

The Transition To Electric Bikes In China: History And Key Reasons For Rapid Growth

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Abstract

Annual electric bike (e-bike) sales in China grew from 40,000 in 1998 to 10 million in 2005. This rapid transition from human-powered bicycles and gasoline-powered scooters to an all-electric vehicle/fuel technology system is special in the evolution of transportation technology and, thus far, unique to China. We examine how and why e-bikes developed so quickly in China with particular focus on the key technical, economic, and political factors involved. This case study provides important insights to policy makers in China and abroad on how timely regulatory policy can change the purchase choice of millions and create a new mode of transportation. These lessons are especially important to China as it embarks on a large-scale transition to personal vehicles, but also to other countries seeking more sustainable forms of transportation.

Keywords: Two- and three-wheelers, bikes, battery electric vehicles, China

1 Introduction

Electric bikes are a category of vehicles in China that includes two-wheel bikes propelled by human pedaling supplemented by electrical power from a storage battery, and low-speed scooters propelled almost solely by electricity (usually with perfunctory pedals to satisfy legal definitions). These vehicles have become a popular transportation mode for Chinese consumers because they provide an inexpensive and convenient form of private mobility and are thus an attractive alternative to public transit or regular bicycling. They are promoted by national and many local governments due to their low energy consumption and zero tail-pipe emissions, especially important in China's congested urban areas. E-bikes are gaining an increasing share of two-wheeled transportation throughout China, and in some cities like Chengdu and Suzhou, have even surpassed the bicycle mode share.

Understanding the transition to e-bikes is important for guiding the future of personal mobility in China and other developing countries. First, China is on the brink of large-scale motorization (i.e. people buying cars). Understanding how and why a large-scale technology system (e-bikes) is successfully adopted may provide insight and provide a foundation for a smoother transition to cleaner vehicle/fuel systems as motorization continues. Secondly, many other developing nations with high two-wheel vehicle (2WV) use are confronting the same air quality and energy issues as China. These countries may be able to learn from China's experience in adopting e-bikes.

1.1 Methodology

The literature on e-bikes in China thus far is relatively limited. Thus this report relies extensively on first-hand interviews. Using a 35-question survey, we interviewed 23 electric bike original equipment manufacturers (OEMs) and component suppliers (including 4 factory visits), 5 e-bike dealers, 12 e-bike customers and 1 government representative. We asked e-bike OEMs and suppliers questions related to their products, manufacturing, the e-bike market, suppliers, costs, quality, government regulations, and R&D. We asked dealers about maintenance issues, e-bike market demographics, and the impact of government regulations on sales. We asked customers about costs of owning and operating, usage behavior, and their attitudes towards e-bikes versus competing travel modes.

For data on consumer travel behavior and attitudes, we conducted a survey of over 450 e-bike users in Shijiazhuang. An in depth analysis of the results of this survey is found in Weinert et al. [1] and reported in this paper. The survey was conducted in Shijiazhuang, a representative Chinese large city that has relatively neutral policies toward e-bikes and are home to a significant number of e-bikes.

Other data and other historic information have mainly been collected from industry reports [2,8], media [6,7,20,30], trade journals [11,13,28], and academic publications [5,9,10,27].

2 Electric Bikes Background and Current Status

There are hundreds of models of electric bikes manufactured in China. Most can be categorized as bicycle style electric bikes (BSEB) or scooter style electric bikes (SSEB) (Figure 1) [2]. There is a spectrum of styles between these two types that almost all electric bikes styles fall into. The SSEBs have many of the features of gasoline-powered scooters such as horns, headlights, brake lights, turn signals and speedometers. Most rely exclusively on electric power, not human pedaling. BSEBs are more similar in appearance and function to standard bicycles, including functioning pedals.



Figure 1: Bicycle Style and Scooter Style Electric Bikes
(image source: www.forever-bikes.com)

The technology of each type of electric bike is similar. The main components of an electric battery include a hub motor, controller and battery. BSEBs typically have 36V batteries and 180-250W motors. SSEBs typically have larger 48V batteries and higher powered motors 350-500W. Electric bikes are regulated not to exceed 20km/hr, but many, especially scooters, can travel at speeds in excess of that limit and some are advertised to go 40km/hr. Electric bikes have a range of 40-50km on a single charge. In most cities, electric bikes are allowed to operate in the bicycle lane and are considered a bicycle from a regulatory perspective (i.e. helmets and drivers licenses are not required).

One of the greatest benefits of e-bike usage is that no new infrastructure is required for recharging. Charging can be accomplished by simply plugging into a standard electrical outlet. The majority of e-bike

users interviewed charge their e-bikes at home during the night when electricity is cheaper. In urban areas, this typically means a multi-level apartment building, thus requiring the user to carry the bike battery into the home for recharging. It is also common to see bikes being charged during the day outside ground-floor shops using standard electrical outlets.

The Chinese electric bike market has expanded more rapidly than any other mode in the last five to seven years, from nearly 40,000 produced in 1998 to over 10 million in 2005 [2]. The annual production of electric bikes is shown in figure 2. The history and reasons behind this remarkable growth will be explored in the next section.

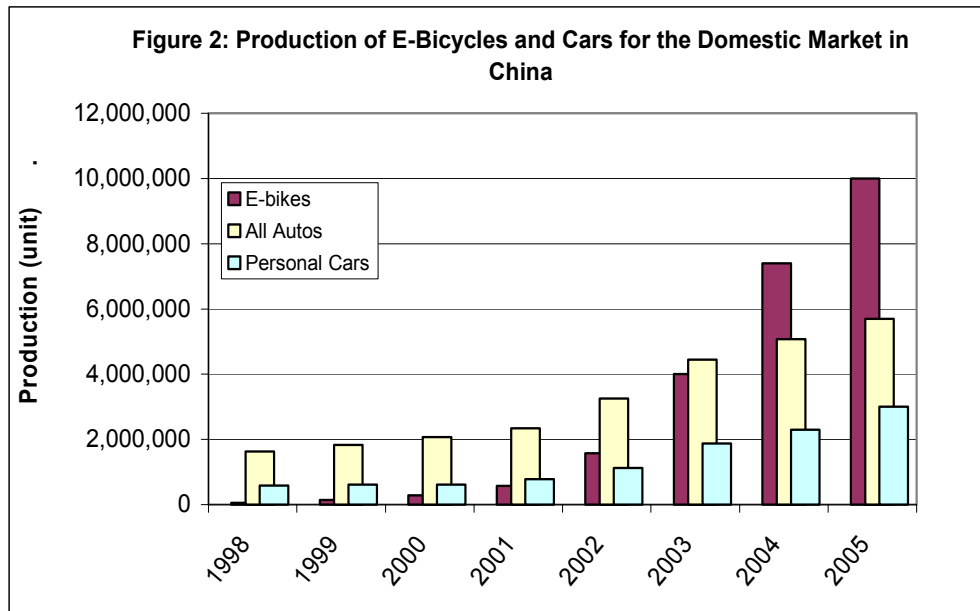


Figure 2: Production of e-bikes and cars for the domestic Chinese market

3 Historical Analysis

The history of e-bikes in China spans over four decades, and can be clustered into three distinct periods [3][4].

3.1 First Phase (1980s)

Research into e-bikes in China first began in the 1960s, though actual products did not appear on the market until the late 80's when consumer demand first began growing. Companies first appeared in Shanghai, Zhejiang, and Tianjin. Total annual e-bike production reached only 10-20,000/yr. At this time, people knew very little about e-bikes because the average person could only afford a normal bike [3].

This peak however lasted only 3-4 years. This introduction of e-bikes was short-lived for several reasons. Firstly, e-bike technology was not advanced enough to fulfill the demand of consumers. In particular, battery quality was low in terms of performance and lifetime, and costs were high. Secondly, the e-bike price was also relatively high due to the high battery cost. E-bikes failed during this phase because they could not compete with inexpensive gasoline motor scooters.

3.2 Second Phase (early 1990's)

E-bikes experienced a second surge during the early 1990s due to the government's push for energy efficiency. This period was short-lived however, again due to their inability to compete with gasoline-

powered scooters. E-bikes again failed to become wide-spread and gain significant market share. E-bikes were being developed and sold in Taiwan, but they failed to gain considerable market share, in large part because no restrictions were placed on gasoline-powered scooters.

3.3 Third Phase (late 1990's-current)

E-bikes again emerged into the market during the late 1990s and witnessed considerable growth that has continued up to the present. The following table lists chronologically important events in the history of e-bikes in China:

Table 1: E-bikes History in China [5]

<i>Year</i>	<i>Event</i>
1987	Electric Vehicle Institute of China Electro-technical society founded
1991	National science Board names e-bike as one of 10 main technology projects during 9th 5 year plan period
1993	Shanghai founded electric vehicle industrialization development center
1994	Shanghai lost automobile research bid for developing electric vehicles to Guangzhou; turns to developing e-bikes (via Crane). Tianjin bans the sale of gasoline-powered scooters. [6]
1995	Prime minister Li Pong declares support for electric vehicles, leading to "Seminar for E-bike Development in Light Industry General Society (Economy and Trade Committee)
1995	100 beta-test Crane e-bikes are deployed [6]
1996	First National Forum on e-bikes held [4]
1996	Shanghai suspends license granting to gasoline-powered vehicles downtown, Mayor declares to "gradually eliminate gasoline-powered assist vehicle and actively develop and promote electro-assist technology"
1997	Crane rolls out first commercial batch of e-bikes (150-180W motor, 7Ah battery capacity) [6]
1998	Guangzhou, Shijiazhuang, and Suzhou ban the sale of gasoline-powered scooters. Many other medium/large cities follow suit in the following years.
1999	National E-bike standards passed, creating uniform specifications for BSEB and SSEB.
1999	Shanghai began annual inspections of gasoline-powered scooters, eliminating those of which exhaust gas emission was unacceptable- 53,000 were eliminated in 1999-Mayor states desire to replace all motor scooters by electric bike in next 4-5 years
1999	Shanghai Economy and Trade Committee lists e-bikes as one of 12 main construction projects in the "Highland"
1999	E-bike licenses are granted in Shanghai, Tianjin, Jiangsu, Zhejiang, Guangdong, Cichang, Yunnan, Anhui, Hebei
2000	Administrative coordinators nationwide recommend promotion of e-bike to Department of State
2000	Dept of State Traffic Control Bureau drafts "Road Transportation Safety Law" to allow e-bikes right to use bike lanes as long as they have pedals and speed is below 20 kph
2000	Zhejiang founds Electric Vehicle Preparatory Team, Ningbo hosts E-bike Festival, and Shanghai hosts first International EV and components Expo
2002	Beijing issues a ban stating they will cease offering e-bike licenses beginning 2006 in order to promote automobile development, Beijing Communicative Administration Department [7]
2002	Fuzhou government bans electric bikes from streets but is later taken to court by a group of e-bike OEMS and citizens, raising the profile of e-bikes throughout China. [8]
2003	E-bike sales surge after the outbreak of SARS when many riders shift from public transit [6]
2004	China passes the "Road Transportation Safety Law" (see 2000 above)
2005	Annual domestic e-bike sales top 10 million [4]
2006	Jan 4, Beijing Public Security Bureau lifts ban on e-bikes [6]
2006	Shanghai e-bike population reaches 1.35 million, the highest ownership level of any city in

3.4 History and Status of the E-bike Industry

The Chinese e-bike industry, with minimal governmental financial support and industry supervision, has developed into the largest producer of e-bikes worldwide. The industry grew from under 10 original equipment manufacturers (OEMs) in 1998 to 481 (according to the official estimate) by 2005 [11]. Unofficial estimates for the number of OEMs range from 1,000-5,000 [12]. E-bike OEMs range in size from as small as 1000's bikes/yr production to 300,000/yr. A large number produce between 10-50,000 e-bikes a year, but there are six companies with an annual product of over 200,000 e-bikes [13].

One reason for the large number of companies in this industry is that component technology is mature, the network of suppliers is vast, and manufacturing is relatively simple [14]. This is evidenced by the low profit margins (average 6%, from eight OEM responses). There is also considerable theft of intellectual property by the small to medium companies according to interviews with the managers from larger e-companies. Because of the low barriers to entry and lax intellectual property (IP) protection, there are many unlicensed e-bike makers selling poor-quality but low-cost e-bikes [15]. Several OEMs predict that there will be considerable consolidation over the next few years and the number of E-bike makers will drop significantly.

The companies that currently make e-bikes come from a variety of industrial backgrounds. Some are established companies producing bicycles, motorcycles, electrical appliances, and even toy cars, that shifted to making e-bikes when demand grew. Some of these companies are over 60 years old, but most did not start producing e-bikes until post-2000. Many companies with no past manufacturing experience entered the industry making e-bikes directly.

4 Important Factors for Rapid E-bike Growth

The reasons for e-bike success in the 3rd phase can be categorized into three important development factors: technology, economics, and policy.

4.1 Technology Factors

Improvements in battery and motor technology since the 90s helped expand the market for e-bikes. E-bikes, reaching ranges of 50-60 km and 250-350W, could finally compete in performance with the incumbent gasoline-powered scooter. The two e-bike components that experienced substantial technology improvement, are the lead(Pb)-acid batteries and in-hub wheel e-bike motors.

4.1.1 Batteries

Over 95% of e-bikes sold in China use Pb-acid batteries [2]. While Pb-acid batteries have been in use for nearly a century in automobiles and other applications, there have been important advances in the past decade rendering them more suitable for e-bikes.

During the first phase of e-bike introduction, batteries used liquid acid electrolyte instead of the fixed electrolyte used today in most Pb-acid batteries today. Liquid-type required more maintenance, and if the battery or bike fell over, electrolyte leaked out and caused property damage. Most e-bikes today use valve-regulated lead-acid types, which, in addition to having higher power density, also minimizes maintenance and electrolyte spills due to its sealed electrolyte [16]. Energy density of e-bike batteries also increased 33% from 1997 to 40Wh/kg while battery life also increased 35% to over 300 cycles [8]. The performance improvements in battery life from one large battery supplier are shown in the table below.

Table 2: Lifetime of e-bike battery vs. time [17]

	1997-1998	2000	2003	2006
Manufacturer Guaranteed Lifetime (months)	3	6	12	12
Anticipated lifetime under normal operating conditions (months)	7-8	12	18	18-24

4.1.2 Motors

In the past decade, e-bike motors saw two significant technology advances. The first was the introduction of brushless motors into e-bikes. E-bikes originally used only brush motors because they used a simpler, cheaper controller. In early 2000s, many e-bike makers started switching to brushless motors. The table compares the characteristics of each and their relative advantages. SSEBs more frequently use brushless motors since users seldom use the pedal function and prefer more power for carrying cargo and passengers.

Table 3: Comparison of Brush to Brushless Motors [18]

	<i>Brush Type</i>	<i>Brushless Type</i>
<i>Rotating speed</i>	2,000 rpm	300 rpm
<i>Average Weight</i>	4 kg	6 kg
<i>Advantages</i>	Has a gear/clutch so it is easier to use pedal-only mode. Better for far travel with few elevation changes	Longer life, lower maintenance requirements, more powerful (better for climbing hills and carrying goods)
<i>Disadvantages</i>	High rpm requires more frequent maintenance	Controller for this motor type is more expensive (3x more than for brush type)

The second advance was in motor efficiency, which improved ~60% between 1995 and 2000 from 50% to 85%. This improvement resulted in a 60% increase in range. In the mid 1990's motors were disc-type and used Fe-O permanent magnets. In 1997, brush-type motors were introduced with a reduction gear system. Around 2000, Ru-Fe-B magnets were introduced into e-bike motors. In 2006, neodymium magnets have been introduced that are increasing motor efficiency even more. Recent joint ventures with foreign companies have also aided in the improvement of technology

4.2 Economic Factors

The most important economic factors explaining rapid e-bike adoption in China are the rising income level of the Chinese, the decreasing cost of e-bike technology, and the rising cost of gasoline.

4.2.1 Rising income level

The rapid development of China in the past decade has raised the standard of living of its residents, bringing the e-bike within closer reach of millions more. This trend is shown in the table below.

Table 4: Income growth and spending of Chinese households, 1997-2004 [19]

	1997	2004	% change
Annual Disposable Income of Urban Households / capita (RMB)	5,160	9,422	82%
% of household expenditures on Transportation and Communications (T&C)	5.2%	11.8%	127%

Note: 8 RMB =1USD

If one assumes 70% of the T&C spending is spent on transportation, the average annual transportation budget of a household is roughly equal to the annual cost of owning and operating an e-bike (766 RMB/yr, see Figure 3 below).

4.2.2 Vehicle Price

The price of e-bikes dropped from their initial introduction to the present, even as e-bike technology and efficiency has improved. In 1999, the BSEBs were ~2,500 RMB, and fell to 2,000 RMB in 2000 due to considerable industrial development. By late 2003, average price dropped again to 1,500, with the cheapest models reaching a bottom price of 1,000. As of 2006, average prices still ranged from 1,000-3,000, despite far better quality and performance. Currently, the e-bike in market is classified into three price levels [8].

Table 5: E-bike Style and Price Range

<i>Style</i>	<i>Description</i>	<i>Share</i>
Luxury (>2600 RMB)	Mainly SSEB and include few very good BSEB	10%
Moderate (1800~2200RMB)	Both BSEB and SSEB	60%
Economical (<1500RMB)	All simple BSEB	30%

Much of this reduction in price can be attributed to larger production scale of both e-bikes and their components.

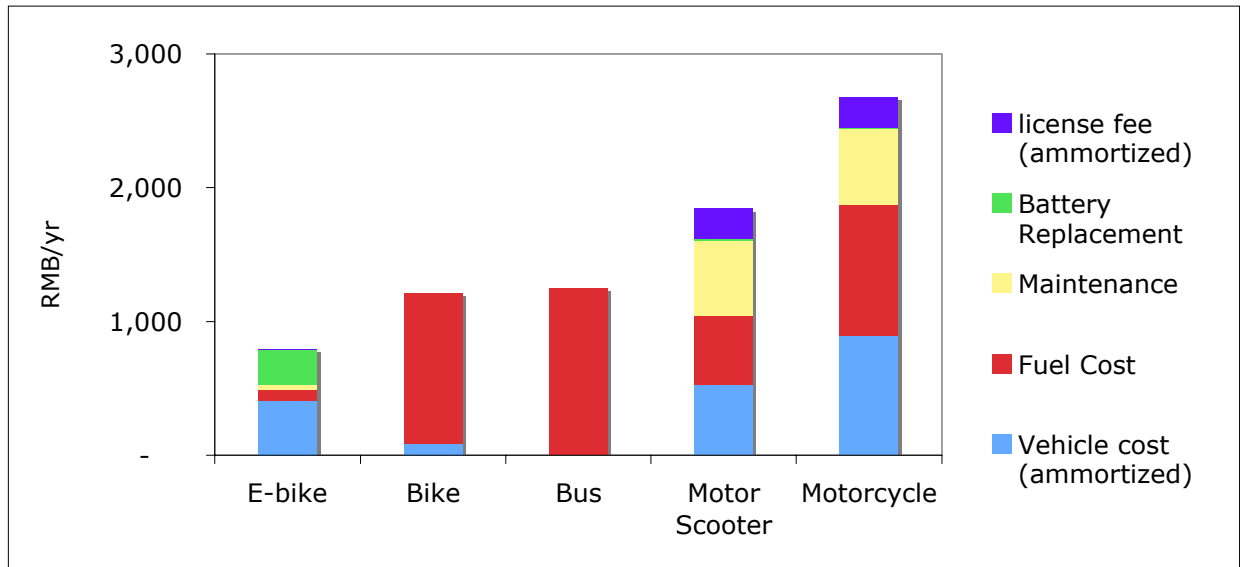
4.2.3 Fuel and Energy Costs

Fuel price has risen substantially in the past 6 years. Gasoline prices in Shanghai increased 45% since 2002 from 3.1 to 4.5 RMB/liter (excluding inflation). Since fuel cost for gasoline scooters is over 30% of the total annual cost, this fuel cost increase effectively increased the cost of gasoline-scooter from 0.29 to 0.33 RMB/km. While this per mile price increase is only 15%, consumers purchase decisions are more sensitive to fuel cost increases since it is a more frequent payment.

Along with rising gasoline prices, electricity prices fell in rural areas. This price decrease was due to significant investment from central government in electricity infrastructure through rural areas nationwide, and the decision to drop rural electricity prices to urban price levels. Before this policy was enacted 1998, electricity price in rural areas was ~50% higher than in urban areas [20]. This decrease in price combined with rising income caused the rural e-bike market to expand rapidly [21]. One electric bike company estimates that in 2005 the rural consumers accounted for 20% of their national e-bike sales and that rural e-bike sales jumped 190% between Quarter 1 and Quarter 2 of 2006 [13].

4.2.4 E-bike relative lifecycle cost advantage

The cost of owning and operating an e-bike is the lowest of all personal motorized transportation in China. The following figure and table compare the life-cycle cost of an e-bike vs. other commonly used 2WV modes and bus public transport.



	<i>E-bike</i>	<i>Bike</i>	<i>Bus</i>	<i>Motor Scooter (LPG)</i>	<i>Motorcycle (gasoline)</i>	<i>Compact car (gasoline)</i>
Total Cost (RMB/km)	0.13	0.19	0.20	0.30	0.43	1.74
<i>Assumptions</i>						
Fuel price (RMB/unit)	0.66/kWh	0.012/kcal (8.6/kWh)	2/ ticket	3.3/L	4.5/L	4.5/L
Fuel Economy (fuel units/km)	0.015 kWh [13]	0.021kWh [22]		0.035 L	0.035 L	0.1 L
Vehicle cost (RMB)	2500	500		3,250	5,500	38,000
Maintenance cost (RMB/yr)	32			560 [3]	560 [3]	1,900
Battery Cost	260			10 [2]	10 [2]	50
License cost (RMB)	30	0		1,400	1,400	3,000

Figure 3: Cost Comparison of Common Urban Travel Modes, Shanghai

Unless stated otherwise, most vehicle and operating cost data is gathered from asking users about their present day costs or from company brochures. We assume every vehicle travels the same distance/yr (20 km/day=6,240 km/yr). This assumption may render car and motorcycle “cost/km” higher than reality since users of these vehicles likely travel longer commute distances and thus amortize the high initial investment cost over more miles. Other assumptions for this analysis are listed below:

Table 6: Vehicle Cost Assumptions

Additional Assumptions	
Vehicle Lifetime	10 years
Interest rate	10%
Battery life for e-bike	300 cycles (1.9 yrs)

4.3 Policy Factors

The following section introduces two important national e-bike policies and describes the impact they had on e-bike growth. Regional differences in policy will then be discussed using four cities as examples.

4.3.1 National Rules for E-bike Use

The national government has set two key policies that have facilitated the development of the e-bike market, the “1999 National E-bike Standards” and the 2004 “Road Transportation Safety Law”.

National E-bikes Standards

In 1999, national e-bike standards were set to establish performance limits for e-bikes with respect to speed, weight, and power. One important part of the specification was that as long as the bike had functional pedals, it could be classified as an e-bike, which allowed SSEBs to be classified under the same rules and regulations as BSEBs.

The effect this part of the standard had was that it opened the doors of what would become a huge, important market for SSEBs. Manufacturers capitalized on this loop-hole in the standard by making SSEBs with pedals that barely functioned and that could be easily removed after purchase. They realized the scooter style could directly compete with the incumbent technology, gasoline and LPG scooters since, besides the powertrain, all other features were equal. Many prefer this style over BSEB because it’s easier to carry cargo and passengers [23], more comfortable (larger seat, lower center of gravity), and creates more opportunities for unique, fashionable styling. In Shanghai, it is estimated that >70% of e-bikes are SSEB [24] This is a common trend in Southern cities, though in Northern cities, BSEB are more popular because batteries run down more quickly in cold weather, requiring users to pedal often.

The standards allowed further design flexibility by having “required” criteria and “recommended” criteria. The following specifications must be met (or the vehicle cannot be licensed): speed limit (<20 km/h), the brake distance (dry: 4m, wet: 15 m) and frame vibration (quiver test: >70,000 cycles without damage). Many OEMs get around the speed requirement by adding vehicle speed restriction devices that are easily removed after purchase. The rest of the specifications such as weight, width, motor power, pedal capability result in a fine for the OEM if not met (and thus “recommended”) [25]. The magnitude of these fines is not fixed and is often directly related to the OEM’s relationship with the local quality supervision department. The flexibility in meeting this standard has thus resulted in faster, heavier, more powerful e-bikes on the roads. Other manufacturers avoid fines by adding vehicle speed restriction devices that can easily be removed after purchase.

Through interviews with several OEMs about the standards issue, we noticed a distinct “wait and see” behavior regarding their future plans to expand. Some stated they are holding off on large, potentially risky investments until the new standards come out, and this hesitation is impacting product evolution.

National Road Transportation Safety Law

Drafted in 2000 and finally ratified in 2004, the Road Transportation Safety Law effectively classifies e-bikes as a non-motorized vehicle, giving them the same rights as bicyclists. This law, besides giving users the right to ride in the bike lane, gave e-bike proponents in industry and government legal standing in defending e-bike use and sale in many cities.

4.3.2 Local Policy Differences

While e-bike standards and road rules are set by national government, it is up to local governments to decide how to enforce these product standards and manage traffic. Due in part to regional variations in

policy enforcement, e-bike penetration is noticeably different from city to city. This section examines different policy attitudes towards e-bikes and how it has impacted their success using four Chinese cities as examples: 1) Shanghai & Chengdu (pro-e-bike), 2) Beijing (anti-e-bike) and 3) Shijiazhuang (neutral).

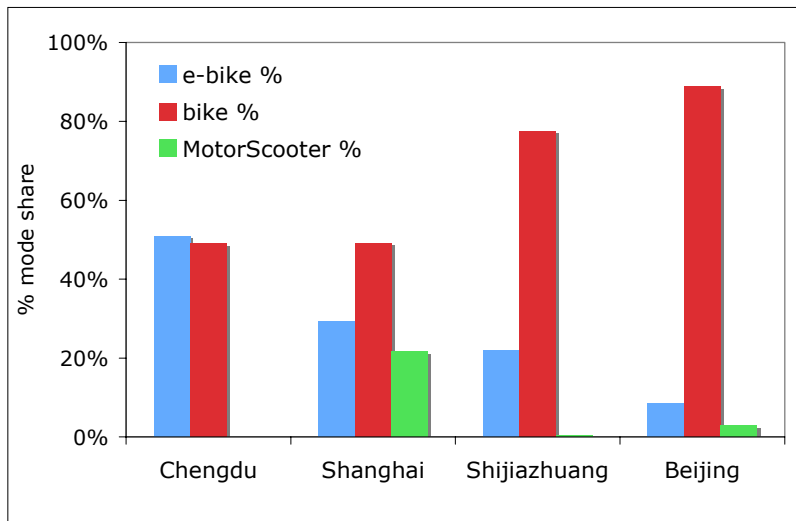


Figure 4: 2WV proportions in select Chinese cities [26]

1. Shanghai: Pro e-bike

In 1996, Shanghai (pop. 17.4 mil, 2005), confronted with poor air quality and high motorized vehicle use, outlawed the sale and use of gasoline scooters in city centers through license restriction. As of 2006, the only 2WV allowed to operate are LPG scooters, e-bikes, and bicycles. Site observation shows that these rules are effectively enforced. The figure below shows the effect of this ban on e-bike growth relative to other 2WV modes in recent years. One reason for such high LPG scooter proportion in Shanghai is that in 1998, the taxi fleet switched to LPG, and thus an extensive fueling infrastructure developed throughout the city. Chengdu is included in this chart to compare a pro-e-bike city without an LPG infrastructure. In Chengdu, where gasoline scooters are also banned, e-bike mode share has surpassed bikes.

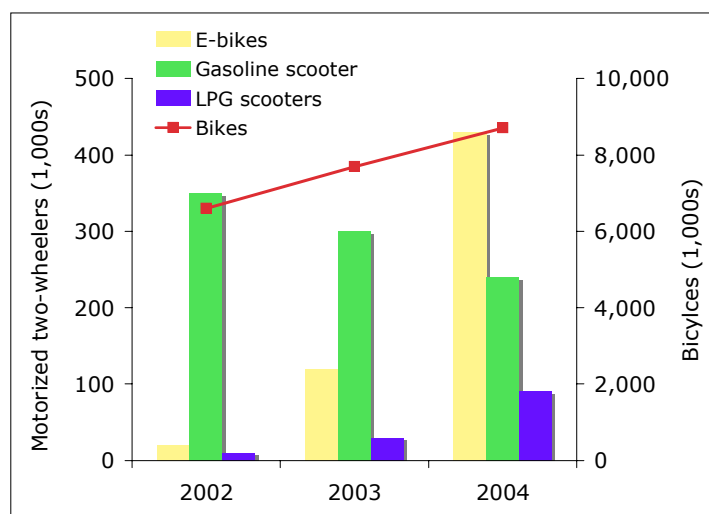


Figure 5: Two-Wheeled Vehicle Growth in Shanghai [27]

2. Anti-E-bike

Some cities view e-bikes as just a prolonging of the bicycle, which they are eager to displace in favor of more advanced, modern modes such as the automobile [7]. Other reasons for mixed attitudes about e-bikes include concerns about their effect in reducing traffic speeds, creating safety hazards in mixed bike and car traffic, and lead-pollution from poor battery recycling infrastructure [7]. Beijing (pop. 14 million, 2004) is an example of one large Chinese city that proposed a ban on e-bikes beginning, but finally reversed itself in 2006. This hostile policy impacted consumer purchase decisions during these key e-bike growth years, resulting in lower e-bike share. Beijing carefully enforces the national e-bike standard and restricts e-bike dealers from selling SSEBs, further discouraging e-bike sales.[28] Fuzhou, Guangzhou, Wuhan and Haikou are examples of other large anti-e-bike cities. The rationale in these cities is that e-bikes are unsafe and have negative impacts on traffic. The China Bicycle Association is an example of a government association that generally opposes e-bikes for fear their high speed will impact bicyclist safety.

3. E-bike neutral

Shijiazhuang (pop. 9 million, 2005) is example of a city that is undecided about the costs and benefits of e-bikes and thus have adopted a “wait and see” approach to managing e-bikes [29]. They neither promote nor restrict them. This city has few cars, unlike Beijing, which has over 2 million cars.

4.3.4 Other Factors

Other factors explaining the e-bike phenomenon are related to demographics, land use and infrastructure. The increasing numbers of women commuters and the mass influx of rural people into cities (urbanization) plays a role. Regional differences between cities such as city area, automobile use, level of public transit service, topography, weather also play a role in the differences in e-bike popularity from city to city. For instance, cities with large geographic area and poor public transit service would likely experience a larger shift of bike and transit users to to e-bike. Cities with high automobile use may have less bike lane infrastructure and more anti-e-bike policies would likely have less e-bike users. There are also random factors involved, such as the 2003 SARS scare and abnormally hot summer when people shifted away from crowded public transportation and e-bikes sales jumped from 20,000/year to 300,000/yr [30]. These factors and more will be explored and quantified in future analyses.

5 Conclusions

E-bikes, though they floundered twice in the 80s and early 90s, experienced extraordinary growth in the late 90s to the present due to a combination of economic, technical, and political factors, summarized below:

1. E-bike technology, specifically motors and batteries, improved significantly during the late 1990's. Simple technology, a vast supplier base, and weak intellectual property protection made it easier for e-bike makers to enter the industry, increasing competition and driving prices down.
2. Due to improving economic conditions nationally, incomes of urban households and the share spent on transportation both rose considerably.
3. As e-bike prices decreased, gasoline prices rose and electricity prices in rural areas dropped, making e-bikes more competitive economically with alternatives like gasoline-powered scooters.
4. National and local government policy motivated by energy and air quality issues created favorable conditions for e-bike growth.
5. National e-bike standards with loop-holes and flexible guidelines created a rich opportunity for manufacturers to create e-bikes that appealed to more users, namely, scooter-style electric bikes.

The history of e-bikes provides an important lesson on the powerful impact of regulatory policy, given the evolution of technology to a market acceptable product. While technological progress was required to meet the customer demands for economics and performance, the regulatory environment provided strong impetus for the market to grow and for further investment in technology evolution. Without this the e-bike market would not have emerged. Support for this conclusion can be found by looking at the lack of growth in “anti e-bike” cities. There is further evidence of the sensitivity to local policy in Shanghai, where an alternative (LPG scooters) emerged in a regulatory environment that was otherwise favorable to e-bikes. Where regulatory policy is favorable / neutral, economics and customer expectations will determine market success.

Looking forward, this analysis hints at future technology evolution paths for China’s 450 million bike users, 22 million current e-bike users, and burgeoning car population. In smaller cities and countryside where incomes are rising, e-bikes may eventually replace bicycles. China’s experience may also have a trickle-down effect in other developing countries with high 2WV use and mounting urban transportation problems. Speculating on the future of technology evolution and trends in China, further technological progress on e-bikes and increasing environmental pressures may create a regulatory environment that ushers in small battery electric cars.

In any case, the implications of how and where this technology system develops are huge. These implications, both positive and negative, on urban traffic, industry development, energy use, and environmental impacts, warrant further investigation.

Acknowledgements

The authors would like to acknowledge Joan Ogden, Dan Sperling, Jack Johnston, Andy Burke, and Ed Benjamin for their thoughtful review of this work. The authors would like to thank the ITS-Davis Hydrogen Pathways Program and the Hong Kong Fok Ying Tung (Huo Ying Dong) Education Foundation, Project No. 94027 for financial support. We would also like to thank the following companies for their helpful interviews, factory visits, and data: (Alphabetical order)

Angell Autocycle
Cycle Electric
Da tian (大天)
Forever Bicycle
Giant
GoodBaby Group, Co,LTD
Lan Tian (Blue Sky Double Cycle)
HaiBao Battery
Lvyuan E-Vehicle
Qingqi
Sanben Aurelia
Shanghai Cranes Electric Vehicle Co.
Shanghai Fenghuang Bicycles Co. Ltd (Phoenix)
Shineroam Electric bicycle Co.,Ltd
Small Antelope
Wettsen Co,LTD
WuYang (Five Rams)
Zhejiang Changtong Electric Bicycle)

References

- [1] Weinert, Ma, and Yang “*Transition to electric bikes in China and its effect on travel, transit use, and safety*”, Aug 2006 (pending publication to TRB)
- [2] Jamerson, F. and Benjamin, E., *2004 Electric Bicycle World Report*, 7th Edition with 2005 update, 2005
- [3] Guo, Ziqiang, *Electric Bike Market and Regulation in Mainland China*, Technical Service Center of the Electric Vehicle Institute of China Electro-technical Society, 2000, p.2-5
- [4] Yu, Shiguang (2006), Shanghai Bicycle Association, personal communication
- [5] Historical facts extracted from Guo (2000) unless stated otherwise.
- [6] Fairley, P. “*Cyclists Take Charge*”, IEEE Spectrum, Jun 2005, <http://www.spectrum.ieee.org/jun05/1213>
- [7] “*Why Electric Bicycle Not Promoted in Beijing*”, People’s Daily, Aug 2002, <http://english.people.com.cn>
- [8] Ni, J. *Feasibility Study: Proposal for the Manufacture of Mini Electric Cars Based on Experience with Large Scale Manufacture of Light Electric Vehicles*, Luyuan Bicycle Company, 2006
- [9] Zhang J, Gao J., Liu S., “*E-bike safety information briefing*”, *Road Traffic Safety*, June 2006 (in Chinese)
- [10] Wang, Jiqiang, “*Brief Overview of Chinese Battery Industry & Market*”, presentation at China International Battery Forum, Beijing, June 2006
- [11] Tianjin E-bike Business Information Magazine, 2006 (*In Chinese*)
- [12] Responses from 15 e-bike OEMs to survey question: “How many e-bike companies exist in China?” Several also noted there are many more than official estimates because many operate without a license.
- [13] Company brochures and interviews with OEMs (Apr, 2006)
- [14] One interviewed e-bike OEM initially started assembling e-bikes using their and their neighbor’s home.
- [15] Interview with e-bike maker, April 2006. One company estimated that only 24 e-bike OEMs in China actually have a license while another company mentioned many don’t even have a trademark.
- [16] McArthur, D., “sub-article in Jamerson (2004), *Electric Bike World Report*, p.100
- [17] Haibao Battery Technical Center, Shanghai, personal interview, Aug 2006
- [18] Data obtained from interview with chief motor engineer at e-bike factory, May 2006
- [19] China Bureau of Statistics, *2005 Annual Report*, 2005
- [20] Xinhua, “Cheaper electricity prices for rural people”, http://english.people.com.cn/200404/23/eng20040423_141320.shtml (accessed Aug 2006)
- [21] China carried out a national electric facilities improvement project which decreased the electric price in rural areas. 2002, http://news.xinhuanet.com/zhengfu/2002-04/08/content_349359.htm, Accessed Jul 2006
- [22] Ulrich, K “The Environmental Paradox Of Bicycling” Working paper, Dept of Operations and Information Management, Wharton School, July 2006, p.3. Surprisingly, a bicycle has lower efficiency than an e-bike because the body is only 22% efficient in turning food energy into work.
- [23] Small children often stand on the foot platform while another passenger sits behind the driver. Site observation shows SSEB carry cargo and passengers more often than SSEBs.
- [24] Based on site observation by the authors of BSEB vs. SSEB shares at various locations in Shanghai
- [25] However, the e-bike can not exceed three “fine” specifications violations on the same e-bike.
- [26] Data on vehicle share was collected by the authors at various points and different times throughout each city and aggregated. In Shanghai, the majority of motor scooters are LPG. In other regions, they are gasoline.
- [27] Kang L. “*Feasible Study On Introducing Fuel Cell Two-Wheeler Technologies Into Shanghai Market*”, Shanghai Jiaotong University Report, March 2004
- [28] http://www.china-bicycle.com/show_news.asp?newsid=869 (In Chinese). Accessed July 2006

[29] Interview with Traffic Police Chief from Shijiazhuang Public Security Bureau, June 2006

[30]Xue, W Cheaper Mopeds to flood the market, Shanghai Daily, 2004, www.shanghaidaily.com