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Journal
Transport Policy, 14(3)

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Publication Date
2007-05-01

Peer reviewed

8.07f/W(Jul162004) +model JTRP : 815 Prod.Type:FTP pp.1–11(col.fig.:NIL) ED:SumalathaP.N. PAGN:Bhaskara SCAN:

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Use characteristics and mode choice behavior of electric bike users in China

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Abstract

In 2005, 10 million electric bikes were produced in China. Strong domestic sales are projected for coming years, raising concerns about the sustainability and potential regulation of this fairly new mode. Policy makers are wrestling with developing policy on electric bikes with little information about who uses them, why they are used, and what factors influence the electric bike travel. This paper probes these questions by surveying electric bike usage in two large Chinese cities, Kunming and Shanghai. Demographic comparisons are made between the different modes and cities as well as differences in travel patterns. Electric bike users are found to travel considerably more than bicycle users. Also, most electric bike users would travel by bus if electric bikes were unavailable. This suggests that electric bikes are less of a transitional mode between human-powered bikes and full-blown automobile ownership, and more an affordable, higher quality mobility option to public transport.

Keywords: Electric bike; Electric motorcycle; Mode choice; China; Shanghai; Kunming; Two-wheeled vehicle; Travel behavior; Sustainable transport; Non-motorized transport

1. Electric bikes in China

Electric bike use in China has skyrocketed over the past decade. Despite annexed bicycle infrastructure and a national policy that promotes car growth and ownership, most commuters still rely on two-wheeled transportation. In 2005, over 10 million electric bikes were produced and sold in China, up from several thousand in 1998. This growth is expected to continue for years to come, pending any heavy regulation. Electric bikes come in many styles and performance characteristics, but the primary technology is the same. The vast majority rely on lead acid batteries to provide energy to a hub motor, usually on the rear wheel. Most electric bikes fall into two categories: scooter style electric bikes (SSEBs) or bicycle style electric bikes (BSEBs) (Fig. 1). SSEBs appear much like gas scooters, complete with headlights, turn signals and horns; with large battery packs under the footboard. BSEBs resemble bicycles, with functioning pedals and usually smaller batteries and a lower power motor. Electric bikes can reach speeds exceeding 30 km/h and weigh between 40 and 60 kg. Recent laws passed by China's central government classify electric bikes, operationally, as regular bicycles. Driver licenses and helmets are therefore not required and electric bikes can be operated in bicycle lanes (China Central Government, 2000).

The growing popularity of electric bikes has raised concerns among Chinese policy makers about their traffic, safety, and environmental impacts, prompting some local officials to regulate them. Taiwan officials promoted and even subsidized electric bike use in the 1990s to provide a clean alternative to gas powered scooters (Chiu and Tzeng, 1999; Taiwan EPA, 1998). Despite this subsidy, electric bikes competed directly with gas scooters and the performance characteristics were not competitive enough to induce a large market shift. Although electric bikes were promoted in Taiwan, several cities in mainland China, notably Beijing, Guangzhou, and Fuzhou, have sought to ban them altogether, citing lead pollution and safety issues (Weinert et al., 2006; Guangzhou Daily, 2006; Beijing

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doi:10.1016/j.tranpol.2007.02.005

Fig. 1. Bicycle style and scooter style electric bikes (image source: www.forever-bikes.com)

Traffic Development Research Center, 2002). These policies are being implemented with little information about who is using this mode and what impact it has on the transportation system. Electric bike rider fatalities might increase in a city, resulting in a ban, but what if all (or a few) electric bike users shifted to cars? The safety and environmental impacts of such a shift might be significantly higher. Are electric bikes a step above bicycles in the modal transition to cars or are they primarily a low-cost mobility option to public transit?

To shed light on the use electric bikes and competitive models—who uses them, for what purposes, and why—we conducted a survey of two-wheeled vehicle users in a Chinese megacity, Shanghai, and in a medium sized city, Kunming. This paper presents the results of surveys on the use of electric bikes, traditional bicycles, and liquefied petroleum gas (LPG) scooters in these two cities. First, background information on the two cities, including their transportation services, is presented. This is followed by a discussion on the survey methodology and sampling approach. The survey results are then discussed, focusing on socio-demographic attributes of two-wheel vehicle users. Next structural models that predict mode choice based on user and mode characteristics and stated preference responses are presented. Last, the policy implications of our research findings are discussed.

2. Case study cities

China has 660 cities and three quarters of its urban inhabitants live in cities are considered small or medium sized by Chinese standards (0.5–4 million people). We chose Kunming, a city of some 3 million residents, as one of our case studies to reflect transportation conditions of most Chinese cities. It is the megacities of more than 10 million residents, however, that face the very worst traffic and environmental conditions, and which are looked to by smaller cities for innovative policy responses. Shanghai, a cosmopolitan city of 15 million inhabitants, served as our megacity case setting.

2.1. Kunming

Kunming is the capital of Yunnan province in southwest China. It is a gateway for trade with southeast Asia and also a major tourism destination. Kunming's urban population exceeds 2.5 million, and its metropolitan population tops 5 million. The per capita gross domestic product of urban residents was 31,700 RMB[1]/year in 2004, below the national average (China Data Online, 2006).

Although it has no urban rail system, in 2002 Kunming became the first Chinese city to inaugurate a Bus Rapid Transit (BRT) service (Joos, 2000; Kunming Urban Traffic Research Institute, 2004). To stave off traffic congestion, motorcycles are prohibited within the city's inner ring road and trucks and rural vehicles are banned within the second ring road (with some exceptions).

The mode splits for all trips in Kunming in 2003 are shown in Fig. 2 (Li, 2006; Kunming University of Science and Technology, 2003). Non-motorized modes—bicycle and walk trips—clearly dominate. In Fig. 2, electric bikes are classified by local officials as a non-motorized mode, like a regular bicycle.

2.2. Shanghai

Shanghai is the major commercial, industrial, and financial center of China and increasingly a linchpin in the global economy. With an official urban population of 13 million in 2004, some estimates peg Shanghai's regional population at around 20 million inhabitants. The city's per capita GDP of 57,000 RMB/year in 2004 is one of the highest in China.

Shanghai is rapidly expanding its transportation infrastructure, including urban rail. Motorcycles and automobiles are heavily restricted through high fees and registration restrictions. When Shanghai's taxi fleet converted to LPG, the fueling infrastructure became available for the growth of LPG scooters. As a result, Shanghai is the only city in China where LPG scooters have gained a significant share of the market. They are not restricted

[1] 8 RMB = 1 USD.

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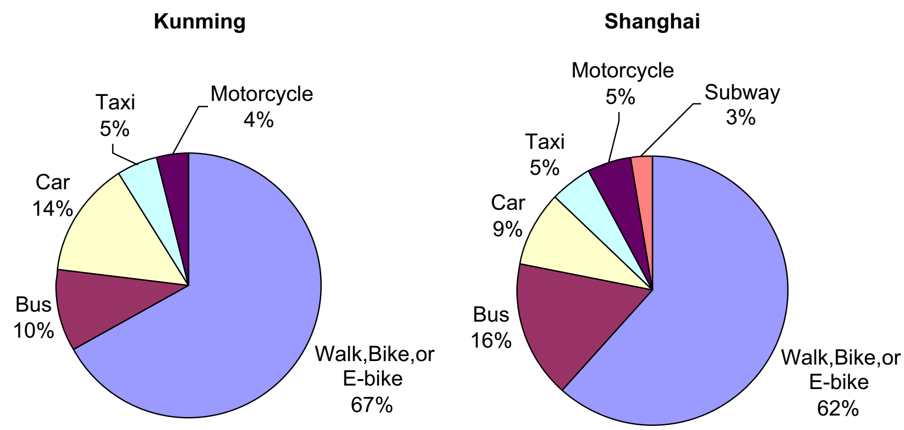

Fig. 2. Mode splits for Kunming and Shanghai, 2003.

from the city center and are required to operate in bicycle lanes along with electric bikes.

3. Survey methodology

Travel diary surveys were conducted in Kunming and Shanghai in early April 2006 and late May 2006, respectively. The surveys targeted electric bike and bicycle users. In the case of Shanghai, LPG scooter users were also surveyed.

The surveys contained two parts: a travel diary for the previous day's travel, which asked information about trip origins and destinations, travel times and alternative modes. The second part asked demographic and attitudinal questions. Conducting random household surveys in China is logistically and institutionally difficult; self-reported surveys are an alien concept among most Chinese. For this reason, targeted intercept surveys were conducted at locations that contain a representative sample of urban two-wheel vehicle users—specifically centralized parking facilities of major activity centers and trip generators throughout the urban area. The surveyed activity centers contain employment, social activities, and shopping outlets that serve a cross-section of urban dwellers. In both cities, undergraduate and graduate students were hired from local universities to conduct the intercept surveys.

3.1. Site selection

In Kunming, surveyors were stationed at five major trip generators in the city center and around the 1st ring road. These locations included major shopping centers that cater to all demographics of users as well as centralized bike parking facilities surrounding a large pedestrian mall in the city center. Importantly, most of the survey sites were within the gas motorcycle restricted zone.

A similar approach was followed in Shanghai. Surveyors were positioned at six major trip generators throughout the city, including locations in city center, the post-1990 district of Pudong, and large residential areas. Additionally, several of the survey sites were near subway stations, so some respondents utilized two-wheeled vehicles to access the subway.

3.2. Sampling approach

In both Kunming and Shanghai, surveyed shopping districts are by centralized bike parking lots that store hundreds of bikes. Since bicycle parking is rarely free, most bike parking lots have a single entrance or exit, where parkers pay an attendant. Surveyors were instructed to position themselves at the entrance of the parking lot and ask every adult entering, regardless of age or gender, if he or she would participate in the survey. If people arrived while completing a survey, the surveyor skipped those individuals and asked the first person arriving after he or she returned to the gate. This sampling method minimized bias. Surveyors conducted the survey during the middle of the week, from Tuesday to Friday, so that the previous day travel diary represented a ''typical'' weekday (Monday to Thursday). After a survey was completed, respondents were offered a small gift (parking fee payment) as a token of appreciation. In Shanghai, 696 responses were collected. In Kunming, the total was 502 responses.

4. Survey results

This section presents the survey results, starting with descriptive statistics on two-wheel vehicle usage and user characteristics. Models are then presented that predict two-wheel vehicle choice as well as the likelihood of switching to other modes if electric bikes were not available.

4.1. Descriptive statistics

Table 1 shows the household demographic attributes of surveyed users of bicycles, electric bikes and LPG scooters in Shanghai and Kunming. Overall, those using these modes come from similar populations. The greatest

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Table 1
Demographics of two-wheel vehicles users in Kunming and Shanghai

Shanghai	Gender (%F)	Mean value of				
		Age **	Education (index)[a] ***	HH income (RMB)[b]*	Wage (RMB)[c]*	HH size
Bicycle	41	35.3 (14.7)	2.424 (1.235)	52626 (29756)	2080 (1722)	3.49 (1.13)
Electric bike	41	36.4 (12.8)	2.352 (1.111)	59209 (29418)	2563 (1862)	3.70 (1.27)
LPG scooter	29	38.2 (11.1)	2.623 (1.131)	66000 (29572)	3270 (1779)	3.56 (1.23)
Kunming	Gender (%F)	Mean value of				
		Age	Education (index)*	HH income (RMB)*	Wage (RMB)*	HH size
Bicycle	50	34.2 (12.0)	2.293 (1.010)	29761 (16774)	1652 (1022)	3.47 (1.41)
Electric bike	51	33.1 (9.6)	2.551 (1.003)	37734 (19411)	1905 (1101)	3.47 (1.22)

Note: *t*-statistics were calculated to identify differences between samples.
*$P<0.05$ all modes different; **$P<0.05$ bike-LPG different; ***$P<0.05$ ebike-LPG different.
Note: Standard deviation in parenthesis.
[a]In calculating the index, the following ordinal values were used: less than high school (1), high school (2), some college (3), college degree (4), and graduate study (5).
[b]Stated yearly income of all workers in the household.
[c]Monthly wage of individual survey respondent.

differences among modal usage are with respect to household income and the surveyee's wage and education level.

The Shanghai survey included LPG scooters, which were significantly different than bicycle and electric bikes on most metrics. However, bicycles and electric bikes were significantly different only in wages and household income.

Kunming does not have LPG scooters and there was a much more notable and significant difference between the demographics of bike and electric bike users. There was about a 50% gender split for both modes and users were in their mid 30s on average. Education and income levels were all significantly higher for electric bike users than bicycle users.

Household vehicle ownership rates of survey respondents are shown in Table 2. Relatively few survey respondents were from households with cars or motorcycles. Most electric bike users were from households with human-powered bicycles. For Shanghai, there was no statistically significant difference in car and motorcycle ownership among surveyed two-wheel users, despite the tendency of electric bike and LPG scooter users to come from higher income households. This is likely due to Shanghai's restrictions on automobile registration and ownership.

4.2. Surveyed travel characteristics

Modal distributions can have a strong influence on traffic conditions, air quality, and in the long term, urban form. As travelers choose faster modes, the number and lengths of trips will likely increase, as will energy use and tailpipe emissions. Faster speeds also promote the spatial separation of land uses. Alternatively, people may choose modes like electric bikes to provide ''easier'' mobility, such as the ability to weave in and out of congested traffic or reduce pedaling, not necessarily to travel faster or more often.

The surveys asked travelers to list characteristics of their previous day's one-way trips by bicycle, electric bike, or LPG scooter. Questions were asked on trip purpose, modal opportunities, previously used modes, trip lengths, and travel times. Table 3 summarizes the characteristics of travel by each mode.

The trip length was calculated as the network distance between stated origins and destinations. LPG scooter users averaged the longest trips while bicyclists averaged the shortest. In Shanghai, the average length of commute trips was about 20% longer than the length of other trips. In Kunming, average lengths were fairly similar across trip purposes. This could be due to Kunming's compact development and smaller size.

Mean travel times were similar across modes in both cities. Thus, while faster speeds allow longer distance travel, total time commitments are similar among all two-wheelers. This conforms to time budget theory that holds people to choose trip origins and destinations and modes so as to maintain a fairly constant daily travel-time commitment. This question is problematic because people often report door-to-door travel time. This includes access and egress time, which would have the effect of underestimating on-vehicle speed of faster modes. Also, people often round to the nearest 5-min and given the short trip distances, estimates of speed from stated travel time could be biased. Even with these considerations, the stated speeds of electric bikes are higher than bicycles by 15% and 10% in Shanghai and Kunming, respectively. A floating vehicle travel time study conducted in Shanghai and Kunming compared bicycle and electric bike speeds and showed a

Table 2
Household vehicle ownership levels

Shanghai	Average number of vehicles in the household				
Surveyed user	Car	Motorcycle	Bicycle**	Electric bike*	LPG scooter***
Bicycle	0.140 (0.378)	0.234 (0.487)	1.504 (0.886)	0.187 (0.409)	0.259 (0.493)
Electric bike	0.155 (0.363)	0.163 (0.402)	0.737 (0.807)	1.060 (0.573)	0.223 (0.463)
LPG scooter	0.156 (0.380)	0.228 (0.425)	0.731 (0.749)	0.269 (0.458)	0.946 (0.562)

Kunming	Average number of vehicles in the household			
Surveyed user	Car*	Motorcycle	Bicycle*	Electric bike*
Bicycle	0.111 (0.359)	0.151 (0.386)	1.452 (0.988)	0.432 (0.039)
Electric bike	0.257 (0.544)	0.178 (0.462)	0.782 (0.913)	1.234 (0.028)

Note: *t*-statistics were calculated to identify differences between samples.
*$P<0.05$ all modes different; **$P<0.05$ bike and others different; ***$P<0.05$ LPG and others different.
Note: Standard deviation in parenthesis.

Table 3
Travel characteristics, surveyed weekday (April–May 2006)

Shanghai	Number of trips[a]	Average trip lengths (km)			Average trip		
		Total trips[b]*	Work trips***	Other trips	Travel time (min)[c]	Speed (kph)[d]*	Weekday VKT[e]
Bicycle	2.06	4.29 (4.39)	4.94 (4.86)	4.07 (4.21)	26.31 (22.35)	11.38 (7.07)	8.84
Electric bike	2.00	4.83 (4.25)	5.66 (4.37)	4.50 (4.16)	25.56 (18.75)	13.04 (7.25)	9.66
LPG scooter	2.06	6.64 (5.96)	7.78 (6.77)	6.16 (5.53)	28.75 (19.81)	14.57 (7.94)	13.68

Kunming	Number of trips	Average trip lengths (km)			Average trip		
		Total trips*	Work trips	Other trips	Travel time (min)	Speed (kph)*	Weekday VKT
Bicycle	2.23	3.38 (1.91)	3.54 (1.79)	3.28 (1.97)	22.95 (12.29)	10.45 (5.74)	7.54
Electric Bike	2.54	3.63 (2.08)	3.75 (2.06)	3.55 (2.09)	20.28 (11.29)	11.85 (5.90)	9.22

Note: *t*-statistics were calculated to identify differences between samples.
*$P<0.05$ all modes different; **$P<0.05$ bike and others different; ***$P<0.05$ LPG and others different.
Note: Standard deviation in parenthesis.
Note: All distances in kilometers.
[a]Trip number is defined as a one way trip, so a trip to work and back would constitute two trips. The number of trips should be at least two for any travel diary that had any trips. A few of the respondents reported no trips on the previous day.
[b]Estimated network distance from stated origin and destination.
[c]Stated total travel time of trip estimated by respondent.
[d]Average speed is calculated as the measured trip length divided by the stated travel time of trip.
[e]Total VKT (vehicle kilometers traveled) is total trip length times the number of trips.

30–35% increase in average speed of electric bikes over bicycles (Cherry, 2006).

Perhaps the strongest correlate of externalities related to two-wheeler usage is daily vehicle kilometers traveled (VKT). As expected, the VKT of electric bikes is 9% and 22% higher than bicycles in Shanghai and Kunming, respectively. The daily VKT of LPG scooters is 41% higher than electric bikes in Shanghai. This increase in VKT could reflect the tendency of those using faster modes to travel farther or more often to access more destinations. It could also be a result of self selection: people who were already traveling far on a previous mode switched to electric bikes or LPG scooters because of their distant travel, i.e. they are not traveling any farther than before, just faster.

Trip purpose by mode and city is shown in Fig. 3. Work trips constituted the overwhelming majority of reported trips for all two-wheel modes in both cities. In Shanghai, more than one-fifth of electric bike trips were for shopping.

Respondents were also asked what mode they would have taken in the absence (or regulation) of their current mode for each trip. Overwhelmingly, respondents said they would take a bus as the alternative mode, followed by

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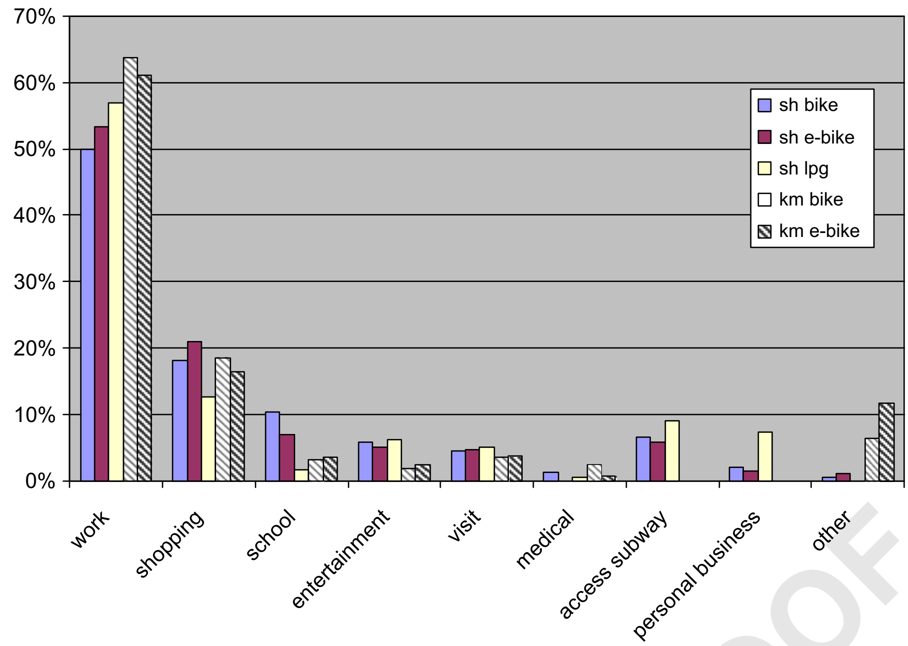

Fig. 3. Trip purpose by mode and city.

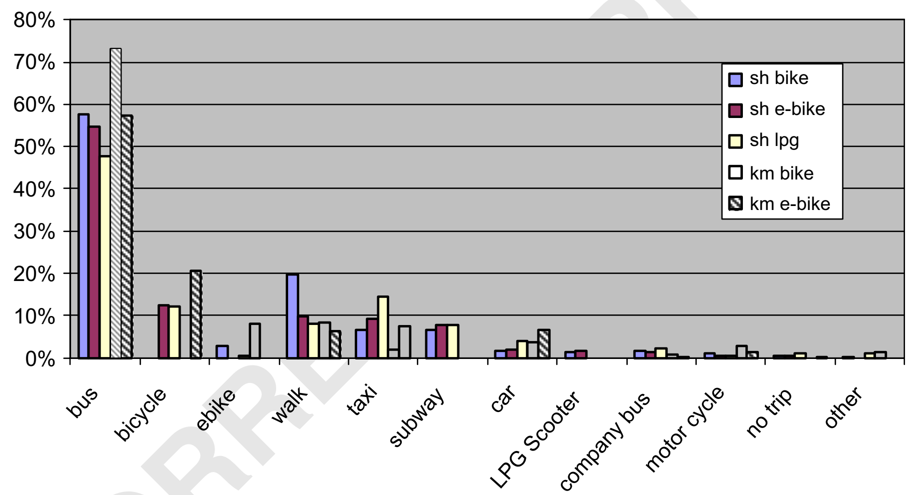

Fig. 4. What mode would you take otherwise.

bicycle and walking (Figs. 4 and 5). In both Kunming and Shanghai, more than half of electric bike users would take the bus instead if they did not own or have access to this mode. Interestingly a fairly large percentage of the electric bike and LPG scooter user respondents would shift to auto modes (taxi and car). This small shift would likely have a large impact on the transportation system.

When asked what mode they used before their surveyed mode of travel, the most frequent response again was bus. A large portion of electric bike users previously rode bicycles for the surveyed trips, but would use bus now if electric bikes were unavailable. This implies that a large group of travelers shifted from bicycle to electric bike in place of shifting from bicycle to bus. Once they were exposed to motorized travel, human-powered mobility was generally not considered a viable option.

The likely displacement effects of banning or regulating electric bikes or LPG scooters is important to know. If banning electric bikes causes a significant increase in bus ridership during peak hours, service expansion may be required which will result in higher energy use and emissions of certain pollutants than individual electric bikes. Alternatively, if most people would otherwise switch to non-motorized modes, little public investment would be required and energy and air-quality impacts would be significantly reduced.

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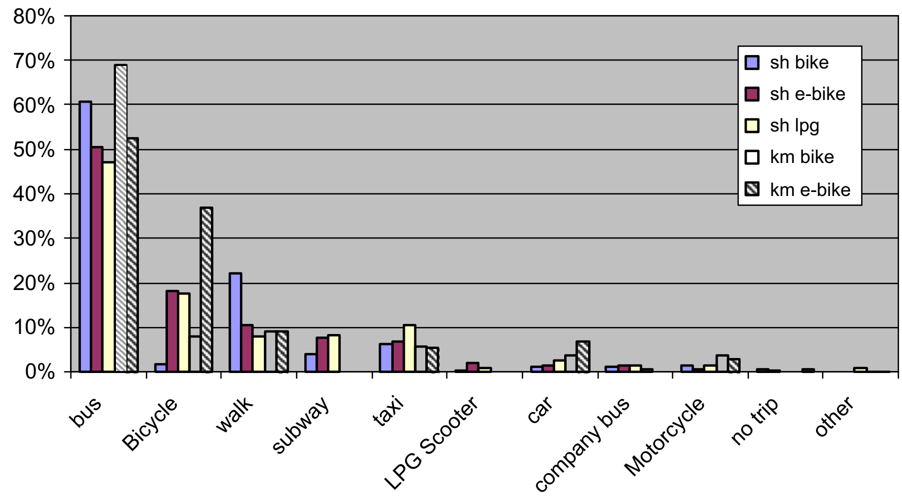

Fig. 5. What mode did you previously use.

4.3. User attitudes

Several attitudinal questions were also asked to probe why people use different two-wheeled modes and how they perceive electric bikes. When electric bike and LPG scooter users were asked why they chose the mode, most responded that faster speed was a primary reason (see Fig. 6). Also respondents cited that these motorized modes require less effort than alternative modes, such as bus or bicycle. Identifying factors that influence attitudes can help explain mode choice.

In order to find out how other users of the bicycle lane perceive electric bikes, respondents were asked if electric bikes should be allowed and developed as a viable mode in the city. Surprisingly, over 70% of bicycle riders in both cities think that electric bikes should be developed more. This suggests that even bicyclists have a positive opinion of them, perhaps in anticipation that they will eventually become electric bike users.

5. Factors that influence two-wheel vehicle choice

In order to gain a better understanding of the factors that influence electric bike use, discrete choice models were estimated based on demographic factors (e.g., income, age) and competitive modal characteristics (e.g., travel time and cost). Models were estimated to address two research questions:

(1) What factors influence the trip mode choice between electric bikes and bicycles?
(2) Among electric bike users, what factors would influence their preferred modal option in the absence of electric bikes?

5.1. Choice between bicycle and electric bike

Our initial hunch was that electric bikes are a stepping stone on China's motorization pathway. That is, bicycle riders will evolve into electric bike users and eventually into owners and users of faster and more comfortable modes, notably cars. A binomial logit model was estimated to predict the probability of choosing an electric bike instead of a bicycle. The data were adjusted to express linked trips as a home-based trip tour. A tour is defined as a series of trips that begin and end at home. For example, a trip from home, to work, to the grocery store then back home is defined as three trips linked into a single tour. In estimating models, each data observation is a tour. This removed potential bias from the models in two ways. One, the level to which individuals were sampled more than once was minimized. For example, urbanites make more than two trips per day, but most only make one trip tour per weekday, from home to work and back (sometimes with intermediate stops). The individual specific parameters are therefore independent between choice situations (e.g., trips links). This reduced the need to correct for this dependence with a mixed logit approach (Train, 1998). Two, the dependence between trip links is captured by tours. For example, if someone chose to ride an electric bike to work, the probability of choosing an electric bike to travel home is very high, and not independent of the person's choice of an electric bike for the previous trip. Combining all linked trips into a trip tour assumes that the individual makes choice decisions based on the entire tour, not just the first link.

The binomial logit results for predicting electric bike choice are shown in Table 4.[2] The bicycle is the base unit of

[2]Electric bikes were oversampled to gain an adequate number of electric bike responses, while not requiring an overly large sample of bicycles. Of the final sample of 669 trip tours that entered the model, 183 were bicycle trips and 486 were electric bike trips. The true ratio of bicycles to electric bikes is about 4.5:1 in Shanghai and Kunming. Choice based sampling

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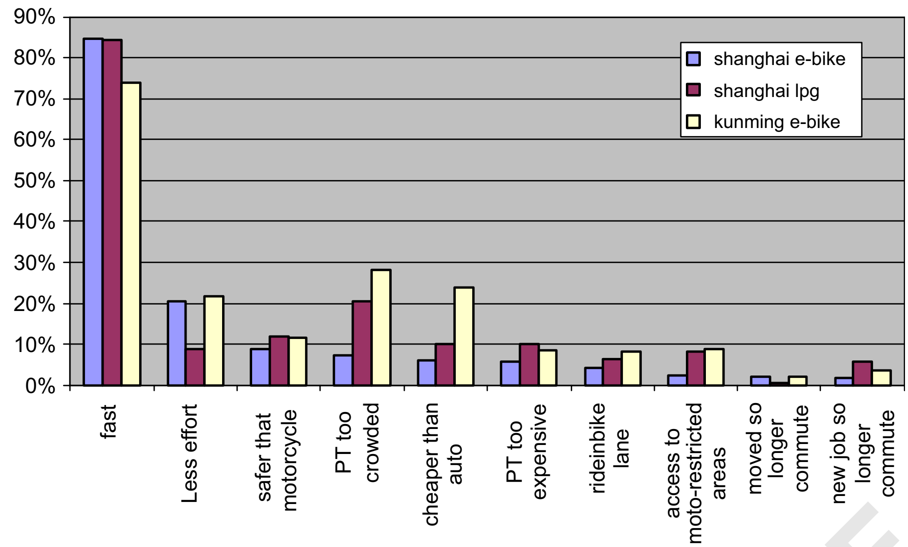

Fig. 6. Why did you choose this mode.

Table 4
Logit model for predicting probability of electric bike mode choice

Variable	β	Std error	t	Prob.	Odds ratio
Travel time for tour by bicycle minus e-bike (min)[a]	0.027	0.013	2.03	0.043	1.028
Number of e-bikes in household	3.736	0.311	12.00	0.000	41.919
Number of bikes in household	−0.756	0.203	−3.73	0.000	0.470
Number of cars in household	0.700	0.291	2.41	0.016	2.014
Pro-ebike attitude (1 if pro-ebike, 0 otherwise)[b]	1.144	0.343	3.34	0.001	3.140
Perceive mode as low effort (1 if low-effort, 0 otherwise)[c]	1.469	0.490	3.00	0.003	4.347
Age (years)	0.267	0.065	4.11	0.000	1.306
Age squared	−0.004	0.001	−3.97	0.000	0.996
Male gender (1 = male 0 = female)*Age	−0.077	0.030	−2.54	0.011	0.926
Male gender*Age squared	0.002	0.001	2.39	0.017	1.002
Constant	−3.488	1.206	−4.95	0.000	

Number of obs = 669
Log likelihood = −170.329
Pseudo $R^2 = 0.566$

[a]This is the total network distance of the trip tour divided by the empirically measured average speed of each mode using a GPS floating vehicle study (Cherry, 2006), it does not use the travel time reported by respondents.
[b]Respondents answered a question asking if they think that electric bikes should be encouraged in the city. If they answered favorably, were coded into the dataset as "pro-ebike".
[c]Respondents stated that one of the reasons they chose a particular mode is because of the low effort required.

comparison, so the coefficients (β) measure the change in electric bike use relative to choosing a bicycle. Variables related to vehicle performance, user demographics and attitudes entered the model. All variables were statistically significant at the 0.05 probability level.

Table 4 shows that, as expected, ownership of an electric bike greatly increases the probability of choosing an electric bike for a trip tour. So does owning a car. This could be an indication that electric bikes act as "second cars" for families with multiple wage earners. Owning a bicycle, however, lowers the probability of using an electric bike. These influences of vehicle ownership were independent of the comparative travel times, the chief control variable in the model. In general, as the time it takes to ride a bike versus use an electric bike increases, so does the likelihood of opting for electric bike.

As expected, respondents with pro-electric bike attitudes and who value low effort when making mode choices are more likely to choose electric bikes. Electric bike usage increases with age up to a certain point and then declines as one reaches older age. This pattern probably reflects the

(*footnote continued*)
causes biased estimates of the alternative specific constants and is corrected by the following equation (Train, 2002): $\alpha_j^* = E(\alpha_j) + \ln(A_j/S_j)$ where α_j^* is the true constant and $E(\alpha_j)$ is the biased estimated constant. The true population proportion for alternative j is A_j and the sampled proportion is S_j. The constant presented in Table 4 represents this adjustment.

reluctance of older generation Chinese to adopt new technology and forsake traditional modes.

Gender enters into the model when interacted with age. The sign on the two interaction variables indicates that the concave curve of electric bike choice as a function of age is flatter for men—that is, across all age categories, men are generally less likely to opt for electric bikes than women.

Factors of note that did not enter the model (due to statistical insignificance) are gender alone, city (dummy variable), household income, household size, level of education, trip purpose and monetary trip cost. These are important findings, particularly the non-appearance of a fixed-effect city variable and monetary cost variable. The failure of the relationships of difference between cities suggests the results are generalizable to other Chinese cities, regardless of local GDP. Also, bicycle and electric bikes users do not pay a large out-of-pocket marginal cost when making a trip or tour. The major cost of operating a bicycle is largely a one time purchase price and the cost of operating an electric bike is paid monthly through electricity bills and when batteries are replaced, normally every year or two.

5.2. Choice of alternative mode

What factors influence the likely choice of alternative modes for surveyed tours if electric bikes were unavailable, perhaps because of regulatory bans? A fixed-effects logit model was estimated to probe this question. Again, trips were categorized into tours and the entire tour was modeled as an independent observation. The problem of over-sampled individuals was reduced using this technique. In this case, the three low-cost modes—bus, bicycle, and walk—with the highest response rate among electric bike users for specific trip tours were included in the choice set.

In the estimated model, shown in Table 5, walk trips were set as the base case, thus the coefficients (β) measure the change in bus or bicycle use relative to walking. The cost of the tour did not enter into this model primarily because the marginal monetary cost differences are small among modes.

As expected, travel time enters the model with a negative sign, indicating the greater the travel time of a particular mode, the lower the probability of choosing that mode. The likelihood of opting for a bicycle increased with age, up to a point. Older survey respondents would walk or bus if electric bikes were unavailable. Interestingly, those who feel that public transit is too crowded are more likely to take the bus than walk, and slightly more likely to take a bus than ride a bicycle (although this difference is statistically insignificant). This could reflect that fact that those who share the opinion that buses are crowded might have little choice but to ride a bus because their travel distances are too far to walk (or bicycle). Finally, electric bike users who have a pro-e-bike attitude are more likely to take the bus than walk or ride a bicycle in the absence of electric bikes.

6. Conclusion and policy inferences

Electric bike use has grown at extraordinary rates over the past few years yet little is known about who uses them and why. Moreover, with rising incomes, Chinese residents are experiencing more travel choices than ever and individual transportation decisions are constantly changing. Researchers need to present information that is timely and relevant to current policy decisions policy makers can guide transportation decisions along a sustainable path.

Policy makers in different Chinese cities are treating electric bikes differently. Some cities have openly embraced

Table 5
Logit model for predicting probability of current electric bike users switching to bus they, bicycle, or walk if electric bikes became unavailable

Variable	β	Std error	Z	$P>z$	Odds ratio
Alternative specific constant-bus	1.628	0.352	4.62	0.000	5.094
Alternative specific constant-bicycle	−3.034	1.542	−1.97	0.049	0.048
Trip tour travel time (min)[a]	−0.042	0.010	−4.07	0.000	0.959
Age of bicycle choosers	0.173	0.086	2.01	0.044	1.189
Age squared of bicycle choosers	−0.003	0.001	−2.27	0.023	0.997
Perceive public transit is crowded (1 if PT crowded, 0 otherwise)-bus choosers[b]	2.172	1.028	2.11	0.035	8.774
Perceive public transit is crowded (1 if PT crowded, 0 otherwise)-bicycle choosers[b]	2.306	1.055	2.19	0.029	10.033
Pro-ebike attitude (1 if pro-ebike, 0 otherwise)-bus choosers[c]	0.655	0.332	1.97	0.049	1.925

Number of obs = 423
Log likelihood = −298.29
Pseudo $R^2 = 0.3396$

[a]For the bike option, travel time was estimated as the total network distance of the trip tour divided by the empirically measured average speed of bicycle mode using a GPS floating vehicle study (Cherry, 2006). Walk times assume 6.5 km/h walk speed. Public transit agencies provide data on bus travel times that include access and egress time, wait time, transfer time and in-vehicle time for the bus option.

[b]Respondents stated that one of the reasons they chose electric bike is because they perceive public transit to be too crowded.

[c]Respondents answered a question asking if they think that electric bikes should be encouraged in the city. If they answered favorably, they were coded into the dataset as "pro-ebike".

Please cite this article as: Cherry, C., Cervero, R., Use characteristics and mode choice behavior of electric bike users in China, Transport Policy (2007), doi:10.1016/j.tranpol.2007.02.005

them as a low cost form of mobility, complementing other transportation options. Others cast a jaundiced eye toward electric bikes because of concerns over environmental, traffic, and safety impacts.

The net environmental, traffic and safety impacts of electric bikes are largely dependent upon the shift of electric bike users to alternative modes. While a full shift from electric bikes to bicycles or buses might improve the road safety and environmental situation of a city, the reality is that electric bikes displace a small amount of car trips (taxis or personal cars) and the negative environmental and safety impacts of that potential shift could far outweigh the benefit of shifting to more efficient modes. Quantifying these costs and benefits is an area of future work.

In order to develop environmentally sustainable and equitable policy regarding electric bikes, a policy maker has to understand what populations are using electric bikes, how they are using electric bikes and what they would choose in the absence of electric bikes. Electric bike users are generally more educated and earn more than bicycle users. Commuters do not use electric bikes in the same way as bicycles. Electric bike users take more and longer trips in an average weekday than bicycle users and LPG scooter users take much longer trips. The result is increased daily VKT and thus energy use and emissions compared to bicycles.

User attitudes also affect why people choose electric bikes. Users primarily cite speed, effort, safety, and crowded transit as factors that swing their electric bike choice. Interestingly, most bicycle riders support electric bike usage of bike lanes.

User attitudes, demographic attributes, and vehicle performance significantly influence electric bike choice. One of the more significant factors that can be controlled by policy makers through regulation is the difference in travel-time between human-powered and motorized two-wheelers. As expected, the higher the travel time difference, the higher the likelihood of choosing an electric bike. Travel time differences are linked to speed, which is a function of congestion levels in the bike lane, network (traffic signal) density, and electric bike performance. Electric bikes are loosely regulated to a maximum speed of 20 km/hr, in which manufacturers rarely comply. In both Kunming and Shanghai, electric bike users were observed to spend a larger portion of their travel time stopped at signals than bicycles, as expected because of their higher free-flow speeds. A way to increase electric bike use is to consider control strategies that limit the number of stops for both modes, through signal coordination or grade separated intersection crossings, thus increasing the travel time advantage of electric bikes.

Travel time of a trip also significantly influences alternative mode choice. Electric bike users would switch to a bus for most trips if electric bikes were banned. Some cities have made an effort to reduce two-wheeled vehicle traffic by providing high quality public transport, such as through reserving exclusive right-of-way for buses.

Presently, policy attitudes toward electric bikes and other emerging modes vary through China. Knowing who uses electric bikes and why, and what modes would be relied upon in the absence of electric bikes, is important toward rationalizing motorized two-wheeler policies in Chinese cities. Without knowing use characteristics, it is impossible to tell if a ban would result in a positive or negative effect on the transportation system. Banning electric bikes would have the effect of increase public transport usage. In some corridors, this could saturate already over-subscribed bus services. The marginal cost of expanding bus services could very well exceed whatever benefits might be attendant with banning electric bicycle usage. Banning electric bikes will also slightly increase demand for automobile travel, possibly negating any positive effect of an electric bike shift to bus or bicycle. Clearly, any movement to regulate electric bikes needs to weigh not only the impacts on safety and environmental conditions but also the redistributive consequences, including the impacts on other motorized modes. Rather than ban electric bikes, improve the performance of bus and bicycle systems such that travel times differences decrease and these modes become more attractive.

Acknowledgments

This work was made possible by funding from the University of California Berkeley Center for Future Urban Transport-A Volvo Center of Excellence. The authors would like to thank academic partners in China, specifically Dr. Pan Haixiao from Tongji University, Shanghai and Dr. Xiong Jian from the Kunming University of Science and Technology as well as all of the Chinese students who aided in this research.

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Please cite this article as: Cherry, C., Cervero, R., Use characteristics and mode choice behavior of electric bike users in China, Transport Policy (2007), doi:10.1016/j.tranpol.2007.02.005