China's Hangzhou Public Bicycle

Understanding Early Adoption and Behavioral Response to Bikesharing

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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 Public Transit Priority to encourage public transport initiatives. As part of this effort, the government of the city of Hangzhou launched Hangzhou Public Bicycle in 2008. This service allows members to access a shared fleet of bicycles. As of March 2011, Hangzhou Public Bicycle 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 nonmembers to identify key differences and similarities between these groups. In total, 806 surveys were completed by 666 members and 140 nonmembers. The authors found that bikesharing was 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 suggested that bikesharing acted as both a competitor and a complement to existing public transit. Members exhibited a higher rate of auto ownership than nonmembers. This finding suggested that bikesharing was attractive to car owners. Recommendations for improving bikesharing in Hangzhou included adding stations and real-time bike and parking availability technologies, improving bike maintenance and locking mechanisms, and extending operational hours.

In the 1970s, China was named the Kingdom of Bicycles because of the nation's heavy reliance on cycling for mobility. China's citizens relied on bicycles because of their relatively low income, the country's compact urban development, and the short trip distances. Over the past 20 years, however, bicycle use has steadily declined because of 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 per 100 households in 1993 to 113 bikes per 100 households in 2007 (*1*). Even some traditional cycling cities, in which the topography and weather are 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*).

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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 to provide 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 uses advanced technologies and management strategies that 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 and check-out 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, personal communication, July 26, 2010).

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 use their public transit cards for bikesharing and receive a transit discount, because the program's principal aim is to enhance and link to transit (*6, 7*). Additional program features include 24-h service centers and 1 full hour of free bikesharing, followed by incremental pricing. The Hangzhou system uses fixed bicycle docking stations. On its launch, the program initially relied on 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 from bike theft and vandalism, the program uses inexpensive, one-speed bicycles.

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

BACKGROUND

Bikesharing Worldwide

Bikesharing was first launched in Europe in 1965. Since then, bikesharing programs have grown exponentially across the globe.

Bikesharing currently 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 more than 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 often either damaged or stolen.

Second-generation systems, also known as "Coin Deposit Systems," improved on first generation systems by incorporating a bicycle lock that required users to insert a refundable deposit to unlock and use a bicycle. Although 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 information technology–based systems, used designated docking stations and smart technology (i.e., smart cards or mobile phones) for bicycle check-in and check-out. 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, multimodal systems." Integration with larger public transport systems via smart cards is a key feature (*5*). Currently, 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 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 with 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.), Vélo′v (Lyon, France), and Vélib′ (Paris) have found that many program users are using bikesharing to make trips they would otherwise have made with private vehicles (*9*–*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 after the launch of a bikesharing program. For example, during the first year of Vélo′v, Lyon experienced a 44% increase in bicycle use (*10*).

Despite the benefits of bikesharing, obstacles, such as limited supportive infrastructure (e.g., 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′ used custom-designed buses to move bicycles. Bixi (Montreal) has augmented this approach by equipping its buses with real-time bike station information. However, both programs use carbon-emitting vehicles to redistribute bicycles. In the future, cleaner redistribution strategies could be used.

Overview of Hangzhou

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 km^2, 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 U.S. $36.2 billion, a 10% increase from the previous year, despite the global financial crisis (*2*).

Hangzhou's economic development also has affected 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%) make up 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 was 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 and 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 many existing initiatives, such as the creation of bus rapid transit 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. Currently, 84% of the secondary and main roads in Hangzhou are physically separated between motorized and nonmotorized 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; $26.35 million; 1 yuan RMB = $0.15, 2010 U.S. dollars) to launch this program and provided 270 million yuan RMB ($39.53 million) discounted governmental loans to the enterprise (Yang Tang, personal communication, April 6, 2010).

The Hangzhou Public Bicycle service is classified as a third-generation bikesharing program, because it uses smart cards, automated check-in and check-out, and distinguishable bicycles and docking stations (*5*). In the future, this system could be classified as a fourth-generation service, because 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 Shaheen et al. (*5*) and DeMaio and Gifford (*15*). The first hour of use is free; this hour is followed by incremental pricing in which users pay an additional 1 yuan RMB ($0.15) for the second hour, 2 yuan RMB ($0.30) for the third hour, and 3 yuan RMB ($.44) after that (*7*). The smart card is also integrated with Hangzhou's public transit system and offers users a 10% discount for taking bus rapid transit or the bus (*6*).

As of March 2011, the service operated 60,600 bicycles and 2,416 fixed stations in eight core districts: Shangchen, Xiacheng, Jianggan, Gongsu, Xihu, Binjiang, Xiaoshan, and Yuhan. The average distance between two stations was approximately 300 m. 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, personal communication, July 26, 2010).

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*). Because of 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 because of bike theft and maintenance concerns. In addition, bikesharing supports one-way trips and intermodal transfers, which private bicycles cannot. Because of high use, the service operates 35 stations 24 h a day, whereas 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-h service stations were added, bringing the total to 40 stations operating 24 h a day. During open hours, program workers at the 100 busiest stations use handheld devices to check-in and check-out 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 ($1.46 million) or more; station billboard revenue is expected to be much higher (*19*).

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 identified four variables that influence the adoption process: (*a*) prior conditions (i.e., previous practice, felt needs, innovativeness, and social norms), (*b*) characteristics of the decision maker (i.e., socioeconomics, personality variables, and communication behavior), (*c*) perceived innovation characteristics (i.e., relative advantages, comparability, complexity, trialability, and observability), and (*d*) communication channels (i.e., interpersonal information and mass media) (*20*).

Many researchers have applied Rogers' model in examining adopter and nonadopter behavior. These studies have explored many innovative products and services ranging from personal computers to residential heating systems (*21–23*). In this section, the authors review the adoption literature of a few environmentally beneficial innovations, including low-emission vehicles, low carbon products, and carsharing (i.e., short-term auto use).

On the basis of a study of electric vehicle (EV) adoption, Gärling and Thøgersen suggested 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 noted 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. Because they were heavy users of similar products, this use facilitated their understanding of EV advantages (*24*). Product-specific innovativeness had a greater influence on early adopters than demographic and personal characteristics because EVs are "high involvement" products (i.e., they have high cost and visibility). Research by Gärling and Thøgersen suggested 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 (*24*).

Roy et al. designed a model to examine factors that influence the adoption and use of low-and-zero-carbon products and technologies (*25*). This model includes four variables that influence the adoption process: (*a*) socioeconomic context (e.g., government promotion, fuel prices), (*b*) communication sources (e.g., government, interpersonal), (*c*) consumer variables (e.g., income, energy use, education), and (*d*) product and system properties (e.g., performance, ease of use, safety). They found that low-and-zero-carbon adoption is complex, and influencing factors differ for specific products. They also identified hotspots (e.g., utility, symbolism, price) or common factors that can influence a wide range of people and products and services at different stages of the adoption–rejection process. Hotspots may be susceptible to change by introducing technical or design improvements, regulation, consumer information, or financial measures (*25*).

In addition, Lane and Potter (*26*) studied the approach by Roy et al. and defined several key factors influencing low-emission vehicle consumer adoption or rejection: (*a*) high purchase price and long payback time, (*b*) ease and convenience of use, (*c*) lack of integration between products and systems, and (*d*) a desire to advertise green credentials (*26*). Caird et al. (*27*) identified variables that influence consumer adoption decisions and low-and-zero-carbon use in the United Kingdom. They found that adopters generally share similar motivation (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 phenomenon has prompted several empirical studies on behavioral adoption. Shaheen 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) affect an individual's decision to participate (*28*).

Meijkamp (*29*) categorized the possible determinants of carsharing adoption as (*a*) personal (e.g., car ownership, auto use frequency), (*b*) service oriented (e.g., carsharing availability near home), and (*c*) context oriented (e.g., rising vehicle costs, fuel price). He compared adopters and nonadopters across two aspects: individual characteristics and carsharing perception. Using a telephone survey, Meijkamp tested differences between adopters and nonadopters. The results showed that some individual characteristics correlate significantly with adoption. They include (listed by importance) (*a*) perception of car costs, (*b*) involvement with car costs, (*c*) familiarity with and frequency of car rental, (*d*) comparison of the private vehicle to public transit, (*e*) prior car ownership, (*f*) consideration of public transit use, (*g*) technology use, (*h*) education, (*i*) private vehicle use in commuting, and (*j*) 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. conducted a meta-analysis of previous carsharing studies (*30*). 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 more likely to be male (*30*). In a study of nearly 6,300 North American carsharing members, Martin et al. found that users were most likely to be between the ages of 30 and 50, have a bachelor's or master's degree, and be female (*31*).

Overall, the studies described identified several common factors to behavioral adoption, including demographics, attitudes, and innovation perception. Building on this understanding, five key variables were used to explore bikesharing adoption: (*a*) before-and-after travel behavior, (*b*) sociodemographics, (*c*) psychographics, (*d*) bikesharing perception, and (*e*) bikesharing conditions. Unlike the study by Rogers and Roy, communication channels were not examined in this study. Although bikesharing is associated with several social and environmental benefits, it is important to note that it has lower learning requirements and innovation costs than carsharing and low-emission vehicles. 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.

METHODOLOGY

Because of 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 used three researchers to implement the survey who were familiar with the Hangzhou bikesharing system and lived in the city. The surveyors received a strict protocol for engaging respondents. The survey was administered on both workdays and weekends to collect a broad range of respondent types. The response rate was approximately 20%, with 806 completed surveys: 666 by members and 140 by nonmembers.

Survey Design and Administration

To gain a subgroup comparison of bikesharing members and nonmembers, 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 nonmembers to identify any differences between their demographic characteristics, travel behaviors, and attitudes.

Both instruments included a variety of questions exploring bikesharing perception. Although nonmembers have not used bikesharing, the service is widely distributed in five districts. Thus, nonmembers were able to comment on their program perceptions even as nonusers. Nonmembers were asked to rate, on a scale of 1 to 5, 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. By contrast, the nonmember survey queried reasons for not adopting bikesharing. Before the survey was launched, a pretest of 10 members and 10 nonmembers 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 on the basis of 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 nonmember surveys. Bikesharing members were intentionally oversampled 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) of 10 refused to take the survey, in contrast to six to seven of 10 older adults (45+). Survey refusal among this subgroup has received special attention (*32*). This phenomenon 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*).

Because this research sought 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 because of the study's restricted time and financial budget. Thus, the authors relied on 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 nonmembers 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

Sample Demographics

In this study, demographic characteristics (e.g., household income, age) were used to profile the study population and statistically evaluate the distinctions between members and nonmembers. Table 1 provides a profile of the sample (including age, income, education, and occupation), with 806 observations: 666 members and 140 nonmembers. Question refusal rates between members and nonmembers were not statistically significant. In total, 17% refused to provide income, 2% refused to provide age, and 0% refused to provide education and occupation. The average age of members was 31.82 and 28.68 for nonmembers. The difference between members and nonmembers was statistically significant ($p = .00$). The results suggest that members are likely to be younger than age 45. The age distributions

TABLE 1 Demographic Profile of Sample

Category	Members (%)	Nonmembers (%)
Age	*N* = 636	*N* = 139
18–25	23	37
25–35	51	55
35–45	19	6
45–55	3	2
55–65	3	0
Income (thousands yuan RMB)	*N* = 548	*N* = 116
Less than 20	6	16
20–40	5	16
40–70	37	23
70–100	36	22
100–150	9	5
150–200	4	10
More than 200	3	7
Education	*N* = 648	*N* = 139
Primary school	1	0
Junior high school	2	1
Senior high school	13	13
Junior college or college	79	81
Graduate or professional school	5	3
Other	0	1
Occupation	*N* = 655	*N* = 139
Elementary or high-school student	0	1
Undergraduate or graduate student	4	1
Government officer	8	4
Housewife	1	0
Staff member of commercial services	13	7
Staff member of company or enterprise	62	81
Freelancer	9	4
Retired	0	1
Guest worker from another place	1	0
District Surveyed	*N* = 666	*N* = 140
Shangcheng	19 (*N* = 127)	19 (*N* = 26)
Xiacheng	22 (*N* = 147)	28 (*N* = 39)
Gongshu	20 (*N* = 135)	12 (*N* = 17)
Jianggan	18 (*N* = 117)	25 (*N* = 35)
Xihu	21 (*N* = 140)	16 (*N* = 23)

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 nonmembers is more dispersed than it is for members. Although approximately 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 nonmembers have this income. By contrast, the nonmember 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 also shows that the occupation of members is spread wider than it is for nonmembers. Whereas 81% of nonmembers are company staff, 62% of members are included in this category. The remaining members are mainly staff members of commercial services or government or college students, and the difference in the distributions is statistically significant ($p = .00$). There is little distinction between members and nonmembers in terms of gender and education level. People older than 45 had a much less education than did 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 over-45 age group; this generational gap likely contributed to differences in survey receptiveness.

Attitudinal Analysis

An analysis of attitudinal variables among members and nonmembers revealed an important schism in the sample. The nonmember sample was asked separately, "Will you begin to use bikesharing within the next 6 months?" Approximately half of the nonmember respondents replied "probably" or "definitely" (hereafter called "prospective members"), and these respondents exhibited a considerable difference in attitudinal variables compared with nonmembers who did not indicate a propensity to join bikesharing (hereafter called "persistent nonmembers"). Table 2 illustrates the differences in the attitudinal response of members, prospective members, and persistent nonmembers.

Among these three subgroups, bikesharing members have the most positive attitudes toward Hangzhou's cycling conditions, and persistent nonmembers were the most negative. Although 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 nonmembers.

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 had similar but a little less positive attitudes. By contrast, persistent nonmembers exhibited a much lower awareness and willingness to change behavior. Because many of these differences are statistically significant, and these divisions are relevant to bikesharing response, these divisions were maintained 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 nonmembers. 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; roughly 230 respondents commuted to work 6 or more days per week.

Analysis of bikesharing usage patterns indicated that 70% of bikesharing members used the service in their commute at least occasionally. By contrast, only 30% regularly used it as part of their commute. Members also used bikesharing for nonwork trips related to shopping,

TABLE 2 Attitudes About Hangzhou Cycling Conditions and Environmental Issues

Attitudinal Statement	Member ($N = 666$) (%)	Nonmember: Prospective Member ($N = 79$) (%)	Nonmember: Persistent Nonmember ($N = 61$) (%)
Hangzhou Cycling Conditions			
The weather is suitable for cycling.[a]	93	85	51
Cycling is safe in Hangzhou.[a,b]	83	70	44
The price of public transit is expensive.[a]	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.[a,b]	93	97	77
I'd be willing to ride a bicycle or take transit to help improve air quality.[a,b]	91	96	77
Global warming is currently happening.[a,b]	90	100	66
Global warming is caused by human activity.[a]	92	96	69

[a]Prospective members and persistent nonmembers differ to degree that is statistically significant at 95% level (Mann–Whitney test).
[b]Members and prospective members differ to degree that is statistically significant at 95% level (Mann–Whitney test).

entertainment, and other errands. Users can make one-way bike trips between stations and use bikesharing far from home and close to work. As a testament to this practice, 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% were divided among proximity to school, bus stations, attractions, and scenic locations.

Not surprisingly, nonmembers exhibited less frequent bike use overall. Only 20% of persistent nonmembers 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, nonmembers who bike to work need the bike for their entire trip. Interestingly, members and prospective members had higher average vehicle ownership. This finding 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 nonmembers. Average bicycle ownership for members is 0.55 bicycles per household and 0.49 bicycles per household for nonmembers. The average electric bike ownership for members and nonmembers is 0.40 electric bicycles per household. For members who do bikeshare, 144 were car owners and the majority (58.3%) also owned one or more bikes, 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 illustrates how bikesharing members shifted their travel modes for all trips because of 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 provides evidence that bikesharing is shifting travel in several ways. The majority of members appear 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 car users, at least 80% indicated substituting bikesharing for commute trips. By contrast, among noncar 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 bottom section of Table 3. This section 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 for 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. Table 4 reinforces this evidence with a member self-assessment of bikesharing's impact on their travel behavior and Hangzhou impressions. The first two columns indicate the percentage of members who 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 because of 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 toward 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 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

Bikesharing perceptions and recommendations were also examined. More than 80% of bikesharing members were very satisfied with the system because of its low cost, smart cards, station abundance, and

TABLE 3 Effects of Bikesharing on Travel Mode

		Before Bikesharing Service Started, How Did You Manage the Part of the Trip You Are Now Doing by Bikesharing?								
Commute Mode	Total	Walking (%)	Private Bike (%)	Motorbike (%)	Electric Bike (%)	Public Transport (%)	Water Bus (%)	Private Car (%)	Taxi (%)	Carpool (%)
Commute with 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, private car	47	89	—	28	34	66	—	87	94	—
Private car	37	54	—	22	24	41	—	78	43	—
Walk	20	50	—	—	—	85	—	—	—	—
Private bike	16	38	38	—	—	38	—	—	31	—
Private bike, bus	2	50	—	—	50	100	—	—	—	50
No commute	10	30	30	—	—	70	—	—	—	—
Bus, water bus	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 Versus 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

NOTE: — = percentage of respondents was less than 20%.

TABLE 4 Self-Assessment of Impact of Bikesharing

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

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 nonmembers. In addition, members indicated that providing real-time information about bike and parking availability more bikesharing stations, and better bike maintenance would improve the service.

For prospective members, improving bike maintenance, providing real-time information for bike and parking availability, and adding more bikesharing stations would be effective. Persistent nonmembers 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 nonmembers 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, Hangzhou bikesharing members and nonmembers were surveyed to examine the impacts of this service on travel behavior and to gain an early understanding of adoption and behavioral response. The program was approximately 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 finding 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 nonmembers. Hence, bikesharing appears to have reduced automobile emissions. Although some of this reduction appears 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. Hours of operation were extended from 6:30 a.m. to 9:00 p.m. to 6:00 a.m. to 9:30 p.m. in January 2011, after the study survey. In addition, members indicated that providing real-time information about bike and parking availability, more bikesharing stations, and better bike maintenance would improve the program. Persistent nonmembers 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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