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Experiences of electric bicycle users in the Sacramento, California area

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ABSTRACT

In some parts of the world, electric bicycles (e-bikes) represent a significant share of daily travel, though they are still rare in the United States. The small size and maneuverability of e-bikes that are assets in cities in China may not be as important in the U.S., where cities are built to accommodate cars, but their potential as a substitute for cars makes them an important part of the discussion around sustainable transportation. In this study we conducted 27 interviews with e-bike users in the greater Sacramento area in which we asked participants about the reasons why they chose to invest in an e-bike, the ways in which they use their e-bikes, positive and negative aspects of using e-bikes, and reactions from friends and family members. Several important themes emerged from the interviews. The functional characteristics of e-bikes, particularly greater speed and acceleration than conventional bicycles with less exertion, contribute to several positive aspects of their use, including enabling more people to bicycle, more trips to be made by bicycle, and more fun for their users. The result, for these users, was an overall decrease in driving, with some users getting rid of their car altogether. Negative aspects cited by users include security concerns, safety concerns, unwieldiness, and range anxiety. Participants also discussed several misperceptions on the part of non-users that could inhibit their adoption. These results provide insights for the development of e-bike policy and guidance for future research.

Introduction

In some parts of the world, electric bicycles – often called "e-bikes" – represent a significant share of daily travel, especially in urban areas (Weinert et al., 2006, 2008). E-bikes provide many benefits in places like China, where annual e-bike sales now exceed $30 million and are projected to grow to $38 million by 2018 (Navigant Research, 2012). E-bikes are faster and require less physical exertion than conventional bikes, and they are cheaper and provide greater health benefits than cars. E-bikes can be fully charged for 15–20 cents depending on the price of electricity and the range and type of battery (NYCEWheels, 2013). In the densely populated settings where e-bikes are most common, traffic congestion makes the agility of e-bikes an important asset in terms of reducing travel times.

Despite the widespread adoption of e-bikes in China and parts of Europe, e-bikes are still rare in the United States. The small size and maneuverability that are assets in China may not be as important in the U.S., where the density of development is lower and auto ownership rates are much higher. In the U.S., the e-bike, like all two-wheeled modes, must compete for road space in an environment that that reflects decades of auto-centric development. With conventional bicycling accounting for just one percent of daily trips in urban areas in the U.S. (Pucher et al., 2011), current e-bike use is negligible. However, a qualitative study of the experiences of e-bike riders in Portland, Oregon found that e-bikes can enable people who could not or would not otherwise make the same trip by conventional bicycle (Dill and Rose, 2012).

This finding raises the possibility that e-bikes could substitute for car trips and thus contribute to a shift towards more sustainable transportation options even in the U.S. Life-cycle emissions analyses have demonstrated that riding e-bikes is a more environmentally-friendly way to travel than driving given that e-bikes emit substantially less pollution per mile than cars (Cherry et al., 2009); one U.S. study estimates that e-bikes emit 40 times less CO_2 than cars (Shao et al., 2012). But while many cities in the U.S. are promoting conventional bicycling as a sustainable mode of transportation through substantial investments in bicycle infrastructure and the implementation of bike-sharing programs, they have given little attention to the role that e-bikes might play. Even the legality of operating an e-bike on city streets is uncertain in places.

The purpose of this study was to consider the potential for wider use of e-bikes in the U.S. by exploring the experiences of early adopters of e-bikes. Our research team conducted 27 interviews with e-bike users in the greater Sacramento area in which we asked participants about the reasons why they chose to invest in an e-bike, the ways in which they use their e-bikes (e.g. trip purpose, trip destination, frequency), positive and negative aspects of using e-bikes as a mode of transportation, and reactions from their friends and family members. While each participant offered a

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unique perspective, several clear themes emerged that could help to shed light on the opportunities and challenges for expanding e-bike use in the U.S.

Background

E-bike use is on the rise around the world. There were an estimated 120 million e-bikes in China in 2010, and that figure has been growing rapidly (Yao and Wu, 2012). In China, e-bike trips are largely replacing walking, bicycling, and bus trips rather than substituting for car trips (Cherry and Cervero, 2007), and some evidence suggests that e-bikes serve as transitional vehicles from conventional bicycles to cars as Chinese incomes increase (Cherry and Cervero, 2007), negating their noted environmental benefits. Although not on the same scale as in China, Europe has also witnessed a rise in the popularity of e-bikes. Approximately 10% of bicycles sold in the Netherlands are electrically assisted, while annual e-bike sales in Germany have jumped from 200,000 to 380,000 in the last three years (Market size, 2013).

While e-bikes have yet to gain much traction in the U.S., their potential may be great. California, with the passage of climate change legislation and the introduction of a cap-and-trade emissions program, is searching for ways to swiftly reduce emissions from the transportation sector. A wider-spread adoption of e-bikes could help to reduce transportation emissions if their use replaces driving. Data collected from the first e-bike sharing program in the U.S. found that just 11% of e-bike trips replaced driving trips, while 58% replaced walking trips, and 11% would not have otherwise been made (Langford et al., 2013). However, the impact on driving might be greater in settings other than universities, where this program was implemented, or with privately owned e-bikes. To better understand how e-bikes might be used for transportation purposes, San Francisco is launching an e-bike sharing pilot program in 2014.

E-bikes provide significant increases in physical activity when they substitute for cars. From a public health standpoint, the largest relative health improvements are gained in the transition from inactivity to moderate physical activity (Gojanovic et al., 2011); thus, encouraging a substitution from cars to e-bikes could provide enormous public health benefits. In certain contexts, even riders of conventional bicycles can derive health benefits from switching to e-bikes. One study found that people using e-bikes exhibited lower levels of muscle strain and physiological stress compared to those using conventional bicycles (Theurel et al., 2012). Their results suggest that e-bikes might provide a safer and healthier alternative for individuals whose occupations frequently require biking for long periods of time, like postal workers or police officers. In another study, sedentary women experienced significantly lower levels of blood lactate concentration and reported higher levels of enjoyment after riding e-bikes than after riding conventional bikes (Sperlich et al., 2012). A controlled study conducted in the Netherlands found that under three different intensity levels of electric assistance, e-bike use was sufficiently high to meet physical activity guidelines for adults as prescribed by the American College of Sports Medicine (Simons et al., 2009). These health benefits help reaffirm the benefits of active commuting, whether on conventional or electric bikes.

However, some have expressed concern as to the safety of e-bikes on the road that could offset the health benefits of increased physical activity. A comprehensive study in China compared conflict incidents and risk-taking behavior by bicyclists and e-bike users at 14 intersections and found that e-bike user conflict rates were significantly higher than those of bicyclists for all types of intersection conflicts, regardless of who was at fault (Bai et al., 2013). E-bike users were 1.4 times more likely than bicyclists to exhibit risky behavior at intersections: 6.7% of e-bike users ran red lights, a figure the authors attributed to the relative confidence of e-bike users in being able to cross an intersection in a short period of time (Bai et al., 2013). In another Chinese study, 27% of e-bike users reported being involved in at least one at-fault accident in the past year (Yao and Wu, 2012). At this point, it is hard to know whether these same types of risky behavior apply in the U.S., where e-bike safety has not yet been studied.

Methodology and analysis

For this qualitative study, we recruited 27 e-bike owners to participate in in-depth interviews about their experiences in the fall of 2011. The interviews were intentionally open-ended and exploratory in nature. This approach, often used when little is yet known about a particular aspect of travel behavior (Clifton and Handy, 2003), allowed us to identify important themes that could serve as the basis for the design of policy-relevant questions in larger-scale quantitative studies. Furthermore, very few people currently ride e-bikes in the Sacramento region, making it difficult to recruit a sample large enough for quantitative analysis.

We employed three recruitment methods. First, we distributed fliers at local businesses that sell e-bikes. Second, we asked store-owners to email the research team's contact information to customers who had bought an e-bike from them. Third, using a snow-ball sampling approach, we asked each person who contacted us to refer other adult e-bike users who live or work in the Sacramento area. We offered a $20 gift card to Target to each participant as an incentive.

Socio-demographic characteristics of the interview participants are compared to the California population in Table 1. Only 10 out of the 27 participants were women, and this sample of e-bike users has average education and household income levels higher than the state average. As there are no available data on the population of e-bike users against which to compare this sample, it is not clear whether it is representative of all e-bike users or biased by the non-random sampling method and/or the demographics of the region from which the sample was drawn. About half of the participants live and/or work in Davis, a suburb of Sacramento well known for its bicycling infrastructure and culture (Buehler and Handy, 2008); Sacramento also has invested heavily in bicycle infrastructure (Handy and McCann, 2011).

We conducted 24 of the interviews in person and the remaining three by phone. We conducted the interviews in a variety of locations, including participants' offices and homes, university facilities, and coffee shops. The interviews took between 20 and 45 min and were recorded with an mp3 recorder. For most interviews, two members of the research team were present, though four were conducted by only one researcher. All interviews were based on the same set of guiding questions and included a mix of open-ended and close-ended questions.

Table 1
Socio-demographic characteristics of participants vs. California population.

	Participants	California	Source
Median age	54	35	1
Percent female	37%	50.3%	1
Education			
High school or higher	100%	80.5%	2
Bachelors or higher	78%	29.7%	1
Average household size	2.6	2.9	2
Average household income	$72,708	$58,935	3

Sources: (1) 2010 U.S. Census; (2) 2005–2009 American Community Survey; (3) 2009 American Community Survey. Retrieved from http://factfinder.census.gov/.

The audio files were transcribed by a professional transcription service. The transcripts were initially read by three members of the research team to identify common themes relating to the benefits and limitations of e-bike use. In order to facilitate the compilation of descriptive statistics, we coded each interview according to these identified themes using the qualitative analysis software package Atlas.ti. Atlas.ti allows the user to specify themes or key words of interest and then code passages of the interviews that express these ideas. In this way, we were able to determine the relative frequency of specific opinions and perceptions among participants. We then used these coded transcripts to assess the nature of early e-bike use in the Sacramento region.

Results

In discussing their experiences with e-bikes, participants often cited the functional characteristics of e-bikes in relation to conventional bikes as well as cars. The most fundamental characteristic is speed: e-bikes travel faster than conventional bikes, though still not as fast as cars. The speed of e-bikes reduces the time required to travel a given distance or increases the range of travel for a given amount of time relative to conventional bikes. E-bikes also accelerate faster than conventional bikes, and accelerating to and maintaining top speeds require less physical exertion. On the other hand, they can be more costly to purchase and operate than conventional bikes, and they are generally heavier than conventional bikes. While the range of a conventional bicycle depends on the energy of the bicyclist, the range of an e-bike depends on the battery charge. In comparison to cars, e-bikes are slower, leave the rider exposed to the weather as well as traffic, and have a more limited range, but they are cheaper and produce far fewer negative environmental impacts. These differences were widely recognized by the participants, and they underpin the themes that emerged from the interviews with respect to the acquisition of e-bikes, the nature of their use, positive aspects of their use, negative aspects of their use, and reactions from non-users to the concept of e-bikes.

E-bike acquisition

The e-bike experiences that participants reported depended in part on the characteristics of the specific type and model of e-bike they had acquired. About half of the participants bought or were given a complete e-bike, and the other half bought a conversion kit that was installed on a conventional bike.[1] The sample included two types of e-bikes: those with full throttles that can be run exclusively on their electric motors, and those with motors with varying levels of power that "assist" the cyclist when pedaling. Most of the participants had e-bikes with lithium-ion batteries, although a few had e-bikes with lead acid batteries purchased in the 1990s. Reflecting the variation in battery type, participants reported ranges that varied from 15 to 65 miles on a single charge. Table 2 shows the specifications for the two most common types of e-bikes that participants owned.

One of the key objectives of the interviews was to identify the factors motivating people to acquire an e-bike. Interestingly, most participants said that they bought their e-bikes after being encouraged by a close friend, family member, or respected community member. This result may be a function, at least in part, of the snowball-sampling approach we used to recruit participants. Nevertheless, it suggests that social networks could play an important role in the adoption of e-bikes in the U.S. The influence of family members and friends are illustrated by these comments:

[1] The large number of conversion kits may be a result of the availability of the Bionx model at a local bike shop.

Table 2
Functional characteristics of common e-bikes.

	Pedego classic comfort cruiser	BionX compact/power/premium series
Battery	Lithium	Lithium
Amps	10 Ah Standard/Optional 15 Ah	9.6/9.6/8.8 Ah
Volts	36 Volt	26/37/48 Volt
Speed	20 mph	25 mph
Range	15–30 miles	40/56/65 miles
Weight	Bicycle = 55 lbs Battery pack = 6 lbs	Motor = 10 lbs Battery = 8 lbs or more
Motor	500 Watt	250/350/350 Watt
Price	$1795	$1195–$2195

Source: Shao et al., 2012, Practical cycle website (http://practicalcycle.com/index.php), BionX website (http://www.bionx.ca/en/).

> *I'm one of those people that if somebody that I know and trust introduces me to something, I don't even need to look further. So the fact that the bicycle went along with someone who I trust who stood behind it, I didn't need to go look for more information.* (Female, 54)

> *[My husband] saw an e-bike demonstration over at [a local bike shop], and he took a ride on it… He was excited about it. So he got it. And I tried it and loved it.* (Female, 62)

In addition to the influence of peers, eleven participants cited physical activity and the accompanying health benefits as the main motivation for their decision to purchase an e-bike. For older participants, purchasing an e-bike allowed them to continue exercising when they otherwise would not be able to.

> *It's better for the environment, and for me, I get more exercise, it's more enjoyable to be outside.* (Female, 24)

> *I've been a bicycle commuter basically my entire life, and my knees are giving out. I have pretty much constant knee pain, and so since I didn't want to drive the car to work, you know, I decided to convert.* (Female, 53)

> *I am aging. And I love riding bikes so it made sense. Because it was starting to get harder and harder and I wanted it to be fun again.* (Male, 53)

In a several instances, participants purchased e-bikes for loved ones in order to be able to work out together:

> *Well, the reason why I bought one for my wife was that, when we rode bicycles, she was much slower than I was, and I wasn't getting enough exercise.* (Male, 75)

Another seven participants were primarily motivated by environmental concerns and turned to the e-bike as a way to reduce driving and thus their environmental footprint. Almost half of the participants acquired an e-bike because they determined it was the best option available to them for low-environmental-impact travel, not because of an inherent preference for bicycling. Many other participants were long-time bicycle enthusiasts who saw e-bikes as a way to extend their bicycling and reduce their driving even further. Examples of such sentiments include these comments:

> *Just eliminating more and more dependence on the automobile. We already only have one car in our household. And there's three adults. And I still felt that the fewer times that car comes out of the garage the better.* (Female, 54)

> *Because I envisioned [the e-bike] replacing more car trips. Right now my personal policy is, if it's in Davis, I will, as often as humanly possible, ride my bike.* (Female, 54)

E-bike use

We asked participants to report the number of days and approximate miles they rode their e-bikes in an average week with good weather. The participants who had regular access to a car also reported their weekly driving. On average, participants rode their e-bikes more frequently (4.3 days/week) than they drove a car (2.8 days/week) (Table 3). E-bike mileage ranged from 2 to 140 miles per week, with an average of 44 miles per week. Although we did not ask about distances for specific trips, participants used their e-bikes for commute trips up to 20 miles each way (in which cases participants charged their e-bike batteries at their work locations). We did not ask respondents how many miles they drive in a typical week.

Participants reported the estimated percentage (0–100%) of their e-bike rides for two purposes: transportation (e.g. commuting, errands, or visiting people) or recreation (e.g. exercise or leisure rides). Over three-quarters of participants stated that they ride e-bikes mostly for transportation purposes, including 10 people who said that they ride exclusively for transportation purposes. Only one participant said that she uses her e-bike exclusively for recreation. Notably, several participants indicated that they had shifted from using their e-bike for recreation – the reason they purchased the e-bike – to using it for transportation after finding it convenient, safe, and fun to ride.

Positive aspects

The higher speed and acceleration of e-bikes and the lower level of physical exertion compared to conventional bikes contribute to the positive aspects of e-bike use cited by participants. These functional advantages enable more people to bicycle and more trips to be made by bicycle, and they contribute to the fun of traveling by e-bike.

More people

Participants pointed out several ways in which the e-bike enables people with physical limitations to begin or continue biking. For example, one participant described a nerve disorder that impedes her ability to ride a conventional bike. She has work obligations at a university campus, and found that it was difficult to find parking close enough to her buildings to meet her various time constraints. The e-bike allowed her to fulfill her campus responsibilities and also save on parking costs. She said about the subject:

> *I have a disability that makes it hard to bicycle on a regular bike. I have nerve problems in my legs, so after a little while I start getting tired or my legs hurt. An e-bike [. . .] lets me go places I wouldn't be able to go otherwise. It lets me get around campus really easily. I think that's the main perk. I wouldn't be able to get around campus, it's even better than driving. You sometimes can't find a disabled parking spot, even. And the lots are really far from the buildings here. You have to walk a lot, and get back in your car, but the e-bike you can always park right next to where you're going.* (Female, 26)

Table 3
Travel behavior of e-bike users in a typical week.

	Minimum	Maximum	Mean
Days of e-biking in a typical week	1	7	4.3
Miles of e-biking in a typical week	2	140	44
Days of driving in a typical week	0	44	2.8
Transportation trips as proportion of total e-bike trips	0%	100%	80%

Additionally, several participants who were long-time bicycle commuters found that their commutes had become more difficult as they aged and began experiencing knee and back pain. These individuals invested in e-bikes so that they could continue to benefit from the physical activity of bicycle commuting. They described the e-bike as being particularly helpful in alleviating the pain and effort required to start from a dead stop and in allowing them to carry more of their belongings. The role of e-bikes in enabling older people to bicycle are illustrated by these comments:

> *It was much easier to break back into riding the bike with the e-bike. It's much easier to get up in the morning and persuade myself to go out for a ride because I can go a little farther than I would without it. I feel confident that I'm going to make it home no matter what.* (Male, 72)

> *I'm getting older so [. . .] I have a feeling I'll use the e-bike even more [. . .] to replace regular bike trips.* (Female, 55)

> *I'm 65, so I don't think people should think age is a barrier. Who would have thought somebody my age would be commuting 20 miles a day on a bike to work?* (Female, 65)

Some participants mentioned that the e-bike's motor-assisted acceleration helped reduce pain and effort when riding up hills and bridges. The Sacramento area is relatively flat, but easing the burden from topography could be more significant in other regions. As one participant described it:

> *Where I'm living right now, it's kind of hilly. So I couldn't commute with the regular bike. . . it would have killed me basically, going up the hill.* (Female, 44)

In some cases, e-bikes functioned as a transitional step between cars and conventional bikes for people who were not sufficiently fit to start directly on a bicycle. Some participants described the e-bike as an "equalizer" that allowed them to match the pace of a family member or friend who is a faster cyclist, though usually in a recreational context. Examples included:

> *One exciting aspect is that it's an equalizer between fitness levels, we could both go on a long bike ride.* (Female, 52)

> *My husband loves to road bike, and he goes really fast. I don't want to be left out every time he goes to Winters – it's my favorite ride. But the e-bike makes it perfectly possible.* (Female, 54)

> *My dad's a real avid cyclist and always goes really fast. My mom's a really small woman. . . and I'm a bigger guy so I can't keep up with my dad. But now it kind of puts us all in the same playing field.* (Male, 25)

More trips

The higher speed of e-bikes relative to conventional bicycles makes bicycling possible for more trips. E-bikes made bicycle commuting feasible for participants for whom conventional bicycling would have taken too long, and they enabled more frequent bicycle commuting for those who occasionally commuted by bicycle. One participant explained that he was initially going to give up bicycle commuting after a residential move that increased his commute distance, but was able to keep biking to work after acquiring an e-bike:

> *When I moved from my house, it's a little bit further from the office, and I know that I want to get back home quickly enough in case my wife needed me.* (Male, 44)

A few participants also noted that the decreased physical effort to cover the distance from home to work (in particular) means that they are able to arrive at their destination and not be particularly

sweaty or require shower facilities. Men and women alike commented on the value of being able to arrive at their workplaces without looking disheveled:

If you had to ride a regular bike, you might say it's a little too long, a little too sweaty, a little too much. But on an e-bike, if you can go 25 miles an hour and not arrive sweaty, and it took 25 instead of 40 minutes, you'd go yeah. (Female, 54)

It's really empowering to go where I need to go, when, in a timely fashion, without getting sweaty and I can go farther because I'm confident I can get back without getting all beat up. (Male, 54)

The higher speed and acceleration of e-bikes also helped to increase participants' comfort with bicycling, thus encouraging bicycling for more trips. Many of the participants noted that their ability to travel 20 to 25 mph made them more confident on the portions of their route that required them to occupy a vehicle lane as opposed to a bike lane or path. Several participants mentioned that the ability to use the throttle to accelerate quickly out of a stop sign reduced the time it took for them to traverse downtown areas where stop signs are frequent, made them less worried about making drivers behind them at stop signs impatient, and greatly decreased the physical effort needed to start from a complete stop, as illustrated by this comment:

It's so easy to accelerate that you're more likely to stop at a stop sign. And it's easier to scoot out of the way. (Female, 59)

On the other hand, e-bikes can also be operated like a conventional bicycle. This flexibility further contributes to the comfort that e-bike users feel:

I like the flexibility of it. I have a boost if I need to get through an intersection, but I can also slow down and mingle with pedestrian traffic on the sidewalk. (Male, 51)

Weather is well-documented deterrent to bicycling (Sears et al., 2012), but most participants reported that they enjoy riding their e-bike even in hot and windy weather (which is common for much of the year in the Sacramento region) because they do not need to exert as much effort as they would on a conventional bicycle. Barring extremely hot weather or very heavy rain, most participants reported that they did not change their e-bike use based on the weather. The following comments illustrate the ability of e-bikes to overcome the obstacle of weather:

Well, I had a regular bike, but Davis is really hot, so I found myself not riding it for like the longer trips. (Female, 39)

I worry that the heat would bother me. I was thinking, "100 degrees. What the heck am I going to do?" But I'm going fast enough that it doesn't bother me. (Female, 65)

There's always some excuse related to weather or time that would just make it easier to [not] get on the bike. But with the BionX, it eliminates the excuse [...] If it's really windy, I'll jump right on my e-bike, where I wouldn't ride my regular bike. If I'm going 6 miles to a friend's house I might say, "Oh, I don't want to do that on my [conventional] bike." So definitely wind. But rain, too. (Female, 54)

In a region with more extreme wetness or cold (which can decrease battery life) than Sacramento, weather may be a bigger concern. The one weather-related concern that a few participants did report was the possibility of rust or damage to their e-bike's electrical components from very wet conditions.

Driving substitution

If e-bikes are enabling bicycling for more trips, it may be at the expense of driving trips. To assess whether or not participants were using their e-bikes as a substitute for driving, we asked participants whether they drive more or less now compared to before they got their e-bikes. Unlike in Europe and China, where e-bikes seem to be a substitute for other active transportation modes, most of our participants reported using them in place of driving. Of the 25 participants who had access to a car prior to getting an e-bike, 20 stated that they drive either "a lot less" or "a little less" now that they have an e-bike. Only five participants said they drive about the same amount as before, and only one said that he now drives more than before getting an e-bike (for reasons unrelated to the e-bike). All of the participants who reported the amount of money they spent on gas before and after getting an e-bike (15 of the 27) said that they spent the same or less on gas afterwards. Before getting an e-bike, participants spent an average of $91 per month on gas, compared to $60 per month after. Other costs sometimes also dropped, as in this case:

[We drive] about half [as much]. We even got a break on our insurance. (Female, 60)

Two participants were able to use their e-bike to replace enough vehicle trips to sell one of their cars:

I got rid of my car. Well it's also true liberty. (Male, 54)

Now I don't even have a car. It's 100% by bike. (Male, 25)

However, e-bike use sometimes replaces conventional bicycling rather than driving, as in these cases:

[I commute on] the e-bike. It should be the regular bike but the e-bike is so much more fun. (Male, 52)

About the same [amount of driving]. I was riding my bike before. (Male, 52)

More fun

More than half of participants noted – unprompted – that even if they had initially purchased an e-bike for pragmatic or environmental reasons, one of the things they like most about the e-bike is that is fun.

I loved it – I was so ecstatic when I first got it – I'm not like that ecstatic on a daily basis, but, every time I'm riding it, I'm just like, "I love it." (Female, 39)

Nobody's going to do something that they don't want to do unless they have to. They'll rationalize their decision with all the things, like it's going to be good for their health, it's going to be good for the environment, it's going to save them money. But those things aren't really actually what does it. They do it because it's fun. (Male, 25)

In at least one case, e-bike use replaced other recreational bicycling, with the side benefit of reducing driving:

The other weird thing that happened is that we got rid of our mountain bikes, because this mountain biking thing, as fun as it is, I really don't like having to put the bikes on the car and then drive the bikes to somewhere else... the e-bike is more fun and you can go further [sic] distances [...] I have just as much fun going to West Sacramento [...] so we eliminated that extra driving to go mountain biking. (Female, 54)

One participant summed up many of the positive aspects of e-bike use, both practical and fun, in this statement:

You can get places fast and carry a lot of stuff. It's as fast as driving. It gives you exercise but doesn't exhaust you. It takes all the drudgery out of bicycling and puts the joy back in. (Female, 59)

Negative aspects

While many of the functional characteristics of e-bikes contribute to positive aspects of their use, others contribute to notable negative aspects. Several of the cited concerns were remarkably consistent across the interviews: security, safety, unwieldiness, and range.

Security concerns

One of the greatest concerns that participants cited was the added anxiety of using a more expensive bicycle. Although bicycle and e-bike prices vary greatly, the addition of a battery and motor makes any given bicycle worth more. In light of the high purchase price of their e-bikes, half of participants expressed concern about the risk of theft. These comments illustrate this concern:

> *Once we get [downtown], there's three things to lock [the bike, the battery, and the front tire]. The security measures are kind of a hassle.* (Male, 58)

> *I can't take [the e-bike] in the building and I don't know where the racks are. The parking is pretty poor. I'd be worried about the hundreds-of-dollars lithium battery.* (Male, 51)

> *It's got a high cost associated with it so I don't like parking it on the sidewalk. And once you add lights or trick it out it might attract too much attention and get stolen or trashed.* (Male, 52)

Safety

Many participants mentioned that despite the higher speed and quick acceleration of the e-bike, they still felt unsafe interacting on the road with cars in many settings. Although most of these concerns apply to bicycling in general, a few issues are specific to e-bikes. At higher speeds than a conventional bicycle, a small crack in the road or a collision with the door of a parked car can cause a much more severe crash on an e-bike, though no participants reported having had such a crash. Several participants said that even though the e-bike's speed and acceleration permitted them to behave more like vehicles, the added danger at those speeds encouraged them to use pedestrian facilities at times. Examples of safety concerns related to infrastructure include the following:

> *I kind of avoid the bike-only paths because they always have cracks and little bumps, and that don't matter when you're going 5 miles an hour, but when you're going 20, it can be kind of jarring.* (Female, 39)

> *I pity the person who has to ride there. Even with so called bike lanes. No, man, people put their rubbish out there. I got doored. On a one way street. It gives me the heebie jeebies riding past parked cars. Someone's going to open their door.* (Male, 53)

> *I refined my route so I don't ride the major streets except for 1/3 mile, where I ride on the sidewalk. Which I know is illegal, but I don't feel safe on the street.* (Female, 52)

Several participants raised the issue of e-bikes on off-street bicycle/pedestrian paths. Currently, California state law prohibits e-bikes from using such paths, but cities can override this law within their jurisdiction. Most participants expressed some desire to be able to use such paths:

> *I have a lot of opinions. The current structure technically legally excludes e-bikes from class 1 bike paths [. . .] It's really kind of ridiculous.* (Female, 60)

> *I am prohibited from class one bike paths. It's very difficult.* (Male, 60)

On the other hand, some participants expressed concern about mixing e-bikes with conventional bicycles and pedestrians. Some participants noted that operating the e-bike at maximum speed, which can be as high as 30 mph, would be scary or unsafe for pedestrian and non-e-bike users, especially on crowded routes.

A potentially significant safety concern is the difficulty of visually distinguishing e-bikes from conventional bicycles. Because mopeds and motorcycles are visually distinguishable from bicycles, car drivers can recognize them and anticipate their speed and behavior accordingly. E-bikes, on the other hand, are visually indistinguishable from conventional bicycles, and car drivers may underestimate the speed at which they approach, as illustrated by the experiences of one participant:

> *It took a little getting used to because I had to be really conscientious of other drivers because they weren't expecting me to approach as quickly as I was. And so, in the beginning, I feel like cars were kind of cutting me off because they thought they had plenty of time. But now I have a better sense and like I'll deliberately slow down like very obviously before I get to an intersection.* (Female, 39)

The difficulty of visually distinguishing e-bikes from conventional bicycles also has potential safety implications for pedestrians, if, on shared facilities or at crossings, they miscalculate the speed on an oncoming e-bike.

Unwieldiness

With the addition of the motor and battery pack, an e-bike weighs between 50 and 70 pounds (NYCEWheels, 2013), much more than a conventional bicycle. Almost all participants said that the weight of their e-bike was an inconvenience, particularly for women and older participants. Some participants reported having trouble maneuvering the bike when the motor was not running, such as when they were trying to park it or lock it to a rack. For example:

> *If you've got to pick up the bike and move it to park it a bunch of times, it's a little more challenging for someone my size. It's lifting 50 pounds, instead of 25 pounds with my hybrid.* (Female, 55)

As one participant simply said, when asked about the downsides of his e-bike:

> *It's heavy.* (Male, 54)

Range anxiety

The extra weight of the e-bike exacerbated "range anxiety," the fear that the e-bike has insufficient range to reach its destination. Because of its weight, once its battery dies, an e-bike is much more difficult to pedal than a conventional bicycle. The need to pay close attention to the battery charge limited the freedom and flexibility of e-bike use for participants. Because the range of an e-bike varies anywhere from 15 to 60 miles depending on how much power one uses, it can be hard to predict exactly how long one charge will last. Most participants said that if charging stations were more readily available, they would feel more comfortable going on longer trips. For example:

> *I might be more inclined to take it farther if there were places to charge it. Like if I didn't have to bring the charger with me.* (Female, 39)

> *What would be nice would be a place to charge it. My boyfriend and I will ride downtown but we have to make sure we have enough energy to get back.* (Female, 24)

There's no real provision made for plugging in an e-bike like there is for e-cars at the moment that I know of, except if you just find the odd plug that wasn't really intended for that. (Male, 73)

Perceptions by non-users

When asked about potential barriers to wider e-bike adoption, participants frequently cited misperceptions among non-e-bike users about who e-bikes are "meant for" and what types of trips they should be used for. These misperceptions – as described by the e-bike users in this study – can be separated into two categories: the perception of e-bikes as meant for recreational use and the stigma that e-bike users are "cheating." These two perceptions might explain why participants also reported that others perceive e-bikes as expensive. Studies of non-e-bike users are needed to determine how wide these misperceptions are and whether they are in fact a barrier to e-bike adoption.

Perception of e-bikes as recreational equipment

Although participants used their e-bikes primarily for utilitarian purposes, some of them expressed a belief that other people view e-bikes as predominantly recreational. The perception of e-bikes as recreational lends itself to stereotypes about what type of people e-bike and might discourage the widespread adoption of e-bikes for transportation. These comments illustrate the beliefs that participants held about the perceptions of others towards e-bikes:

They thought of the bicycle not so much as a means of transportation, but as an exercise tool. That's not what this is for. This is to get me to work. And so I think that's something that people haven't accepted yet. (Male, 58)

If the e-bike replaces a bike, [their reactions] are negative, because you need the exercise. If it replaces a car, it's positive. (Male, 51)

One of the participants was a local e-bike dealer, and he expressed the belief that some of his customers tended to view e-bikes as recreational equipment and not meant for transportation:

I know a lot of people view [e-bikes] as toys... I wish people would take it a little more seriously. This is transportation. They come in and laugh and say, "Maybe when I'm old." And then put their 5000 dollar carbon bike on the back of your SUV because you're too scared to ride on the road... I'll give you an e-bike... you really can take this seriously as an alternate form of transportation. (Male, 53)

Perception that e-bike users are "cheating"

Several interview participants said that the perception of e-bikes as being for recreational purposes led their peers to consider e-bikes as "cheating" because they require less physical exertion. When asked what their families, friends, and colleagues thought about their e-bike use, some participants said that they are regularly told that using a bike with an electric motor is cheating, for example:

The prevailing attitude is always, "Well, that's cheating." Or, "That defeats the purpose of a bike," which is a ridiculous statement. (Male, 25)

I must have known a lot of people who are very avid bikers who probably kind of turn up their nose at it because they think it's cheating, you know, because they're into regular bicycles. (Male, 73)

Perception that e-bikes are expensive

The main barrier to e-bike adoption that the participants reported hearing from their family and friends was cost. It is possible that this perception derives from the assumption that e-bikes are meant to be used for recreational activities (i.e. as a substitute for road bikes or other forms of recreation) and not for transportation (i.e. as a substitute for cars). One participant described how this perception of cost can affect a potential buyer's decision:

My coworkers have tried it out and one guy seriously considered getting it for his son because he has a ten mile commute to school, but I think he doesn't want to spend that much money. (Female, 53)

Although e-bikes are expensive relative to some conventional bikes, their true cost depends on what kinds of trips they are used for. When compared to a car, e-bikes are significantly cheaper, and, as some of our participants noted, the savings from gas and insurance costs can make e-bikes even more cost effective.

Conclusions

This study points to several ways in which e-bikes might gain traction in the U.S. and the kinds of benefits they could generate. Most importantly, these interviews suggest that e-bikes can play an important role in expanding the range of people for whom biking is feasible. Their functional advantages over conventional bicycles in the form of speed, acceleration, and reduced effort can enable people with physical limitations or time constraints to take up or continue bicycling, and they can enable bicycling for more trips, overcoming barriers such as distance and weather. However, participants identified several negative aspects of e-bike use that may need to be addressed before e-bikes will be more widely adopted, and they expressed the belief that many non-users misperceive the role as well as the cost of e-bikes. Indeed, since these interviews were conducted, significant advances in e-bike battery efficiency, cost, and weight have been made, thereby reducing some of the barriers identified by participants.

A motivated community could consider several measures to encourage e-bike use. The starting point might be educational programs and outreach campaigns targeting groups for whom e-bikes could be especially beneficial, including people with physical limitations, to raise awareness of the potential of e-bikes as a mode of transportation and to overcome any existing misperceptions as well as basic lack of knowledge of e-bikes. Incentive programs might be created to encourage the purchase of e-bikes or conversion kits for conventional bicycles, modeled after programs designed to encourage investments in energy conservation. Well-designed facilities with smooth surfaces and appropriate separation from car traffic would improve the comfort and safety of e-bike use, further encouraging their adoption. The appropriate regulation of e-bikes as vehicles must also be addressed, though it remains a challenging issue worldwide (Rose, 2012).

The importance of experiencing e-bikes firsthand should not be underestimated in efforts to encourage e-bike adoption. As noted, many participants in this study bought their e-bikes at the urging of a trusted friend or family member, and they suggested that their family members and friends were more likely to consider the e-bike as a viable means of transportation (as opposed to a recreational toy) after trying out the e-bike for themselves, as illustrated in this comment:

Everybody loves it when they get on one. My friends made fun of me a little bit until they tried it, but now they all want one. (Male, 25)

Research on e-bike use in the U.S is limited, particularly in comparison with the recent explosion in research about conventional bicycling. By exploring the experiences of early e-bike adopters in the Sacramento region, this study provides new insights into

the use of e-bikes and provides useful guidance for future studies. Future studies could further explore and more rigorously document factors motivating e-bike acquisition, patterns of e-bike use, and positive and negative aspects of e-bike use, as well as knowledge and perceptions of e-bikes among non-users. To begin to track trends in e-bike use, travel surveys should be revised to include e-bikes as a specific transportation mode, separate from both conventional bicycles and mopeds, motor-scooters, and the like. Before-and-after studies of programs to promote e-bikes would provide solid evidence of their effectiveness and guide the development of subsequent programs. It will also be important to assess the effect of regulatory policies in encouraging – or discouraging – e-bikes and in enhancing – or inhibiting – their safety.

Although this study focused on just a small sample of users, it suggests that the future population of e-bike users could be substantial, and that the environmental benefits of growth in e-bike use in the U.S. would be significant. If so, further exploration of these possibilities on the part of policy makers and researchers is warranted.

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