



ELSEVIER

Transport Policy ■ (■■■■) ■■■-■■■

TRANSPORT
POLICYwww.elsevier.com/locate/tranpol

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

Christopher Cherry^{a,*}, Robert Cervero^b^a*Institute of Transportation Studies, University of California, Berkeley, 2614 Dwight Way #1782, Berkeley, CA 94720, USA*^b*Department of City and Regional Planning, University of California, Berkeley, 228B Wurster Hall #1850, Berkeley, CA 94720-1850, USA*

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.

© 2007 Elsevier Ltd. All rights reserved.

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

*Corresponding author. Tel.: +1 510 642 4914; fax: +1 510 643 5456.

E-mail addresses: cherry@berkeley.edu (C. Cherry), robertc@berkeley.edu (R. Cervero).



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 RMB¹/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

¹8 RMB = 1 USD.

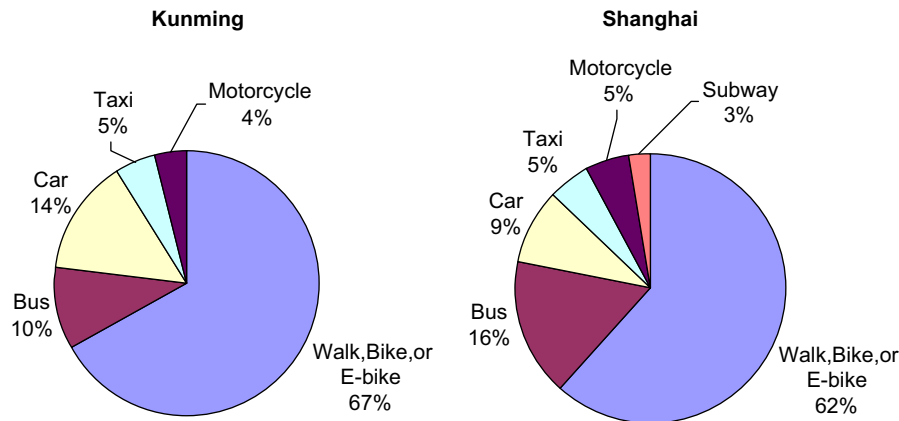


Fig. 2. Mode splits for Kunming and Shanghai, 2003.

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. Addition-

ally, 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

1 Table 1
 2 Demographics of two-wheel vehicles users in Kunming and Shanghai 59

3 Shanghai							61
5	Gender (%F)	Mean value of					63
		Age **	Education (index) ^a ***	HH income (RMB) ^{b*}	Wage (RMB) ^{c*}	HH size	
7 Bicycle	41	35.3 (14.7)	2.424 (1.235)	52626 (29756)	2080 (1722)	3.49 (1.13)	65
8 Electric bike	41	36.4 (12.8)	2.352 (1.111)	59209 (29418)	2563 (1862)	3.70 (1.27)	
9 LPG scooter	29	38.2 (11.1)	2.623 (1.131)	66000 (29572)	3270 (1779)	3.56 (1.23)	
11 Kunming							67
13	Gender (%F)	Mean value of					69
		Age	Education (index)*	HH income (RMB)*	Wage (RMB)*	HH size	
14 Bicycle	50	34.2 (12.0)	2.293 (1.010)	29761 (16774)	1652 (1022)	3.47 (1.41)	71
15 Electric bike	51	33.1 (9.6)	2.551 (1.003)	37734 (19411)	1905 (1101)	3.47 (1.22)	

17 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.

18 Note: Standard deviation in parenthesis. 75

19 ^aIn calculating the index, the following ordinal values were used: less than high school (1), high school (2), some college (3), college degree (4), and
 20 graduate study (5). 77

21 ^bStated yearly income of all workers in the household. 79

22 ^cMonthly wage of individual survey respondent. 79

23 differences among modal usage are with respect to house- 81
 24 hold income and the surveyee's wage and education level. 81

25 The Shanghai survey included LPG scooters, which were 83
 26 significantly different than bicycle and electric bikes on 83
 27 most metrics. However, bicycles and electric bikes were 85
 28 significantly different only in wages and household income. 85

29 Kunming does not have LPG scooters and there was a 87
 30 much more notable and significant difference between the 87
 31 demographics of bike and electric bike users. There was 89
 32 about a 50% gender split for both modes and users were in 89
 33 their mid 30s on average. Education and income levels were 91
 34 all significantly higher for electric bike users than bicycle 91
 35 users. 93

36 Household vehicle ownership rates of survey respon- 95
 37 dents are shown in Table 2. Relatively few survey 95
 38 respondents were from households with cars or motor- 97
 39 cycles. Most electric bike users were from households with 97
 40 human-powered bicycles. For Shanghai, there was no 99
 41 statistically significant difference in car and motorcycle 99
 42 ownership among surveyed two-wheel users, despite the 101
 43 tendency of electric bike and LPG scooter users to come 101
 44 from higher income households. This is likely due to 103
 45 Shanghai's restrictions on automobile registration and 103
 46 ownership. 105

49 4.2. Surveyed travel characteristics 107

50 Modal distributions can have a strong influence on 107
 51 traffic conditions, air quality, and in the long term, urban 109
 52 form. As travelers choose faster modes, the number and 109
 53 lengths of trips will likely increase, as will energy use and 111
 54 tailpipe emissions. Faster speeds also promote the spatial 111
 55 separation of land uses. Alternatively, people may choose 113
 56 modes like electric bikes to provide "easier" mobility, such 113
 57 as the ability to weave in and out of congested traffic or 81
 58 reduce pedaling, not necessarily to travel faster or more 83
 59 often. 83
 60 The surveys asked travelers to list characteristics of their 85
 61 previous day's one-way trips by bicycle, electric bike, or 85
 62 LPG scooter. Questions were asked on trip purpose, modal 87
 63 opportunities, previously used modes, trip lengths, and 87
 64 travel times. Table 3 summarizes the characteristics of 89
 65 travel by each mode. 89
 66 The trip length was calculated as the network distance 91
 67 between stated origins and destinations. LPG scooter users 91
 68 averaged the longest trips while bicyclists averaged the 93
 69 shortest. In Shanghai, the average length of commute trips 93
 70 was about 20% longer than the length of other trips. In 95
 71 Kunming, average lengths were fairly similar across trip 95
 72 purposes. This could be due to Kunming's compact 97
 73 development and smaller size. 97
 74 Mean travel times were similar across modes in both 99
 75 cities. Thus, while faster speeds allow longer distance 99
 76 travel, total time commitments are similar among all two- 101
 77 wheelers. This conforms to time budget theory that holds 101
 78 people to choose trip origins and destinations and modes 103
 79 so as to maintain a fairly constant daily travel-time 103
 80 commitment. This question is problematic because people 105
 81 often report door-to-door travel time. This includes access 105
 82 and egress time, which would have the effect of under- 107
 83 estimating on-vehicle speed of faster modes. Also, people 107
 84 often round to the nearest 5-min and given the short trip 109
 85 distances, estimates of speed from stated travel time could 109
 86 be biased. Even with these considerations, the stated speeds 111
 87 of electric bikes are higher than bicycles by 15% and 10% 111
 88 in Shanghai and Kunming, respectively. A floating vehicle 113
 89 travel time study conducted in Shanghai and Kunming 113
 90 compared bicycle and electric bike speeds and showed a

Table 2
Household vehicle ownership levels

Shanghai					
Surveyed user	Average number of vehicles in the household				
	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					
Surveyed user	Average number of vehicles in the household				
	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.

^aTrip 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.

^bEstimated network distance from stated origin and destination.

^cStated total travel time of trip estimated by respondent.

^dAverage speed is calculated as the measured trip length divided by the stated travel time of trip.

^eTotal 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

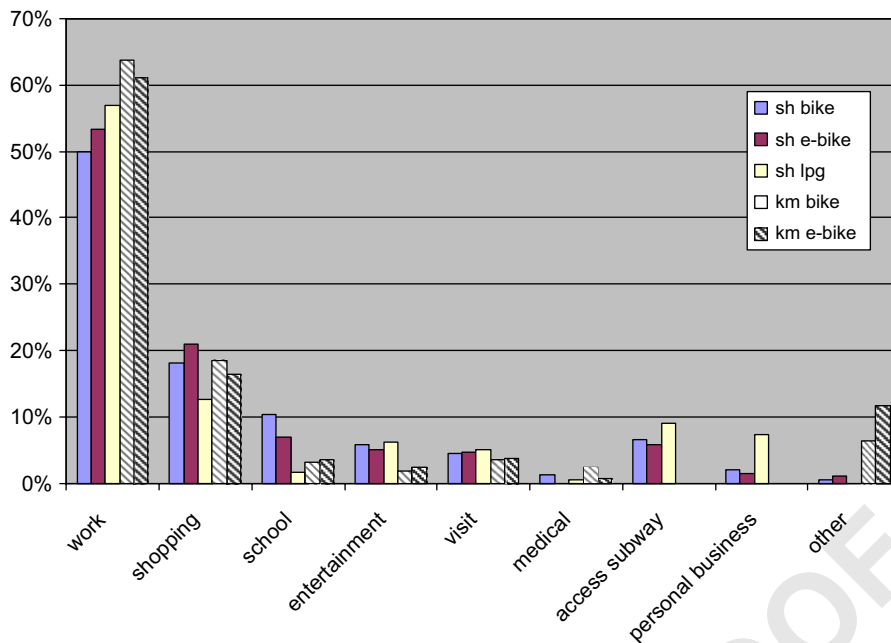


Fig. 3. Trip purpose by mode and city.

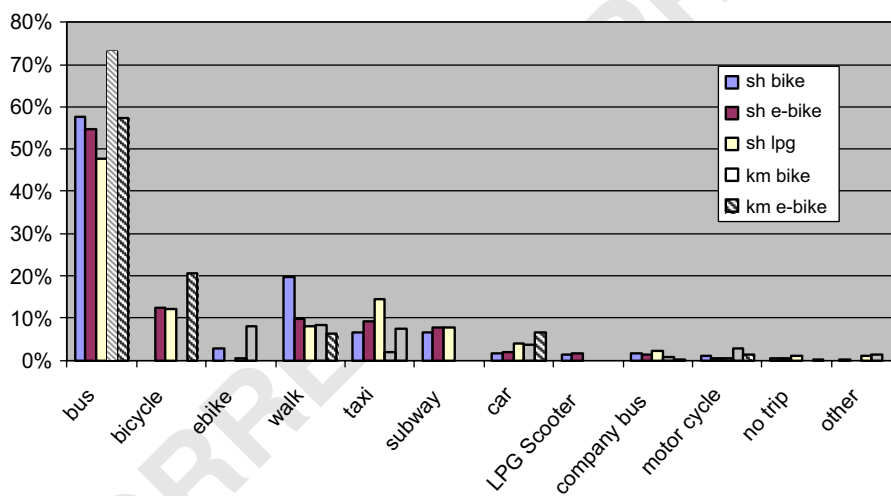


Fig. 4. What mode would you take otherwise.

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.

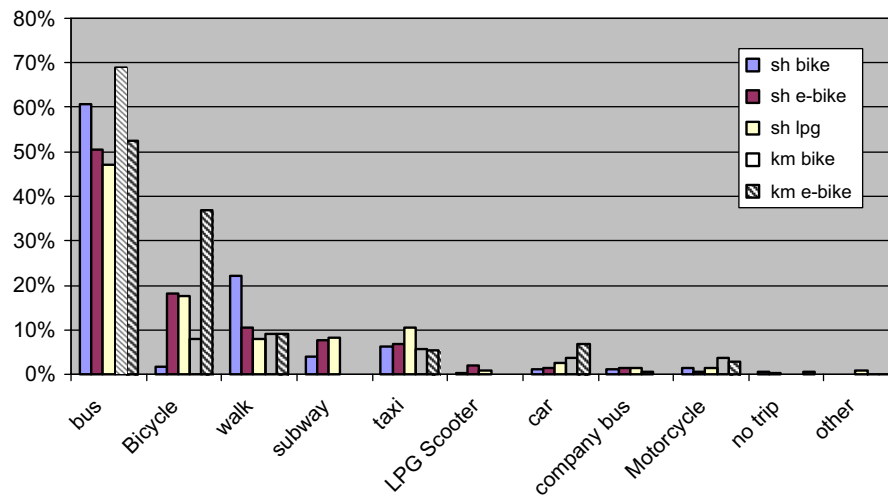


Fig. 5. What mode did you previously use.

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

²Electric 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

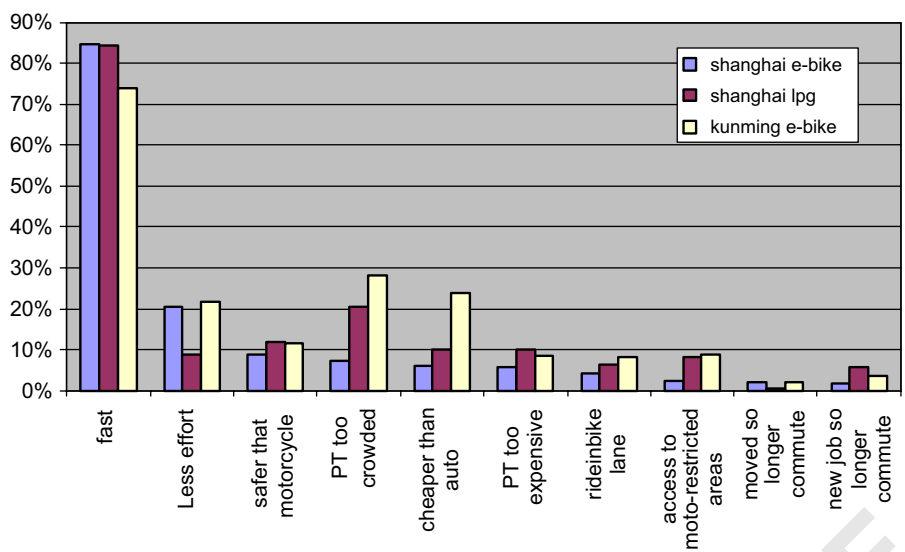


Fig. 6. Why did you choose this mode.

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					

^aThis 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.

^bRespondents 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".

^cRespondents 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

(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.

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

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.

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					

^aFor 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.

^bRespondents stated that one of the reasons they chose electric bike is because they perceive public transit to be too crowded.

^cRespondents 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”.

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

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

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

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

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

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

53 Travel time of a trip also significantly influences
54 alternative mode choice. Electric bike users would switch
55 to a bus for most trips if electric bikes were banned. Some
56 cities have made an effort to reduce two-wheeled vehicle

57

58 traffic by providing high quality public transport, such as
59 through reserving exclusive right-of-way for buses.

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

83 Acknowledgments 85

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

94 References 95

- 96 Beijing Traffic Development Research Center, 2002. Report on How to
97 Manage the Development of Electric Bicycles in Beijing.
- 98 Cherry, C., 2006. Implications of electric bicycle use in china: analysis of
99 costs and benefits. UC Berkeley Center for Future Urban Transport-
100 Volvo Summer Workshop. Berkeley, CA.
- 101 China Central Government, 2000. National Road Transportation Law.
- 102 China Data Online, 2006. accessed 7-6-2006
- 103 Chiu, Y.C., Tzeng, G.H., 1999. The market acceptance of electric
104 motorcycles in Taiwan experience through a stated preference analysis.
105 Transportation Research Part D 4.
- 106 Guangzhou Daily, 2006. Guangzhou bans electric bikes. Guangzhou
107 Daily.
- 108 Joos, E., 2000. Zurich-Kunming Sister-City Project: bus rapid transit
109 comes to China. Sustainable Transport 11.
- 110 Kunming University of Science and Technology, 2003. Kunming
111 Municipal Transportation Synthesis: Management and Countermea-
112 sure Research.
- 113 Kunming Urban Traffic Research Institute, 2004. Kunming BRT System
114 Study.
- 115 Li, J. H., 2006. Shanghai's rail transportation and city spatial structure.
116 Transit Oriented Development Global Experiences and Opportunities/

- 1 Challenges for China—A Workshop for Public Officials in Urban
Development, Shanghai, China. 9
- 3 Taiwan EPA, 1998. Taiwan steps up promotion of electric motorcycles.
Environmental Policy Monthly. 11
- 5 Train, K., 1998. Recreation demand models with taste differences over
people. *Land Economics* 74. 13
- 7 Train, K., 2002. *Discrete Choice Methods with Simulation*. Cambridge
University Press, Cambridge.
- Weinert, J. X., Ma, C. T., Cherry, C., 2006. The transition to electric bikes
in China: history and key reasons for rapid growth. In: *EVS22-The
22nd International Battery, Hybrid and Fuel Cell Electric Vehicle
Symposium and Exhibition*. Yokohama, Japan.

UNCORRECTED PROOF