E-bikes and Transportation Policy: Insights from Early Adopters

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ABSTRACT

Electric bikes (e-bikes) are increasingly common in China, but are relatively rare in the U.S. To further understand the potential market for and use of e-bikes in the U.S., this paper presents findings from interviews with 28 e-bike owners in the Portland, Oregon region. The interviews revealed several possible demographic markets for e-bikes that could expand the overall share of the population bicycling: women, older adults, and people with physical limitations. In addition, owners noted the ability to travel with relative ease longer distances and over hills and to arrive at a destination, such as work, less sweaty or tired than with a regular bicycle. These features may overcome some of the common barriers to bicycling. Most of the e-bike owners interviewed were using their e-bikes to substitute for travel by either human-powered bicycles or traditional motor vehicles (cars, trucks, etc.). Therefore, the e-bike should be viewed as one option to address concerns over private vehicles contributing to health problems related to inactivity and pollution and other public policy problems. Whether or not e-bikes need specific policies to increase their adoption requires further research. The potential for conflict between e-bike and regular bike riders due to speed differentials is a concern. Whether speed differentials will pose a significant problem in the future will depend not only on the extent of adoption of e-bikes but the characteristics of the riders.

INTRODUCTION

The bicycle has a potentially valuable role to play in responding to the many challenges cities face in relation to traffic congestion, injury and loss of life from road crashes, local air quality, climate change, obesity and physical inactivity, energy availability and security. There are many factors that affect the extent to which bicycling will be a viable urban transportation mode although research consistently highlights the importance of adequate infrastructure and supportive policies (1-4). The performance of the bicycle, in relation to other modes, is however dependent on the physical ability of the rider and the rider's willingness to provide all the energy needed to reach their destination. Because of this, bicycle trips tend to be shorter than motor vehicle trips and cyclists tend to avoid hilly locations (5). The provision of power assistance to the rider has the potential to expand the role of the bicycle in urban transport by addressing the limits of trip distance and terrain. In addition, power assistance could allow people with physical limitations, including older adults, to bicycle more (6-8).

The provision of power assistance on a bicycle is not new. At the beginning of last century the Singer Company in Britain began manufacturing motorized back wheels, powered by a small 2-stroke engine, that could be fitted to existing heavy-duty bicycle frames (9). Improvements in battery technology which were commercialized in the 1990s (10; 26) have resulted in electric powered models now dominating the market. While electric bicycles, referred to generically as e-bikes, are growing in popularity, they have received limited attention from transportation researchers and policy makers. A recent review of e-bikes in the context of urban transportation (11) highlighted there is little research which deals with demand, supply and operational issues with these vehicles, particularly in the context of western countries. Most of the attention on e-bikes to date has focused on China, where the number of such bikes is estimated at over 120 million (12, 13). Electric two-wheeled vehicles in China come in two categories: "bicycle-style" where pedaling is supplemented by battery power and "scooter-style" where electricity supplies nearly all of the power. The latter often come with pedals to satisfy the

legal definition differentiating them from motorcycles (14). Combined, these vehicles make up from under 10% to over 60% of the two-wheel vehicle traffic in some Chinese cities (13).

The reasons for the rapid adoption of e-bikes in China are numerous, including improvements in technology, rising incomes and falling prices, national standards and policies, and changing travel patterns (14), as well as bans or limits on gasoline-powered motorcycles in some cities (12,14) . National law in China classifies e-bikes as non-motorized vehicles, giving owners the right to ride them in bike lanes and without a driver's license or helmet (14). Surveys in Shanghai and Kunming found that e-bike riders are more educated and earn higher incomes than bicycle riders, but few lived in households with cars or motorcycles. For most riders the e-bike substituted for taking the bus. Trips taken on e-bikes were longer than those on bicycles. The primary motivation for choosing an e-bike was speed, with over 70% of e-bike riders citing that factor, followed by less than 30% of respondents citing the reduced level of effort, lower cost than cars, and crowded public transit as motivations (15). Researchers in Kunming found that e-bikes averaged nearly 22 km/hr, about 7 km/hr faster than bicycles (16).

These findings from China, while enlightening, are not entirely transferable to the North American context. Some motivations for adoption, such as bans on motorcycles, are not on the near-term horizon, though speed and travel time is clearly a motivation for travel mode choice nearly everywhere. But, China is not alone in its adoption of e-bikes. E-bikes are making up a growing share of the new bicycle market in the Netherlands (6), a country well-known for supportive bicycle policies and infrastructure and a model many U.S. cities are following. Research on e-bikes in North America and Europe is limited. Our qualitative examination of blogs discussing e-bikes (22) helped to identify topics for future research. We found that e-bikes:

- are used for utilitarian travel including commuting to work and shopping;
- have replaced car trips on journeys of up to 24 km (15 miles);
- help to overcome constraints imposed by geography in the context of longer distance trips and in hilly areas; and
- potentially suit older riders, or individuals who have a medical condition such as arthritis, which makes riding a bicycle difficult.

However, reactions were not all positive. Non-users expressed concerns or negative opinions, including the following:

- e-bikes were not "real" bikes;
- costs and battery technology (specifically the weight and storage capacity which limits the range over which assistance is provided) may limit widespread adoption;
- concerns over mixing e-bikes and bicycles in bike lanes or paths due to differential speeds; and

  questions regarding the environmental impacts of using electricity to power bicycles.

Technology diffusion is often characterized as following a somewhat predictable transition as the market grows from innovators, to early adopters to the early majority, to the late majority and finally to the laggards (20). Moore (21) conceptualized that a chasm exists in the early adopter market which can be difficult for some products to cross. Current North American e-bike users can be considered "early adopters" given that US consumers are being presented with a broader range of e-bike options through a range of specialist bicycle store and electrical retail outlets (11). Understanding the early adopters may help to identify issues of relevance to transportation planners, modelers, and policy makers. For example, there is a need for a greater understanding of the role that e-bikes might play in household mobility decisions, particularly

the potential for substituting for bike, transit or auto trips. Alternatively they would potentially moderate growth in motor scooter and motor cycle demand which is a concern in many jurisdictions where strong growth in motorcycle and motorbike registrations are translating into both great numbers and also greater severity crashes (17, 18). The growth of e-bikes in China has raised safety concerns (19) because lack of enforcement in China means that many vehicles which are in regular use there are capable of much higher speeds than specified in the regulations (13). Such fears are leading some North American cities to consider limits on where e-bikes operate (6).

There is considerable uncertainty about the potential of e-bike technology in the context of urban transportation. Will they 'cross the chasm', remain a novelty or carve out a niche market? Garrison and Levinson argue that technologies may rise to prominence where they fill a 'transport gap' (24: 8). They note that the Segway Personal Transporter is marketed as filling a gap in the "too far to walk and too close to drive" market. Perhaps that is where the e-bike will find a niche although there is no evidence of the Segway crossing the chasm to win a larger share of the urban mobility market. Shaheen et al (25) suggest that e-bikes could be a feature of the next generation of city bikesharing schemes. The launch of the first fully automated e-bike sharing scheme on a university campus in the US (26) will provide valuable lessons in that context.

METHOD

Since e-bikes are very much in the early adoption stage in the U.S., their limited penetration into the urban transportation system presents a challenge to traditional quantitative research methods. There is growing recognition that qualitative research techniques can play an important role in transportation research in general and travel behavior research in particular (27). Qualitative research techniques have, for example, provided valuable insight into understanding the factors motivating early adoption of hybrid motor vehicles in the USA (28). Qualitative techniques can be particularly insightful when little is known about a topic and can form the basis of future quantitative work. Our research on e-bikes began with an analysis of discussions on the topic on popular blogs (22). These findings helped identify issues to explore further through in-depth interviews of e-bike owners.

To further the understanding of the potential market for and use of e-bikes in the U.S., this paper presents findings from interviews with e-bike owners in the Portland, Oregon region. Since there can be subtle differences in e-bike regulations from state to state it is appropriate to summarize the relevant local regulations. The Oregon state code classifies electric assisted bikes as bicycles as long as they have fully operative pedals for human propulsion, have an electric motor with a power output no higher than 1,000 watts, and are capable of operating at no higher than 20 mph on level ground (23). Owners do not need to register or insure the vehicle (23). Riders must be 16 or older, and be eligible for driving privileges (23). A person whose driving privileges are suspended or revoked could possibly be charged with operating any motorized vehicle on public roads while suspended/revoked (23). Since e-bikes are classified as bicycles they may be ridden in travel lanes as well as in bike lanes or paths. However Oregon Statute Section 814.410 specifies that it is an offence to operate an electric assisted bicycle on a sidewalk.

A total of 28 people were interviewed. They were solicited through three primary methods: (1) referrals by e-bike store personnel (n=3); (2) personal contacts (n=4); and (3) an invitation to participate in the study posted on a popular website, Bikeportland.org (n=21). A

structured interview script was used that covered information about the owner (demographics, housing characteristics, travel patterns, use of "green" energy); motivations for purchasing an e-bike; the purchase process (e.g. what options were considered); use of the e-bike; e-bike features; and policy issues. Each interview was conducted in person with one or two interviewers and lasted approximately 45 minutes. The interviews were taped and transcribed for analysis. The study was reviewed and approved by Portland State University's Human Subjects Research Review Committee. The interview subjects did not come from a random sample and, therefore, findings from the interviews may not accurately represent the population of e-bike owners. Aside from the fact that all subjects live in the Portland region, the sample was selected to have some gender balance and to focus on purchasers of bikes already equipped with electric assist units or installed by e-bike stores, rather than "do-it-yourself" owners. The latter might be considered "innovators" rather than "early adopters."

RESULTS

Who were the e-bike owners?

The e-bike owners interviewed ranged in age from 24 to 64; the median age was 48. Twelve of the owners were women. The sample appears to be concerned about the environment, as about two-thirds purchase green or renewable energy as an option for their home from their electric utility. The owners lived in a range of terrains, with five living in neighborhoods with steep hills. All but five of the owners indicated that there was at least one other motor vehicle (car, truck, SUV, etc.) in their household. Levels of bicycle ownership were high; twelve of the interviewees owned at least two other bicycles (non e-bikes) and all of them had at least one other bicycle (non e-bike) in their household.

What e-bikes were purchased and why?

Only ten of the e-bike owners converted an existing bike to an e-bike; the majority purchased e-bikes. Twelve of the e-bikes had a throttle, and nearly all of these were conversions. Most of the bikes had detachable batteries and of those owners who worked outside the home, over half charged their battery at work (as well as home). Over half of the e-bike owners had limited experience riding e-bikes prior to their purchase, such as a single test ride. The range of knowledge of e-bikes varied prior to purchase, with about one-quarter having no or very little knowledge and one-third with extensive knowledge.

The top motivation for purchasing an e-bike was the capabilities it provided beyond a conventional bicycle (n=20). This was consistent with the next most popular motivation – an alternative to a car (n=15). Environmental concerns were mentioned by just under one-third of the owners. A handful of the owners were facing health problems that limited their ability to ride a conventional bike, either due to age or other health factors. One long-time bicyclist noted that "I probably wouldn't have given these things a moment's thought 10 or 15 years ago." Another owner who had suffered serious injuries in a bike crash found that the e-bike was the only option to continue riding, given lasting health issues, which also limited her ability to drive or use transit comfortably. She noted that "I've been on my bike every day since I got it. I've been able to bike every day. …I felt like it, it kind of changed my life back. … I got back something I'd lost."

Several owners noted the potential for e-bikes to increase cycling among some populations:

"I think for women especially there are benefits since there are less women on bikes than there are men."
"I feel like the electric bike has the potential to reach people that wouldn't normally ride and to make cycling more attractive."
"I think there's growing acceptance to augmented bicycle riding. I mean in particular people of my age that you know, can't ride like they used to."

How were the e-bikes used?

The e-bikes were primarily used for utilitarian travel. Of the owners that worked outside the home, nearly all of them used their e-bike for commuting at least part of the time. About two-thirds rode their e-bike for errands or shopping.

E-bikes do appear to change owners' bicycling behavior and do substitute for driving a motor vehicle to some extent. A large majority of the owners (23 of 28) indicated that they had increased their overall amount of cycling since purchasing their e-bikes. The increase in cycling was usually for commuting or other utilitarian purposes, with only six owners saying that they increased their recreational cycling. In some cases, the e-bike was a reason to change from driving a car to bicycling to work. One owner noted that "I was able to turn the worst part of the day, which is getting in the car and driving to work into the best part of the day by bicycle commuting." Another explained that they were able to get rid of a car with their e-bike purchase. One owner had been an avid recreational cyclist prior to her e-bike purchase, but lived in a very hilly area which prevented her from cycling from her home to any destination (or for recreation). The e-bike now allows her to bike commute. A few of the owners did note riding their e-bike in the rain more than they would a regular bicycle: "I'm more apt to ride in the rain… Because I feel like it's safer. It's not as messy. Because I can go a little faster, I'm just not absorbing quite as many raindrops."

About half indicated that they ride to different destinations and a similar share take different routes with the e-bike. In some cases, the e-bike allowed them to take more direct routes with more hills, compared with a regular bicycle, or a route with higher speed traffic, where the e-bike helped them keep up and feel more confident.

What are the positive and negative aspects of e-bikes?

Positive owner experiences but some small reservations

Owners noted several positive aspects of their e-bikes. The following characteristics were volunteered by a majority of the owners:

- They arrive less sweaty or more energized at the end of their trip
  Example: "I decided to use the electric bike because I didn't want to feel tired the rest of the day."
- Climbing hills is easier
  Example: "The e-bike just really helps flatten out the hills between my house and work."
- E-bikes can accelerate up to the speed of cars and/or go faster than conventional bikes
  Example: "I find I can actually ride the bike faster than the bus."
- E-bikes allow them to carry more or heavier items.

Some owners tried to promote e-bike use by letting others test ride their e-bike:

"Everyone that I've let try the bike has thought it was really fun. I don't know that I've ever actually sold anyone on getting their own."

> *"I love letting people ride my e-bike. Because whatever negative feeling they have about e-bikes is gone once they get on it."*

Four of the owners explicitly noted that allowing others to ride their e-bike lead to an e-bike purchase.

About half of the owners noted that the additional weight was a problem, making the bike difficult to lift generally, difficult to fit on a car rack, or difficult to lift or fit onto the bike racks on transit vehicles. Eight of the owners were concerned about an increased risk of theft. Five noted increased difficulty in fixing a flat tire or making other minor repairs. Several noted a need for a longer battery range.

Speed benefits and safety implications

E-bike riders regarded increased speed as a positive factor for a variety of reasons. For example, one owner noted that the e-bike made riding with her male partner a more positive experience: "What I love about it is he's a stronger biker than me, and it used to be with regular bikes that he'd periodically have to wait for me…. Now, you know, I let him get a little bit ahead, and then I just flip on the e-bike, and then I catch up with him." Another woman noted that "As a woman, it just seems like that was the extra little oomph of power that put me at an advantage, or put me in line with some of the other zippier cyclists." One-third of the owners specifically noted that the e-bike allowed them to operate more like a motor vehicle (aka "vehicular cyclist").

In addition, about one-quarter of the owners noted that the additional weight or size of the e-bike, compared with a conventional bike, made them feel safer or more stable. Only three of the owners were worried about going too fast and only two of the owners noted that they wanted more power.

Several owners raised concerns related to public policy and e-bikes. One owner did fear that the potential conflict stemming from the differential speeds could lead to government bans on e-bikes in bike lanes, so that she tried to "tone it down" while riding. The fear of more regulation came up in a few of the interviews. One owner noted that "When e-bikes become main stream, there will be lots of laws controlling them" while another advocated for regulations that would prevent e-bikes from "getting to be too much like motorcycles."

Physical activity implications

Even with the electric assistance, several owners noted that the e-bike provided a satisfactory level of physical activity:

> *"It doesn't do it for you. You still have to work."*
>
> *"I personally feel that, even riding an e-bike is healthier than not riding a bike at all. People with e-bikes are obviously people that are not in cars."*
>
> *"I lost about twelve pounds, I think, during the summer when I was riding, you get the physical fitness benefit from it"*

However, one owner with a throttle-style e-bike noted switching back to a regular bike when he felt out of shape.

Legitimacy

There does appear to be some conflict in opinions about the legitimacy of e-bikes or their value relative to human-powered bikes, particularly from other bicyclists. For example, in response to our request for interview subjects on a local website, one reader responded "E-bikes are for overweight and lazy people." Of our interviewees who mentioned reactions from peers about

their e-bikes, a slight majority noted positive feedback, while the others noted that their peers expressed negative feelings towards e-bikes. One owner noted that "...I do hear a lot of snarky comments about it, like, oh that's cheating" and another specifically noted that cyclists he passed on a street with a bike lane "got bent out of shape." Another noted more negative reactions from other cyclists than from car drivers. Some of the owners themselves were a little conflicted or self-conscious:

> *"Now, I do worry a little bit about people relying on them a little bit too much instead of pedaling, but I think it's a lesser evil than cars."*
> *"I feel like I'm cheating when I'm on the road with other bikers; I feel very self conscious."*
> *"I haven't told a whole lot of people. Because I think they're gonna go. Oh my gosh. She got old. She got an electric bike."*
> *"You know, I guess there is a little bit of feeling apologetic about it since you're out biking and everyone else is working hard and you're having an easy time."*

CONCLUSIONS AND RESEARCH NEEDS

In the U.S. context, e-bike owners should be considered early adopters. In Rogers' theory of diffusion (20) an innovation might transition from the stage of early adopters to an early majority. Whether e-bikes will follow that pattern is open to debate. This research attempted to gather some insights about early adopters to help identify potential policy issues and areas for future research.

The interviews revealed several possible demographic markets for e-bikes that could expand the overall share of the population that bicycles for transportation: women, older adults, and people with physical limitations. Most of the e-bike owners interviewed were using their e-bikes to substitute for travel by either human-powered bicycles or traditional motor vehicles (cars, trucks, etc.). The e-bikes were not viewed as an option to or substitute for motorcycles or scooters. And, where the e-bike was substituting for a regular bike, the owner often had experienced some change (e.g. aging, injury, or change in travel distances) that would have reduced their bicycle travel were it not for the e-bike.

E-bike features may overcome some of the common barriers to bicycling for all types of riders. Owners noted the ability to travel with relative ease longer distances and over hills and to arrive at a destination, such as work, less sweaty or tired than with a regular bicycle. Though none of the owners specifically noted so, an e-bike could facilitate parents transporting small children who cannot ride their own bikes.

Even with the electric assist, e-bike riders are getting some physical activity while riding their e-bike. Therefore, the e-bike can be viewed as one option to address concerns over reliance on private motor vehicles contributing to health problems related to inactivity. However, further research is needed to understand the implications of e-bikes on physical activity levels. Future studies could examine how, when and to what extent the power assistance provided by the e-bike is used in conjunction with pedaling. It would also be desirable to gain more insight into the extent to which e-bikes are replacing trips by conventional bike, transit or car since those options have very different implications for changes in physical activity levels associated with choice of an e-bike.

Whether or not e-bikes need any specific policies to increase their adoption is unclear. Just as electric cars are more expensive than gas-powered cars, e-bikes are generally more expensive than regular bikes. While e-bike conversion kits start around $500, purpose built e-

bikes range from about $1,500 for a base model to over $5,000 for a premium brand fitted with extended range batteries. Electric car purchases are promoted through federal and state tax incentives and feebate schemes (29), and some of the e-bike owners suggested something similar for e-bikes. Whether or not a subsidy would increase adoption, or the magnitude of a resulting sales increase, is not a question this research could answer, since we interviewed people who had made the investment without a subsidy. Further focus group or survey research of potential owners could help answer that question.

There may be other policy responses that would promote e-bike adoption. Range anxiety has long been considered a factor that impacts negatively on consumer interest in electric vehicles. However, there is evidence that it decreases substantially for electric vehicle field trial participants because their experience in using the vehicles results in improved understanding of vehicle capabilities, appropriate driving techniques and journey planning (32). Public charging or battery swap stations may be a supportive initiative to overcome e-bike range limitations, though the interviews did not reveal a clear need for them. Battery swapping has been deployed in one European country (Switzerland) to support bicycle touring by e-bike (33). Many e-bike owners charged their bike battery at work without any problems. Having the option to take their bike on transit, as they do in Portland, also eased fears of dead batteries among some of the owners interviewed. However other e-bike owners noted that bike racks on transit vehicles did not accommodate the weight or design (longer wheel base) of their e-bikes. Design changes might address that problem. Therefore, the issues of range limitations and "range anxiety" that are driving the need to install public charging stations and battery swap facilities (34) for electric cars may not be analogous to e-bikes. However, these interviews were of early adopters who may be more willing to take risks in trying out a new technology. Accessible charging stations for e-bikes might appeal to later adopters. Further research could help address this question. Rather than adopting policies or facilities specific to e-bikes, several of the e-bike owners suggested policies that would promote all bicycle use, including bike infrastructure and disincentives for car use (e.g. higher gas taxes).

The potential for conflict between e-bike and regular bike riders should be a concern for planners and policy makers. About half of the e-bike owners noted negative feedback from other cyclists, sometimes due to the speed differential. However, some of the negative feedback was also due to perceptions of level of effort, i.e. e-bike riders weren't working as hard, they were "cheating." The latter perceptions may only be addressed as the technology is more widely adopted and social networks increase awareness and acceptance. From a sociological perspective, there is also scope to consider e-bikes in the context of a cities' underlying cycling culture given the increased awareness of its role in promoting and sustaining increased levels of cycling (30, 31). Many current e-bike owners have acted as goodwill ambassadors for e-bikes, letting people test-ride and answering questions.

However managing speed differentials may require different approaches. Oregon's (and other states') vehicle code limits the performance speed of e-bikes, which can help reduce the differential. Wider bike lanes would allow faster cyclists to easily pass slower cyclists. Speed limits on bicycle facilities are another option. However, the extent of the potential problem is unclear and the need for or type of policy intervention requires more research. Several of the e-bike owners interviewed, particularly women, noted that the e-bike allowed them to travel at speeds comparable to, not necessarily faster than, other cyclists. Others noted that they avoided riding too fast out of courtesy or fear of conflict. As with any mode of transportation, some road users will operate in a manner that annoys other users and poses potential safety risks. The

appropriate policy response may need to target the particular behavior, regardless of mode of technology. Moreover, whether the speed differential poses a significant problem in the future will depend not only on the extent of adoption of e-bikes but the characteristics of the riders. E-bikes may appeal more to riders who do not necessarily want to go significantly faster than other cyclists. More extensive quantitative research could help assess this issue further.

This study has focused on e-bike users in one US city and there would be merit in considering more geographically diverse locations in research of this type. As the number of e-bike users grows there will be scope to go beyond the qualitative data collection that underpinned this study and collect a broader range of quantitative data. That could include measuring travel behavior before and after the purchase of an e-bike to understand their impact on the use of other modes and on physical activity levels. It would be possible to monitor e-bike rider's travel activity with GPS to study their speed profiles and utilization of bicycle facilities (off-road paths versus bicycle lanes versus travel lanes). It would also be valuable to collect information about the experiences e-bike users have when sharing facilities with conventional bicycles and pedestrians including details of how they interact as well as cases of near misses or collisions .

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