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Electric Two-Wheelers in China

Effect on Travel Behavior, Mode Shift, and User Safety Perceptions in a Medium-Sized City

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Despite rapid economic growth in China during the past decade and the rise in personal car ownership, most Chinese still rely on two-wheeled vehicles (2WVs) or public transport for commuting. The majority of these 2WVs are bicycles. In recent years, concern about poor air quality in urban areas and rising energy costs have caused cities to ban gasoline-powered scooters in city centers. Simultaneously, a new 2WV mode emerged to fill the void: the electric bike (e-bike). This shift to e-bikes is occurring rapidly throughout China, especially in its cities. E-bike sales reached 10 million per year in 2005 as more bike and public transit users shifted to this mode. City planners and policy makers are undecided on how to plan for and regulate e-bikes because it is not yet clear what effect they will have on travel behavior, public transportation use, and safety. To begin to understand these effects, bike and e-bike users were surveyed in Shijiazhuang, a medium-size city with particularly high 2WV use, to identify differences in travel characteristics and attitudes. The following conclusions were reached (partial list): (a) e-bikes are enabling people to commute longer distances, with important implications for energy use, accessibility, and urban expansion of cities; (b) people underserved by public transportation are shifting to e-bikes; and (c) women feel safer crossing intersections on an e-bike compared with a regular bike, but they have strong reservations about increasing e-bike speed capability.

Two-wheeled vehicles (2WVs) [e.g., bicycles, electric bikes (e-bikes), motor scooters, motorcycles] have historically been an important component of traffic throughout China and many other developing countries. In medium and large Chinese cities such as Shijiazhuang, the dominant 2WVs are bicycles.

Bicycles, estimated at 450 million nationally in 2004 (1), have been and still remain the dominant 2WV in Chinese cities, owing mainly to low income, high population density (and thus short trips), and extensive bicycle infrastructure (e.g., lanes, parking). On the basis of a statistical report in 2005, bicycle trip share is still more than 50% in many large cities such as Tianjin, Xi'an, and Shijiazhuang (2).

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Gasoline-powered motor scooters (GMSs) used to make up a larger percentage of the overall 2WV population; however, beginning in the late 1990s, many large cities (population > 1 million) and most capital cities have stopped licensing these vehicles. Total GMSs in China numbered 80 million in 2005 (3). Although numbers are still growing in the wide rural areas and small cities, it is estimated that without urban restrictions, 4 million to 5 million more would be on the roads (4).

In recent years, however, as a result of an improved standard of living and rapid urbanization, Chinese are shifting from bike (or public transit) to electric bikes (e-bikes) as they demand more flexible, convenient, and comfortable mobility. In 2005, there were an estimated 20 million to 22 million e-bikes in China (5). Production is expected to grow 80% annually during the next 5 years (6).

Throughout China, however, government views about e-bikes and their effect on traffic are mixed. In May 2006 a national government agency issued a report promoting e-bikes for their air quality and energy-saving benefits (6). In November 2006, however, Guangzhou became the third city in China to ban e-bikes (behind Fuzhou and Zhuhai), under advice from the traffic management bureau citing traffic safety concerns (7). The safety issue of e-bikes mixed in traffic is a key consideration in drafting the new national e-bike standards, which are under revision and intense debate. The standard regulates the performance and specifications of e-bikes (see section below). Bicycle proponents (e.g., China Bicycle Association) want to limit e-bike performance to make them more similar to the bicycle and for fear that faster, heavier e-bikes will make them dangerous to cyclists. E-bike manufacturers, however, want to broaden the limits on weight, width, and power to be able to build products that they claim customers want. Whatever new standard is adopted will greatly affect the future direction of e-bike development in China.

E-BIKE BACKGROUND

E-bikes can be classified as a “semimotorized” vehicle because they can run on either human power or electricity. They have become a popular transportation mode in China because they provide an inexpensive form of private mobility and are thus an attractive alternative to public transit or regular bicycling. With an average energy consumption of 1.2–1.5 kWh/100 km, e-bikes offer extremely efficient transportation with zero local air pollution. Although local pollution is negligible, they do operate on electricity generated mainly from coal-fired power plants. Perhaps the most problematic environmental issue with electric bikes is the use of lead acid batteries that experience high lead loss rates during production, manufacturing, and recycling processes (8).

There are two main types of electric bikes: bicycle style (BSEB, or simple style), and scooter style (SSEB) (9). Although the SSEB looks more like a typical scooter, both styles are subject to the national e-bike standards (10):

1. Top speed = 20 km/h,
2. Maximum weight = 40 kg,
3. Minimum range per charge = 25 km, and
4. Maximum power = 240 W.

Despite these standards, most e-bikes exceed these performance limits owing to strong consumer demand for better performance coupled with lax enforcement of the standard. A small subsurvey of 14 e-bike users revealed top speeds from 25 to 40 km/h and ranges of 25 to 50 km on a single charge, which requires 6–8 h. E-bikes range in cost from US\$125 to US\$300 compared with gasoline scooters at \$500–\$600. Operating costs (include fuel, maintenance, and battery replacement) are \$0.007/km compared with \$0.031/km for a gasoline scooter (11).

Different cities have adopted e-bikes at different rates. On-street surveying of e-bike proportions versus other 2WV modes by the authors in various cities has shown that some cities have low adoption, such as Beijing (<10%), whereas others have high adoption, such as Chengdu (>50%). In Shijiazhuang, e-bikes make up 22% of all 2WV traffic (bicycles = 77.5% and motor scooters/bikes 0.5%). The level of e-bike adoption is related to income, local regulation, public transit service quality, terrain, and other factors. Most cities in east China are situated on relatively flat terrain and amenable to bicycle and electric bike use.

SHIJIAZHUANG BACKGROUND

Shijiazhuang City is located in south-central Hebei Province. As the capital of the province, it has recently developed into an important commercial port and regional agricultural and distribution center of industrial products in northern China. The total and the urban population in 2005 was 9.2 and 2.2 million, respectively. Total and urban area is 15,900 and 3,850 km², respectively. The topography in this area is low (70 m above sea level) and flat because it is situated in the Huabei Plain of China. The climate ranges from an average high of 26.9°C in July to an average low of -2.4°C in January.

Shijiazhuang's urban layout follows the typical Chinese model of a monocentric city with a high-speed ring road encircling the urban area. The urban area is divided into four quadrants by two railways, and the city's commercial district is centered on the railway station. Residential areas stand mainly in the northwest, center, and east sections of the city.

Bicycles and e-bikes compose the largest daily trip mode share in Shijiazhuang. A previous survey conducted by Shijiazhuang showed that in 2002, cycling trip share was 54% and reached a volume of 3 million trips per day. For comparison, public transit trip share was only 4.3% (12).

METHODOLOGY

Because of the institutional and logistical difficulty in conducting random household surveys in China, an intercept survey of 751 bike and 460 e-bike users throughout Shijiazhuang was designed and implemented. The survey was administered at bicycle and e-bike parking lots along the main travel corridor (Zhongshan Lu) in Shijiazhuang to capture a diverse range of respondents from many different parts of the city. The survey was administered on both a workday and weekend day

in June 2006, from 7:30 to 11:30 a.m. and 3:00 to 6:00 p.m. to collect as broad a range of respondent types as possible (i.e., workers, retirees, students, etc.). Separate surveys were given to bicycle and e-bike riders to identify any differences between their travel behavior and attitudes.

Before this survey was launched, a trial survey on 50 bike/e-bike users was first administered to identify the potential problems with the survey and uncover any unintentional biases. Some of the response choices were found to be inappropriate, and certain questions were confusing. These problems were corrected before the final survey was administered.

Potential Sampling Biases and Inaccuracies

Surveyors kept the sample balanced in gender and age. However, on the basis of site observation, the proportion of male and female e-bike users is not evenly balanced; in a random sample of 180 e-bike users, 62% were female, 38% were male. Thus, a 50–50 sampling of men and women may lead to an underrepresentation of female attitudes and travel behavior concerning e-bikes.

The same problem also occurs in representing the elderly age group. The survey was conducted during the daytime on 2 days with hot weather. Because elderly people in China are more active in the early morning and also because of the hot daytime weather, this age group may be underrepresented.

The survey was carried out only in the downtown areas of Shijiazhuang. This location may result in a slight bias toward higher income users as well as individuals who use electric bikes for work commute trips.

To calculate trip distance, rather than ask people their trip distance directly, respondents were asked to locate their origins and destinations using a grid map. They were then asked to estimate their travel time. The data collection method for trip distance and thus travel speed could have inaccuracies if respondents chose a special route that was longer or shorter than the distance calculated using their origin–destination coordinates.

Data Processing

The results in the section below were calculated using Excel. Data from the survey were input into an Excel spreadsheet, and response choices for each question were added together. The data were sorted by demographics when appropriate.

Because the streets in central Shijiazhuang follow a grid pattern, trip distance was calculated by measuring the ΔX and ΔY from respondents' stated origin and destination, which they located using a grid map attached to the survey. Trip speed is calculated by dividing calculated trip distance by stated trip time. Calculated trip speeds were then averaged together to find the absolute average trip speed. Trip speed results exhibit the most uncertainty because the calculated responses ranged from 5 to 26 km/h for bike users and 4 to 34 km/h for e-bikes. Responses under 6 km/h were thrown out.

RESULTS

Two-Wheeled Vehicle User Demographic Differences

The differences in age, gender, and income between bike and e-bike users are presented in the sections below.

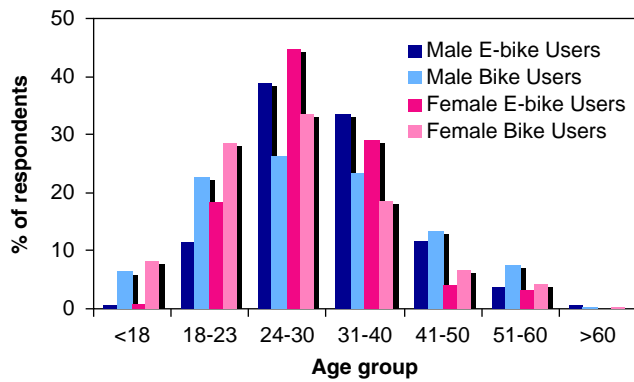


FIGURE 1 Bike and e-bike users by age and gender.

Age and Gender

Of the 751 bike riders and 460 e-bike users, 49% were male and 51% female. Figure 1 shows the distribution of bikes and e-bikes among men and women of different age groups. E-bikes are most popular among the 24–30 age group, especially among women. Almost half of all female e-bike riders are in this group. Nearly 73% of all e-bike users are between 24 and 40, compared with 51% of all bike riders. This could reflect higher-income, career-age commuters choosing e-bikes.

Income

Figure 2 shows the distribution of income levels of bike users and e-bike users. The average income difference between bike users and e-bike users, 18,000 and 22,000 RMB/year (8.0 RMB = US\$1), respectively, is surprisingly small. The small income gap indicates that there are other factors behind purchasing an e-bike than just price. These other factors are revealed in analyzing the trip characteristics of the two groups in the next section.

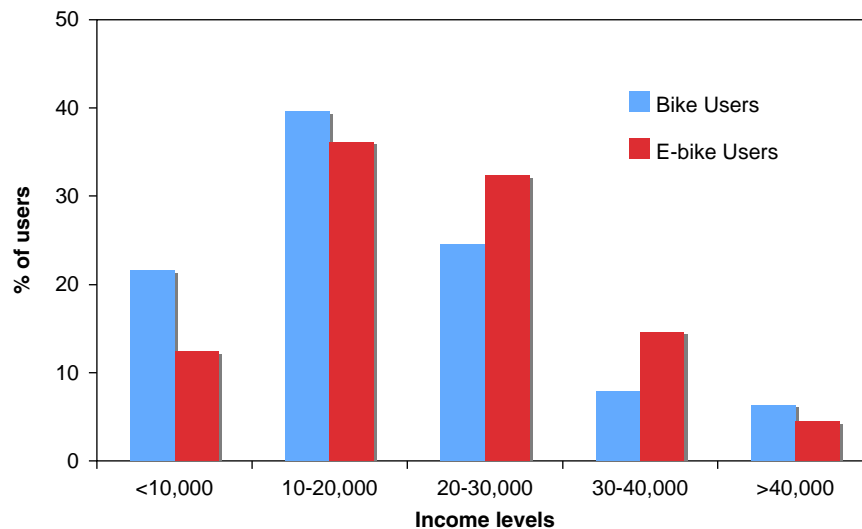


FIGURE 2 Income levels of bike and e-bike users [(yuan/year); 7.8 yuan = \$1.00 (2006)].

Trip Characteristics

The differences in trip characteristics between bikes and e-bikes are explored in the following section. Trip distance, time, speed, purpose, and frequency are included.

Trip Distance

Figure 3 shows the distribution of trip distance for 2WVs in Shijiazhuang. E-bike riders in general travel 32% farther than bicycle riders (5.8 versus 4.4 km/trip average).

Trip Time

E-bike riders’ travel time is about 10% longer on average than bike riders (27.2 min versus 24.7 min, respectively). Approximately 80% of bikers make trips less than 30 min, which concurs with a previous survey of 14 Chinese cities (population > 1 million) in 1995 (13). Only 70% of e-bikers made trips less than 30 min, indicating that people are willing to travel for longer periods of time by e-bike.

Trip Speed

E-bike average speed is 17% higher than that of bike users: 14 versus 12 km/h. This is not surprising because they travel farther distances over the same commute time, and they are supported by electric propulsion. The statistical significance of this result however is uncertain because of the data collection method. Speed studies in Shanghai and Kunming show about a 30% difference in speeds (14.5 km/h versus 11.1 km/h and 14.7 km/h versus 10.9 km/h, respectively), which is consistent with users in Shijiazhuang with longer trip distances (14). The difference in speeds might be underestimated if respondents included their access and egress times. This would more heavily underestimate the on-vehicle speed of faster modes.

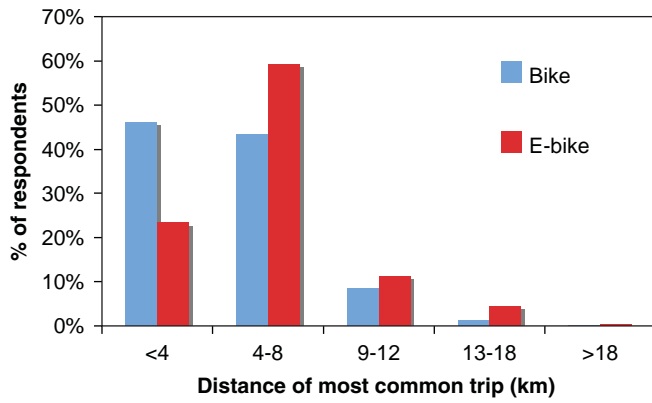


FIGURE 3 Distribution of trip distance for bike and e-bike.

Trip Purpose

Commuting is the dominant trip purpose for both bike and e-bike users (61% and 77%, respectively). Going to school, picking up children from school, and shopping make up the smaller share of trips. “School” is a more common trip purpose for bike users because people under 23 more commonly ride a bicycle.

Trip Frequency

Both bike and e-bike users on average make between two to four trips per day. There is no significant difference between e-bike and regular bike users.

Passenger and Cargo Carrying

Site observation and survey results revealed that e-bike users carry cargo and passengers more often than do bicycles. SSEB users are commonly seen carrying as many as two passengers. Clearly, the increased power offered by the battery and motor makes this behavior much easier.

Vehicle Performance in Traffic

Because of the higher acceleration and speed of e-bikes (>20 km/h), typically they lead each wave of nonmotorized vehicles (NMVs) traveling through the bike lane from one intersection to the next. E-bikers tend to reach the intersection before bicyclists and thus quickly accelerate through the intersection once the signal turns green, unimpeded by bicyclists. Bicyclists are typically the last to pass through an intersection.

Travel Mode Choice

To make better urban planning decisions about road capacity, public transport, and traffic policies affecting bike and e-bike users, it is important to understand why 2WV users choose these modes, how they would travel if these modes weren’t available, and their plans to switch modes. The following section presents results from the survey on these issues.

Reasons for Choosing Bike or E-Bike

Respondents were asked why they chose to ride a bike or e-bike for commuting. They were given 10 options and could select multiple answers. The five most popular responses for bike and e-bike users are shown in Figure 4.

These results indicate that the e-bikes are offering users a better alternative to biking and riding the bus. They also reinforce results about trip distance that people are commuting farther to work. For bike users, results show that people choose to ride a bike for reasons other than just low income. Road congestion, health, and convenience are also important factors.

Two-Wheeled Vehicle Users and Public Transit

Results of the survey indicate that the public transit network in Shijiazhuang is an important part of the 2WV users’ transportation system. Users of 2WVs were asked questions about their bus-riding habits and attitudes. They were first asked why they do not ride the

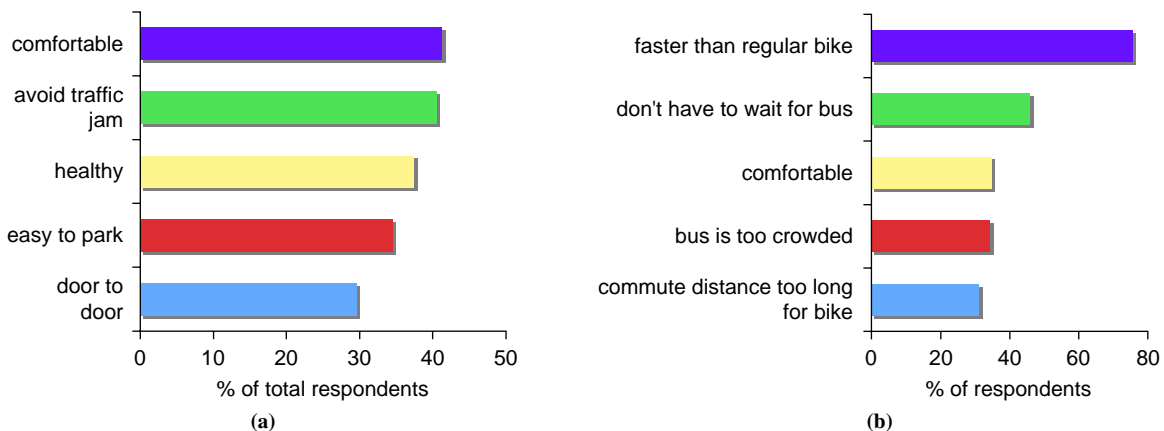


FIGURE 4 Reasons for commuting choice: (a) bike and (b) e-bike.

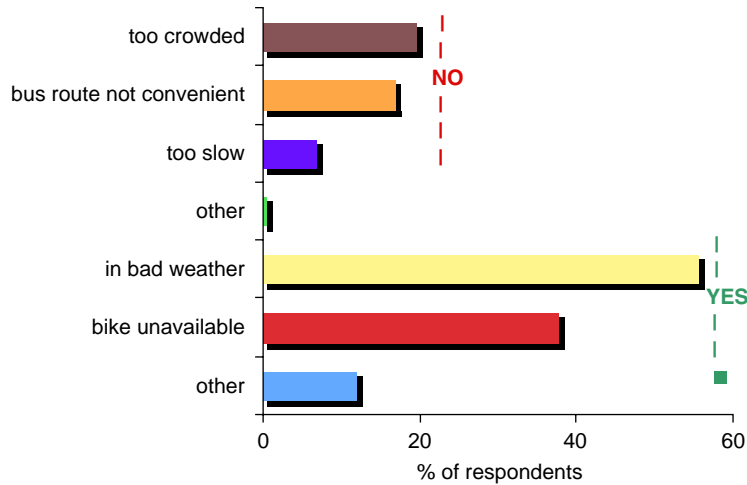


FIGURE 5 Bike and e-bike users' reasons for choosing or not choosing bus.

bus, and if they sometimes ride the bus, why (Figure 5). The majority of 2WV users (~60%) depend on the bus during bad weather and often use it when their bikes are unavailable.

Users of 2WVs do not regularly ride the bus because it is too crowded, the bus route is inconvenient, and it is too slow. Another reason revealed through the survey is that some people are concerned about thieves on buses and thus choose to ride bikes.

The 2WV users were also asked how they would choose to commute if biking were no longer an option. Figure 6 indicates that the bus is the next best alternative for more than 60% of bike users. The bus system therefore plays a critical backup role if the biking option is unavailable. Surprisingly, 7% of bike riders would travel by car, which indicates some are choosing biking for reasons other than economic necessity.

A similar survey carried out in Kunming and Shanghai found slightly different results. In both of these cities, most of the e-bike users would otherwise choose a bus for their trips, 54% and 58% for Shanghai and Kunming, respectively. The second most popular response was bicycle, with 12% and 21% of the responses in Shanghai and Kunming, respectively. In both of these surveys, an overwhelming majority of respondents chose bus, perhaps because of the higher quality of the bus service and city size difference (i.e., longer trip distances), compared with Shijiazhuang.

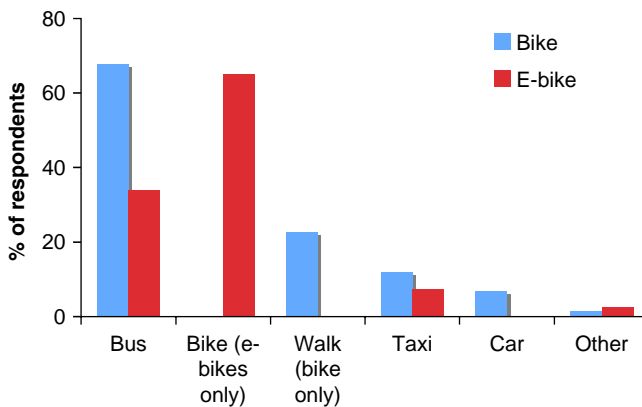


FIGURE 6 Next best alternative for bike or e-bike users.

Future Plans to Change Travel Mode

To understand the future of 2WV use in Shijiazhuang, current 2WV users were asked whether they had plans to switch to different travel modes in the next year. Responses are shown in Figure 7. The most popular future option for bicyclists was found to be the e-bike. Current e-bike users plan to switch to a better e-bike or a car. Very few 2WV users plan to switch to riding the bus. Many Chinese cities (e.g., Shanghai) believe that improving public transport services is the final solution for inner-city transportation challenges; however service has lagged behind demand. Thus users who face long trip distances have resorted to e-bikes.

Stratifying results based on income level shows that future purchase plans are dependent on income. Of the low- and mid-income bike users who plan to change modes in the next year, the majority plan to switch to an e-bike. For high-income 2WV users (both bike and e-bike) who plan to switch modes, the most popular choice was to buy a private car. Other options such as bus, taxi, or (other) were minimal.

Traffic Safety

Traffic safety for 2WVs is a serious problem in China. There were an estimated 500,000 traffic deaths between 2000 and 2005, 60% of which were 2WV users (15). From site observation and interviews

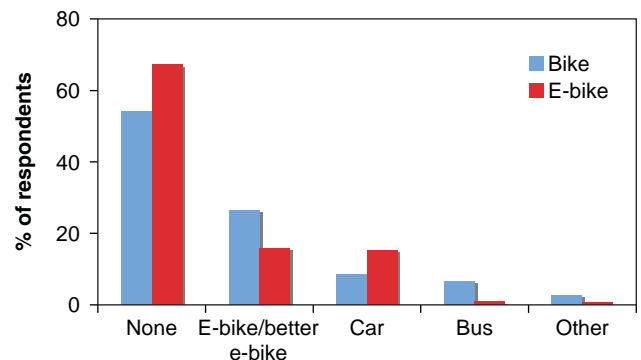


FIGURE 7 Future purchase plans of bike or e-bike users.

with traffic management, the most difficult and dangerous part of a 2WV users' journey occurs at intersections because of the mix of automobiles, various 2WVs, and pedestrians (12). In Shijiazhuang, intersections were particularly chaotic because of the massive number of 2WVs crossing the street from both directions and their strong tendency to disobey traffic lights.

Another safety issue is the mixing of bikes and e-bikes in the bike lane. Thus 2WV users were surveyed on their attitudes about safety at intersections and e-bike speed. Survey respondents were asked to rank how much they agree or disagree with several statements described in the following paragraphs (1–5; 1 = strongly agree; 5 = strongly disagree). An example can be seen in Figure 8.

Safety at Intersections

Results show that generally both bikers and e-bikers are satisfied (avg. response = “agree”) and feel safe using their mode of travel and feel that traffic police do a good job maintaining order at intersections (Questions 1, 3, 5). E-bikers feel slightly more satisfied with their mode than bikers, but they also feel slightly less safe.

However, both bike and e-bike users were on average neutral about the ease of crossing intersections (Question 2), and there were a large number of both “agree” and “disagree” responses for both bikes and e-bikes. Sorting these responses by gender reveals that female bike riders have the most difficult time crossing intersections, whereas male e-bike riders find it easiest. Responses showed that women find it easier to cross the intersection when riding an e-bike. That points to one reason that e-bikes are so popular among women. Site observation also confirmed that e-bike users generally have an easier time crossing intersections. The highly “stop-and-go” nature of intersections makes crossing easier with the aid of electric propulsion.

Conflict Between E-Bikes and Bikes

Several attitudinal questions were asked about the more controversial issues of e-bikes to reveal the nature and reality of the conflict between bike and e-bike riders. In regard to e-bike speed, the majority of bike riders agree that e-bikes are too fast in the bike lane (Figure 8). Although e-bike riders on average felt neutral about e-bikes being too fast, there are more e-bike users who agree that e-bikes are too fast than disagree.

E-bike riders were also asked whether they would like a faster, more powerful e-bike. Results uncovered a large gender difference

in responses. Whereas men have a neutral opinion about this issue, women are strongly opposed.

The second issue relates to the nature of the conflict between e-bikes and bikes (i.e., “who is bothering whom?”). Survey results revealed that a conflict indeed exists between bike and e-bike users; however it is bidirectional and pedestrians are also included. Respondents were asked what is most bothersome to them during their commute (they could choose multiple options). Results show that the biggest annoyances to 2WV users are in fact other 2WV users (Figure 9). E-bike riders feel that other bicyclists and pedestrians are most bothersome. Bicyclists feel crossing intersections is most bothersome; pedestrians and other bicyclists are ranked second and third most bothersome. Automobiles were low on the list, most likely because of Shijiazhuang’s extensive network of segregated bike lanes and relatively small car population. Other included the bus, improper signal timing, and taxis.

One reason for this problem among 2WV users and pedestrians is the poor enforcement of traffic rules for this group. Interviews with local traffic police revealed two reasons for weak enforcement: (a) they have a responsibility to maintain vehicle flow and thus they do not have time to strictly monitor NMVs and (b) the NMV population is so large and violations so frequent, they do not have the resources to punish them.

Another reason for this conflict is likely the speed difference between bikes and e-bikes, which is easily observed along bike lanes throughout Shijiazhuang. E-bikes generally travel faster and thus are often interrupted by slower bikes.

CONCLUSIONS

Electric bikes are providing low-income commuters with a mode of transportation that provides high levels of personal mobility at low personal cost. As cities expand, e-bikes are allowing people to commute longer distances and reach more goods and services than do alternative modes. This improved mobility could lead to further urban expansion in the long term.

People are choosing e-bikes for a number of reasons, including reduced travel times, increased range compared with bicycles, increased cargo- or people-carrying capacity, comfort, and ease of use. Electric bikes have improved the mobility of the elderly, who often have the responsibility of transporting children.

E-bike users would mostly use a bus or bicycle in the absence of electric bikes. E-bikes appear to be acting as a near-term remedy for people who are underserved by public transportation. This mode appears to fill the transportation niche, providing personal

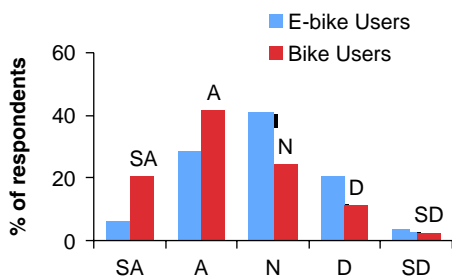


FIGURE 8 Bike and e-bike user attitudes on speed of e-bikes (SA = strongly agree, A = agree, N = neutral, D = disagree, and SD = strongly disagree).

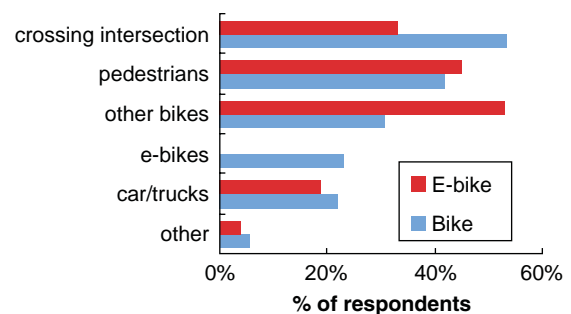


FIGURE 9 Most bothersome aspects for bike and e-bike users.

transportation to people who do not have traditional transportation patterns. Many users however still rely on bus transit in the case of bad weather.

On the basis of the mode shifting behavior revealed by the survey, the use of e-bikes will continue to grow in popularity as incomes rise and cities expand. It is clear that income is not the only factor contributing to the popularity of electric bikes; their performance characteristics make them a popular mode for all income classes. Many electric bike owners state that the next step along the transportation pathway will be a personal car, implying that electric bikes could be a transitional mode on the motorization pathway.

One of the reasons cited for regulation of e-bike use and performance characteristics is safety. The survey results show that e-bike users, especially women, feel safer when crossing intersections compared with when using a bicycle. Most users feel that bicyclists and pedestrians are the greatest source of traffic conflict. Surprisingly, bicyclists identify the most conflict with other bicyclists; however, they do think that e-bikes operate too quickly in the bike lane. Female e-bike users are generally opposed to electric bikes with higher speed characteristics.

RECOMMENDATIONS

Traffic Management

- Impose a license system for e-bikes. Licensing vehicles makes it easier to enforce traffic laws and control the e-bike population, thus improving safety. E-bikes are required to register and have a special license in some cities such as Shanghai, Tianjin, and Suzhou. But some cities such as Shijiazhuang have no specific e-bike regulations.
- Enhance traffic management at intersections to improve traffic safety for both 2WVs and pedestrians. Enforcement of local traffic violations such as red light running will benefit all road users and improve traffic conditions by reducing vehicle interactions.

E-Bike Standards

New standards should consider allowing an increase in weight, but keeping speed constant. The survey has revealed that e-bike users do not want an increase in speed. However, weight limits should be increased to accommodate larger batteries for longer commute distances and to improve e-bike safety. Increased weight would enable larger battery capacity, a sturdier frame, better braking systems, and more comfortable vehicles.

Areas for Future Analysis

Future studies will examine the regional differences between bike and e-bike travel behavior. Shijiazhuang is classified as a medium-size city; it would therefore be useful to examine the differences between a small and large city as well. China is a large country and thus the differences between city size, income level, regional climate, terrain, transit service levels, and average travel distance may result in different conclusions.

The effect of land use policies on travel behavior and the shift from bikes to e-bikes also warrant future analysis. The housing policy reform initiated in the early 1990s (employees were no longer forced to live in government-provided housing close to work) has had a considerable effect on commuter behavior, travel distance, urban trans-

port, and land use. Future study could examine whether e-bike use is a result of the expansion of cities or is partially responsible for the expansion.

The environmental costs and benefits of e-bikes are not yet fully understood, and thus it is necessary to carefully evaluate the positive and negative externalities of e-bike use to guide the policy debate on this transport mode.

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