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Bicycle Evolution in China: From the 1900s to the Present

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ABSTRACT
This article examines four phases in bicycle evolution in China from initial entry and slow growth (1900s to 1978), to rapid growth (1978 to 1995), bicycle use reduction (1995 to 2002), and policy diversification (2002 to present). Two bicycle innovations, electric bikes, and public bikesharing (the shared use of a bicycle fleet), are also explored in this article. Electric bikes could provide a transitional mode on the pathway to bicycle and public transportation integration or to small battery electric cars. Four lessons have been learned from China's electric bike experience relevant to government policy and management. Public bikesharing represents an important step towards integrating the bicycle with bus, metro, and rail systems. Five early operational lessons have been identified from China's limited public bikesharing experience.

Key Words: bicycle, China, electric bike, evolution, public bikesharing

1. INTRODUCTION

The bicycle has developed in China since the 1900s and has been a mainstay in the nation's transportation system since the late-1970s due to relatively low incomes, compact urban construction, and short trip distances. After the mid-1990s, however, bicycle use steadily decreased as a result of economic growth, increased urbanization, expanded city areas, and a gradually deteriorating cycling environment. For example, as the Chinese Ministry of Housing and Urban-Rural Development declared, bicycle modal share declined from 54% in 1986 to 23% in 2007 in Beijing and from 30% in 1995 to 4% in 2007 in Shenzhen.

This decline was also accelerated by governmental policies, which have focused primarily on motor vehicle use and resulted in a negative attitude toward bicycling. In 1995, the central government declared that the large number of bicycles on the road caused conflicts between motorized and non-motorized vehicles, and this should be controlled in big cities (China State Bureau of Technical Supervision, 1995). Some local governments also adopted policies to decrease bicycle use. For instance, the Transport Master Plan of Guangzhou (1993) established that Guangzhou would cut the bicycle modal share from 33.8% in 1992 to 13.3% in 2010 (Ma, 2004).

However, since dramatic motor vehicle growth has resulted in increased energy consumption, traffic congestion, traffic accidents, and environmental concerns in Chinese cities, doubts and criticisms against motorized transport have arisen. For example, in Shanghai, the number of traffic accidents rose from 12,634 in 1994 to 23,996 in 1998 (Zacharias, 2002). In addition, electric bikes and public bikesharing (the shared use of a bicycle fleet) have spread quickly in China since 1998 and 2005, respectively, making bicycle transport faster and more convenient than traditional bikes. Indeed, the number of electric bikes produced in China increased from 300,000 in 1998 to 30 million in 2010 (Zhen et al. 2008; ResearchInChina, 2011). By the end of February 2012, twelve cities in China had formal public bikesharing programs, with 5331 stations and 180,500 bikes. Under this situation, both the central and local governments have begun to rethink cycling policies. Some strategies were sought to oppose bicycle use restrictions and overcome cycling barriers, such as new separated bike lanes in Beijing, Shenzhen, and Guangzhou.

At present, the central government has not yet announced an explicit plan for bicycle transport, and local government bicycling policies vary from city to city. For example, policymakers' attitudes toward electric bikes are quite different among cities; some of them encourage electric bike use, some ban them, and others are neutral. In addition, even in the same city, bicycling policies change from year to year. For instance, Beijing—which banned electric bikes in 2002—repealed this in 2006. Dalian, which declared the city as a ''non-bicycle city'' in 2000, is planning to add public bikesharing and rebuild its bicycle lanes.

While more than 60% of trips are made by walking and cycling in China and bike ownership is ubiquitous (1.13 bikes per household in 2008), the bicycle is often ignored by researchers and policymakers despite its prominent role in daily mobility since the late-1970s (Xinhua Network, 2009). Data about the bicycle are rare; studies on the bicycle are scarce and conceptual, and the future of the bicycle is unclear. In this article, the authors present an overview of the evolution of the bicycle in China, employing limited data from the China Statistical Yearbook (1980–2009) (National Bureau of Statistics of China, 2009), transport planning documents for many Chinese cities, and survey data from different cities.

This article is organized into four main sections. First, the authors describe the four phases of the bike's evolution in China, based upon bicycle ownership, bicycle modal share, and

governmental policies for bicycling. The next section examines the characteristics of bicycle trips, including bicycle users, distance, and trip time. Third, two bicycle innovations in China, electric bikes and public bikesharing, are discussed. Finally, the authors provide a conclusion and recommendations.

2. BICYCLE EVOLUTION IN CHINA: FOUR PHASES

The authors have identified four phases in China's bicycle evolution: (1) initial entry and slow growth (1900s to 1978), (2) rapid growth (1978 to 1995), (3) bicycle use reduction (1995 to 2002), and (4) policies diversification (2002 to present). These four phases are summarized in Figure 1. The division of these four phases is based on some symbolic events, they include: (1) the ''economic reformation of China'' in 1978, which led to an intense economic and social restructuring until today, separates phases one and two, and (2) the release of the Standard of Urban Road Traffic in 1995 marks the beginning of the third phase, as it is the central government's first and only document that gave explicit direction on bicycle transportation and caused a reduction in bicycle use, and (3) the White Paper of Shanghai Urban Transport Development is the beginning of phase four, it is the first document that defined bicycle as a complement to public transportation rather than a competitive mode. Since then, although bike ownership and bicycle modal share continued to decrease as in phase three, the government's attitude towards bicycle transport began to change.

The evolution is discussed with respect to three key aspects: (1) bicycle ownership and growth trends, (2) bicycle modal share, and (3) governmental bicycle policies.

2.1. Bicycle Ownership and Growth Trends

In the 1900s, the royalty imported the bicycle to China as a luxury good. Bicycle use grew rather slowly over a long time period, as only the rich could afford bikes. Things changed when China started its economic reform in 1978. Since this time, China opened to the outside world and began a remarkable transformation in terms of economics, politics, and culture. As a result, bicycles became affordable by even relatively low-income households, and ownership grew quickly. The peak in bicycle ownership occurred in urban and rural China (197 and 147 bikes=hundred households) in 1993 and 1995, respectively. After that, bicycle ownership decreased steadily (see Fig. 2).

Bicycle ownership can be associated with many factors, among which income may be the most important. As Figure 3 shows, bicycle ownership among the richest 10% of households was somewhat higher than that of middle-income households before 1988, and it was much higher than the poorest 10%. However, after 1988, bicycle ownership for middle-income households was almost the same or higher than the richest 10%; this may be due to the richest households acquiring other vehicles, such as motorcycles, electric bikes, or private automobiles. However, bicycle ownership for middle-income households is still higher than the
poorest 10%, at present.

While bicycle ownership fell rapidly after 1996, motorcycle and electric bike ownership increased at a notable rate (see Fig. 4). Although almost all Chinese cities show a similar bicycle evolution, differences in bicycle use among Chinese cities are more pronounced than before. For example, bicycle ownership in Hunan—a place where the weather and topography is not suitable for cycling—was 155 bicycles=hundred households (or 79 bikes=hundred households lower than Beijing in 1991, with 234 bicycles=hundred households). In 2006, Hunan had 49 bicycles=hundred households, which was 142 bikes lower than Beijing at that time (i.e., 191

bicycles=hundred households). This growing disparity is likely due to individuals having more modern transportation choices today than in the past (National Bureau of Statistics of China, 1981–2007).

Phase One: Initial Entry and Slow Growth (1900s to 1978)
• Bicycle entered China as a luxury good for rich people; • Number of bicycles grew slowly; • Bicycle ownership was 103 bikes/hundred households in Chinese cities in 1978*; and • Government encouraged bicycle for fuel savings.
Phase Two: Rapid Growth (1978 to 1995)
• The "economic reformation of China" in 1978 is the beginning of phase two; • Bicycle was available for low-income families; • Number of bicycles increased rapidly due to tremendous economic development; • Bicycle ownership was 197 bikes/hundred households in Chinese cities in 1996*; • Average bicycle modal share in ten selected Chinese cities was 46% in 1980s, and 44% in 1990s†; • Government built bicycle infrastructure (e.g., bicycle paths); • Bicycle became the main transport mode for people's daily mobility; and • China was characterized as a "Bicycle Kingdom."
Phase Three: Bicycle Use Reduction (1995 to 2002)
• The release of *Standard of Urban Road Traffic* by the Central Government in 1995 is the key point separating phases two and three; • Bicycle possession and bicycle modal share decreased quickly; • Bicycle ownership was 143 bikes/hundred households in Chinese cities in 2002*; • Average bicycle modal share in ten selected Chinese cities was 35% in the 2000s†; • Bicycle was treated as a competitor to public transportation; • Bicycle was treated as a source of traffic conflict; • Some local governments developed strategies to discourage bicycle use; • Some cities were identified as "non-bicycle cities"; and • Electric bikes emerged as an innovation from the traditional bicycle and spread quickly since 1998.
Phase Four: Attitudes and Policies Diversification (2002 to Present)
• The release of the *White Paper of Shanghai Urban Transport Development* in 2002 marks the beginning of phase four; it defined the bicycle as a complement to public transportation rather than a competitive mode for the first time; • Bicycle possession and bicycle modal share continued to decrease; • Bicycle ownership was 113 bikes/hundred households in Chinese cities in 2008*; • Bicycle began to be treated as a complement to public transportation rather than a competitive mode (i.e., public bikesharing); • Government attitudes toward bicycle diversified; • Some cities adopted special bicycle plans; and • Public bikesharing emerged in some cities as a new form of mobility and spread quickly since 2008.

Figure 1. Four phases of bicycle evolution in China. Sources: China Statistic Yearbook (1981 to 2009); Wang 2006.

2.2. Bicycle Modal Share

Changes in bicycle modal share are consistent with changes in bicycle ownership over time. Table 1 summarizes the bicycle modal share during the 1980s, 1990s, and 2000s in some Chinese cities. The average bicycle modal share in these cities was 46% in the 1980s, 44% in the 1990s, and 35% in the 2000s. In spite of the lower average percentage in the 1990s, bicycle modal share increased in several cities in the early-1990s (i.e., Shanghai, Tianjin, and Xuzhou). Table 1 also showed that cities with more than four million people (the upper half of Table 1) had a lower sub-average of bicycle modal share than the total average across all three-time periods: 5.8% lower in the 1980s, 5.1% lower in the 1990s, and 4.7% lower in the 2000s.

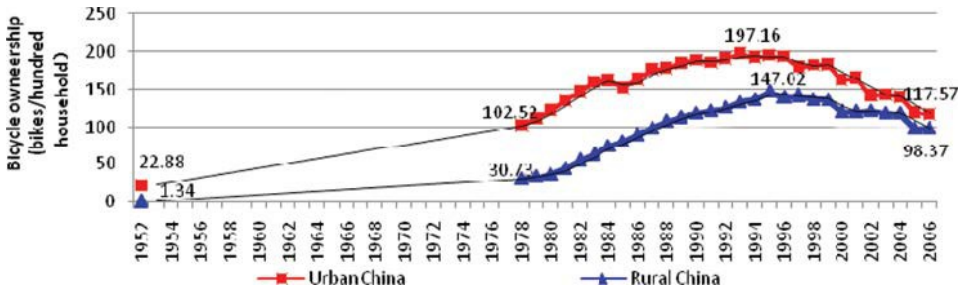

Figure 2. Bicycle ownership during 1952–2006. Note. Data for bicycle ownership during 1953–1977 cannot be found, so the authors used a moving average trend line (period=2) to show the growth trend of bicycle in both urban and rural China. Source: China Statistic Yearbook (1981–2007). (Figure appears in color online.)

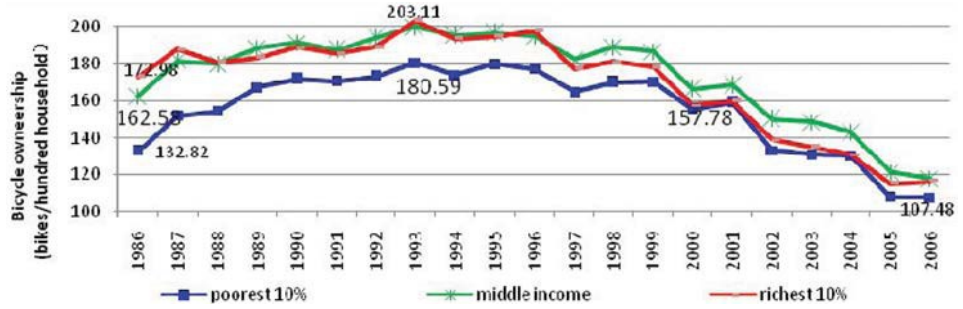

Figure 3. Bicycle ownership among different income groups during 1986–2006. (Figure appears in color online.)

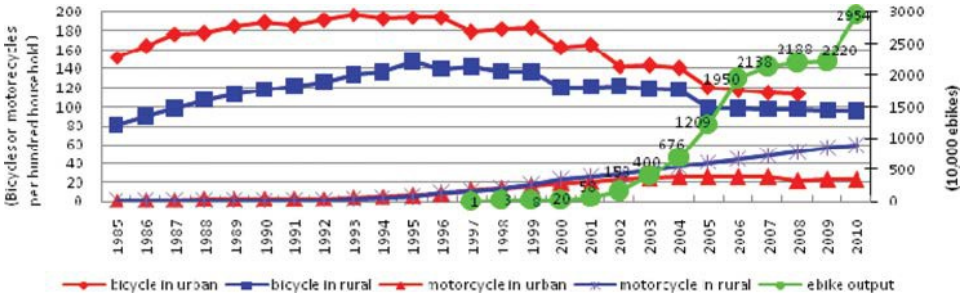

Figure 4. Bicycle ownership, motorcycle ownership, and electric bike production during 1986 to 2010. Sources: Data source for bicycle and motorcycle ownership, China Statistic Yearbook (1981–2011); data source for ebike output, National Bicycle Industry Information Center. (Figure appears in color online.)

Table 1. Bicycle modal share in some Chinese cities over three decades: 1980s, 1990s, and 2000s.

City name	Non-agri-cultural population in 2005 (10,000)	Bicycle modal share (%)	Statistical year	Bicycle modal share (%)	Statistical year	Bicycle modal share (%)	Statistical year
Shanghai	1128	30.5	1981	41.18	1995	27.8	2007
Beijing	858	54.03	1986	38.5	2000	23	2007
Wuhan	800	35.25	1987	28.2	1998	19.2	2008
Guangzhou	617	34.05	1984	21.47	1998	14	2006
Tianjin	533	44.54	1981	60.48	1993	47.6	2003
Nanjing	410	44.1	1986	40.95	1999	48.28*	2007
Sub average		40.41	1980s	38.46	1990s	29.98	2000s
Chengdu	358	54.53	1987	51.5	1995	36	2005
Shijiazhuang	224	57.8	1986	54.38	1998	54	2000
Xuzhou	154	41.8	1982	50.29	1998	54.7	2003
Fuzhou	146	65.91	1989	50.96	1999	22.2	2006
Total average		46.25	1980s	43.59	1990s	34.72	2000s

Source: Wang 2006.
*This number is the survey result for bicycle modal share in the city zone of during the rush-hour in 2008.

While bicycle modal share decreased in almost all Chinese cities, the relationship of the bicycle and other modes—especially the bike and public transport— varied by city type. Table 2 lists the transport modal share in select cities after 2000. According to their bicycle modal share, the authors classify these cities into three groups: (1) high bicycle use (more than 40%), (2) medium bicycle use (20 to 40%), and (3) low bicycle use (less than 20%). In most high bicycle use cities, the public transport modal share is lower than 20%, which suggests that the bicycle is providing mobility to areas less served by public transportation. Shijiazhuang—the capital of Hebei Province—had the highest bicycle modal share and lowest public transport share. In medium bicycle use cities, the public transport modal share was between 10 to 30%, nearing the average for Chinese cities. This ratio seems to be suitable for small or less developed cities, such as Shenyang, Ji'nan, and Lanzhou. In considering mega cities, such as Beijing and Shanghai, the low proportion of public transportation may result in a growing demand for private motorized vehicles. Weather or topography, which is less conducive to cycling, is the main reason there is less than 20% bicycle modal share in the six cities in Table 2. All six cities are located in mountainous and hilly areas, and all have low bicycle use.

Table 2. Transport modal share in select cities after 2000.

City	Walking	Bicycle	Public transport	Motorized vehicles	Statistical year
Shijiazhuang	30.63	55.75	2.87	10.75	2005
Zhengzhou	30.6	48.7	6.47	14.23	2000
Nanjing	12.81	48.28	19.5	19.41	2007
Tianjin	24.7	47.6	15.2	12.5	2003
Ningbo	26.9	47.3	13.2	12.6	2001
Hangzhou	27.61	42.77	22.2	7.42	2000
Chengdu	29	40.1	14.8	16.1	2002
Shenyang	29.22	38.88	18.8	13.1	2006
Ji'nan	32.4	38	15.6	14	2004
Xi'an	22	33.62	25.53	18.85	2000
Beijing	–	30.3	29.8	39.9*	2005
Shanghai	28.9	27.8	23.2	20.1	2007
Fuzhou	35.7	22.2	17.26	24.84	2006
Lanzhou	54.9	21.1	20.2	3.8	2001
Wuhan	44.5	19.2	23.5	12.8	2008
Changsha	27.6	12.6	37.9	29.4	2007
Guangzhou	45.75	10.01	28.85	15.39	2003
Dalian	37	3	54	6	2004
Guiyang	62.4	2.7	26.6	8.3	2001
Chongqing	62	1	28	9	2002

Source: http//www.chinautc.com; Transportation Plan of Chinese Cities; The Annual Report for Sustainable Transport Development in Main Chinese Cities, 2007.
*Beijing does not treat walking as a separate transport mode, and the mode share of car is 29.8% in 2005.

2.3. Government Policy on Bicycle Development

Overall, government policy has changed from ''encouraging the development of bicycle transport'' to ''decreasing and limiting bicycle use in big cities,'' and then to ''local governments' cycling policies varying from city to city'' in the bicycle's evolution in China. During the first two phases of the bicycle's evolution, both central and local governments encouraged bicycle purchase and use as a symbol of economic growth, as well as a solution to fuel shortages. Bicycle lanes were built during that period. However, government policies directed at bicycle management did not emerge until the mid-1990s, when the government began to treat the large number of bicycles on the road as a conflict between motorized and non-motorized vehicles. During the third phase, the central government and some local governments issued policies that opposed the development of bicycles in cities, which resulted in a notable reduction in bicycle ownership and use. Not surprisingly, in light of growing traffic congestion and environmental concerns, many policymakers began to reconsider the bicycle in 2002; this marks the start of Phase Four. Figure 5 lists numerous bicycle policies by the central government and several Chinese cities over time.

The Central Government: In September 1995, the State Bureau of Technical Supervision and the Ministry of Construction released the *Standard of Urban Road Traffic.* It was the central government's first and only document that gave explicit direction on bicycle transport and caused a reduction in bicycle use; this marks the beginning of the third phase in China's bicycle evolution. This document proposed the following opinions: (1) medium and big cities should prioritize public transport to replace long-distance bicycle trips; (2) a large volume of bicycles on the road is a main cause of motorized and non-motorized vehicle conflicts, and this should be controlled in big cities; (3) the ratio of bicycle and public transport trips should range between 1:1 (one bicycle trip to one public transit trip) to 3:1 in large cities, 3:1 to 16:1 in medium cities, and in small cities the rate does not need to be controlled; (4) bicycles and motorized vehicles should use separate lanes; and (5) the suitable distance for a bicycle trip is 0 to 6 km in middle and large cities and 0 to 10 km in small cities.
Shanghai: In 2002, the Shanghai government issued the *White Paper of Shanghai Urban Transport Development*. This document outlined two principles for bicycle transport: (1) actively guide long-distance bicycle trips to public transport and, (2) encourage bicycles for short trips and integrate with public transportation. This marks the beginning of the fourth phase of China's bicycle evolution, as it defined the bicycle as a complement to public transportation rather than a competitive mode for the first time. This was adopted by some Chinese cities, and the trend is continuing at present. In August 2008, the Shanghai Urban Planning and Design Institute completed the first detailed plan for non-motorized transport for the Hongkou district in which 25 bike lanes were designed to connect to the metro system.
Beijing: In 2008, the Beijing Municipal Commission of Transport released four themes for improving pedestrian and bicycle transport on main streets, core areas, and central business districts. This is the first time that the Beijing government provided recommendations for a special bicycle design and viewed the bicycle as a solution to traffic congestion. In July 2009, the Beijing Municipal Government published the *Action Plan of Beijing Municipality for a People-Oriented, High-Tech Urban Communications System (2009–15)* (Beijing Municipal Committee of Transport, 2009). According to this plan, Beijing will have 1,000 public bikesharing and bike rental stations, with at least 50,000 bikes available near major rail stations and bus terminals by the end of 2012.
Shenzhen: In November 2007, the *Shenzhen Urban Master Plan* specified that Shenzhen would give priority to public transport, pedestrians, and bicycles. In 2009, *Planning for Pedestrian and Bicycle Transport in Shenzhen* was announced. It established a clear target that Shenzhen will have 490 km bi-directional bicycle lanes at the end of 2011, including 270 km new bike lanes (Jiangmen Daily, 2009).
Guangzhou: Guangzhou focused on bicycle transport much earlier than other cities in China. In 1993, in the *Transport Mater Plan of Guangzhou*, the city clearly established that Guangzhou would decrease and limit bicycle use; it required bicycle modal share to decrease from 34% in 1992 to 13% in 2010 (Ma, 2004). Attitudes toward the bicycle did not change for ten years. In 2003, Guangzhou began to merge bike lanes with sidewalks, and automobile lanes replaced a majority of bicycle lanes. This led to a sharp reduction in bicycle ownership and use. In 2003, bicycle modal share in Guangzhou was 10%, compared to 34% in 1992. In 2009, Guangzhou announced that it would provide bike paths along bus rapid transit routes, and public bikesharing emerged with 104 bikes available at two bikesharing stations. The city is planning to have 300 stations with 40,000 bikes by the end of 2013 (Guangzhou Evening News, 2009).

Figure 5. Government policies on bicycle development in China.

3. CHARACTERISTICS OF BICYCLE TRIPS

3.1. Users

Very little research has examined bicycle user characteristics. Cherry and Cervero's survey (2007) found that 41% and 50% of bicycle users were female in Shanghai and Kunming, respectively; the average age of bicycle users was 35.3 in Shanghai and 34.2 in Kunming. Further, when evaluated on a scale of one to five for average education level (1.less than high school, 2.high school, 3.some college, 4.college degree, 5.graduate study), the average education level for bicycle users was 2.4 in Shanghai and 2.3 in Kunming. In 2006, the average

monthly wage of bicycle users was 2080 Yuan RMB (US $306) in Shanghai and 1,652 Yuan RMB (US $243) in Kunming, which is less than the average level of these cities. Weinert, Ma, Yang, et al.'s (2007) survey in Shijiazhuang had similar results: the main bicycle users are people in their 20 s to 40 s, with a medium or low education and income level, with nearly 50% female.

3.2. Trip Time and Trip Distance

The slowing trend in bicycle use during the late-1990s led to several studies of the suitable trip time and distance for bicycling. After a survey of 19 cities, Xu and Zhang (1994) found that trip distance in those cities in 1994 was 1.9 to 5.2 km, with an average of 3.3 km; the average trip time was 24 minutes. Bicycle trip distance in these cities was 2.7 to 5 km, with an average of 4.1 km; the average bicycle trip time was 20 minutes. Bicycles comprised the majority of trips between 11 and 30 minutes in length. The authors indicated that most trip distances in urban China were short and suitable for bicycling in 1994. The dominant trip time and distance for bicycles in big cities with high-quality public transport was 0 to 20 minutes and 0 to 4 km. In small cities, which lack good public transportation, the dominant bicycle trip time and distance is 0 to 30 minutes and 0 to 6 km.

Along with economic development, bicycle trip distances increased. For example, the average cycling trip distance in Beijing was 6 kilometers (km) in 1986, 8km in 2000, and 9.3km in 2005 (Beijing Municipal Committee of Transport, 2005), 85% of cycling trips in Shanghai were for 8 km or less in 2002 (Zacharias, 2002). In 2004, 33% and 14% of bicycle trips in Xi'an and Qingdao, respectively, were 30 minutes or longer (Xi'an Police Traffic Administrator Detachment, 2004).

3.3. Trip Purpose and Reasons for Cycling or Not Cycling

Commuting is the dominant trip purpose for bicycle use. Cherry and Cervero's (2007) study in Shanghai and Kunming observed that more than 50% of bike trips were work trips. Weinert, Ma, Yang, et al.'s (2007) study in Shijiazhuang found that 61% of traditional bicycle trips and 77% of electric bike trips were work related. Going to school, picking up children from school, and shopping, make up a smaller share of bicycle trips. In 2009, China Youth Daily conducted an Internet survey of 1,000 respondents on cycling. The results showed that 58% of respondents use bicycles for commuting, followed by errands (42%), entertainment (33%), and physical exercise (27%). When asked the reasons of choosing bicycling, 62% of respondents said that cycling is a good replacement for walking, followed by health benefits (58%), environmental protection (53%), no parking hassles (46%), avoid-ing traffic jams (39%), and other transport modes are inadequate (e.g., public transport is too crowded; taxi or private car is too expensive) (33%). Approximately 50% said that riding a bicycle in their city is difficult. Respondents offered several reasons for not cycling. The most popular reason cited by 49% is ‘‘too many motorized vehicles on the road; cycling has become dangerous.’’ This was followed by ‘‘no bike tracks’’ (44%), ‘‘tailpipe emissions are harmful for bicycle users’’ (31%), and ‘‘bike theft’’ (25%) (China Youth Daily, 2009).

4. TWO NEW FORMS OF BICYCLE IN CHINA

There are two new bicycle forms in China, which have made cycling faster and more convenient. The authors present them in sections 4.1 and 4.2.

4.1. Electric Bike

Although the electric bike appeared in China in the 1960s, it did not emerge into the market until the late-1990s (Weinert, Ma, and Yang et al., 2007). Starting in 1998, despite the dramatic reduction in traditional bicycle use, the electric bike began to grow rapidly; this has continued up to the present (Cherry and He, 2010; Lin et al. 2008). The output of electric bikes in China has increased from 30,000 in 1998 to 30 million in 2010 (see Fig. 4). In 2007, electric bike ownership in Chinese cities reached 17 electric bikes per hundred households (Wang, 2008). There are two types of electric bikes in China: the bicycle-style electric bike (BSEB) and the scooter-style electric bike (SSEB). While BSEBs are propelled by human pedaling and supplemented by battery electric power, the SSEBs are propelled almost entirely by electricity, although they have a perfunctory pedal function to meet legal definitions (Weinert, Ma, and Cherry, 2007). These two types of electric bikes are different in form but are similar in underlying technology; the main components of electric bikes include the motor, battery, and electric controller.

Government attitudes toward electric bikes were quite different before and after 2002. Both the central and local governments offered energy efficiency discounts for electric bikes prior to 2002. In 1999, the National Bicycle Standardization Committee adopted the National Electric Bike Standard, which required all electric bikes to weigh less than 40 kilograms (kg) and to run slower than 20 km=hour. This policy established standards for electric bike performance, but it also opened the door of a notable loophole: it allowed SSEBs to be classified under the same rule as BSEBs as long as SSEBs had a functional pedal. After that, manufactures capitalized on this loophole by making SSEBs with pedals that barely functioned and could be easily removed after purchase. The result is that most electric bikes exceeded a safe weight (less than 40 kg) and speed limitations (slower than 20 km=hour)—clearly defined by the National Standard—make them a hazard for users, pedestrians, and traditional bicycle users. Consequently, in 2002, Beijing announced that it would cease to offer electric bike licenses starting in 2006. While the ban was repealed in January 2006, the earlier pronouncement resulted in a widespread prohibition of the electric bike. In 2004, the State Traffic Control Bureau published the Road Transportation Safety Law, which defined the electric bike as a non-motorized vehicle and granted local governments the power to regulate them. Since then, local policymakers have treated electric bikes differently. There are three types of electric bike approaches. The first is the anti-electric bike city, which explicitly bans electric bikes, including such cities as Fuzhou, Zhuhai, Guangzhou, Wuhan, Wenzhou, Shenzhen, and Haikou. The second is the pro-electric bike city, which has allowed electric bike use and developed a licensing system for them, including Shanghai, Hangzhou, Suzhou, Guangxi, Nanjing, and Chengdu. The third is electric bike neutral cities that have adopted a ‘‘wait-and-see’’ approach to managing the electric bike, such as Shijiazhuang.

Cherry and Cervero (2007) and Weinert, Ma, and Cherry’s (2007) studies revealed that the majority of electric bike users were previously bus or bike riders (depending on the city) who would use a bus or traditional bike if electric bikes were banned. Existing and future bans of the electric bike would further aggravate already overloaded bus services.

In 2006, the China Bicycle Association conducted a survey among electric bike manufacturers, sellers, and consumers in 18 cities. The results indicated that there were some key factors that influenced a consumer’s electric bike purchase. Forty-eight percent of respondents noted that ‘‘the battery is light and portable for home recharging’’ as a main consideration in their purchasing decision. This was followed by ‘‘low power consumption’’ (45%), ‘‘safety’’ (43%),

‘‘durability’’ (39%), and ‘‘low price’’ (33%) (China Bicycle Association, 2007). Another 2008 survey by the China Bicycle Association of 14 provinces provided some general information about electric bike use: people between 18 to 39 years old accounted for approximately 80% of all electric bike users; electric bikes were used mainly for short- to middle-distance trips, while 42% of electric bike trips were less than 10 km, and 28% were 10 to 20 km. The price of most electric bikes is between 1,500 (US $220) to 2,500 yuan RMB (US $366) (China Bicycle Association, 2009).

Since the electric bike market in China has experienced considerable growth for over ten years, some lessons can be learned from past experience and should be addressed in the future. Because government attitudes and regulatory policy have the most powerful impact on the electric bike in China (Weinert, Ma, Yang, et al. 2007), the authors list four key lessons relevant to government policy and management in Figure 6: (1) regulatory policy and standards, (2) safety, (3) battery improvement, and (4) management of the electric bike industry.

In addition, other issues, such as bike parking shortages and increasing electric bike theft, are growing concerns. Although the majority of users charge their electric bikes at home during the night when electricity is cheaper, more standard electrical outlets and new infrastructure are required so electric bikes can also be charged during the day at home.

4.2. Public Bikesharing

Public bikesharing, as defined by Shaheen, Guzman, and Zhang (2010), is flexible short-term public bicycle access, which targets daily mobility and allows users to access shared bikes at multiple stations. Public bikesharing emerged in 1965 and has developed three generations of bikeshating systems. It rapidly spread after Ve´lib’s launch in Paris, France in 2007 (at the time of this writing, Ve´lib’ operated over 20,000 bicycles at 1,800 stations, which are available every 300 meters, 24-hours a day, and seven days a week). Users are encouraged to employ bicycles for short trips by offering the first thirty minutes of cycling free and incremental pricing after that. Shaheen et al. defined the fourth generation of public bikeshar-ing as ‘‘Demand Responsive, Multi-Modal Systems’’ that include the integration of bikesharing with larger public transportation systems via smartcards; real-time public transit information display screens; and clean energy solutions, such as solar docking stations, alternative fuel bicycle redistribution trucks, and electric bikes (Shaheen, Guzman, and Zhang, 2010, 2012; Shaheen et al. 2011). At present, many cities are exploring ways to seamlessly link public bikesharing programs with citywide transportation; public bikesharing represents an important step towards integrating the bicycle with bus, metro, and rail systems. For example, the Hangzhou public bikesharing program uses the same smartcard for bikesharing and public transit. In addition, it offers bikesharing users a 10% discount for taking bus rapid transit or the bus (Song, 2009).

Regulatory Policy and Standards: While the growth of electric bikes is the result of a combination of economic and technical factors (e.g., substantial technology improvements for lead-acid batteries and in-hub electric bike motors, decreasing electric bike price, and higher fuel prices), government attitudes and regulatory policy have the most powerful impact (Weinert, 2007b). Since electric bikes have some advantages over traditional bikes (e.g., faster and more convenient) and public transport (e.g., door-to-door service, not crowded, flexible), it would be challenging and inappropriate to completely prohibit electric bikes. A new national standard for electric bikes is recommended. SSBEs and BSEBs should be distinguished so electric bikes are treated as non-motorized vehicles and can share bike lanes or bike paths with traditional bikes.

Safety: Safety emerged as the most important issue facing the electric bike's rapid growth. Despite existing standards, most electric bikes exceeded the speed limit (20 km/hr), which was clearly defined by the National Standard due to consumer demand for better performance (Note: The highest speeds that can be reached are as high as 40 to 60 km/hr). In addition, electric bikes are very quiet during operation, so they can hardly be heard. This makes electric bike users vulnerable, as well as being dangerous to pedestrians and traditional bicycle users (Weinert et al., 2007b). In 2006, it was reported that Shanghai had more than 740 traffic accidents due to the use of electric bicycles; 92 people died and 774 were injured in these accidents (The Legal Daily, 2006).

Battery Improvement: Lead pollution is one of the key issues for electric bikes. Before 2006, 95% of electric bikes in China were powered by lead-acid battery, Cherry, Weinert, and Yang (2009) reported that lead emissions per passenger kilometer are several orders of magnitude higher for electric bikes than for buses. In addition, lead-acid batteries for electric bikes weigh nearly 20 kg, often making electric bikes exceed the weight limitation of 40 kg. Other lead-acid battery concerns include: short lifespan (i.e., one to two years on average), high electricity consumption, lower energy density (i.e., 30 to 38 watt hour per kilogram), and high recharging frequency (Liu, 2006). After 2006, the trend toward Lithium-ion (Li-ion) batteries in electric bikes is increasing not only to prevent lead pollution, but to improve user convenience (e.g., less recharging time). In 2008, there were 350,000 electric bikes sold in China, which were powered by Li-ion batteries (Xing, 2008). Although a Li-ion battery costs about four times more than a lead-acid battery, it has two to three times the lifespan (i.e., four to six years). Furthermore, Li-ion batteries in electric bikes often weigh less than 3 kg, which are much lighter than lead-acid batteries. In the future, Li-ion battery technology should continue to improve to lengthen lifespan, reduce weight, and lower price.

Management of Electric Bike Industry: The electric bike industry in China has developed from less than 10 licensed manufacturers to more than 1,000 in 2008, due to the maturity of component technologies, growing demand, relatively simple manufacturing procedures, low barriers to entry, and the lack of intellectual property (IP). Most of the electric bike manufacturers produce 10,000 to 50,000 electric bikes per year; only six of them have an annual production of more than 200,000 (Weinert, 2007b). This development of the electric bike industry has lead to two key issues. First, with more than 1,000 electric bicycle brands in China, less than 10 famous brands provide a product warranty and post-sale services (e.g., Giant Bicycles, Forever Bicycle). Second, due to the lack of IP, there is very little impetus for manufactures to invest in technological improvements. Competition is focused around price, design, and higher speed. This has impeded improvements in the electric bicycle industry and fueled complaints about quality.

Figure 6. Electric bike lessons learned.

As of February 2012, there were 151 public bikesharing programs operating around the world, with over 245,116 shared bicycles and 13,748 stations (Shaheen and Stacey, unpublished data). Among all the public bikesharing programs worldwide, one of the largest is in Wuhan, China. It launched in April 2009; it had 1218 stations and 70,000 bikes at the end of February 2012. The first public bikesharing program in China was launched for profit in Beijing in 2005 by a private bicycle enterprise—The Fangzhou Bicycle (Beijing) Co., Ltd. While this program developed very slowly, it did not gain much attention and has ended in 2011 because of the Fangzhou Bicycle (Beijing) Co., Ltd's Bankruptcy. Public bikesharing in Hangzhou, which launched in

May 2008, is notably larger (2674 stations and 65,000 bikes at the end of February 2012) and has led to a surge of bikesharing activity in the nation. At the end of February 2012, twelve cities in China had formal public bikesharing programs, with 5331 stations and 180,500 bikes. Another nine cities (Nanjing, Dujiangyan, Foshan, Haiko, Shenzhen, Qingzhou, Suzhou, Wuxi, Yinchuan) had pilot public bikesharing programs, with 483 stations and 10,430 bikes. Zhengzhou, Nanning, and Qingdao are planning to launch public bikesharing in 2012. Table 3 provides an overview of existing formal public bikesharing systems and business models in China. There are three different non-profit models. Each is outlined in the Table 3.

Government attitudes toward public bikesharing programs in China is supportive. The main difference among the existing public bikesharing systems in China are related to their operational model. There are five key operational lessons from bikesharing experience in China: (1) land provision for stations, (2) program financial sustainability, (3) bicycle redistribution, (4) integration with public transport, and (5) pricing (see Fig. 7).

Shaheen et al. (2010) provided five key lessons learned from their analysis of worldwide public bikesharing: (1) bicycle theft and vandalism, (2) bicycle redistribution, (3) information systems, (4) insurance and liability considerations, and (5) prelaunch considerations. While bicycle theft, vandalism, and insurance are not notable concerns in China (Shaheen et al. 2011), land provision, financial sustainability, pricing, and public transportation integration are important in light of China's governmental structure (top-down management approach) and high-density urbanization. Compared to some other public bikesharing programs in developed countries, Chinese bikesharing programs lack an effective real-time information system due to technological constraints, only the Hangzhou public bikesharing program has began to build a real-time information system since 2011. Not surprisingly, some locations that already provide public transportation networks that people can walk to in less than five minutes, such as Naning in Guangxi Province, may not be optimal locations for integrated public bikesharing services.

Table 3. Public bikesharing systems and business models in China.

Business model		Revenue sources	Deposits and usage fees	City	Date started	Stations	Bicycles
Hangzhou model	• Non-profit; • Public transit agency establishes a state-owned company to manage bikesharing services; • Government provides land for stations and integrates bikesharing with public transport; • Government provides supportive policies; • The company receives revenue from advertisements from bikes and billboard at stations.	Governmental subsidies; advertisements on bikes and billboards at stations; member/non-member user fees.	Nearly 200 yuan RMB deposit ($30). First period of using time (1–3hours) is free, followed by an incremental pricing sytem for additional hours.	Hangzhou Jiangyin Zhoushan Tongliang Zhuzhou Yantai Guangzhou	May 2008 September 2008 October 2009 October 2009 June 2011 July 2010 August 2009	2,674 30 12 20 500 60 113	65,000 900 500 500 10,000 2000 5,000
Wuhan model	• Non-profit; • Private enterprise provides services under government guidance; • Government provides land for stations; • Government provides supportive policies; • Enterprise takes full responsibility for profits and losses; • Enterprise receives revenue of advertisements on bikes and billboards at stations.	Bank loans; advertisements on bikes and billboards at stations; member/ non-member usage fees.	Before July 2011: No deposit, no usage fee; bikes need to be returned for every four hours. After July 2011: Need 300 RMB Yuan ($50) deposit.	Wuhan Nanchang Chizhou	April 2009 August 2009 October 2009	1,218 80 50	70,000 6,000 1,500
Shanghai model	• Non-profit; • Enterprise provides bikesharing services; • Government purchases services for public; • Government and enterprise share the revenue of advertisements from bikes and billboards at stations.	Municipality funding; advertisements on bikes and stations.	No deposit, no usage fee. Bikes need to be returned for every two hours.	Shanghai	September 2008	574	19,100

Land provision for stations: While a robust network of multiple stations is critical to bikesharing system success, finding land for stations is very difficult and expensive for private enterprises without governmental support. Although Beijing has the longest history of public bikesharing in China, it has no more than 200 stations for all its running period and the system finally ended in 2011. Forever Bicycle Co. LTD, the operator of bikesharing in Shanghai, found it is very difficult to expand public bikesharing in the city because the company cannot afford the notable land costs for establishing the bikesharing stations that are needed near rail or bus stations (The Legal Daily, 2010). In contrast, the Hangzhou and Wuhan models are exempted from this problem as the government provides the land at these stations. In Hangzhou, the distance between two stations in the core area is no more than 300 meters (Daily Business, 2009a).
Program Financial Sustainability: As most Chinese bikesharing programs are non-profit, it is important to produce revenue for program survival rather than to rely upon governmental subsidies in the longer term. The Wuhan model has the best experience in identifying advertising revenues. They have sold advertisements on bikes and station billboards; they have also integrated bikesharing stations with existing on-street bookstores and public phone stations to ensure program sustainability. After more than two years of running, the Hangzhou Public Transport Bicycle Service Development Company sold advertisements on bikes and station billboards through a public bidding in December 2012, the Simei Fax Media Co., LTD won the bid, the bid price was 28 million Yuan RMB (US$ 4.4 million) per year, with an annually increasing rate of 10% (Xuejun Tao, unpublished data).
Bicycle Redistribution: When bikesharing programs grow and cover larger areas, the redistribution of bikes among stations becomes an increasingly important issue. An investigation in Hangzhou showed that more than 25% of bikesharing complaints were focused on the lack of parking spaces when returning bikes (Urban Transport, 2009). This problem is most serious during peak hours. The Hangzhou bikesharing system has tried many strategies to resolve this problem, such as an alarm system for bicycle vacancy or occupy, instant delivery (i.e., employing trucks to redistribute bicycles from one station to another), and manual bicycle return to busy stations during peak 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).
Integration with Public Transportation: Both China's central and local government for urban transportation have adopted the "Public Transit Priority" policy to address growing environmental and traffic concerns and to encourage greater public transport use. Among the existing bikesharing programs in China, only Hangzhou has integrated bikesharing with public transportation through the use of one smartcard for the two modes, as well as a bikesharing discount for public transportation users. In this way, the bicycle acts as a main transport mode for short distance trips and is designed to solve “first and last mile” problems. Integrating public bikesharing with public transit is consistent with the government’s long-term goal of promoting public transportation use and will likely be a key trend in bikesharing development in the future.
Pricing System: Different bikesharing models in China employ different pricing systems. While the Beijing model is for-profit and charges users through a membership card with very low using rate of bikes, the other three are non-profit. The Wuhan and Shanghai bikesharing systems have no deposit or usage fees (Wuhan model began to charge a deposit in 2011), while Hangzhou requires users to pay a refundable deposit and adopt a gradually increasing charging system after the first free hour. Results indicate that public satisfaction with bikesharing in Hangzhou is as high as 80% and is no lower than that of Wuhan and Shanghai (Fang, 2009). Not surprisingly, as users in Wuhan and Shanghai can use the bicycles for a long time at no cost, the bicycle turnover rate in these two cities is lower than in Hangzhou (Yang Tang, Xuejun Tao, unpublished data). These results imply that operating a bikesharing service for-profit (i.e., Beijing public bikesharing system before 2011) may result in less service use; however, if it is entirely free to users for a longer time, this may reduce the bicycle turnover rate. In the future, pricing systems used for public bikesharing should be closely evaluated to encourage both service use and efficiency. Indeed, free use for an initial period, followed by gradually increasing pricing could be the most suitable pricing system for bikesharing in China.

Figure 7. Public bikesharing lessons learned.

In addition, fourth-generation public bikesharing systems may be more likely to incorporate electric bicycles, which enable longer-distance trips, encourage cycling on steeper hills and slopes, and lessen physical exertion requirements, particularly when users are commuting or making work trips in business attire (Shaheen et al. 2010).

5. CONCLUSION AND RECOMMENDATIONS

The bicycle has transitioned through four phases in China over more than one hundred years. During these four phases, bicycle ownership and modal share increased quickly after 1978, but

declined steadily after 1995. Governmental bicycle policies have evolved over time. Along with the evolution of bicycle transportation, studies on bicycle transport have increased, and understanding of bicycle trips has become more clear in China. At present: (1) commuting is the dominant trip purpose for bicycle use; (2) the main bicycle users are people in their 20 s to 40 s, with a medium or low education and income level; (3) the dominant bicycle trip distance has increased over time; (4) people choose cycling as a replacement for walking; (5) cycling is difficult in many Chinese cities; and (6) the main deterrence for cycling is safety concern.

During the bike's evolution in China, two new bicycle forms emerged. The first is the electric bike, which has increased in modal share at a notable rate since 1998. Along with its expansion, many problems emerged, among which safety and lead pollution are the two key issues. As a result, local government attitudes toward electric bikes are inconsistent, some support it, some are against it, and some are neutral. Since electric bikes have some advantages over traditional bikes and public transportation, a careful consideration of electric bikes is recommended, particularly in light of overloaded bus services. New national electric bikes standards should be formulated to help mitigate the negative impacts of electric bikes through technology improvements (e.g., advanced technologies such as Lithium-ion batteries), improved traffic management (e.g., SSEBs and BSEBs should be distinguished according to their running speeds for safety requirements), improved management of the electric bike industry (e.g., intellectual
protection, standard entry barriers), and performance standard enforcement.

The second new form of bicycle use is public bikesharing. Although the history of bikesharing in China is short, twelve cities in China had formal public bikesharing programs, with 5331 stations and 180,500 bikes at the end of February 2012. There are three types of public bikesharing business models in China right now, these systems vary based on their business model, revenue source, deposits, and usage fees. Key lessons can be learned from China's current public bikesharing experience: (1) land provision for stations is critical to system expansion; (2) program financial sustainability is challenging but evolving; (3) bicycle redistribution and maintenance are essential to customer satisfaction; (4) integration with public transport is the main trend for public bikesharing development in the future; and (5) free use for an initial period, followed by incremental pricing could be the most effective pricing system for China.

The bicycle, which is a substantially faster mode than walking and more flexible than public transportation, can serve as a feeder service to public transport. Since middle- to low-income families primarily use bicycles to commute, it could be detrimental to eliminate large numbers of bikes from the roads, particularly due to their environmental, health, and social equity benefits. However, due to increasing motorization, cycling has become challenging in many Chinese cities. A key concern is how to make cycling safer through improved transportation infrastructure (e.g., physical separated bicycle lanes) and management (e.g., new electric bike standards, bicycle phasing-traffic signals to provide priority to cyclists). Another key concern is government policy on bicycle transport. Although the central government has not yet announced an explicit plan for bicycle transport and local government attitudes are inconsistent, the government's attitude toward the bicycle has become more positive, and many cities have launched public bikesharing programs. This implies that the future policy considerations might include redirecting long-distance bicycle trips to public transportation, encouraging the bicycle for short-distance trips, and integrating bikesharing with public transit. Ongoing research and evaluation can aid the government and private stakeholders in

understanding how to target and improve bicycle use, satisfaction, safety, and multi-modal integration moving forward.

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