation of past mobility behaviors.

Despite the noted survey limitations, this study provides preliminary insights into behavioral response and adoption trends among early members and non-members of bikesharing in Hangzhou. However, these results cannot necessarily characterize bikesharing response in other regions in China, which may be different. For similar locations, however, this survey can inform researchers of what to explore and perhaps can enable improvements in future studies.

RESULTS

The study results are organized into four sections. The first includes a demographic profile of members and non-members with comparisons to the Hangzhou population. The next section evaluates the difference in attitudinal variables among members and non-members. The authors differentiate two subgroups within the sample of non-members, based on their stated intention to join bikesharing in the near future (i.e., next six months). Next, the authors explore the travel patterns of members and non-members and how travel has shifted among members due to bikesharing use. The final section analyzes how members and non-members differ in their bikesharing perception and recommendations to improve the service.

Sample Demographics

In this study, the authors used demographic characteristics (e.g., household income, age) to profile the study population and statistically evaluate the distinctions between members and non-members. Table 1 provides a profile of the sample (including age, income, education, and occupation), with a total of 806 observations: 666 members and 140 non-members. Question refusal rates between members and non-members were not statistically significant. In total, 17% refused to provide income, 2% age, and 0% education and occupation. The average age of members was 31.82 and 28.68 for non-members. The difference between members and non-members is statistically significant (p=0.00). The results suggest that members are likely to be under age 45. The age distributions of both samples depart from the general Hangzhou age distribution, which includes a larger proportion of older adults. Nevertheless, the sample provides a good comparison between bikesharing members and people who could adopt bikesharing but have not.

The income distribution indicates that household income for non-members is more dispersed than members. While about 73% of members have a mid-household income between 40,000 yuan RMB ($5,857) and 100,000 yuan RMB ($14,641), only 46% of non-members have this income. In contrast, the non-member sample exhibited higher proportions of lower and higher incomes. The income distribution of the overall sample is reflective of the Hangzhou income distribution.

TABLE 1 Demographic Profile of the Sample

Table 1 also shows that the occupation of members is spread wider than non-members, while 81% of non-members are company staff, 62% of members are included in this category. The remaining members are mainly staff of commercial services/government or college students, and the difference in the distributions is statistically significant (p=0.00). There is little distinction between members and non-members in terms of gender and education level. The authors found that individuals over 45 have a much lower education than younger respondents. These demographics exhibit an important fact: China has undergone a huge expansion in higher education since 1978. Particularly after 1999, higher education has transformed into a mass access system. Thus, there is a considerable generational gap in education between the younger and the 45+ age group; this likely contributed to differences in survey receptiveness.

Attitudinal Analysis

An analysis of attitudinal variables among members and non-members revealed an important schism in the sample. The non-member sample was asked separately: "Will you begin to use bikesharing within the next six months?" About half of the non-member respondents replied "Probably" or "Definitely" (hereafter called "prospective-member"), and these respondents exhibited a considerable difference in attitudinal variables in comparison to non-members who did not indicate a propensity to join bikesharing (hereafter called "persistent-non-members"). Table 2 illustrates the differences in the attitudinal response of members, prospective-members, and persistent-non-members.

TABLE 2 Attitudes on Hangzhou Cycling Conditions and Environmental Issues

Attitudinal Statements Percent Strongly Agree and Agree		Member (n=666)	Non-Member	
			Prospective Member (n=79)	Persistent-Non-Member (n=61)
Hangzhou Cycling Conditions	The weather is suitable for cycling*	93%	85%	51%
	Cycling is safe in Hangzhou†*	83%	70%	44%
	The price of public transit is expensive*	68%	62%	39%
	Public transit is often crowded	88%	77%	69%
	Waiting time for public transit is often long	64%	84%	72%
Environmental Issues	Motor vehicle usage is an important reason for environmental problems†*	93%	97%	77%
	I'd be willing to ride a bicycle or take transit to help improve air quality†*	91%	96%	77%
	Global warming is currently happening†*	90%	100%	66%
	Global warming is caused by human activity*	92%	96%	69%

†Members and Prospective-Members different to a degree that is statistically significant at 95% level (Mann-Whitney)
*Prospective-Members and Persistent-Non-Members different to a degree that is statistically significant at 95% level (Mann-Whitney)

Among these three subgroups, bikesharing members have the most positive attitudes toward Hangzhou's cycling conditions and persistent-non-members the most negative. While there are modest differences between members and prospective-members in their perception of Hangzhou's cycling conditions, bigger differences were found between the prospective-members and persistent-non-members.

With respect to environmental attitudes, the authors found that although prospective-members had not adopted bikesharing, they were most aware of environmental problems and expressed the highest willingness to shift behavior. Members have similar but a little less positive attitude. In contrast, persistent-non-members exhibited a much lower awareness and willingness to change behavior. Since many of these differences are statistically significant, and these divisions are relevant to bikesharing response, the authors maintain these divisions in the travel behavior analysis.

Travel Behavior

The bikesharing system in Hangzhou appears to be playing an important role in facilitating new forms of travel behavior among residents. This role is evident from the commute patterns of members and non-members. Overall, the existing commute profile suggests that public transit and bicycling are major components of commuting behavior within the sample. The sample commuted to work an average of 5.32 days per week, as roughly 230 respondents commuted to work six or more days a week.

The authors' analysis of bikesharing usage patterns indicates that 70% of bikesharing members used the service in their commute *at least occasionally*. In contrast, only 30% *regularly* used it as part of their commute. Members also use bikesharing for non-work trips related to shopping, entertainment, and other errands. Users can make one-way bike trips between stations and use bikesharing far from home and close to work. As testament to this, 40% of members stated the station they used most is closest to work. Another 40% reported the station they used most was closest to home. The remaining 20% was divided among proximity to school, bus stations, attractions, and scenic locations.

Not surprisingly, non-members exhibited less frequent bike use overall. Only 20% of persistent-non-members used their personal bicycle for work, and only 30% of prospective-members used bikes to commute. As of this writing, personal bicycles were not permitted on the bus system. Hence, non-members who bike to work need the bike for their entire trip. Interestingly, members and prospective-members had higher average vehicle ownership. This implies that, at least in the near term, auto ownership is not associated with lower bikesharing adoption.

Bicycle ownership for traditional or electric bicycles was not statistically significant between members and non-members. Average bicycle ownership for members is 0.55 bicycles/household and 0.49 bicycles/household for non-members. The average electric bike ownership for members and non-members is 0.40 electric bicycles/household. For members that do bikeshare, 144 were car owners and the majority (58.3%) also owned one or more bike—traditional or electric. As a result, the majority of bikesharing members who owned a personal vehicle also owned an electric or traditional bicycle.

Table 3 below illustrates how bikesharing members shifted their travel modes for all trips due to bikesharing, as categorized by how they commuted at the time of the survey. Many members still commute without bikesharing and may substitute other trips with it or use it less frequently to commute.

TABLE 3 Travel Effects Due to Bikesharing Use

Category	Commute Modes	Total	Before bikesharing service started, how did you manage the part of the trip you are now doing by bikesharing?								
			Walking	Private Bike	Motorbike	E-bike	Public Transport	Water Bus	Private Car	Taxi	Carpool
Commute using Bikesharing	Walk Bikesharing	75	83%	73%	--	79%	96%	--	--	31%	20%
	Walk Bikesharing Bus	49	92%	55%	--	63%	94%	--	--	--	--
	Bikesharing	26	27%	35%	--	27%	35%	--	--	23%	--
	Walk Bikesharing Electric-bike	0	--	50%	--	100%	100%	--	43%	43%	--
	Walk Bikesharing Electric-bike Bus	0	100%	100%	--	100%	100%	--	--	100%	100%
	Bikesharing Bus	10	60%	40%	20%	70%	70%	--	20%	40%	20%
	Bikesharing Electric-bike	0	83%	83%	--	100%	83%	--	--	--	--
Commute without Bikesharing	Walk Bus	177	47%	--	--	--	82%	--	--	21%	--
	Bus	70	49%	--	--	21%	74%	--	--	29%	--
	Electric-bike	0	62%	21%	--	69%	62%	--	--	21%	--
	Electric-bike Bus	0	89%	67%	36%	84%	67%	--	20%	24%	--
	Bus PrivateCar	47	89%	--	28%	34%	66%	--	87%	94%	--
	PrivateCar	37	54%	--	22%	24%	41%	--	78%	43%	--
	Walk	20	50%	--	--	--	85%	--	--	--	--
	PrivateBike	16	38%	38%	--	--	38%	--	--	31%	--
	PrivateBike Bus	2	50%	--	--	50%	100%	--	--	--	50%
	No Commute	10	30%	30%	--	--	70%	--	--	--	--
	Bus WaterBus	4	--	--	--	25%	100%	--	--	25%	--
	Walk Electric-bike	0	83%	50%	33%	83%	67%	--	--	33%	--
	Other	3	100%	67%	--	67%	100%	--	--	33%	33%
Total		546	75%	38%	11%	50%	92%	7%	21%	37%	15%
Car Owners v. Carless	Car Owning Households	144	62%	17%	25%	40%	49%	3%	78%	63%	2%
	Carless Households	522	61%	35%	5%	41%	83%	6%	0%	22%	15%

Because I use bikesharing I…	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Walk more often	21%	39%	36%	4%	0%
Use public transit more often	3%	38%	45%	14%	0%
Make fewer trips by auto	6%	62%	23%	6%	4%
Save money on transportation	18%	56%	20%	6%	0%
Have postponed buying a private bike	17%	42%	28%	14%	0%
Have postponed buying a car	0%	37%	33%	23%	7%
Like Hangzhou much more	37%	59%	3%	0%	0%
Think cycling is much more convenient in Hangzhou than before	36%	48%	15%	1%	0%

-- Percent of respondents amounted to less than 20%

Table 3 provides evidence that bikesharing is shifting travel in several ways. A large majority of members seem to be using bikesharing for trips in which they previously walked or took bus transit. Thus, bikesharing is becoming a substitute for these modes and is taking people off bus transit. In addition, 30% are substituting bikesharing for taxi trips. Among auto users, at least 80% indicated substituting bikesharing for commute trips. In contrast, among non-car members the substitution of public transit with bikesharing is dominant.

The most convincing evidence of bikesharing's impact on the auto commute is evident in the middle section of Table 3, which shows how respondents within car and carless households shifted travel patterns. A striking result is that 78% of car-owner respondents stated that they used bikesharing for trips previously taken by auto. Roughly 50% of car households also used bikesharing to substitute bus transit. Among carless households, more than 80% indicated that they previously used bus transit for trips they now take with bikesharing. Furthermore, 60% of carless households substituted walking and 20% substituted taxi trips with bikesharing.

The bottom section of Table 3 reinforces this evidence with a member self-assessment of bikesharing's impact on their travel behavior and Hangzhou impressions. The left light gray columns indicate the percentage of members that agree or strongly agree with each statement. A majority felt they walked more often, made fewer auto trips, saved money on transportation, postponed buying a private bike, liked Hangzhou much more, and felt it was more convenient to bicycle due to bikesharing. A minority felt bikesharing caused them to use public transit more often and made them postpone a car purchase.

Overall, these results strongly suggest that bikesharing is shifting people towards bicycle use. In particular, the system appears to be drawing users from bus transit, auto use, and walking. Bikesharing is improving the modal share of biking at the expense of most other modes. The Hangzhou bus transit system has limited capacity. Bus transit is the mode with the highest use among the sample, and it is also the mode from which the greatest share is drawn. Despite growing auto travel in Hangzhou, bikesharing adoption appears to have reduced the total amount of auto trips (private car, taxi, carpool, and motorbike).

Bikesharing Perceptions and Recommendations

The authors also examined bikesharing perceptions and recommendations. Over 80% of bikesharing members were very satisfied with the system due to its low cost, smart cards, station abundance, and minimal problems. Nevertheless, there were complaints related to limited parking space and bike availability (weekends) and inconvenient hours of operation. Only 12% of members thought the operating hours were convenient; this percentage was much lower in contrast to prospective-members and persistent-non-members. In addition, members indicated that providing real-time bike/parking availability information, more bikesharing stations, and better bike maintenance would improve the service.

For prospective-members, improving bike maintenance, providing real-time bike/parking availability, and adding more bikesharing stations would be effective. Persistent-non-members had the lowest perception across most bikesharing aspects. Key reasons for not using bikesharing included the hassle of the smart card application process (i.e., inconvenient office location, long lines); fear of not obtaining a bicycle or parking when needed; and cycling dislike. Despite these concerns, persistent-non-members offered suggestions for system improvement including enhanced bike locking technologies and more bikesharing stations.

CONCLUSION

Despite China's moniker as the "Kingdom of Bicycles," the nation's bike use has steadily declined over the past 20 years. In 2004, the Hangzhou Municipal Government adopted the "Public Transit Priority" policy to address growing environmental and traffic concerns and to encourage greater public transport use. The Hangzhou Public Bicycle service is part of this effort. In 2010, the authors implemented a survey of Hangzhou bikesharing members and non-members to examine the impacts of this service on travel behavior and to gain an early understanding of adoption and behavioral response. The program was about 1.5 years old at the time of the survey.

Overall, the authors found that bikesharing is capturing modal share from bus transit, walking, autos, and taxis. In addition, nearly 30% of members incorporated bikesharing into their most common commute. Members indicated that they most frequently used a bikesharing station closest to either home (40%) or work (40%). These modal shifts suggest that bikesharing acts as both a competitor and a complement to the existing public transit system. In addition, bikesharing appears to be reducing automotive travel, especially for bikesharing households that own cars. This suggests that car ownership does not lead to a reduced propensity to use bikesharing. In fact, members exhibited a higher rate of auto ownership in comparison to non-members. Hence, bikesharing appears to have reduced automobile emissions. While some of this reduction seems to come at the expense of public transit ridership, in a city where buses are very crowded, a reduction in transit use among those that shift to bikesharing may provide new capacity for others that cannot.

The majority of bikesharing members were very satisfied with the service (i.e., low cost, smart cards, station abundance, and program management). Nevertheless, recommendations were made for improvement including increased parking space and bike availability (weekends) and extended hours of operation. Indeed, only 12% of members thought the operating hours were convenient. Please note the hours of operation were extended from 6:30 a.m. - 9 p.m. to 6:00 a.m. – 9:30 p.m. in January 2011, after the authors' survey. In addition, members indicated that providing real-time bike/parking availability information, more bikesharing stations, and better bike maintenance would improve the program. Not surprisingly, persistent-non-members had the lowest bikesharing perception. Key issues included perceived hassle of the smart card application process, fear of not obtaining a bicycle or parking space when needed, and cycling dislike. Suggestions among this group to encourage their participation included enhanced bike locking technologies and more bikesharing stations. To summarize, the insights gained from this study provide an understanding of early adoption behavior and response to the world's largest bikesharing service, as well as opportunities for improving and expanding membership in Hangzhou and perhaps other bikesharing cities.

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