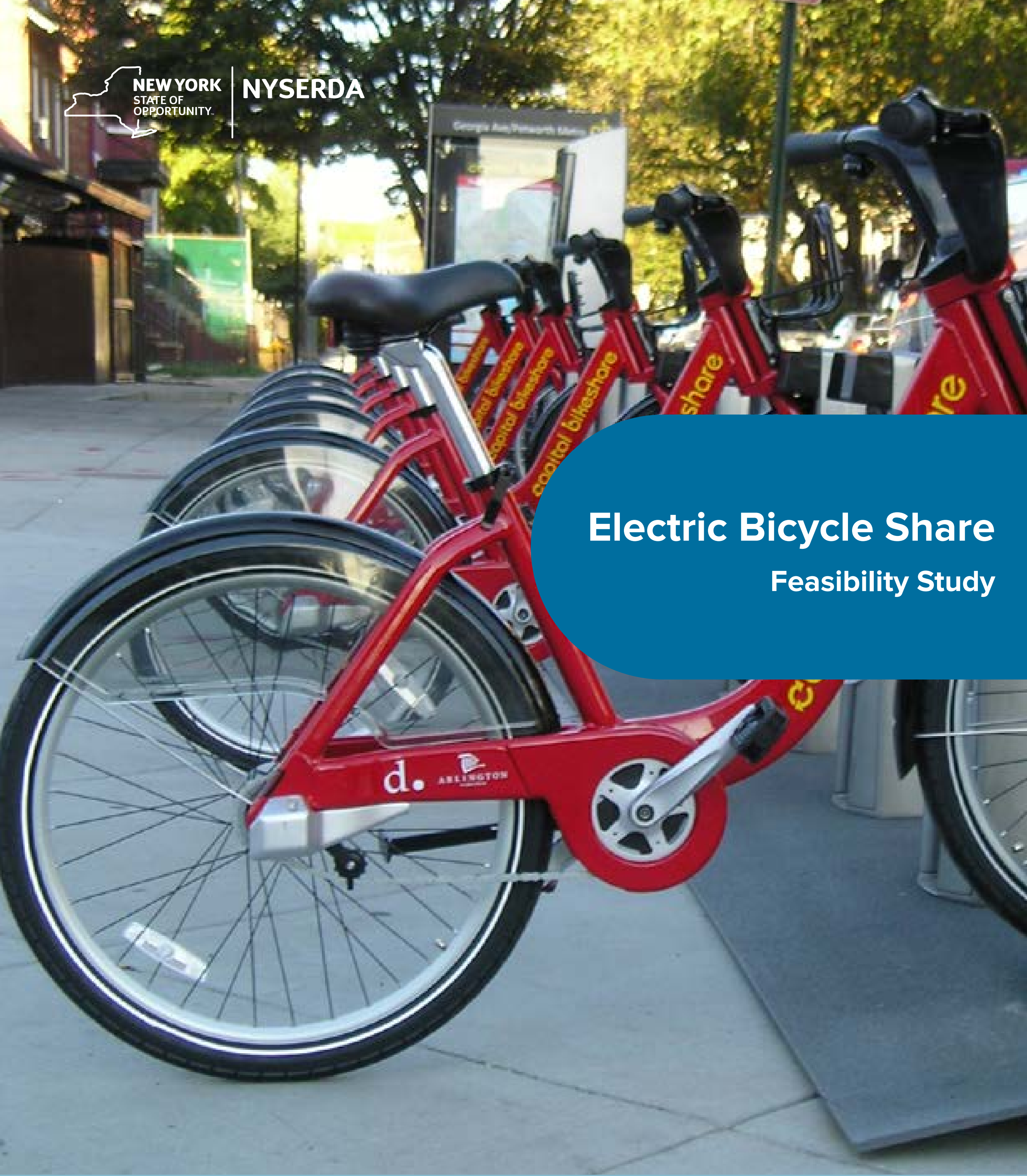

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Electric Bicycle Share

Feasibility Study

June 2015

Report Number 15-18

NYSERDA's Promise to New Yorkers:

NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Mission Statement:

Advance innovative energy solutions in ways that improve New York's economy and environment.

Vision Statement:

Serve as a catalyst – advancing energy innovation, technology, and investment; transforming New York's economy; and empowering people to choose clean and efficient energy as part of their everyday lives.

Electric Bicycle Share

Feasibility Study

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ELECTRIC BICYCLE SHARE FEASIBILITY STUDY

INTRODUCTION

PROJECT OUTLINE

The objective of this project, funded by the New York State Energy Research and Development Authority (NYSERDA), is to develop a concept for an electric bicycle share program that can overcome some of the limitations of traditional, station-based bicycle share programs.[1] This will be done by exploring the use of Inductive Charging Electric Bicycles (ICE-Bikes) in new and existing systems, focusing on potential deployments in New York State. It will also consider opportunities for a system to be manufactured within New York State with an expanded target market throughout the US. The entire project is broken into three phases:

Phase 1 - Proof of concept and feasibility study

Phase 2 - Prototype design and deployment

Phase 3 - Fabrication and commercialization

This NYSERDA Electric Bicycle Sharing Feasibility Study represents Phase 1. Whether or not Phases 2 and 3 will be undertaken hinge on the results of this study and assessments by relevant decision-makers at NYSERDA.

In partnership with NYSERDA, this study is produced by a project team consisting of Alta Planning + Design and GreenPs, LLC.

PHASE 1 EXECUTIVE SUMMARY

This document provides a summary of tasks undertaken during Phase 1 to determine the core concepts, definitions and feasibility of electric bicycle sharing systems. Key issues, including the potential technology considerations and legislative status are addressed. In general, there are no major “red flags” presented in this analysis.

Bicycle sharing programs are becoming a major part of the urban transportation fabric in cities worldwide. In the spring of 2013, New York City launched a 330 station/6,000 bike system in parts of Manhattan and Brooklyn. The system has already exceeded expectations, recording almost 14 million trips as of November 2014. Similar programs operate in Washington D.C., Boston, Chicago, San Francisco, and many other US cities. The technology is growing globally, with major new systems in Asia, Europe and South America.

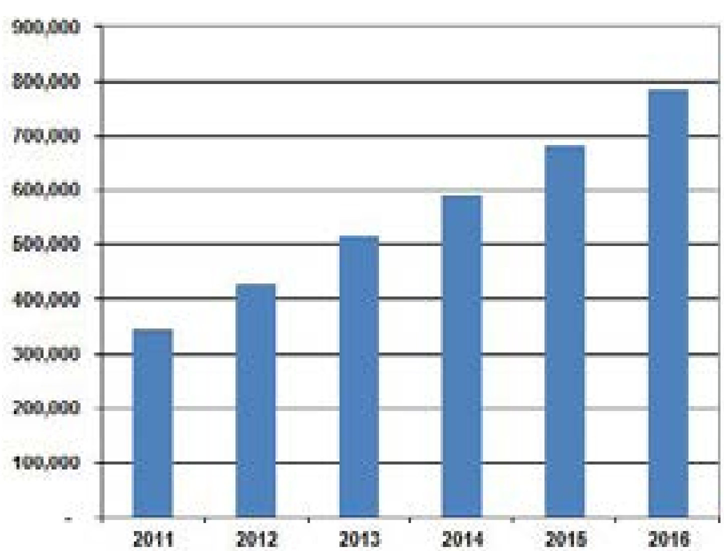
Although successful, traditional bicycle share programs are somewhat limited by factors such as the distance that can be covered on a traditional pedal-powered bicycle, steep terrain, dispersed land use patterns, potential users’ fitness and comfort levels, or the level of effort that needs to be expended in making a trip. Electric bicycles offer an opportunity to open traditional bicycle share systems to a broader set of users by offering a solution to these issues. Indeed, as the graph on this page indicates, sales of electric bicycles have been rising steadily every year since 2011, and are expected to continue apace.

Capitalizing on this trend, the first US bicycle sharing system to incorporate electric bicycles is slated to launch in Birmingham, AL in fall 2015. This follows on the heels of several existing European electric bicycle sharing systems.

1 Traditional systems are fully defined in chapter 1.

Key findings of this stage of the research include the following, and are presented in more detail throughout this document:

1. **Bicycle Share Status:** This study quantifies the success of several existing US bicycle share systems; identifies the progress that select cities in New York State have made towards the implementation and continued operation of bicycle share programs; and posits the success of a US electric bicycle share system.
2. **Definitions:** For the purposes of this project, an electric-assist bicycle (EAB) is the preferred concept, with a bicycle that is primarily human powered, combined with a low-powered electric assist motor that has a maximum assisted speed of less than 20mph.
3. **Legal Status:** The EAB is currently considered a bicycle by the Consumer Product Safety Commission (CPSC) in the U.S. In New York State, a clarification of the definition of this type of bicycle is necessary, and could be accomplished by state-level legislation that has passed the Senate and is in front of the Assembly as of June 2015.
4. **Technology:** Advanced new battery, recharging, and bicycle share-related technologies are being developed, and the ability to integrate these systems into the urban landscape is supported by data from current bicycle sharing operations.
5. **Costs & Market Analysis:** The study identifies the costs associated with an electric-assist bicycle sharing system and identifies consumer benefits and the potential for market expansion. Currently, the consumer and market benefits are projected to justify the costs associated with the development of the system outlined in this study.



Annual electric bicycle sales in the United States, 2011-2016
Source: Pike Research

THE NORTH AMERICAN BICYCLE SHARE EXPERIENCE

2.1 BICYCLE SHARE IN NORTH AMERICA

There are currently no large-scale electric bicycle sharing systems in North America. However, bicycle share systems utilizing standard bicycles have blossomed since the first wave of systems arrived in 2009 and 2010. The launch and expansion of many systems coincided with the development of so-called 3rd generation bicycle share equipment, initially developed in Europe but created for the North American market by the City of Montreal. Prior to Montreal's "Bixi" system, only small-scale programs existed in a handful of cities and college campuses. The programs featured either a fleet of free bicycles for community use, or a bicycle-library style system in which members could "check out" a bike for the day, week, or month. One exception was the Tulsa Townies program in Oklahoma, which included a more vandal-resistant design that was free for use, but required member accounts with deposits tied to credit cards. Many of the free bike and bike library systems were soon abandoned as they were plagued by theft, vandalism, poor maintenance and lack of consistent funding.

The Bixi system was quickly followed up by B-Cycle equipment, a spin-off of the Trek Bicycle Company based in Wisconsin. Both systems shared similar technologies and operations protocols that ensured a quality product. The characteristics of a 3rd generation system include:

- Transaction kiosks and docking points, connected to heavy, but moveable steel plates
- Used by annual/monthly members or casual (24 hour) users tied to an account by using a credit card for identification and deposit
- Typically solar powered, with some hard wired stations
- Wi-Fi communications
- Custom-made, sturdy bicycles designed for high wear and tear

Currently, there are only a handful of equipment providers for bicycle share systems in the U.S.. The two dominant companies include Public Bike System Company (PBSC), who created the initial 3rd generation system in Montreal, and B-Cycle. PBSC has recently emerged from a bankruptcy caused by software related issues, and a competing system made by 8D in Montreal has entered the market in the past year. A Brooklyn-based company named Social Bicycles could soon become a major player as its unique, "smart lock" technology is poised to launch in up to five cities in 2015 (after launching in Tampa and Phoenix in 2014). Currently, the Buffalo company Shared Mobility, Inc. is working working with Social Bikes to develop a prototype bike share/car share system. Other companies are actively moving forward to enter this market with a variety of new systems and technologies.

As of today, 17 of the 25 largest cities in the U.S. feature a bicycle share program, with the most notable exception being Los Angeles. Many of the existing programs feature a "city-wide" system where service-area coverage includes large swaths of the city and a variety of neighborhoods (eg. Chicago, Denver, Minneapolis, Boston and Miami Beach). Many others are focused primarily in the Central Business District, as highway barriers, land use patterns or lack of funding preclude more significant coverage outside of the city core. Most of these are considered small systems. Small systems with fewer than 25 stations operate in Kansas City, Salt Lake City, Omaha, and Spartanburg, SC, but New York City's 300+ stations could also be considered to fall within the Central Business District-focused bicycle share system category (until it expands in future phases). Other programs are regional in nature and offer stand-alone, satellite systems that are part of the overall network but too far from the core to realistically allow for riding between primary clusters. The few regional systems that exist in the U.S.—Capital Bicycleshare in Metro Washington DC and Bay Area Bicycle share in California—are tied together by regional rail-based mass transit.

CaBi bicycles (shown above, left) provided by the company PBSC represent the type of bike and station combination that is most common in US cities. Some cities have begun to implement station-less systems with smart-locking bicycles (shown above, right) sources: flickr; www.tampabay.com

Three bicycle share systems are highlighted in the following pages to help understand the system development process. The three systems include one large system (New York's Citi Bike), one medium (Boston's Hubway) and one small (Salt Lake City's GREENbike). Like all other systems in the U.S., these systems use standard manually-powered bicycles, since electric bicycle systems have not yet broken into the North American market. These programs were chosen in part because there is data available from each that could be analyzed for use later in this study.

CITI BIKE, NEW YORK CITY

New York City's Citi Bike was launched from 59th Street through Lower Manhattan and parts of northwest Brooklyn in late May of 2013. Funding came from the private sector, as Citibank and Master Card joined forces to pay for the system in exchange for branding rights. The 310 stations feature equipment supplied by PBSC of Quebec and installed/operated by Motivate (formerly Alta Bicycle Share). Because PBSC decided to use different software from the successful software used in Montreal, Boston, Washington DC and elsewhere, there were technical glitches during the initial launch. After a rocky start, Citi Bike has proven to be extremely popular and well-used. One million trips were taken within 7 weeks of launch, and nearly 70,000 people became members within the system's first three months of operation. Some areas of Manhattan, especially near key transit hubs like Penn Station, are so popular that users regularly experience empty or full stations as Motivate works to rebalance the bicycles during the peak periods of demand. With a recent infusion of private capital, Citi Bike plans to expand to 600 stations by 2017. It will also increase its geographic range to include parts of Manhattan above 59th Street, western Queens, and additional Brooklyn neighborhoods that surround the existing area of operation.

The Citi Bike program was launched as part of a coordinated effort to make NYC more bike friendly and livable.

Citi Bike stations integrate with the street and function well alongside existing traffic.

HUBWAY, GREATER BOSTON

The Hubway bicycle share program initially launched with 60 stations and 600 bicycles within the City of Boston in the summer of 2011. By the following spring, the cities of Cambridge and Somerville and the Town of Brookline introduced 36 more stations to respond to the high demand seen in Boston. Capital funding for the equipment came from the Federal Transit Administration (FTA)[2] and a public-private partnership including title sponsor New Balance.

In the first three full seasons of Hubway, the system has proven itself to be an integral part of the region's transit network as many stations have been sited adjacent to transit hubs. Hubway stations lie in a diverse range of business districts and neighborhoods throughout the four cities. The range of trips to/from stations is over 300 trips per day to 4 per day at stations sited at the outer edges of the system, or in lower-density neighborhoods. One element of note is that Hubway has been on the cutting-edge nationally with equity-focused programs that promote bicycle share usage among low-income communities based on subsidized memberships, encouragement programs, and proactive station siting in high-poverty and/or minority neighborhoods.

Hubway has proved to be a popular transportation mode

GREENbicycles are supplied by the American company, B-Cycle

GREENBIKE, SALT LAKE CITY

In the Western U.S., bicycle share has been slower to penetrate most city markets. Before 2013, bike share west of the Mississippi existed only in Denver, Texas and a few college campuses. GREENbike in Salt Lake City was an early arrival in the Mountain West, with the launch of a 10-station system in 2013. Focused on downtown, the system proved to be popular and doubled in size for its second season. While the system size doubled, ridership tripled between July 2013 and July 2014. Utilizing B-Cycle equipment, the station siting has been done in coordination with an aggressive program of new bike facilities downtown. Owned and operated by a non-profit, the funding has come from a mix of downtown business interests, along with sponsorship funding from SelectHealth and Rio Tinto, the aluminum supplier for B-Cycle.[3]

SYSTEM DATA

An overview of selected data from the bicycle share systems highlighted above is included in the table on the following page, with the addition of Chicago's Divvy system. This highlights the early success that these systems have been experiencing, and provides a baseline for later assumptions about the potential performance, cost, and market appeal of an electric-assist bicycle share system.

2.2 ELECTRIC-ASSIST BICYCLE SHARE SYSTEMS IN NORTH AMERICA

With the exception of two-station test system of cycleUshare at the University of Tenessee-Knoxville (UTK) that mixed standard bicycles and electric-assist bicycles, no full-scale electric-assist bicycle share systems have been implemented in North America. Although limited, UTK's cycleUshare system reported that "factors of speed and convenience played major roles in participants' decisions to use the system, and speed and comfort were the most influential factors in the selection of an e-bike rather than a regular bicycle."[4] Indeed, wherever usage spiked during the test, the electric-assist bicycles appear to have experienced the highest demand. The positive results of this experiment are encouraging, and bode well for the rollout of a bicycle share system in the US that utilizes electric-assist bicycles. This system will be discussed further in chapter 6.

More recently, a bicycle share system that mixes standard and electric-assist bicycles plans to begin operating in Birmingham, Alabama in fall 2015. The system will feature 400 bicycles spread over 40 stations, 100 of which will be electric-assist bicycles "to lessen barriers to using the system for people not as experienced with hillier areas of the city."[5] Despite the fact that only a quarter of the initial system rollout will be comprised of electric-assist bicycles, it will be a case study to watch as the first municipal bicycle share system in the US to take advantage of e-bike technology.

2 An agency within the United States Department of Transportation (DOT), the FTA provides financial and technical assistance to public transportation systems.

3 Bolte, Ben. GREENbike's General Manager. Data provided through email correspondence. January 2015.

4 Cherry et. al, "North America's First E-Bike Share." Transportation Research Record 2387 (2013).

5 Smith, Mike D. "Bike sharing comes to Birmingham, brings new technology and work for Alabama." AL.com, 2015. http://www.al.com/news/birmingham/index.ssf/2015/04/bike_sharing_comes_to_birmingh.html#incart_river_mobile

Tables 1 & 2: Bicycle Share Data [a,b,c,d]

Selected Bicycle Share System Characteristics											User Demographics		
City	System Name	Equipment Type/Vendor	Population (2012)	Launch Date	Bikes (stations) at Launch	Bikes (stations) Current	Current Service Area	Operator	Seasonal vs. Annual	Annual Members	Age	% Minority	% Wom-en
New York	Citi Bike	Public Bike Share Company	8,405,000	May 2013	5400 (310 stations)	5400 (330 stations)	Manhattan and Brooklyn	Private Vendor: Motivate	Annual	102,000	70% between 24 and 39; average age 34 *	20% *	33% *
Salt Lake City	GREEN-bike	Public Bike Share Com-pany	809,798	July 2013	55 (10 stations)	150 (20 stations)	Downtown Salt Lake City	Non-profit: SLC Bike Share	Seasonal (8 months)	Data not available	85% between 24 and 55	No Data Available	32%
Boston	Hubway	Public Bike Share Company	878,786	July 2011 (Boston only)	600 (60 stations)	1,300 (140 stations)	Boston, Brookline, Cambridge, and Somerville	Private Vendor: Motivate	Seasonal (8 months), annual in Cambridge	6,300	50% between 24 and 39; average age 39	17%	39%
Chicago	Divvy	Public Bike Share Company	2,720,000	June 2013	730 (69 stations)	3000 (300 stations)	City of Chicago	Private Vendor: Motivate	Annual	21,000	66% between 24 and 39; average age 36	21%	36%

	Usage Data After First Full Year/Season						Cumulative Usage Data					
System Name	Annual Members	Casual Users	Number of Trips	Number of Miles	Average Trip Length (miles)	Daily Trips per Bike (peak month)	Annual Members	Casual Users	Number of Trips	Number of Miles	Average Trip Length (miles)	Daily Trips per Bike (peak month)
Citi Bike	102,000	117,600	8,500,000	15,300,000	1.8	6.4	84000 (as of Nov 1, 2014)	181000 (1.5 full seasons)	13,890,000 as of Nov 1, 2014	24,200,000 (as of Nov 1, 2014)	1.74	6.4
GREEN-bike	Data not available	Data not available	25,361	65,300	2.6	1.9	14,538 annual and casual members combined		71,625	207,232	2.89	1.7
Hubway	6,300	53,200	311,000	first year data unavailable	NA	2.9	12,700 annu-al w/ 2,000 monthly members (as of Nov 1, 2014)	253,000 (3 full seasons)	2,670,000 as of Nov 1, 2014	3,860,000 (as of Nov 1, 2014)	1.45	4.5
Divvy	21,000	318,000	1,666,000	3,014,000	1.81	4.8	23,000 (as of Nov 1, 2014)	500,000 1.5 full seasons	3,300,000 as of Nov 1, 2014	6,633,000 (as of Nov 1, 2014)	2.01	5.3

* figures are projections based on analysis of data from Boston and Chicago

a Alta Bicycle Share Data, Nov 13, 2014
b SLC GREENbike data, Aug 2014 and 2014 annual report
c Nicole Freedman Presentation at 2013 Moving Together conference in Boston, "The Hubway Influence on New Riders"
d 2014 user survey, via Emily Stapleton

2.3 BICYCLE SHARE IN UPSTATE NEW YORK

CAPITAL DISTRICT

The City of Albany completed a bicycle share feasibility study in June 2013. From July 10 to August 15 of 2014 the region implemented a pilot program to gauge interest in and utilization of bike share for one week each in Albany, Schenectady, Troy, and Saratoga Springs under the leadership of the Capital District Transportation Committee (CDTC), the local Metropolitan Planning Organization (MPO). The pilot program also asked users to complete a survey. CDTC has compared the station-based and station-less options for feasibility, but has not yet determined which program is best suited for the region. To help CDTC with its decision making, a bicycle share symposium was held on February 2015, attended by roughly 50 stakeholders, city agency staff, and advocates from the Capital Region.

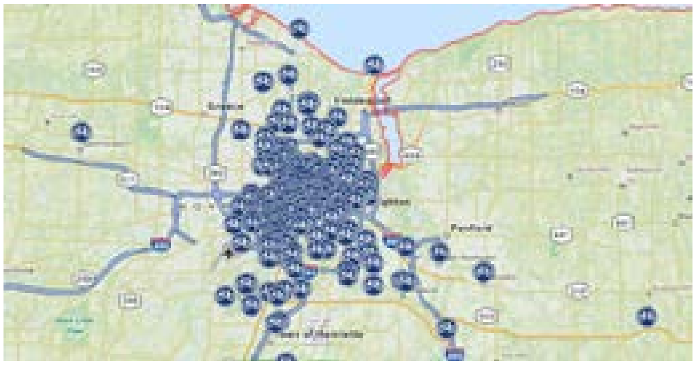
The biggest obstacle facing the region at this point is a lack of sponsorship, but the pilot program has attracted some interest from potential partners.

The lack of a funding source is one of the factors preventing progress on a Capital Region bicycle share program. Distances between destinations, topography and climate are also important considerations. The sharing economy has gained some momentum in the Albany area, however, with the introduction of Capital Carshare in summer 2014 and student- and staff-only "bicycle share lite" at Skidmore College. A formal bicycle share program could be the next step.

SYRACUSE

The City of Syracuse has prioritized the development of its bicycle infrastructure prior to pursuing bicycle share, and it has made some important strides in this area. A recent Connective Corridor study will provide transit and active transporation enhancements to a major route between Syracuse University and downtown Syracuse. In addition, the City is pursuing bicycle wayfinding signage and will soon close part of Onandaga Creek Boulevard to vehicle traffic.

Complementary to the City's efforts, Syracuse's educational institutions have been progressing bicycle share initiatives of their own. Syracuse University is planning to kick off a bike share program on April 1, 2015. SUNY College of Environmental Science and Forestry (SUNY ESF) has had a bike share program for two years. It has only 5 bikes with approximately 100 students enrolled, and is apparently underutilized. An associate professor at SUNY ESF estimates the bikes are checked out approximately 40 times per semester. There are efforts by the campus bike safety committee and local advocates to get better bicycle infrastructure on campus and in the community, but the current lack of infrastructure is seen as limiting bicycle use in general. Nonetheless, it is estimated that there are 350-400 private bicycles on campus when the weather is good.



Bicycle share station locations suggested by residents of Rochester

ROCHESTER

In conjunction with the City of Rochester, the Genesee Transportation Council completed a bicycle share feasibility study in December 2014. The study was the result of four policy goals:

1. **Mobility:** to offer additional transportation options for residents of, students and employees in, and visitors to Rochester.
2. **Equity:** to increase equitable and affordable access to public transportation.
3. **Economic Development:** to increase the attractiveness of Rochester as a place to live, work, visit and do business
4. **Bicycling:** to increase the amount of bicycling in Rochester and improve air quality and safety of cycling as a result.

Interest in bicycle share within Rochester appears significant, based on the fact that the Genesee Transportation Council (GTC) has already completed a feasibility study and the numerous suggested bicycle share locations that emerged from that study (as demonstrated by the interactive public input map above). Additionally, an online survey showed that 91% of respondents believed a bicycle share program was a good idea for Rochester.

There appears to be great potential for bicycle share in Rochester. A 2011 survey found that 1.1% of all daily trips in the Rochester Transportation Management Area were by bicycle. Yet, that same survey found that over 40% of those same daily trips were a length of three miles or less. The opportunity exists to replace many of those shorter automobile trips with bicycle trips through bicycle share.

The study found that a bike share program was feasible if planned in four phases, with 250 bikes added in each phase, across central Rochester, out to and including Brighton and the University of Rochester. However, the area beyond the city's outlying villages was found to be unconducive to bike share, with some exceptions including the Village of Brockport, East Rochester, Pittsford, and Fairport, the RIT Campus, and parts of Greece and Brighton. While no specific choice has been recommended, an analysis comparing the advantages and disadvantages of smart docks and smart bikes has been undertaken for the study. The study also suggests a time line of approximately 18 months to launch the first phase of the program. Funding is a notable obstacle. The study found that $2.5 to $5 million over 5 years would be needed for capital, while $3.3 million would be necessary for operational funding in addition to the projected system revenue. The Erie Canalway Trail through the Rochester region could also be a potential model for a toursim-oriented bike share system.

BUFFALO

The City of Buffalo has as an existing bike share program (Buffalo BikeShare) that is operated under the umbrella of Shared Mobility, which also oversees the city's car sharing program (Buffalo CarShare). Pricing is $3 per hour after 60 minutes of free riding time, although Shared Mobility sees its bicycle share system as more of a pilot program than a full-fledged system. Indeed, registration is unrestricted only for University of Buffalo students; City of Buffalo residents face a limited enrollment process. Like the other cities, it lacks serious funding and as such the program has not cultivated a major presence in the city.

Buffalo Bike Share began on the campus of the University of Buffalo (UB) and has only begun to expand beyond the campus to a few select neighborhoods) over the past couple of years (from Amherst to University Heights, to Elmwood Village and Allentown, to the Cobblestone District). The program considers approximately 2.5 miles of Elmwood Avenue and all of Allen Street as two "hubs" since members can park their bikes anywhere along the street within both those segments. Bicycle availability is very limited. During the two days that bicycle availability was checked on their system map, all 16 of their hubs were vacant. This suggests that interest is could be greater than the supply of bikes.

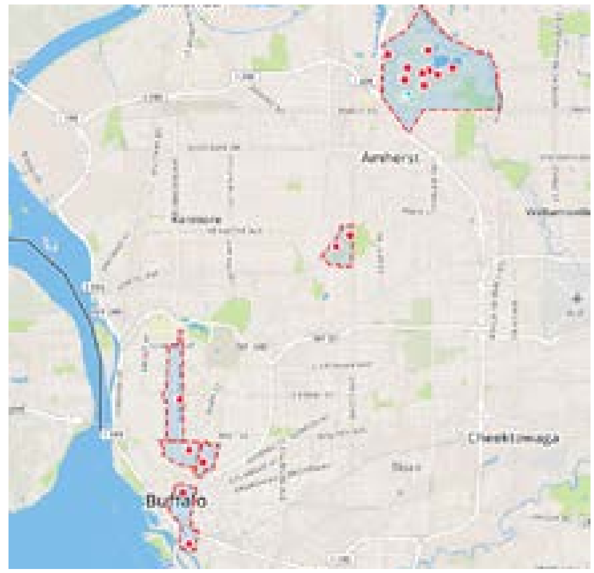
While the bike share program has been successfully implemented on the UB campus the lack of a significant city presence in addition to the lack of a marketing campaign has kept the program from taking hold in the city of Buffalo. They hope to expand to further neighborhoods, but are waiting to test the reliability and manageability of the new technology released by Social Bikes (SoBi), the bicycle providers for the program. Shared Mobility has, however implemented a smartphone app called Social Cyclist that allows Buffalo area bicyclists to suggest where they'd like to see bicycle share expand.

CONCLUSIONS & RELEVANCE OF FINDINGS

Although bicycle share has gained a modest foothold in Buffalo, most of Upstate New York is still in the planning phases and/or is struggling to gain the necessary social and financial support. At the same time, most Upstate communities are making improvements in bicycling infrastructure, and there is significant latent demand for bicycling.

Despite the hurdles this relative lack of progress presents, the fledgling status of the Upstate bicycle share market could also be seen as an advantage. In particular, electric bicycles would not need to contend with the operational inertia that would complicate the incorporation of this emerging technology into larger, more established bicycle share systems like Citi Bike. If institutional support, public interest, and financial resources continue to develop, then Upstate New York's cities could be fertile testing grounds for an electric bicycle share system.

A Sobi bicycle locked up on Buffalo's busy Elmwood Ave



Buffalo Bike Share's system map displaying "hub" areas

2.4 EXPLORING THE POTENTIAL FOR ELECTRIC BICYCLE SHARE IN NEW YORK

As bicycle share technology evolves, there are a range of potential benefits for a system that utilizes electric bicycles. This study identifies ways that an electric bicycle share system could improve upon the early successes of traditional bicycle share systems like Citi Bike. It will also consider the benefits and mobility advantages that an electric bicycle share system could provide to potential "clean slate" markets in select cities in Upstate New York when compared to a standard bicycle share system.

In the interest of gauging the potential for an electric bicycle share system in the United States, The following section will lay out technical definitions for the range of electric bicycles that are on the market today. It will also identify the type of electric bicycle that will be evaluated throughout this study for its potential to be incorporated into a bicycle share system. The legal environments at the federal, state, and local levels that surround the manufacture, sale, and use of electric bicycles are analyzed in the next section as well. Particular emphasis will be placed on where this study's envisioned electric bicycle technology stands within those legal environments, especially in New York State and New York City. Three existing European electric bicycle share systems are then assessed prior to analyzing the potential for connecting to the electricity grid and examining the market and consumer benefits.

Comparison of Upstate Bicycle Share Progess (Select Cities)			
City/Area	*Progress*	*Obstacles*	*Level of Interest*
Capital District	• Completed feasibility study (June 2013) that found bike share feasible • Implemented pilot program with low level of survey response • Compared station-based and station-less program options • Held bike share symposium in 2015	• Lack of program sponsorship • Lack of organization seeking sponsorship • Lack of funding • Public concerns about bicycle safety • Lack of bicycle infrastructure throughout the Capital District	• Interest appears to be high, Based on anecdotal evidence and the creation of a feasibility study
Buffalo	• Existing bicycle share program, but it is limited in scope • Management group sees the bike share as a pilot program within the 5 year old car share program • Program has expanded from isolated University area to specific urban neighborhoods • Management group in talks with interested parties to discuss expansion of program	• Program's lack of urban presence or marketing program • Unproven bicycle technology • Limited bike availability may decrease opportunities to use bike share and limits program's presence	• Interest is high in the original bike share service area: UB campus • Expansions to more urban neighborhoods demonstrates increased interest
Syracuse	• City of Syracuse actively pursuing bicycle infrastructure enhancements • Syracuse University has plans to implement a bike share program in 2015 • SUNY ESF has a limited bike share program with approximately 100 enrollees, but it is underutilized	• Lack of bicycle infrastructure in the City of Syracuse • Students tend to own their own bicycles, which undercuts the usefulness of current efforts at Syracuse University and SUNY ESF • Steep topography limits connections between University Hill and downtown Syracuse.	• Difficult to estimate the level of interest at this stage, but recent efforts suggest that interest does exist within the general public.
Rochester	• December 2014 completed a bike share feasibility study finding bike share feasible if planned in 4 phases adding 250 bikes at each phase • Performed analysis comparing smart docks and smart bikes • Suggested timeline of 18 months to begin phase 1	• No pilot program has been implemented • Funding has not been identified • Dispersal of density (unconcentrated) within the region	• Based on the creation of a feasibility study and the public reaction to interactive public input map within the study, interest appears to be high

LEGAL ENVIRONMENT: DEFINITIONS & POTENTIAL FOR ELECTRIC BICYCLES IN THE US

3.1 ELECTRIC BICYCLE DEFINITIONS

The electric bicycle industry is a relatively new one, and as such there are numerous official colloquial definitions in circulation. This study utilizes the most recent nomenclature available. To this end, the recent National Institute for Transportation and Communities (NITC) August 2014 report “Regulations of Electric bicycles in North America: A Policy Review” will provide the basis for the definitions outlined below. These definitions will be used throughout this study.

Defining different types and categories of electric bicycles is particularly important when considering the legislative status of this emerging mode of transportation, as a later review of relevant electric bicycle legislation in the US will make clear.

CATEGORIZATION

Although there are many types of electric bicycles on the market and in development, they can usually be categorized as a bicycle-style electric bike (BSEB) and a scooter-style electric bike (SSEB).

Each general type of electric bicycle can be further broken down into more specific categories. Figures on pages 12 and 13 provide an overview of how these different types relate to each other.

SCOOTER-STYLE ELECTRIC BICYCLES (SSEB)

An SSEB is an electric bicycle that has a frame geometry that de-emphasizes pedals, that is based on the relatively heavy frame of a motor scooter/moped, and generally uses larger and more substantial motor scooter-like components (for example, larger wheels and more robust seats.)

Between SSEBs and vehicles like motor scooters/mopeds, the key differences are the motor size, top speeds, and fuel type. For example, motor scooters/mopeds are often gasoline-powered, have top motorized speeds of well over 20 mph, and feature motors that are larger than what an SSEB would be outfitted with.

This study does not consider SSEBs. Being generally bulkier, faster, and more automated than traditional bicycles, they are largely inconsistent with the goals of the type of electric bicycle share system considered here. It is important, however, to be able to distinguish between the different types of electric bicycles currently on the market.

BICYCLE-STYLE ELECTRIC BICYCLES (BSEB)

A BSEB is an electric bicycle with a powered motor that generally provides up to 750 watts of power, and is capable of reaching speeds of up to 20 mph on motor power alone. These electric bicycles have pedals that can be used with or without the assistance of the motor. Sometimes, motor output can be as high as 1,000 watts. The BSEB category can be broken down into the two sub-categories of a ***powered bicycle (PB)*** and an ***electric-assist bicycle (EAB)***.

A powered bicycle (PB) is similar to a moped or motorcycle in certain respects, particularly in that it often has a handlebar throttle that can be twisted to engage the electric motor absent any human pedaling effort. However, these electric bicycles still have operable pedals that can be used to propel the bike forward. PB’s typically occupy the higher levels of motor output, e.g. closer to the 750 - 1,000 watt range, although they can certainly utilize lower outputs.

Although closer to a traditional bicycle than something like an SSEB, this study does not consider PBs suitable for an electric bicycle sharing system due to the fact that they can be operated with a throttle at higher speeds and power outputs than would be desirable.

An electric-assist bicycle (EAB), on the other hand, usually has a motor that can produce less power (often 300 watts and lower), and cannot be ridden without human pedaling power. In fact, the electric motors on EABs engage only while a rider is pedaling, providing motorized “assistance” in order to more easily maintain cruising speeds or navigate hilly terrain. In addition, the motor can be outfitted with an electronic controller that stops the motor when the rider is not pedaling and/or when the bicycle has reached an internally specified speed limit, which may be less than 20mph.

EABs are very close to traditional bicycles in form and bulk, especially when compared to bicycle share bicycles. They cannot be operated solely by motor power, and speed cutoffs for motor assistance can be built in. For these reasons, EABs are the type of electric bicycle that is most likely to be viewed favorably by US cities and states for local use as a "bicycle" rather than a motor vehicle.

This feasibility study will focus on an electric-assist (EAB) model as the suggested prototype for use in an electric bicycle share system. Specifically, the bike-share enabled EAB this study envisions would carry no more than 200 watts of motor power, only provide power that is in proportion to the pedaling effort of the rider, and be programmed to cease providing power assistance when a speed of between 10 to 20 mph has been reached. As the following section will make clear, these technical specifications fall well within the federal definition of an electric bicycle and could fit very easily within existing and proposed electric bicycle legislation at the state level.

In the following legal analysis, the general term "electric bicycle" will be generally employed to encompass the wide range of vehicles that many states consider electric bicycles, but the focus will remain on EABs when it comes to assessing legislation.

Electric-Assist Bicycle (EAB)

Example of a bicycle-style electric bike (BSEB), specifically an electric-assist bicycle (EAB). Source: gobike.com

Scooter-Style Electric Bicycle (SSEB)

Example of a Scooter-style electric bicycle (SSEB) Source: NITC

Flow chart hierarchy of electric bicycle types

Electric Bicycles

Bicycles utilizing a small electric motor

Bicycle-Style Electric Bike (BSEB)

- An electric bicycle that with an electric motor powered up to 750 watts, sometimes as high as 1,000 watts
- Typically cannot reach speeds over 20mph
- Have operable pedals that may be used to operate the bicycle with or without the motor
- Motor may propel the bicycle with or without pedaling

Also known as:

- *Low-powered electric bicycles*
- *Low-speed electric bicycles*

Scooter-Style Electric Bicycle (SSEB)

- Seat forward / pedals behind frame geometry (pedals ergonomically inefficient)
- Larger and heavier motor scooter- / moped-style components and frames (e.g. wheels and seats)

Powered Bicycle (PB)

- Hand-controlled throttle can be used to engage motor
- Ability to accelerate without pedaling

Also known as:

- *Throttle-assisted bicycle*
- *Electrically-propelled bicycle*
- *Electric bike power-on-demand (POD)*
- *On-demand bikes*
- *Motorized bicycle*

Electric-Assist Bicycle (EAB)

- Motor only engages when rider is pedaling in order to "assist" the pedaling effort
- Motor often disengages when producing power when rider is not pedaling and/or when a specified speed limit has been attained
- Sometimes, motor is calibrated to power the bike only in proportion to the pedaling effort

Also known as:

- *Pedal-electric cycle (Pedelec)*
- *Pedal-assisted bicycle*
- *Power-assisted bicycle (PAB)*
- *Electric pedal-assist cycle (EPAC)*
- *Human-powered hybrids*

3.2 NATIONAL LEGISLATION

In the United States, the federal government does not dictate the licensing and/or use of vehicles. It does, however, regulate the manufacturing, sale, and safety requirements of vehicles. As such, the Consumer Product Safety Commission (CPSC) and the National Highway Transportation Safety Administration (NHTSA) are the primary entities involved in legislating electric bicycles at the federal level.[6] The Federal Highway Administration (FHWA) also has an impact, to the extent that requirements associated with federal funding have any impact on the ability of electric bicycles to be ridden on infrastructure that is built with that funding.

CPSC ROLE & DEFINITIONS

The CPSC is a federal agency charged with regulating products to protect American consumers from "unreasonable risks of injury or death"[7] that could result from the use of products that pose potential fire, electrical, chemical, or mechanical hazards.

In 2002, Congress introduced and approved Public Law 107-319, which amended the Consumer Product Safety Act (administered by the CPSC) to apply formal definitions to electric bicycles manufactured in the United States. The definition is laid out here:

> "(b) For the purpose of this section, the term 'low speed electric bicycle' means a two- or three-wheeled vehicle with fully operable pedals and an electric motor of less than 750 watts (1 h.p.), whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weighs 170 pounds, is less than 20 mph."[8]

Notably, this section defines a "low speed electric bicycle" as having fully operable pedals, utilizing a motor that provides less than 750 watts/1 h.p. of power, and limited to a speed of 20 mph or less without human input. This definition allows for a faster and more powerful bicycle than the type of EAB that will be contemplated in this study, particularly in that the proposed EAB will not have the ability to be powered solely by its motor. This means that there are no apparent legal issues at the federal level surrounding the manufacture or sale of the bicycle share-oriented EAB that is envisioned, and they would not require Vehicle Identification Numbers (VIN). In addition:

> "(d) This section shall supersede any State law or requirement with respect to low-speed electric bicycles to the extent that such State law or requirement is more stringent than the Federal law or requirements referred to in subsection (a)."[9]

This excerpt makes clear that states cannot enact local laws that contain more stringent definitions for the manufacture and sale of a low speed electric bicycle than has been outlined in this law. For example, no state could, for the purposes of manufacture or sale, limit the definition of a low speed electric bicycle to a bicycle that provides a maximum power output of anything less than 750 watts. Finally:

> "For purposes of motor vehicle safety standards issued and enforced pursuant to chapter 301 of title 49, United States Code, a low-speed electric bicycle (as defined in section 38(b) of the Consumer Product Safety Act) shall not be considered a motor vehicle as defined by section 30102(6) of title 49, United States Code."[10]

The above makes clear that vehicles fitting the CPSC's definition of a low speed electric bicycle will not be considered a motor vehicle, and thus will not be subjected to manufacturing requirements that would normally affect a motor vehicle.

NHTSA ROLE & DEFINITIONS

The National Highway Traffic Safety Administration (NHTSA) is an agency of the US Department of Transportation (USDOT) and operates in a spirit similar to that of the CPSC, although it is focused specifically on the regulation of transportation safety and expands its mission to encouragement, information dissemination, and research and development. In its own words:

> "NHTSA sets safety standards for motor vehicles and associated equipment, investigates possible safety defects, assures that products meet safety standards and are not defective (through recalls if necessary), and tracks safety-related recalls. The agency also enforces regulations on fuel economy, odometer fraud, and vehicle theft."[11]

Given this mission, it is important to determine the extent to which an EAB would be subject to NHTSA regulation and oversight. The agency's website states that:

> "The following scooters or scooter-like vehicles are not "motor vehicles" that must be manufactured to comply with all applicable FMVSS [Federal Motor Vehicle Safety Standards] and be so certified to be lawfully imported into the United States:

- Scooters lacking seats that are operated in a stand-up mode.
- Scooters that are incapable of a top speed above 20 mph.
- Electric bicycles with operable pedals, and an electric motor of 750 watts or less, whose maximum speed on a paved level surface, when powered solely by such a motor while ridden by an operator who weights 170 pounds, is less than 20 mph."[12]

The last bullet point appears to be drawn directly from the definition of a low speed electric bicycle in Public Law 107-319, indicating that the NHTSA would be consistent with the CPSC in not considering an EAB a motor vehicle. Correspondingly, EABs in a bicycle share system would not be subject to Federal Motor Vehicle Safety Standards (FMVSS) like requiring rearview mirrors, brake light systems, etc.

6 NITC-RR-564, "Regulations of Electric bicycles in North America" (2014).
7 About CPSC, accessed February 2015. http://www.cpsc.gov/en/About-CPSC/
8 PUBLIC LAW 107–319 — DEC. 4, 2002
9 Ibid

10 Ibid
11 DOT HS 810 552. "This is NHTSA" (2006).
12 NHTSA Importation and Certification FAQ's, accessed February 2015. http://www.nhtsa.gov/cars/rules/import/FAQ%20Site/pages/page3.html

The NITC and a recent industry report further suggest that this is, or would be, NHTSA's view on low speed electric bicycles, although they express that the agency's current opinion is heavily predicated on the 20 mph speed limit of such vehicles.[13, 14]

FHWA ROLE & DEFINITIONS

The Federal Highway Administration (FHWA) is a division of the United States Department of Transportation (USDOT) that, through financial and technical assistance, aids states and local governments in the design, construction, and maintenance of roads that receive federal funding.[15]

The FHWA can incorporate the planned use of proposed road infrastructure in funding decisions, so their definition of electric bicycles is important to ensure that a municipality's allowance of vehicles like EABs on federally-funded roadways would not trigger any funding restrictions.

The United States Code, which is incorporated into MAP-21,[16] defines electric bicycles as the following in Title 23, Chapter 2, Section 217:

> "(2) Electric bicycle. - The term "electric bicycle" means any bicycle or tricycle with a low-powered electric motor weighing under 100 pounds, with a top motor-powered speed not in excess of 20 miles per hour."

An EAB would easily fall under this definition, which primarily relies on determinations of weight and speed. The inclusion of electric bicycles as a vehicle category within section 217 also indicates that the regular use of such vehicles in a municipality that an EAB bicycle share system necessarily entails would very likely not affect funding that the FHWA distributes. In addition, electric bicycles appear to be eligible for use on federally funded off-street infrastructure like trails:

> "(h) Use of Motorized Vehicles. - Motorized vehicles may not be permitted on trails and pedestrian walkways under this section, except for -
>
> > (1) maintenance purposes;
> >
> > (2) when snow conditions and State or local regulations permit, snowmobiles;
> >
> > (3) motorized wheelchairs;
> >
> > **(4) when State or local regulations permit, electric bicycles; and**
> >
> > (5) such other circumstances as the Secretary deems appropriate."[17]

Although the US Code seems to consider electric bicycles as motor vehicles, this designation does not appear to have policy or funding implications that would affect the municipality that hosts an EAB bicycle share system and allows those EABs on local trails and walkways.

In addition, the code makes clear that it delegates the permission or prohibition of electric bicycles on trails and pedestrian walkways to state and local governments.

CONCLUSION

All of the available resources on national legislation indicates that the EAB as it will be defined in this study would not be subject to federal manufacturing, sale, or safety requirements above and beyond that of a standard bicycle. This makes it appear as if the manufacture and sale of an EAB for use in a bicycle share system would be subject to no more federal regulation than a bicycle share system utilizing standard bicycles would be.

Additionally, the way electric bicycles are categorized in the US Code implies that the regular use of EABs in an electric bicycle share system on federally-funded infrastructure would pose no more issues than a bicycle share system that features standard bicycles. This would particularly be the case when the state and/or local government also allows for the use of electric bicycles on off-street trails.

Although the existing federal definitions of electric bicycles within entities that have regulatory ability relating to manufacture/sale easily exempt EABs from consideration as motor vehicles, the power to govern the actual use of EABs lies with states and local governments. As such, the position of states and local governments is especially important to the successful development and implementation of a bicycle share system that utilizes EABs. These positions will be examined in the next section of this document, with particular emphasis on New York State and New York City.

13 NITC-RR-564. "Regulations of Electric bicycles in North America" (August 2014).
14 Hansen, S. (2013). Legal analysis: Confusion over electric bike regulations. Bicycle Retailer. Retrieved from http://www.bicycleretailer.com/opinion-analysis/2013/07/29/legalanalysis-confusion-over-electric-bike-regulations.
15 "About FHWA," accessed February 2015. http://www.fhwa.dot.gov/about/
16 **MAP-21 explanation here**
17 US Code, Title 23, Chapter 2, Section 217

3.3 STATE & LOCAL LEGISLATION

The legal status of electric bicycles within individual states is of utmost importance, since the federal government delegates the power to regulate and determine the use of different types of vehicles to the states.

At the time of this writing, many states have divergent laws on their books regarding the use of electric bicycles. Strikingly, there appears to be no general legal consensus even on key aspects of how to define electric bicycles (such as power and speed requirements) despite the previously-discussed federal definition that is used for regulating manufacture and sale.

One way of assessing how "friendly" a state is towards electric bicycles is to determine whether or not its laws generally treat an electric bicycle as a standard bicycle. In states that do so, electric bicycles are usually free to operate on public rights-of-way just as a non-motorized bicycle would. Figure 4 at right shows that many states regard electric bicycles as standard bicycles, while many do not. The technical definition of what actually constitutes an electric bicycle varies from state to state, however, and some states that consider an electric bicycle a standard bicycle carry a definition of an electric bicycle that could encompass even the heightened speed and power specifications of a scooter-style electric bicycle (SSEB). [18]

This confusion is well-represented by the wide range of names that are given to electric bicycles throughout the US. In Pennsylvania, they are referred to as "Pedalcycle with Electric Assist," as "Motorized Bicycle" in Indiana, as "Electric Power-Assisted Bicycle" in Virginia, and as "Motor-Assisted Bicycle" in New York.[19]

The absence of a standardized definition from state to state, as well as the fact that the technical parameters specified in the federal definition of a low-speed electric bicycle have not always been embraced by states that are friendly to electric bicycles, has resulted in a confusing national legal environment when it comes to any bicycle that is not solely human powered.

NEW YORK STATE

New York State is one of many states in the US that does not currently categorize an electric bicycle as a standard bicycle. As we will see, this is less a result of specific prohibitory legislation than a set of existing regulations that does not distinguish between different types of bicycles.

US states that categorize electric bicycles as a standard bicycle. (Source: NITC)

PRESENT LEGAL STATUS

Electric bicycles are not explicitly defined in New York State traffic law, and thus by default have been included by the New York State Department of Motor Vehicles (DMV) in the category of a motorized vehicle. In §102 of the New York State Vehicle & Traffic Law (VTL), a bicycle is defined as:

> "Every two or three wheeled device upon which a person or persons may ride, propelled by human power through a belt, a chain or gears, with such wheels in a tandem or tricycle, except that it shall not include such a device having solid tires and intended for use only on a sidewalk by pre-teenage children."[20]

This definition does not explicitly include any sort of electric bicycle, but nor does it necessarily exclude electric bicycles, as they almost always have pedals that are allow them to be "propelled by human power" (as the definition of a bicycle states). Accordingly, certain types of electric bicycles could actually fall under New York State's definition of a standard bicycle.

Still, New York State's definition of a motor vehicle in §125 of the VTL could potentially encompass an electric-assist bicycle as well. This is particularly the case if the following definition is considered in isolation, which considers motor vehicles as:

"Every vehicle operated or driven upon a public highway which is propelled by any power other than muscular power..."[21]

Looking further in the section, however, there are numerous exemptions to this seemingly binary definition. For example, the above definition holds true except for in cases like the following:

> (a-1) electric personal assistive mobility devices operated outside a city with a population of one million or more..."[22]

18 NITC-RR-564, "Regulations of Electric bicycles in North America" (2014).
19 Ibid

20 New York State Vehicle & Traffic Law, Article 1, Section 102
21 New York State Vehicle & Traffic Law, Article 1, Section 125
22 Ibid

The definition of the electric personal assistive mobility device mentioned above includes electric vehicles like Segways.[23] Certain restrictive provisions apply to Segways and other electric personal assistive mobility devices, such as only being operated outside of cities with a million or more inhabitants and being limited to roads with a 30 mph speed limit or below. However, the fact that these electric devices are exempted from motor vehicle status suggests that there is a notable precedent for conveyances like electric-assist bicycles to not be considered motor vehicles.

Still, DMV has categorized electric bicycles as a motor vehicle that must be licensed and registered for legal use on the State's roadways and public thoroughfares. As discussed, however, the federal definition of electric bicycles for the purpose of manufacture and sale does not require electric bicycles to be provided with a VIN or outfitted with safety features that are normally associated with a motorized vehicle, and which are prerequisites for vehicle registration. The New York State DMV states that:

> "You cannot register or operate any of the motorized devices from the list below on any street, highway, parking lot, sidewalk or other area in New York State that allows public motor vehicle traffic. You may be arrested if you do...
>
> ...**Motor-assisted Bicycle** - a bicycle to which a small motor is attached. A motor-assisted bicycle doesn't qualify for a registration as a motorcycle, moped or ATV and doesn't have the same equipment."[24]

Within this list, the motor-assisted bicycle is in the company of vehicles like golf carts, go-karts, off-road motorcycles, and motorized scooters.

The legal situation of electric bicycles in New York State can be summed up as follows: since EABs are not explicitly included in the definition of a standard bicycle in the New York State Vehicle & Traffic Law, the DMV treats them as motorized vehicles and requires them to be registered as such. However, since the federal definition of electric bicycles exempts them from regulations that would require items like a VIN and motor vehicle safety equipment outlined in the FMVSS, there is no way that most types of electric bicycles can actually be registered in New York State.

The result of this current impasse between New York State regulation and federal law is a Catch-22 that leaves electric bicycles (both PBs and EABs) in a state of legal limbo.

DISCUSSION WITH DMV

In order to gain a better understanding of the DMV's position on EABs, a representative of NYSERDA joined the project team on April 22, 2015 for a phone call with two DMV officials: one representative with the Legal Bureau and one representative with the Traffic Safety office.

During the phone call, the DMV representatives reiterated the interpretation of electric-assist bicycles as a motor vehicle due to the presence of a motor, regardless of the terms of its pedaling assistance or power output. However, they support legislation that would clarify them as bicycles rather than motor vehicles.

PROPOSED LEGISLATION

Indeed, there is an electric bicycle bill that passed the Senate on May 19, 2015 and is in front of the Assembly as of June 2015.[25] If this bill passes the Assembly during the current 2015-2016 legislative session, it would clarify the legality of electric bicycles in New York State and remove most prohibitions on their use. Such bills have consistently been passed by the Assembly in prior years, but have failed to clear the Senate, which enhances the bill's chances given that the Senate has already passed it. Specifically, the proposed legislation targets what the bill refers to as "electric assisted bicycles."

The bill passed by the Senate was S00997, sponsored by Senator Martin Malavé Dilan of the 18th District (North Brooklyn) and co-sponsored by Senator Kathleen A. Marchione of the 43rd District (Upper Hudson Valley/Saratoga). The Assembly bill is A00233, sponsored by David F. Gantt of the 137th District (Rochester).

As drafted, the bills carve out a specific definition for an electric assisted bicycle (or EAB) by adding a new section (§102-c) to the existing definition of bicycle in §102 of the New York State Vehicle & Traffic Law:

> "Electric assisted bicycle. A bicycle with two or three wheels which has a saddle and fully operative pedals for human propulsion and also has an electric motor. The electric assisted bicycle's electric motor shall: have a power output of less than seven hundred fifty watts; have a maximum speed of less than twenty miles per hour on a paved level surface when powered solely by such a motor while ridden by an operator who weighs one hundred seventy pounds; and be incapable of further increasing the speed of the device when human power is used to propel the device at or more than twenty miles per hour."[26]

23 New York State Vehicle & Traffic Law, Article 34-C

24 New York State DMV. "Motorized devices that cannot be registered in New York," accessed 2/17/15. http://dmv.ny.gov/registration/motorized-devices-cannot-be-registered-new-york#footnoteref1_t3d3qul

25 Draft New York State Assembly Bill A00233 & draft New York State Senate Bill S00997

26 Ibid

Clearly, this definition takes direct cues from the CPSC's definition by utilizing the 20 mph powered speed requiring fully operable pedals, and limiting the maximum power output of the motor to 750 watts. However, it is more sophisticated than the CPSC definition by explicitly referencing the boundaries of the electric assistance function, stating that the motor's assistance must not continue to aid human pedaling above and beyond the 20 mph threshold. The definition also seems to encompass a PB, as it implies that the motor may be used to reach up to 20 mph without any human pedaling input at all. As we will see, this potentially conflicts with New York City's local ban on "motor scooters" (i.e., PBs and/or SSEBs).

Importantly, the draft bills prohibit riding the defined electric assisted bicycles without a helmet, and prohibit anyone under 16 riding as either the primary operator or as a passenger.[27] During an interview with the New York Bicycling Coalition (NYBC) about this legislation, NYBC mentioned that the age and helmet prohibitions may be an issue for bicycling advocates. However, the Senate bill has been passed, so these issues have so far not created any real impasses. No matter what happens during the rest of the 2015-2016 legislative session, it seems unlikely that the core definition of electric assisted bicycles in the bills would change to preclude the relatively light technical specifications of the bicycle share-enabled EAB that this study is considering.

NEW YORK CITY

When it comes to transportation, New York City is a special case within the state. The relationship between road users in the city has often been strained, and the expanding use of electric bicycles has not been spared from the tensions. Indeed, New York City is the only jurisdiction in New York State that has drafted its own electric bicycle laws.

MOTOR SCOOTER LEGISLATION

In a response to popular opposition to the widespread use of electric bicycles by New York City's ubiquitous restaurant delivery riders, the New York City Council recently reinforced its opposition to certain types of electric bicycles by enacting Local Law 2013/40 on May 15, 2013. The law amends a previously-existing law directed against what New York City classifies as "motor scooters:"

> "the term 'motorized scooter' shall mean any wheeled device that has handlebars that is designed to be stood or sat upon by the operator, is powered by an electric motor or by a gasoline motor that is capable of propelling the device without human power and is not capable of being registered with the New York State Department of Motor Vehicles."[28]

This amendment updates definitions and civil penalties to determine what is affected, and what punishment is meted out, under New York City's existing 2004 law, which states that:

> "No person shall operate a motorized scooter in the city of New York."[29]

As defined above, a "motor scooter" generally matches what would be called a PB in electric bicycle parlance, which means that, as written, New York City's electric bicycle prohibitions would not apply to a low-powered EAB.

For the most part, the New York City Council seems to have enacted their recent update of the local motor scooter law in the hopes of countering the growing commercial use of PB- or SSEB-style vehicles, and not the private use of the more benign EAB.

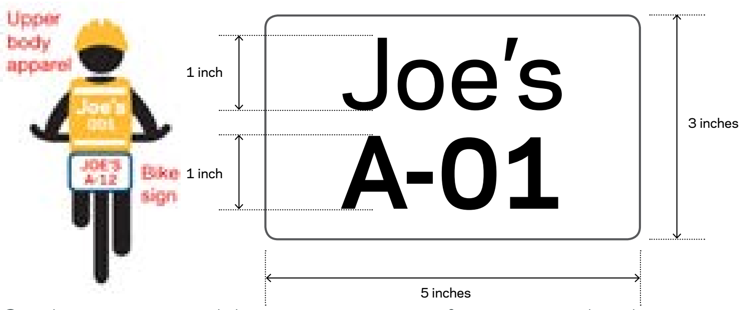
COMMERCIAL BICYCLING

Indeed, New York City's focus on the commercial use of PBs is clear in the way the City has recently amended its regulation of commercial bicyclists. In 2012, the New York City Council amended §10-157 of the City's administrative code (relating to apparel for commercial bicyclists) by requiring that:

> "A business using a bicycle for commercial purposes shall provide for and require each bicycle operator employed by such business to wear and each such bicycle operator shall wear a retro-reflective jacket, vest, or other wearing apparel on the upper part of such operator's body as the outermost garment while making deliveries, or otherwise riding a bicycle on behalf of such business, the back of which shall indicate such business' name and such bicycle operator's individual identification number as assigned pursuant to subdivision c of this section in lettering and numerals not less than one inch in height so as to be plainly readable at a distance of not less than ten feet."[30]

According to NYBC and other sources, this amendment seems to have largely been motivated by the resentment that many New Yorkers feel towards the riding behavior of commercial bicyclists (delivery riders), which some perceive as unsafe. Many feel that electric bicycles exacerbate the situation by enabling these commercial bicyclists to ride at faster speeds throughout the City, and the requirement within the above legislation that commercial bicyclists provide visual identification allows consumers to report any unsafe cycling behavior - whether that questionable conduct is on a standard bicycle or an electric bicycle.

27 Ibid
28 New York City Council. "Local Law 2013/40 - Enforcement of motor scooter provisions" (2013).
29 N.Y. ADC. LAW § 19-176.2: NY Code - Section 19-176.2: Motorized scooters
30 New York City Council. "Local Law 2012/052 - Providing reflective equipment to operators of bicycles used for commercial purposes." (2012).



Graphic representing bike sign requirements for commercial cyclists in NYC. Source: NYCDOT

Underscoring this opposition to the commercial use of electric bicycles, the New York City Department of Transportation (NYCDOT) reiterates the ban by stating on its website that "The New York State Department of Motor Vehicles does not register electric bicycles, therefore their operation is prohibited in New York City."[31] This pronouncement occurs in the same place that the apparel and signage requirements for commercial riders are detailed in the images below.

There are two common elements in the recent New York City legislation and agency pronouncements that target (directly or indirectly) the use of electric bicycles in the City. The first are the references to the DMV's inability to register electric bicycles, and the second is how the legislation seems to target PB- or SSEB-style vehicles ("motor scooters") and not EABs. This suggests that one of the primary factors preventing the non-commercial use of electric bicycles (especially low-powered EABs) is the legal situation at the state level.

CONCLUSION

As of spring 2015, New York State's relationship with electric bicycles is defined by ambiguity. That ambiguity has the potential to be lifted at the state level, provided that the Assembly and Senate successfully pass a version of the bills currently under their review that provide a definition for electric bicycles that allows them to be treated as standard bicycles under the law.

Per state law, any legislation passed by the state modifying §102 of the New York State Vehicle & Traffic Law would be applicable to all cities in New York State as well, and any negotiated definition will almost certainly include low-powered EAB that this study is targeting. In addition, given that New York City's ban only applies to PBs/motor scooters and tends to emphasize prohibitions on their commercial use, it seems unlikely that an EAB with a speed limited to under 20 mph (or 10-15 mph, in the case of the EAB this study envisions) would garner much local opposition.

As written, however, the electric bicycle bill in front of the Assembly does contain a potential pitfall. The proposed electric-assist bicycle definition appears to encompass the use of a PB, since it references a 20 mph speed limit when powered solely by its motor. This provision may conflict with New York City's ban on motor scooters, as any vehicle "powered by an electric motor or by a gasoline motor that is capable of propelling the device without human power"[32] is subject to the City's local ban. Still, the bill appears poised to become law, and it would still make electric-assist bicycles legal in New York City since the City's existing ban only applies to powered bicycles.

With so many other states successfully defining and allowing the use of EABs and PBs (even, occasionally, SSEBs), with the emerging lobbying efforts of electric bicycle advocates and industry groups, and with representatives of the DMV expressing that they are unopposed to the use of EABs (should clarifying legislation be passed), it appears to be only a matter of time before EABs can be used legally on any street in New York State where standard bicycles are permitted.

31 NYCDOT. "Commercial cycling," accessed 2/17/15. http://www.nyc.gov/html/dot/html/bicyclists/commercial-cyclists.shtml

32 New York City Council. "Local Law 2013/40 - Enforcement of motor scooter provisions" (2013).

INTERNATIONAL CASE STUDIES:
THE EUROPEAN PEDELEC EXPERIENCE

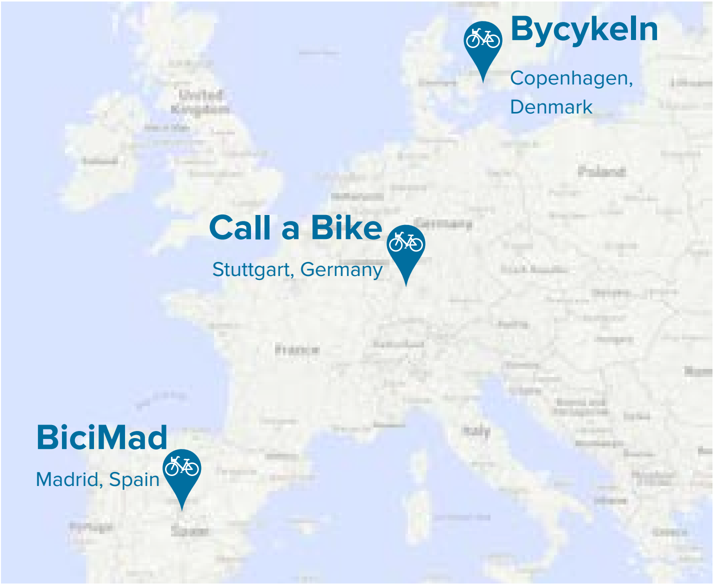
4.1 INTERNATIONAL CASE STUDIES

Bicycle share systems have seen worldwide adoption in recent years. From 2012 to 2013, there was a 60% increase in the number of cities launching new bicycle share systems, up from 90 in 2012 to 150 in 2013. The 2013 figure is a dramatic rise from the period between 1995-2002, during which less than 10 systems were operational globally.[33] Technological advances over the past decade, including mobile technology, electronic payment, solar power and GPS enabled devices, have enabled the modern era of bicycle share to become established.

Over this recent period of rapid bicycle share growth, trends have begun to emerge that are coming to define modern bicycle sharing systems. Most systems are comprised of a fleet of robust bicycles that can be rented for a fee and parked at an abundance of static stations located throughout the city. The stations are either fixed in place and hard-wired to provide electricity, or they are flexible, meaning that they are electrified by solar power and can be moved from one location to another in less than 24 hours. This type of station is desirable because stations can be moved to adjust to changes in demand and, overall, installation costs are decreased since the stations do not have to be hard-wired. Some cities are experimenting with station-less systems with smart locking bicycles, but this type of system has yet to see widespread adoption. The technologies and bicycles vary in design and manufacturer, and an entire industry has emerged to fulfill the international supply chain demand for bicycle sharing.

Globally, bicycle share now provides a reliable mobility option for millions of people, and cities have come to recognize that having a bicycle share system is important to maintain mobility and economic competitiveness. New technologies are emerging that could again disrupt urban transportation and usher in a new era of bicycle sharing. Increased investment in the electric bicycle market is driving down costs and making them more attractive to consumers. Different mechanisms for propelling electric bicycles have emerged as well, and the one that is seemingly most appropriate for integration into bicycle share systems is the pedal assist electric bicycle (pedelec). As discussed in the definitions section of this document, a pedelec is the favored term for an EAB in Europe. Unlike other electric bicycles, the motor on EABs/pedelecs is only engaged when the cyclist is pedaling, and disengages when a certain top speed is reached.

The following section describes the development of three European bicycle share systems (see map below) that are comprised fully or partially of pedelec bicycles. The narrative discusses the process by which the systems were implemented, provides specifications regarding the equipment used in the system, and elaborates on the pricing structures of the systems. Overall, pedelec bicycle sharing systems have not yet been widely implemented, but judging by the rapid advancement in technology, the next generation of bicycle share could be driven by pedelec bicycles.



The three European systems highlighted above were researched for this report

33 Meddin, Russell. The Bicycle sharing World – End of 2013. The Bike-Sharing Blog. December 2013. http://bike-sharing.blogspot.com/2013/12/the-bike-sharing-world-end-of-2013.html

GOBIKE

GoBike is a European electric bicycle share company that has been progressing the pedelec industry for the past 7 years. The company has its roots in Spain, and began with the concept of bringing electric bicycle share to cities. Recognizing that bicycle mobility has historically been less appealing in hilly cities, GoBike committed itself to manufacturing a bicycle that could minimize the impact of topography. They believed that an electric assist bicycle (EAB/pedelec) was the solution, and in 2008 began designing and building pedelecs that were compatible with bicycle sharing systems.

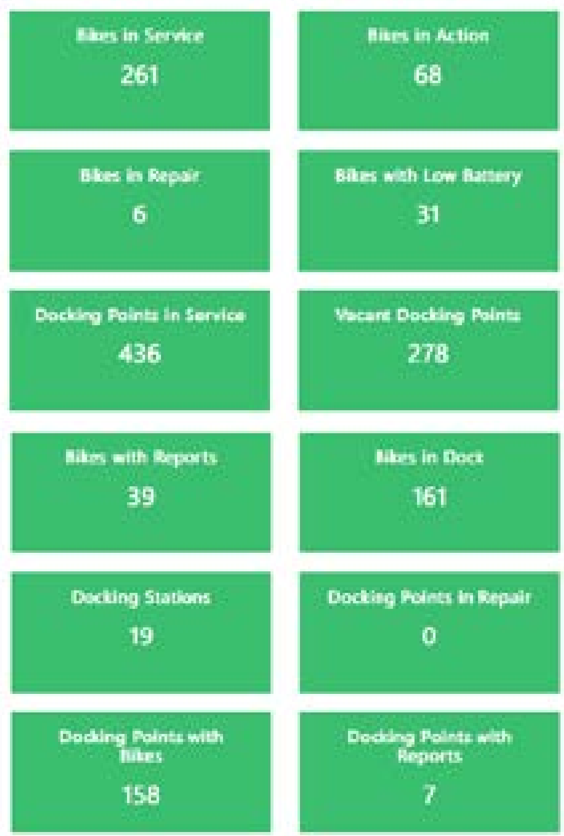
In order to become a competitor in the international bicycle share market, the company grew from a team of designers and fabricators to include experts in IT, urban mobility, finance, and bicycle share. As the company was growing and refining its business model, the Danish State Railway and the City of Copenhagen were soliciting a bid for a new bicycle share system to replace the phased out, coin-operated Bycyklen system. The original Bycyklen system, which was seen as a pioneering bicycle sharing system when it launched in the 1990s, had become obsolete as newer high-tech systems emerged. Copenhagen, a city that prided itself on being at the forefront of the urban bicycling movement, sought an innovative system that would help it retain its position as the world's bicycling capital.

GoBike submitted a proposal to provide the bicycles/stations and operate the Copenhagen system. Although the RFP did not require electric bicycles be used in the system, GoBike indicated in their proposal that, if selected, they would supply pedelec bicycles. In 2012, GoBike won the Copenhagen contract. After two years of research and development, a trial version of the system was launched in the spring of 2014. This fifty bike test phase was successful, and an additional 250 bicycles were added when the system officially launched later that Spring. By the Fall of 2014, financing was secured to scale up the system up to include 2,000 bicycles and 3,000 docking points at 105 different stations. After securing the Copenhagen contract, GoBike went on to win contracts in other European cities, including Frederiksberg, Denmark; Stavanger, Norway; Rotterdam, the Netherlands; and Barcelona, Spain, all using the same equipment and operating platform. The Barcelona system has launched with 40 bicycles, while the other systems are still in the planning stages.[34]

In Copenhagen, GoBike manufactures the equipment and operates the new Bycyklen system through its subsidiary Cykel DK. GoBike developed proprietary IT software to manage the operation of the system. Some of the key data points that the company monitors in real-time are shown in the graphic at right.

Most large cities in Europe can boast bicycle share systems, but very few employ bicycles that are powered by anything but human power. This makes the pedelecs that are at the heart of the Bycyklen system a true innovation. But this innovation comes with a cost. While the typical bicycle share bike ranges from $1,000 to $2,500 US dollars, the GoBike bicycle costs much more – about $7,300 each to purchase and maintain for the bike's 8-year expected life-span.[35] This additional cost can be attributed to two characteristics that are unique to GoBicycles: the electric pedal assist motor, and the on-board GPS enabled tablet. The bicycles are powered by a 250 watt front hub electric motor. The motor is only engaged when the person is pedaling, and will assist the rider up to 22 kmh (14 mph).[36] The motor automatically shuts off when the person ceases pedaling. There are four power settings for the motor, plus a manual "no-assist" option. The power levels are

A GoBike bicycle docked at a station in Copenhagen's Bycyklen system.



System statistics that are monitored by GoBike's operations software (source: GoBike)

34 About Gobike. 2014. http://gobike.com/about/history-about-gobike/

35 Stanners, Peter. The Future of city bicycles or a waste of money?The Copenhagen Post. August 2013. http://cphpost.dk/news/the-future-of-city-bicycles-or-a-waste-of-money.6618.html

36 How to use the electric bike. Bycyklen. 2014. http://bycyklen.dk/en/how-to/how-to-use-the-electric-bike/

controlled by the tamper-proof tablet affixed to the handlebars. In addition to monitoring the motor, the tablet also provides bike booking assistance, system station information, and since it is GPS enabled, provides point to point navigation. Another unique feature of the bike is that it can be parked anywhere, and be locked with an on-board mechanism that pinches the rear wheel so that it cannot spin. The bicycles are heavy, and without a rotating rear wheel, the weight and rigidity of the locked bike is a theft deterrent. Moreover, since the bicycles are equipped with GPS sensors, a stolen bike could be easily traced and recovered. Users therefore do not have to park the bicycles at stations.[37]

The stations are also supplied by GoBike. When the bicycles are docked, the battery, which is mounted on the rear rack of the bike, charges. Bicycles that have a low charge cannot be rented until the charge meets a minimum threshold. Unlike other modern bicycle share systems that benefit from "flexible" stations, or stations that are solar powered and can be easily relocated since they do not need to be hardwired, GoBike stations are fixed and must be hardwired.

In order to recoup the additional expense of the GoBikes, the pricing system has a more aggressive structure than other modern bicycle share systems. In most modern systems, the first 30-minute bicycle trip is free, meaning no additional fee is incurred if the bike is returned to a dock before the first 30 minutes expires. Trips over this time limit incur increasingly higher fees the longer the user keeps the bike out. This fee

BONOPARK

Unlike relatively flat Copenhagen, Madrid, Spain is a city with hills. The city, which has a nascent bicycle culture, has been slow to implement a bicycle sharing system, lagging behind other capitals that have had systems operating for years. Plans to bring bicycle sharing to Madrid began in 2012. After it was determined that a bicycle share system was indeed desirable, a formal RFP was released. A Spanish company, BonoPark, responded to the bid in collaboration with the North American bicycle share company Alta Bicycle Share (now Motivate). The initial RFP called for conventional bicycles, but BonoPark responded with a bid that proposed the use of electric assist bicycles (EAB/pedelec) for the system.

Despite incorporating pedelec bicycles into their bid, BonoPark's fee proposal was approximately the same as responses that employed conventional bicycles, and BonoPark was selected to supply the equipment and operate Madrid's system, branded as "BiciMad." The company took its experience from operating a successful pedelec bicycle share system in Donostia-San Sebastian, Spain, to implement the Madrid system.[39]

The bicycles used in the Madrid system are similar to GoBike bicycles, in that they are pedelecs equipped with a motor that only engages when the rider is pedaling, and that shuts off when the rider ceases to pedal. Per-bike cost estimates were not available for the bicycles, but given the fact that

	5/4/2014	5/3/2014	Week	Month	Year
Number of accumulated hours of bike rent	208:24	405:58	1683:49	1383:48	6950:11
Distance (km)	1025.1	954.8	4691.4	4196.5	13977.5
Average time(hours)	0:56	1:15	1:09	1:08	1:17
Average Distance(km)	4.7	3.0	3.2	3.5	2.6
Income	6713.00	12311.00	47122.00	41466.00	169182.00
Revenue	6598.00	10620.00	40835.00	34790.00	146599.00
Billing hours	237	482	1901	1527	6357
Trips	220	322	1456	1206	5407
"MonthlySubscription - E-bike" trips	22	72	320	245	934
"DSB Plus Subscription" trips	3	5	49	38	90
"Pay as you go" trips	139	233	888	774	3313
"ZERO" trips	49	9	197	147	1068

Bikes	261
Docking Stations in operation	28
Docking Points in operation	448
Trips/Bike	0.8

Users by subscription	
Total	3402
"MonthlySubscription - E-bike"	227
"Sa"	1
"DSB Plus Subscription"	29
"Pay as you go"	3109
"Monthly Subscription - Manual bike"	0
"ZERO"	36

User statistics that are monitored by GoBike's operations software (source: GoBike)

37 Laursen, Lucas. Copenhagen Pioneers Smart Electric-Bicycle sharing. December 2013. IEEE Spectrum. http://spectrum.ieee.org/transportation/alternative-transportation/copenhagen-pioneers-smart-electricbike-sharing

38 Pricing. Bycyklen. 2014. http://bycyklen.dk/en/pricing/

the initial bid was comparable to other conventional bicycle share bids, one could assume that unit costs for the pedelecs are comparable to conventional bicycle share bicycles. The bicycles are heavy at 48 lbs, but the 36-volt, 10-amp electric motor minimizes the issue the weight could potentially pose, propelling the bike up to 18 km/h (~11 mph) while the rider is pedaling. Above this speed, the motor disengages until the speed is reduced below the threshold. The on-bike battery is programmed to last 18 hours and has the ability to propel the bike for 70 kilometers. It is anticipated that individual bicycles will travel less than this distance per day, and that the batteries will recharge overnight.[40]

Similar to the GoBike, the pricing structure of BiciMad is more aggressive than other bicycle sharing systems. Two pricing structures are available: an occasional user rate and a subscriber rate. For occasional users, less than 1 hour costs a flate rate of 2 euros. The second hour costs an additional 4 euros. Subscribers pay an annual fee of 25 euros to become a member of the system . Once subscribed, users pay 0.50 euros for the first 30 minute trip, and 0.60 additional euros for each half hour of use thereafter. After the second hour, the price rises to 4 euros per hour. A discounted subscription price of 15 euros is available for those with a Madrid Transport pass. The pricing structure is flexible, so that if a user returns a bike to a station that has few bicycles (<30% docks occupied) they are given a 0.10 euro discount on the trip, and if they pick up a bike from a station that has a surplus of bicycles (>70% of docks occupied) they receive the same discount.[41]

The organizers of the system said this decision was deliberate, and the increased cost had more to do than just covering costs. Many bicycle share trips in other cities are short in duration, and likely replace walking trips. Bicycle share in Madrid is part of a wider agenda to reduce trips by carbon emitting vehicles. By charging for the first 30 minutes, the hope is that bicycle share does not become a substitute for walk trips, but rather, becomes a substitute to travel by personal vehicle. Also, the fee rates increase the longer that the bicycles are rented, in part to reduce the new system's impact on local bike rental businesses. The hope is that those seeking longer term rentals will rent bicycles from shops, and the system will not compete directly with these established businesses.[42]

Initially, the system consisted of 120 stations in the historic center of Madrid. Each of the stations has a capacity for 26 bicycles. When the system is fully built-out, it will include 1,560 bicycles, with 3,120 docks at 123 docking stations. Ideally, a station will be located every 300 meters. Within three weeks of the system's launch, the system had attracted 8,000 users. Together these users made about 2,500 daily journeys. By the fourth year, BonoPark is hopeful that the system will have 90,000 users, making an average of 15,000 daily trips.[43]

CALL A BIKE

Call A Bike bicycle share systems are available throughout Germany, and are provided through a partnership between

A BonoPark bicycle docked at a station in Madrid's BiciMad system.

German municipalities and the German Railway Company Deutsche Bahn AG (Deutsche Bahn). The first Call A Bike systems were rolled out in 2007, and since then the Call A Bike platform has expanded rapidly and systems under this name now operate in about 50 German cities. The pricing structure of the systems and equipment used is generally consistent, with the exception of a few cities which have integrated pedelec bicycles into their Call A Bike fleets. The City of Stuttgart was one such city that pioneered the integration of pedelec bicycles in 2009 after obtaining a grant worth 3 million euros from the German Government.

The new Call A Bike system in Stuttgart launched in 2011 after two years of system planning, with 44 stations providing 60 pedelecs and 450 conventional bicycles. The pedelec has the same frame as the conventional bicycles used in the system, but are equipped with a 250 watt electric motor and battery and weigh about 20 kg (44 lbs). The motor was provided by the company BionX, and is only engaged when the user is pedaling up to 25 kmh (15mph). Riders have three gear options that are used to control the speed of the bicycles.

The incorporation of electric bicycles into the bicycle share fleet required new stations to be developed and installed. The stations were wired underground so that they could be provided with power to charge the docked electric bicycles. A cable is used to lock the bike to the station, and this cable in integrated with a plug. When the bike is locked, the cable charges the bike. The stations were co-developed by a local electric bicycle/scooter company, EnBW. This company recognized the benefit of having stations throughout the city that could charge electric bicycles, and therefore provided resources to develop and install the stations. The kiosk was outfitted so that one side instructs private electric bicycle riders how to use the station to charge their bicycles, and the other side instructs Call A Bike users how to rent the bicycle share pedelecs.[44]

In Stuttgart, bicycles can only be picked-up and returned to fixed stations. Prices to rent a bike within the Stuttgart system

39 Leach, Susan. Madrid's Bicycles are Buzzing. UBM's Future Cities. April 2014. http://www.ubmfuturecities.com/author.asp?section_id=394&doc_id=526691

40 Gonzalez, Luis. BiciMad Madric Gets a Electric Bicycle sharing Program. Clean Technica. June 2014. http://cleantechnica.com/2014/06/29/bicimad-madrid-gets-crazy-electric-bike-sharing-program/

41 BiciMad The Public Bike Rental Service in Madrid. Accessible Madrid. 2014. http://www.accessiblemadrid.com/en/blog/bicimad-public-bike-rental-service-madrid

42 Frequently Asked Questions. BiciMad. 2014. http://www.bicimad.com/index.php?s=preguntas

43 Laursen, Lucas. Madrid Begins Electric Bicycle sharing. IEEE Spectrum. July 2014. http://spectrum.ieee.org/tech-talk/transportation/alternative-transportation/madrid-begins-electric-bike-sharing

vary by the type of bike being rented. Renting a pedelec Call A Bike costs 0.12 euros per minute. Riders are charged from the first minute that they rent the bike. Conventional bicycles cost 0.08 euro per minute, but this fee is only imposed after the first 30 minutes have expired. Trips less than 30 minutes on conventional bicycles are free. The maximum cost per day for an e-call a bicycle is 22.50 euro, while the maximum fee from conventional bicycles is 15.00 euro. Discounts are also available for users with railway cards and for students. [45]

CONCLUSION

Pedelec bicycle sharing has not been widely adopted among European cities that have implemented bicycle share systems. Call A Bike pioneered the integration of electric bicycles into a bicycle share system in the late 2000s, but other cities did not replicate their approach in large numbers. Over the past 5 years, there has been a worldwide proliferation of bicycle sharing systems, but still the great majority of systems use conventional bicycles.

The research indicates that there are two avenues to take when creating a pedelec bicycle share systems. One option is to develop a system where all the bicycles within the system are pedelecs, like Madrid and Copenhagen did. This option is more feasible in a city that is implementing bicycle share for the first time, or where an existing system is being entirely replaced. The other option is to integrate pedelecs into an existing bicycle share fleet. To achieve this end, stations need to be modified to accept and charge pedelecs. A sub-option of this approach is to only modify a portion of the docks to accept pedelecs, which would likely lead to a cost savings.

The Madrid and Copenhagen systems provide unique case studies because they were implemented recently and launched after the recent wave of bicycle share systems (2007-2014), which overwhelmingly used flexible stations with conventional bicycles. New technological advances provided these two cities with the opportunity to design bicycle sharing schemes that utilize electric bicycles. Presented with the opportunity to use conventional bicycles or electric bicycles, both cities chose to use pedelecs/EABs. In Madrid's case, the cost of the pedelec system was comparable to the bids submitted by conventional bicycle share system providers. The decision by both cities to go pedelec may be an indication that a new generation of bicycle sharing is emerging, one that is higher tech and potentially more desirable, especially in cities with weather and topography that might act as a deterrent to the use of standard bicycles.

A Call A Bike bicycle docked at a station in Stuttgart

In general, new systems will likely opt to use pedelecs/EABs, while established systems may seek opportunities to integrate pedelecs/EABs into their existing fleets. Since the vast majority of major cities have operational bicycle share systems, the adoption of electric bicycle share globally may be markedly slower than if pedelecs had been widely available just a few years ago before the launch of many of the major systems. If the systems in Madrid and Copenhagen prove successful and therefore more desirable, the additional capital investment to retrofit a system to accommodate electric bicycles may soon be seen as a prudent investment.

44 Public Bike Rental System with Pedelecs. GoPedelc. November 2011.

45 Stuttgart. Prices. DB Bahn. 2010. https://www.callabike-interaktiv.de/index.php?id=480&f=500

Pedelec Bike Share
SYSTEM COMPARISON BY THE NUMBERS†

YEAR LAUNCHED

BiciMad, Madrid	Bycyklen, Copenhagen	Call A Bike, Stuttgart
2014	2014	2009

NUMBER OF PEDELECS

BiciMad, Madrid	Bycyklen, Copenhagen	Call A Bike, Stuttgart
2000	1560	60*

*Number does not include conventional bicycles used in the system.

NUMBER OF STATIONS

BiciMad, Madrid	Bycyklen, Copenhagen	Call A Bike, Stuttgart
105	123	44

PER HOUR RENTAL COST (USD; CASUAL USER)

BiciMad, Madrid	Bycyklen, Copenhagen	Call A Bike, Stuttgart
$2.28	$3.80	$2.70

MAX SPEED OF PEDAL ASSIST

BiciMad, Madrid	Bycyklen, Copenhagen	Call A Bike, Stuttgart
11 mph	14 mph	? mph

† Data provided by various sources referenced in the previous section.

4.2 PROPOSED ELECTRIC-ASSIST BICYCLE VS. EUROPEAN PEDELEC MODELS

It is likely that electric bicycles will become a popular alternative to conventional bicycles in North America. Thousands of electric bicycles have already been sold in the region, and the popularity of electric bicycles is only anticipated to increase. This section compares the EAB, the type of electric bicycle that this study believes has the greatest chance of being integrated into American bicycle share systems, with the types of pedelecs used in the European systems outlined here.

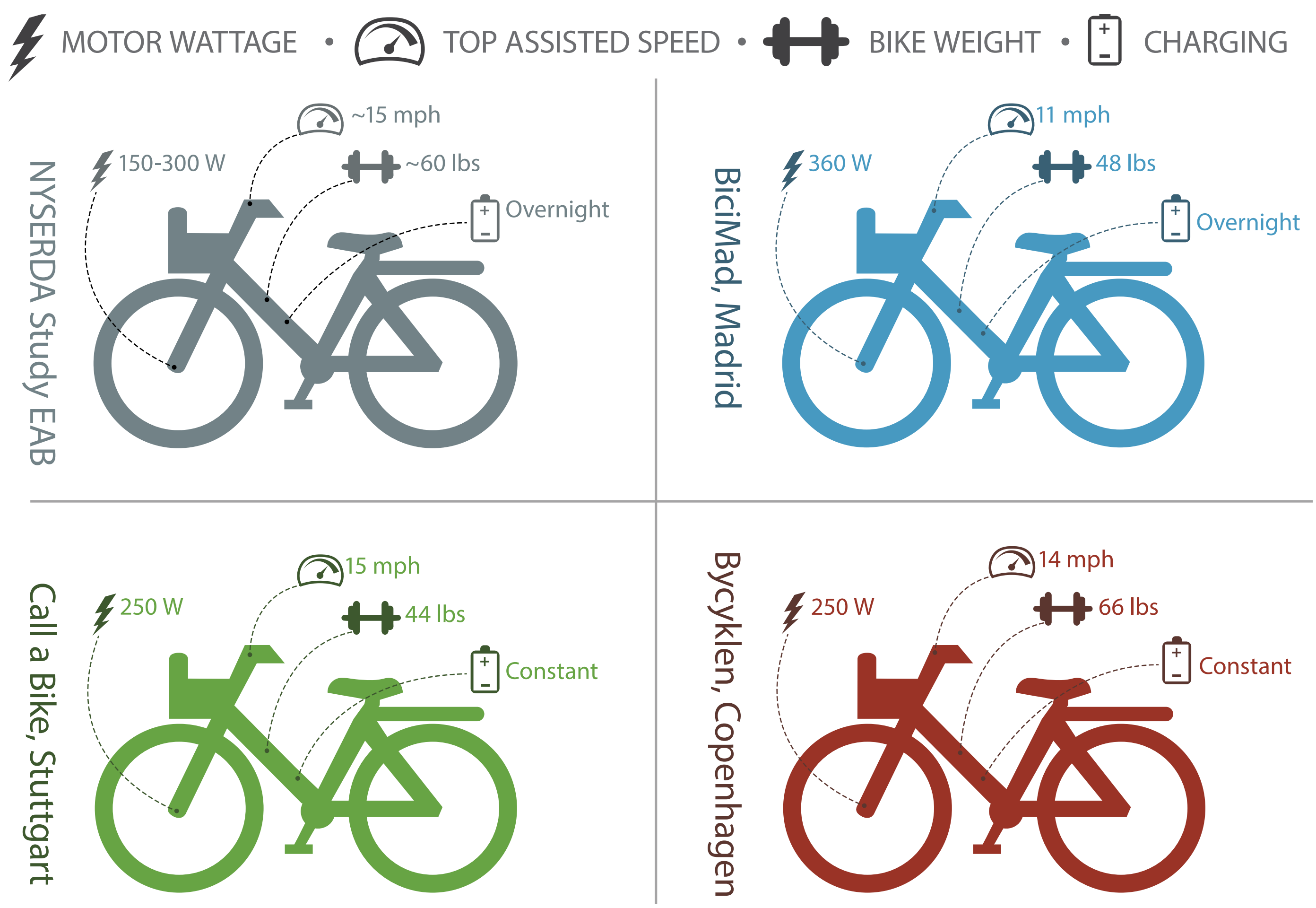
The EAB discussed in this study is essentially the same thing as a European pedelec, although technical specifications can vary from bike-to-bike. As discussed, motors on EABs and pedelecs only engage when the rider is pedaling, and disengage after a preset top speed is reached. The result is a safer riding experience that maintains the integrity of a traditional bicycle. Since EABs cannot be propelled unless the rider is pedaling, it is legally defined as a bicycle in many US states. The choice to use EABs for North American bicycle share systems is consistent with the three European systems researched, all of which employ pedelec bicycles in their fleets.

The specifications listed represent the EAB that is being proposed for this study in particular. These specifications were determined through conversation with manufacturers and electricity providers:

- Weight: similar to an existing, standard bicycle share bike (~60 lbs).
- Watts: About 150 to 300 watts motor output (likely on lower end of the spectrum).
- Speed Governance: A speed cutoff for the power assist function when the bicycle speed reaches between 10 - 20mph.
- Station Electrification: Stations connected to the grid, but not trenched or dug in. A temporary plug-in to the grid would be most desirable, with metering used to charge for power use. It is most practicable to place stations in close proximity to stop lights and street lights (or similar grid access points), and places with very low off-peak electricity fees.
- Battery: Two options are available. The first would be a large battery that would only charge overnight, or a smaller battery with continuous charging when docked.

BiciMad and Bycyklen stations use temporary plugs to connect to the grid, while Call A Bike stations are trenched.

The graphic below compares some of the general specifications of the EAB proposed in this study to the pedelecs used in the three European systems highlighted in the report.



GRID CONNECTION FEASIBILITY:
POWERING THE SYSTEM

5 GRID CONNECTION FEASIBILITY

The technical specifications of the proposed bicycle share EAB will not constitute excessive demands on the electrical grid. Still, the ability to successfully connect to a reliable power source will be essential to the success of an electric-assist bicycle share system, because solar power is not anticipated to provide adequate power for battery recharging in the short-term.

Non-trenched, grid-connected electric bicycle sharing stations would be considered temporary installations and fall under metering rates that are in accordance with a small general/ commercial use. “Non-trenched” simply means that aside from the temporary electrical connection, stations will not be permanently affixed to a street or sidewalk. This is consistent with the physical setup of existing bicycle share stations.

While the nuances of connecting to the electrical grid will vary by municipality, this study focuses on Con Edison. Con Edison serves New York City, and its grid connection dynamics are expected to be more complex than National Grid, which serves Upstate New York.

CON EDISON DYNAMICS

To make this general determination of grid connection feasibility in New York City, the team met with two representatives of Con Edison (John Shipman and Sherry Login - “the representatives”), on February 12, 2015, at the Con Edison headquarters near Union Square.

The subject of the meeting was the feasibility of connecting Citi Bike docking stations to Con Edison’s grid in a way that would support the battery charging needs of electric-assist bicycles. During the meeting, potential hurdles associated with connecting the docking stations to Con Edison’s grid from a technical, legal, and commercial perspectives were reviewed and discussed. The following sections summarize these topics of discussion.

TECHNICAL

After an initial assessment of the charging needs for the bikes, it is reasonable to consider that the battery-charging rate need not exceed 150 watts per bike. For most docking stations that contain between 20 and 60 bikes, this would translate into a maximum power draw of between 3 kW and 9 kW. It is also expected that battery charging will occur at night, when load is minimum and off-peak pricing is in effect at a rate of less than $0.01 per kWh hour (not including other grid customer charges).[46] The total amount of energy that is expected to be necessary for effective charging operations is in the order of 1 kWh per bike per each 24 hour period of use.

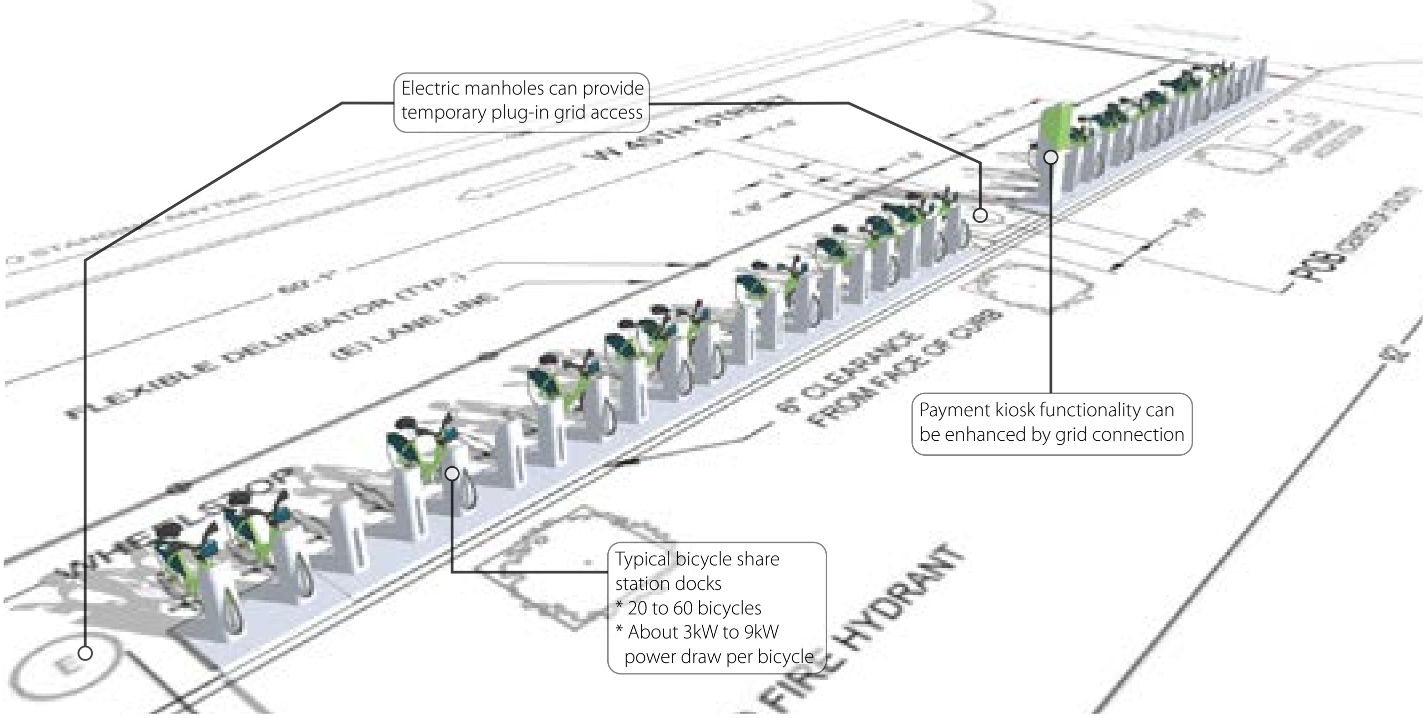
Further technical assessment will be necessary to conclude with certainty, but single phase service is likely to suffice for the power needs of the docking stations. The representatives indicated that single phase service for rather low load and power draw will be readily available at street level within a short range of most docking stations, as long as the legal framework allows for the temporary grid connection to be made.

The figure on page 28 provides a visualization of a sample station at West 45th Street & 6th Avenue in New York City, and indicates where temporary grid connections could be made.

The project team has reviewed 50 sample schematics drawn from the the existing Citi Bike system’s docking stations, and has found that 60% of stations in this sample are located within 10 feet of an access point to the Con Edison power grid. This indicates that accessible grid connections should be fairly easy to come by when planning for electric-assist stations.

While further technical assessments will be required, technical issues associated to the grid connection are not expected to be unsolvable and are not considered fatal to potential future phases of this project.

46 Con Edison Schedule for Electricity Service, P.S.C. No. 10 – Electricity. Leaf 398, SERVICE CLASSIFICATION NO. 2 - Continued GENERAL - SMALL.



LEGAL

The representatives were very supportive of the electric-assist bicycle sharing idea and concept that the project team presented. However, they did mention that legal issues may be among the more difficult obstacles.

The representatives referred to a rate adjustment process that was in progress as of the meeting, in which Con Edison has recently filed a new rate case to change how they can charge customers for revenue requirements. Tariffs were apparently proposed to eliminate regulatory obstructions to temporary service in light of other temporary grid access efforts, like "Simply Grid" for food vendors, that have recently been making headway in New York City. Simply Grid, now owned by Move Systems,[47] has been working with Con Edison's team to develop a way to connect New York City food carts to the electricity grid. Although likely providing a lower power output than what would be required for electric-assist bikes, Simply Grid's system is conceptually very similar to the type of connection what would need to occur for the proposed electric-assist bicycle stations.

Part of the new rate case filing addresses the statute of temporary structures and their right to be connected to Con Edison's grid, and would allow Con Edison to cover the cost of certain temporary grid connections. Currently, such costs would be borne by the connecting customer. The representatives indicated that the outcome of this filing may be known within 12 months from filing, which would roughly coincide with a potential subsequent phase of this project.

Currently, Citi Bike docking stations would fall under the above provisions of the new rate case filing. They are designed to be movable and have no hardware attaching them permanently to the sidewalks or roadways, which make them temporary structures in Con Edison's view.

While this temporary classification may present short-term hurdles, given Con Edison's focus on providing service to permanent structures, upcoming regulatory revisions and the success of recently-implemented temporary installations such as Simply Grid indicate that low energy drawing temporary installations such as electric-assist bicycle share stations may be easier and more cost-effective in the near future.

Some final legal considerations involve those of labor requirements and permitting. Specific union labor may be required to perform any work that creates connections to the Con Ed grid, and the permitting process may necessitate extra time and resources. However, the project team expects that the benefits of providing bicycle share customers with electric-assist bicycles, as well as the operational benefits of the grid-connected stations themselves, will be great enough that these collective positives will outweigh logistical and cost-related concerns. These benefits are discussed in chapter 6.

First Simply Grid system for food cart in NYC (Photo Credit: www.simplygrid.com)

47 www.movesystems.com

CONSUMER BENEFITS & MARKET ANALYSIS: ATTRACTING NEW RIDERS

6 CONSUMER BENEFITS & MARKET ANALYSIS

A GROWING INDUSTRY

The bicycle share industry has experienced notable growth throughout the world in recent years, and as the data in chapter 1 illustrates, the US is no exception. In particular, the systems in Boston, Chicago, and Salt Lake City have more than doubled their number of stations since their respective launches, and New York City's Citi Bike system is in the midst of an expansion into Queens, Upper Manhattan, and neighboring Jersey City. In the case of Chicago's system, the number of stations has more than quadrupled from 69 stations in June 2013 to 300 stations as of February 2015. High levels of usage have enabled this growth, with Citi Bike reporting over 8.5 million trips in February 2015. Additional usage figures are available on page 1-7.

Beyond existing systems, interest in bicycle share among mid- and smaller- sized cities has been expanding apace. As previously noted, Buffalo Bike Share has been serving the City of Buffalo in a limited fashion through the station-less bicycle share technology Sobi, and both Albany and Syracuse have produced feasibility studies in an effort to gauge potential and figure out next steps in the process.

If this sort of rapid growth in operations and interest continues, then the bicycle share industry will increasingly attempt to expand not only in terms of geographic coverage, but also in terms of the types of users their systems can attract. While systems like Citi Bike have popularized bicycling and appear to have appealed to riders that may not otherwise have attempted to get around their cities on two wheels, there are clear opportunities to encompass a larger segments of the urban market. Utilizing electric-assist bicycle technology is one of these opportunities, perhaps particularly for parts of Upstate New York that are hillier and considerably less dense than New York City.

EXISTING ELECTRIC-ASSIST BICYCLE SHARE

As introduced in chapters 1 and 3, electric-assist bicycle share systems are already in use in several European cities, and one mixed standard/electric system is slated to open in Birmingham, Alabama in fall 2015. In addition, the University of Tennessee-Knoxville conducted a limited two-station test of a system offering electric-assist bicycles along with standard bicycles (cycleUshare) that reported positive results.

UNIVERSITY OF TENNESSEE-KNOXVILLE (UTK) "CYCLEUSHARE"

Usage

UTK's cycleUshare system was very small, but its first year of operation was closely monitored by professors and students at the university. These observations produced some very important market-related findings for electric-assist bicycle share, including the fact that system users preferred the electric-assist bicycles over the standard bicycles that were also available. As cited previously, the report asserted that "factors of speed and convenience played major roles in participants' decisions to use the system, and speed and comfort were the most influential factors in the selection of an e-bike [electric-assist bicycle] rather than a regular bicycle."[48] The figure on page 31 provides specific usage numbers by day from August 2011 to April 2012. This has important implications for a potential electric-assist bicycle share market, as it quantifies user preference at a level of detail that is not available elsewhere. Most importantly, of course, the results indicate a clear preference for electric-assist bicycles.

As the study mentioned, part of this preference was due to the relative ease of powering the electric-assist bicycles, a bias that is supported by the finding of a subsequent follow-up study authored by UTK's Brian Langford. His study concluded that "e-bike trips require on average 24.5% less power from the user than the same trip on regular bicycles."[49] Langford's study

48 Cherry et. al, "North America's First E-Bike Share." Transportation Research Record 2387 (2013).

49 Langford, Brian Casey. A comparative health and safety analysis of electric-assist and regular bicycles in an on-campus bicycle sharing system. Pg 109. August 2013. UTK.

also found through its survey of cycleUshare's electric-assist bicycle users that "the extended mobility and removal of terrain barriers are major advantages to the e-bikes."[50]

The study also surveyed the cycleUshare system's electric-assist bicycle users regarding trip purpose and duration, finding that:

> "...while most regular bicycle trips are of shorter distances and with a singular purpose, e-bike trips are typically for greater distances under a shorter time frame and allow for additional stops. While the destinations for most trips in this study are class-related, a number of them included a destination off campus. Trips by e-bike are shown to have a wider variety of trip purposes than regular bicycle trips."[51]

While based upon a limited sample, this finding suggests that a system that incorporates electric-assist bicycles into their fleet, or that bases their fleet entirely upon electric bicycle technology, could capture a wider range of trip types than a system utilizing only standard bicycles.

Supporting these findings, a Portland State University survey that was completed in 2013 reached 553 existing e-bike riders and owners regarding their e-bike usage patterns. Created by The League of American Bicyclists, the infographic on page 32 distills some of the survey's findings. It highlights that 73% used their e-bike to a different destination than a standard bicycle, and that 60% of respondents cited living in a hilly area as one of their main reasons for using an e-bike.

These results make a compelling case for the ability of e-bikes to both serve a wider variety of trip types and make existing bicycle trips more efficient. This study does not differentiate between types of e-bikes, and thus are not specific to electric-assist bicycles. Still, the primary mobility benefits are similar.

Safety

Although not directly related to consumer benefits or the cultivation of a potential market, the ability to test the benefits of electric-assist bicycles have often been curtailed by regulations in states or municipalities that consider electric bicycles less safe than traditional bicycles. The same study referenced above has contributed to challenging this conception by outfitting the cycleUshare system's electric-assist bicycles and standard bicycles with GPS units to track the rider behavior of each type of bicycle, in particular monitoring speed on roadways and shared use facilities, behaviors at intersections, and wrong way travel. The results indicated that:

> "While differences in behavior exist [between electric-assist bicycles and standard bicycles], and these differences have bearing on overall user safety while operating the two bicycle types, the differences are generally small and generally explained by other factors, unrelated to the bike itself. This infers that the advantages that users gain from e-bikes have little overall effect on user safety as compared users of regular bicycles."[52]

Especially in light of the fact that electric-assist bicycles operate at speeds similar to those of standard bicycles, this study helps address fears that electric-assist bicycles could impede the development of a market by introducing safety concerns above-and-beyond those involved in a typical bicycle share system. The former Alta Bicycle Share (ABS) company facilitated more than 30 million trips on its bicycle share systems with zero fatalities, and there is no reason to believe that the record for an electric-assist system would shape up any differently.

EUROPEAN SYSTEMS

Several existing European electric-assist bicycle sharing systems were presented in chapter 3, an overview that included Copenhagen (Bicyklen), Madrid (BiciMad), and Stuttgart (Call-a-Bike). The two largest systems were BiciMad and Bicyklen, with 2,000 and 1,560 electric-assist GoBikes respectively, and have been operational since 2014. Since they are relatively new systems, there are few available statistics on usage.

As noted in the table on page 21, however, the Bicyklen system utilizes the GoBike company's reporting methods and offers some limited data on income, revenue, and usage from that system's initial rollout in Copenhagen. The figures are largely positive, and achieving 3,402 total subscribers shortly after the system launched is a very good indicator of demand, and offers a solid stepping stone from which the system can expand. Indeed, the Bicyklen system has already been planning its expansion (for spring 2015), which includes expanding the system to all of the stations represented on the map below.

Although the European electric-assist systems are relatively new players, at least one has been successful enough to plan an immediate expansion, and the idea has recently spread to Birmingham, Alabama. It is reasonable to expect the emerging electric-assist bicycle sharing industry to continue growing both domestically and abroad.

POTENTIAL BENEFITS OF ELECTRIC-ASSIST BICYCLES

OVERVIEW

As discussed in other parts of this study, electric-assist bicycles offer a range of benefits to existing bicycle share customers. Importantly, these benefits could have such an impact that not only will they provide a better bicycle share experience for the individual consumer, but they also have the potential to expand the practical use of bicycle sharing systems to an expanded range of consumers (e.g. older or less physically fit customers) and trip types (e.g. longer trips, bad-weather trips, and trips that necessitate riding through hilly terrain). Electric-assist bicycles are also have an appeal that is very in line with the preferences of a technology-oriented global market, which could help expand the lure of bicycle sharing to a group that would be less than enthused by the prospect of traveling on a standard bicycle. These benefits would be magnified if a system that is based entirely upon electric-assist bicycles were to be introduced, but would remain tangible even if electric-assist bicycles were incorporated into an existing standard bicycle share system, as the UTK experience has shown.

50 Ibid

51 Langford, Brian Casey. A comparative health and safety analysis of electric-assist and regular bicycles in an on-campus bicycle sharing system. Pg 107. August 2013. UTK.

52 Langford, Brian Casey. A comparative health and safety analysis of electric-assist and regular bicycles in an on-campus bicycle sharing system. Pg 108. August 2013. UTK.

In sum, a partial or full incorporation of electric bicycles into a bicycle share fleet could:

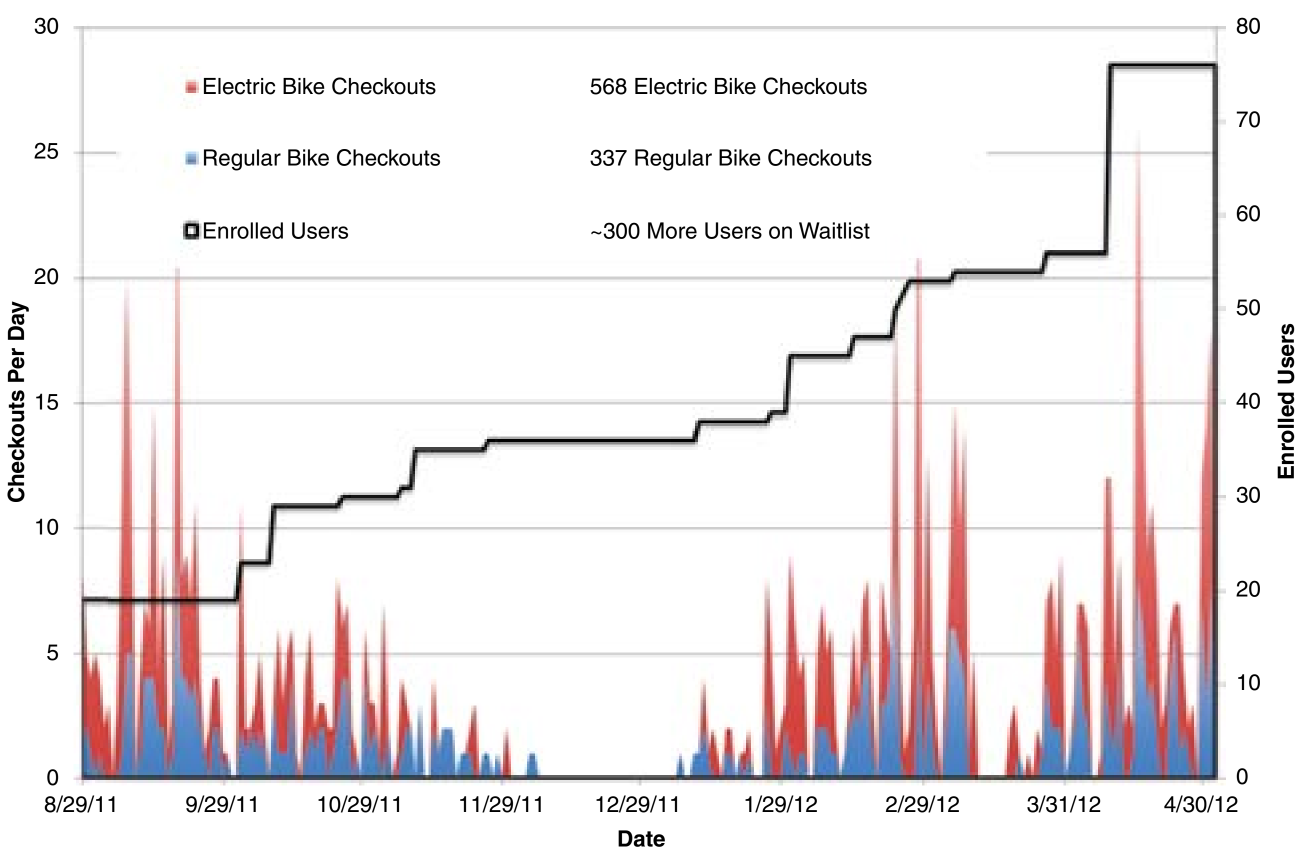
- Offer new perks for existing bicycle share customers.
- Expand the appeal of bicycle share to new types of customers.
- Expand the appeal of bicycle share to a wider range of trip types.
- Less exertion means reducing or eliminating excess sweating and other discomfort that often requires end-of-trip shower facilities or a change of clothes.
- Provide a "hi-tech" experience that could draw in new customers.
- Help cities with significant hills like Ithaca, Syracuse, or Albany "sell" bike share as a transportation option for the entire urban core, not just flat and easily accessible neighborhoods.
- Present a high-coverage system that could make fundraising easier.
- Draw in new annual/subscription members who see the relative ease of riding electric-assist bicycles as a more practical solution to their daily commuting and transportation needs.
- Entice new casual users who perceive (rightly or wrongly) that the city they live in or are visiting is too hilly to bicycle through.
- Introduce a unique technology with a "gee whiz" factor that could draw media attention prior to and after launch.

Of course, many of these potential benefits carry assumptions about how electric-assist bicycle technology would operate within a bicycle share setting. Particularly, the projected benefits outlined above assume the following:

1. ***Ease of Travel:*** Using the low end of the general technical specifications presented at the end of chapter 3, the assistance of the electric motor aids pedaling enough to make travel amidst hilly terrain or in hot/humid weather conditions markedly more pleasant and expedient when compared to the same trip on a standard bicycle share bicycle.
2. ***Service Area Expansion:*** More destinations and/or stations can be reached during a trip from a given electric-assist bicycle share station than when compared to the same trip with a standard bicycle share bicycle.
3. ***Battery Life:*** Battery life limitations will not detract from the customer experience.

Prior chapters have offered sound evidence for the legal, technological, and regulatory feasibility of electric-assist bicycle share, and has also offered a range of precedents for such a system. However, the assumptions listed above will be examined further in the following pages, as their collective validity is essential in determining the true potential for electric-assist bicycles to expand the market for bicycle share industry in the US in general, and in New York State in particular.

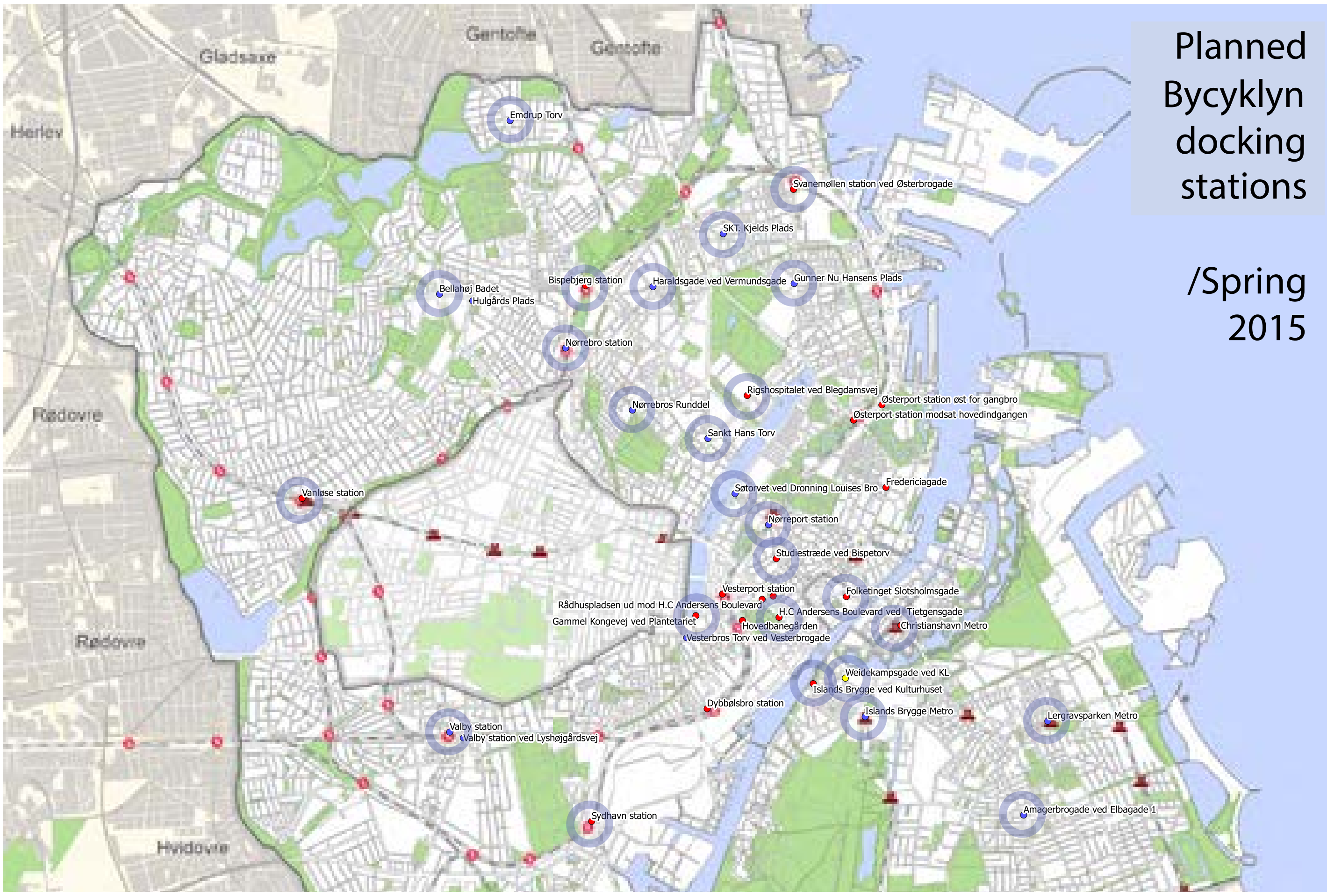
A comparison of e-bike checkouts vs. regular bike checkouts at UTK
Source: Cherry et. al, UTK



E-bike trip statistics drawn from a 2013 Portland State University survey (Infographic Source: The League of American Bicyclists)

553 responses regarding e-bike usage were received from existing e-bike owners and users across the US and Canada. (Source: E-Bikes in the North America: Results from an online survey)

Map of Bicyklen's planned spring 2015 expansion in Copenhagen (Source: bicyklen.de)



EASE OF TRAVEL

Electric bicycles have an enormous potential to make bicycling trips require less effort, particularly when negotiating steep terrain or riding in unpleasant weather conditions. Several factors of the electric-assist motor create this potential, primarily:

- Faster acceleration from a full-stop position.
- More consistent pedaling power during uphill climbs regardless of weather conditions.
- Ability to remain at a consistent cruising speed with less manual pedaling input on both flat and hilly terrain, and in less comfortable weather conditions.

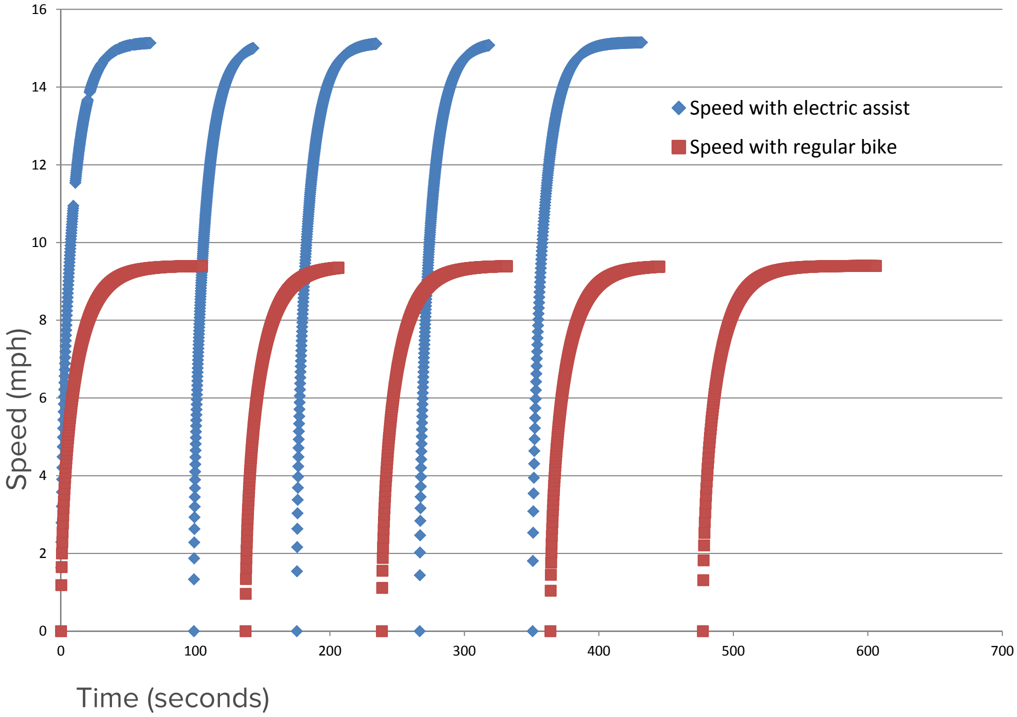
In order to fully understand these benefits, the project team developed several physics models that simulate different types of electric-assist bicycle trips and compares them to the same trips as undertaken on a standard bicycle. The technical specifications assumed throughout this chapter are the same as those described in chapter 3, except where otherwise noted.

Assistance on Flat Terrain

The graphs on page 34 show an 1800m trip on flat terrain that consists of five sections of different distances, with stops of same duration between each section. In this scenario, the baseline standard bicycle is shown as riding for 10.1 minutes at an average of 7 mph.[53] With an electric-assist bicycle, that same trip with identical pedaling effort from the cyclist and containing the same number of stops would take about 7.2 minutes at an average of 9.3 mph (conservatively assumes a 100 Watt motor).

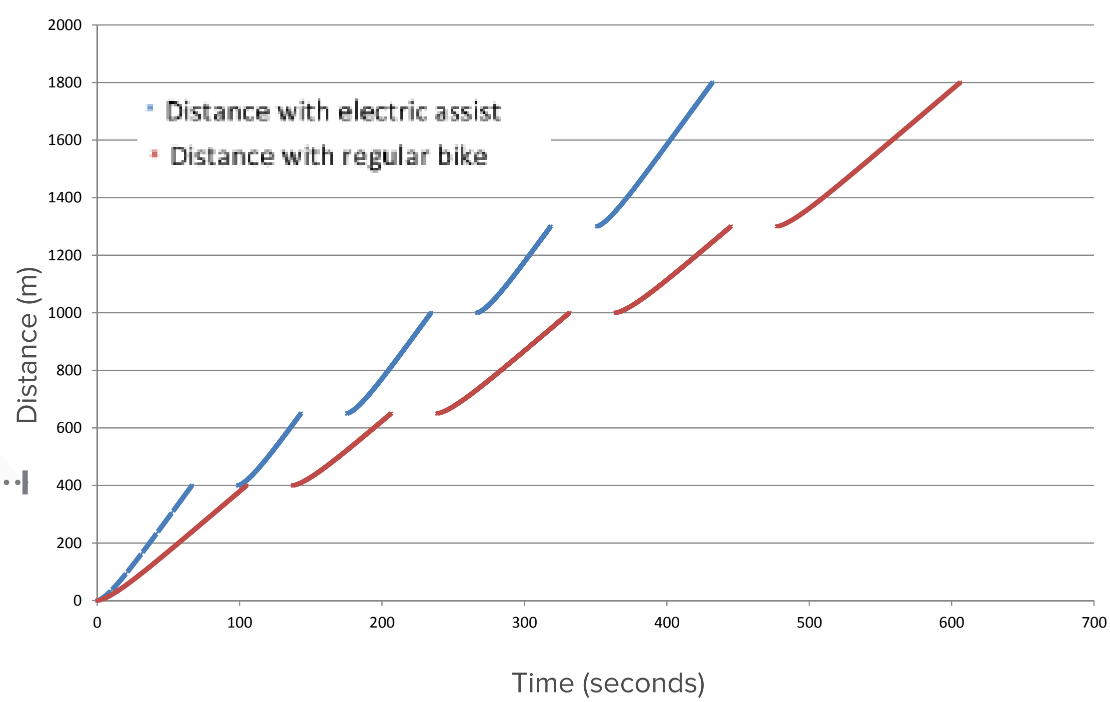
While real-world variables are of course not so constant, these graphs allow one to visualize how, even over flat terrain, the electric-assist bicycle's higher rates of acceleration and the ability to keep them at a higher speed result in an ability to travel greater distances over the same amount of time.

53 As of February 2015, 1800m over 10.1 minutes at about 7 mph is the median travel distance/travel time/travel speed on standard bicycles for subscribers of the Citi Bike system in New York City. This baseline was chosen for the flat terrain analysis since it can be considered representative of bicycle share trip distances undertaken by residents in a city with an established bicycle share system. Netting the behavior of residents (annual subscribers) is important, since the system's occasional or one-time (casual) users are more likely to be visitors that display less rational riding patterns.



Speed-time series illustrating the electric-assist bicycle's faster acceleration from a complete stop, when compared to a standard bicycle

Distance-time series illustrating the electric-assist bicycle's greater distance coverage, and how that coverage diverges over time.



Assistance on Hilly Terrain

As the Portland State University survey helps illustrate, one of the major benefits of electric-assist bicycles is the ability to climb hills more quickly and with less effort. But exactly how much easier is climbing a hill with the assistance of an electric motor, and does the power of the motor have a large impact on the benefit?

To examine this, the project team developed a model that uses the average 4.6% slope of the Brooklyn Bridge as a case study. Using three different types of electric-assist motors (100 watts, 150 watts, and 200 watts), the graphs below and on page 36 compare the climbing ability of these electric-assist bicycles with that of a standard bicycle.

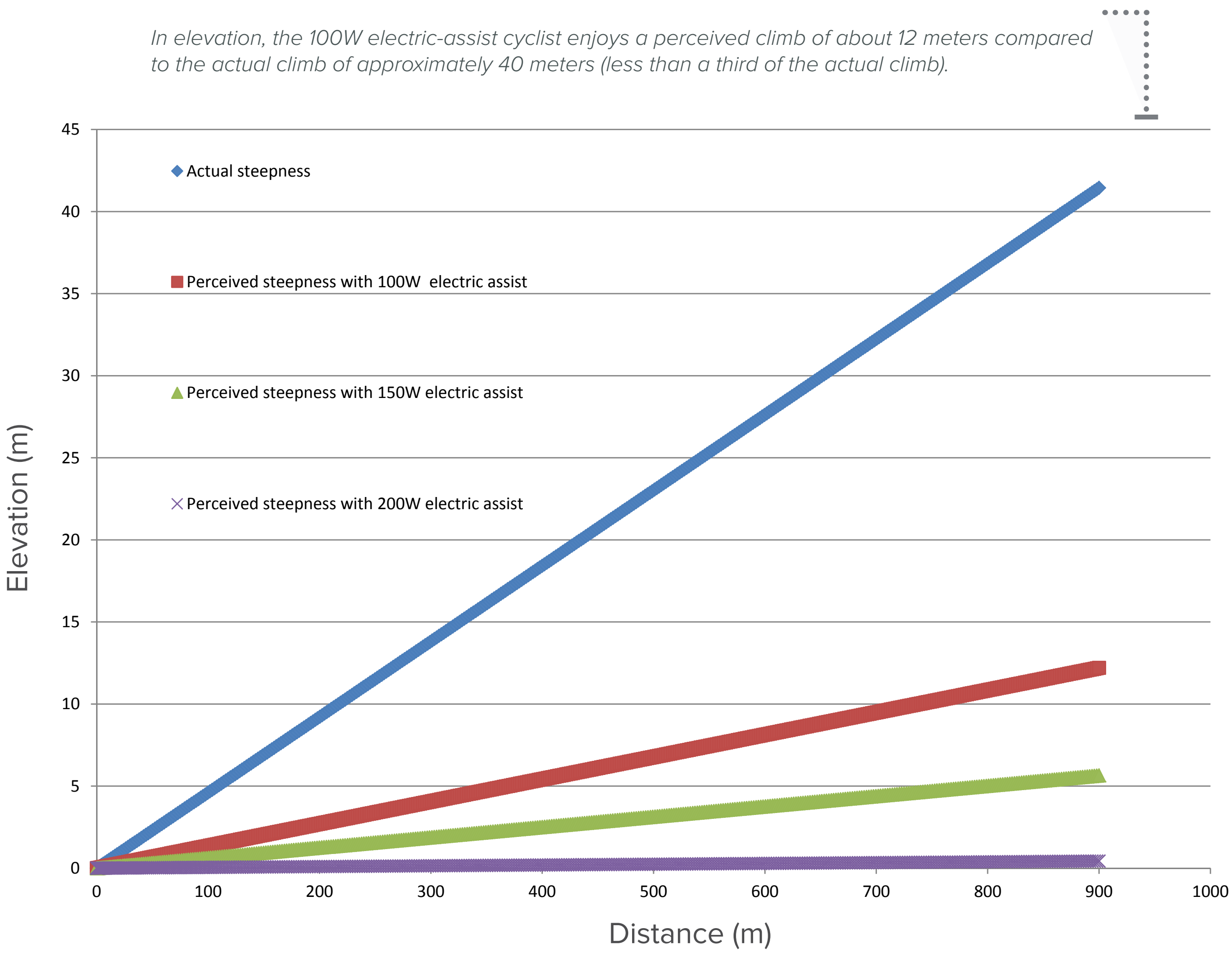
Even at the low end of the electric-assist spectrum, the advantages are very visible; the average 4.6% Brooklyn Bridge slope would feel more like an average 1.4% slope for the electric-assist rider, and it would take about 25% less time to cover the climb than it would if a standard bicycle was used for the same trip. In terms of elevation, the electric-assist cyclist's perceived climb is less than a third of the elevation of the actual climb.

Again, although real-world variables may be more complicated, the model quantifies the ability of even a low-powered electric-assist motor to flatten slopes for bicyclists. This translates to less overall effort, which would be especially valuable in hot weather or for customers that are older, less fit, or disinclined to exert themselves when traveling around a city.

To more accurately gauge the impact of this expected hill climbing benefit, all of the publicly available NYC data from July 2013 to December 2014 (~10 million trips) was analyzed for a potential customer pattern of hill avoidance. The analysis found that subscribers to Citi Bike were at least 3.51% more likely to bike downhill vs. uphill, with uphill defined as a climb of 30 meters or more. The fact that this bias plays out in New York City is telling, given the low numbers of hills relative to other cities in New York State that could benefit even more from this dynamic - such as Ithaca or Albany.

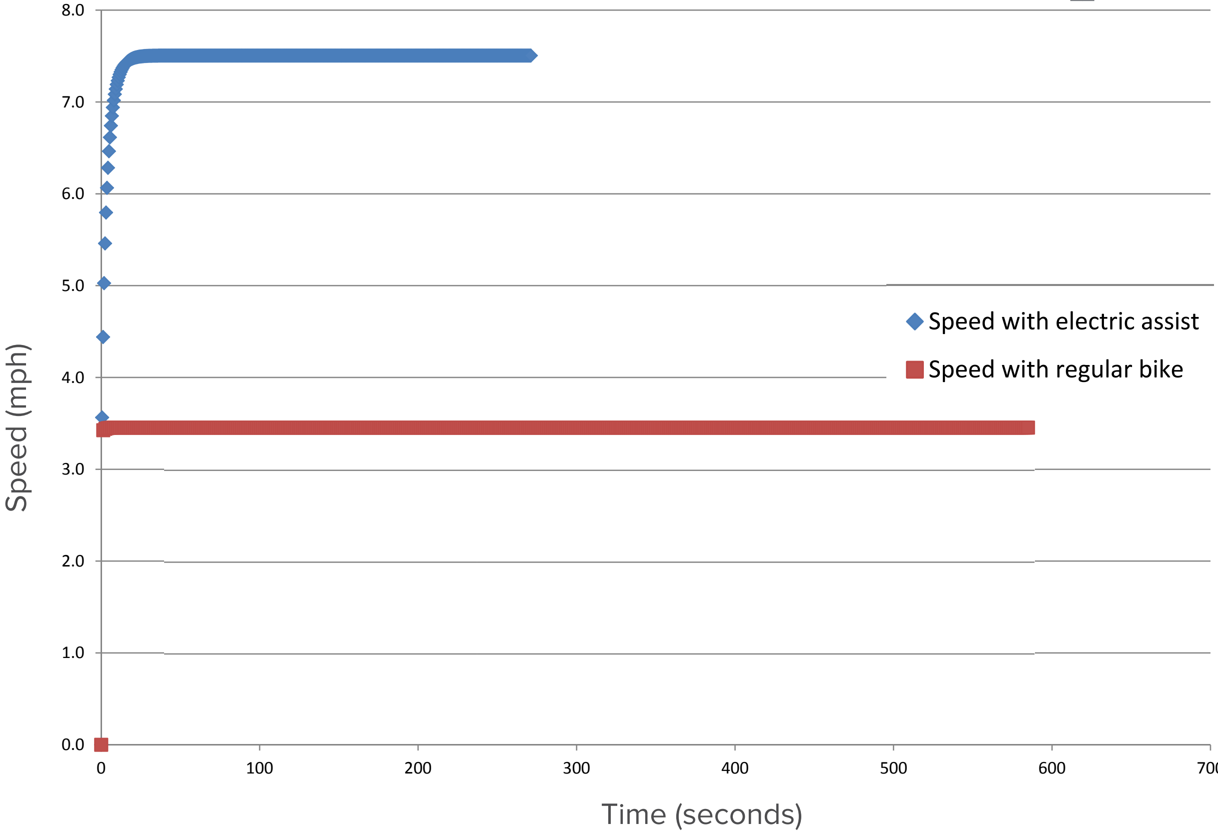
An electric-assist cyclist assisted by a motor of only 100W flattens the average 4.6% slope of the Brooklyn Bridge to a perceived slope of 1.4%.

In elevation, the 100W electric-assist cyclist enjoys a perceived climb of about 12 meters compared to the actual climb of approximately 40 meters (less than a third of the actual climb).



With a slope of almost 5%, a trip over the Brooklyn Bridge is steeper than it might seem. (Source: Dave Winer via Flickr)[54]

An electric-assist motor providing only 100W of assistance can result in a 25% reduction in the time required to climb a slope similar to that of the Brooklyn Bridge.



54 https://www.flickr.com/photos/scriptingnews/4565816695/

SERVICE AREA EXPANSION

While easier travel has the ability to enhance the bicycle sharing experience of existing customers and to attract new users, it also has the potential to increase the range that each bicycle could travel from a given station within a given amount of time. This study defines this range as a station's service area.

Expanding the service area of a station has several implications, the most important of which include:

- More destinations and neighborhoods within a city accessible from a single station.
- A greater number of stations within a bicycle share system accessible from a single station.
- The ability to space stations further apart in areas that it makes sense to do so.

Both of these factors have important effects on the market for bicycle share, although those effects differ depending on the context of the system in question.

In addition to the differing effects, to what extent would the service area of an electric-assist bicycle fleet within cities in New York State actually increase when compared to the service area of a standard bicycle fleet? This section answers this question by employing a Geographic Information Systems (GIS) network analysis (explained below), and discusses the potential impacts of the service area increase on two types of systems: large, established systems and smaller, newly-launched systems.

GIS Network Analysis Process & Assumptions

Albany, Buffalo, New York City, and Syracuse are used as examples for comparing the estimated service areas of electric-assist bicycles and standard bicycles. To determine these estimated service areas, a GIS network analysis was used to trace all of the potential routes along a street network that a bicyclist could take from each bicycle share station, given a constant travel speed and time (bicyclist behavior) and incorporating the effects of topography, one-way streets, and stops at stop lights/stop signs (network factors). The flow chart below visualizes this process.

The network factors were incorporated using available GIS data, and bicyclist behavior was derived through an in-depth analysis of Citi Bike system data through February 2015. The analysis of Citi Bike usage data revealed that:

- Median speed per trip was 3.1 meters per second (about 7 mph) for subscription (annual) members.
- Median time spent traveling per trip was about 10.1 minutes for subscription members.

These two data points were used as baseline bicyclist behavior inputs for the service area analysis in each city, with the median speed being the variable that changes in the electric-assist service area.[55] As in the ease of travel model, subscription member data was utilized due to the fact that they are presumed to be more representative of a locally-based population that is familiar with their city's streets and thus likely display more rational bicycle share ridership patterns.

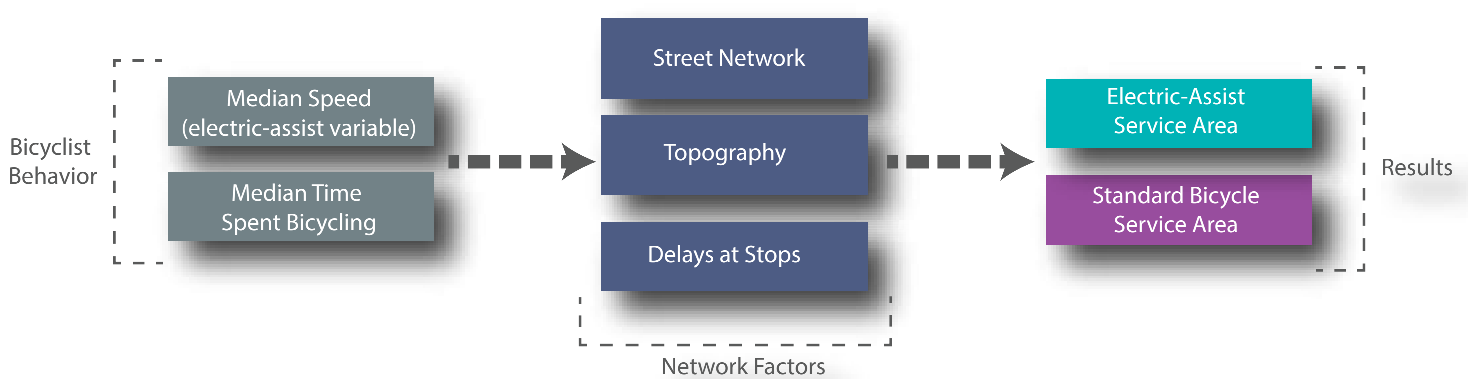
The two graphs on page 38 visually display the spreads of each median that was calculated.

Large/Established Systems (Citi Bike)

In a major existing bicycle share system like Citi Bike in New York City, the system's approximately 330 stations form a tight network that covers a large area. This network of stations is directly accessible to a wide variety of destinations, communities, and transportation hubs.

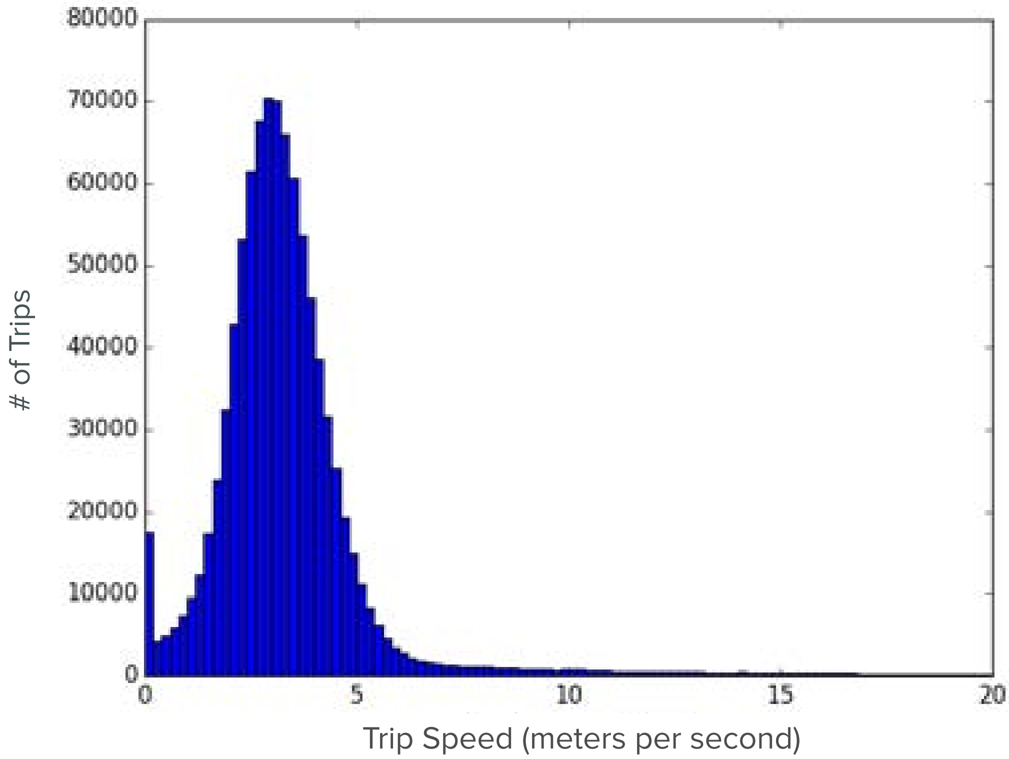
Given Citi Bike's impressive existing coverage and its plans to expand to new areas in 2015, the most important effect of a service area expansion in this context would be the ability for the average customer to use electric-assist bicycles to reach a wider range of stations and destinations.

To determine an estimated increase in service area, the GIS network analysis described on page 39 was employed on all the stations in the Citi Bike system. Of those stations, the project team chose to focus on two stations: Penn Station in Midtown (7th Ave & 33rd St), and Hanover Square in Lower Manhattan (at Pearl Street). These stations were chosen due to their locations, and focusing on two stations enables a clear visualization of the results of the analysis.



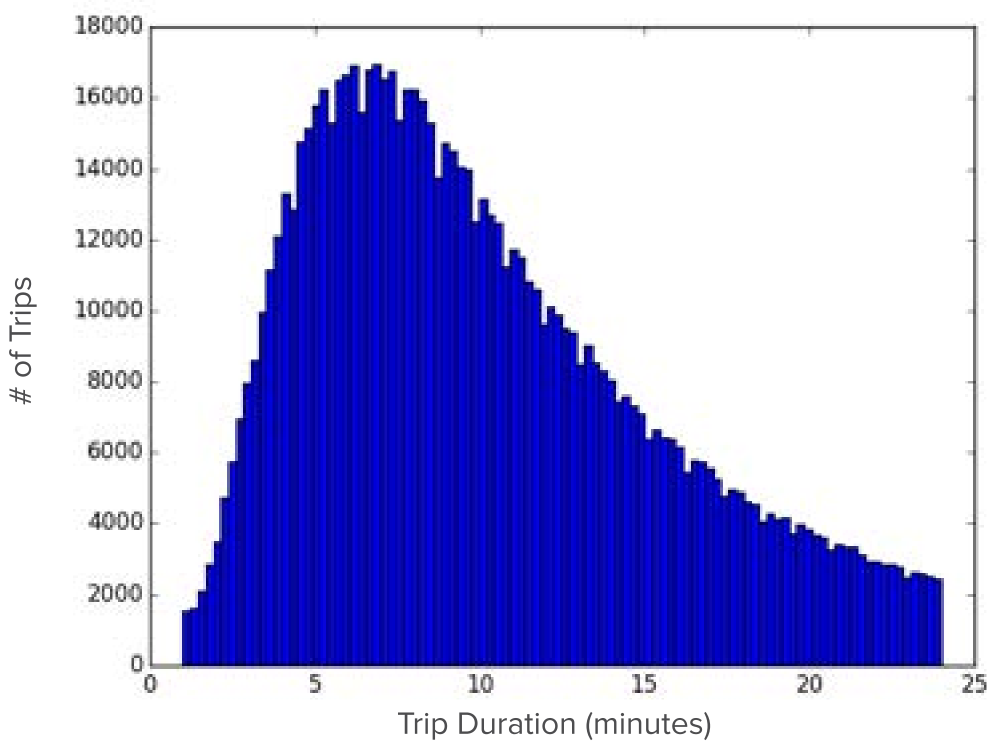
55 The increase in median speed from a standard bicycle to an electric-assist bicycle was determined using a 100W version of the flat terrain physics model shown on page 5-37.

Median Subscriber Speed (per trip)



**1m/s = 2.24 mph*

Median Subscriber Travel Time (per trip)



The map on page 40 displays the results. The estimated service area coverage from each station utilizing a standard bicycle is shown in purple, and the estimated service area coverage from each station that could be achieved with an electric-assist bicycle is shown in cyan. Existing Citi Bike stations are represented by the blue dots throughout the map, and it the map makes it clear that an electric-assist bicycle offers a noticably enlarged service area when compared with the median performance of standard bicycles in the Citi Bike fleet.

Examining each of the two stations, the table below summarizes the difference in station coverage.

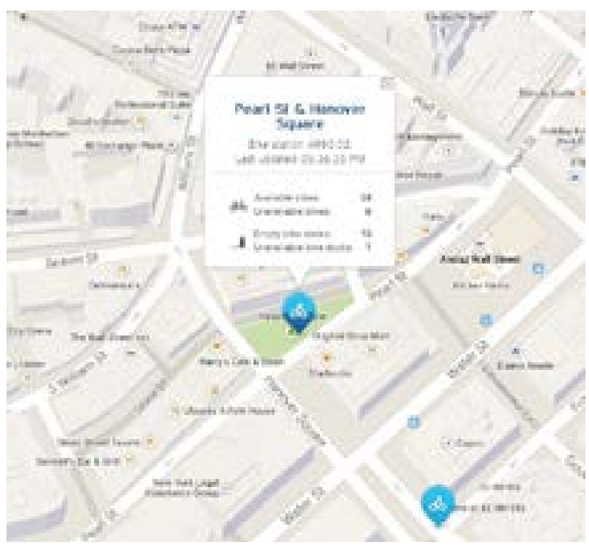
With expanded station coverages as large as +85% and +63%, utilizing electric-assist bicycles in a large, established bicycle share system like Citi Bike has the potential to allow members to reach many more stations in a single trip with the same time and effort expended on a standard bicycle trip. In addition to enhancing the bicycle share experience, this could also aid in rebalancing efforts[56] by making stations easier for customers to reach and perhaps even by incorporating software-based incentives to encourage user-intiated rebalancing. For example, a software-based incentive could offer the member a discount when their bicycle is returned to a dock that has a low inventory of bicycles.

In addition to expanded station coverage, the popularity of a large system like Citi Bike could be bolstered by the additional trip types that the longer range of electric-assist bicycles would make possible. Both the UTK studies and the Portland State University survey indicate that this impact on trips is happening in a majority of cases where people ride e-bikes regularly, and this would likely carry over to a bicycle share setting as well.

Since stations that are enabled to support electric-assist bicycles are anticipated to require a connection to the Con Edison grid, the reliable, high-powered supply of electricity could enable additional station-based operations such as advertising, wi-fi hot spots, and other perks that could attract a wider customer base over time.

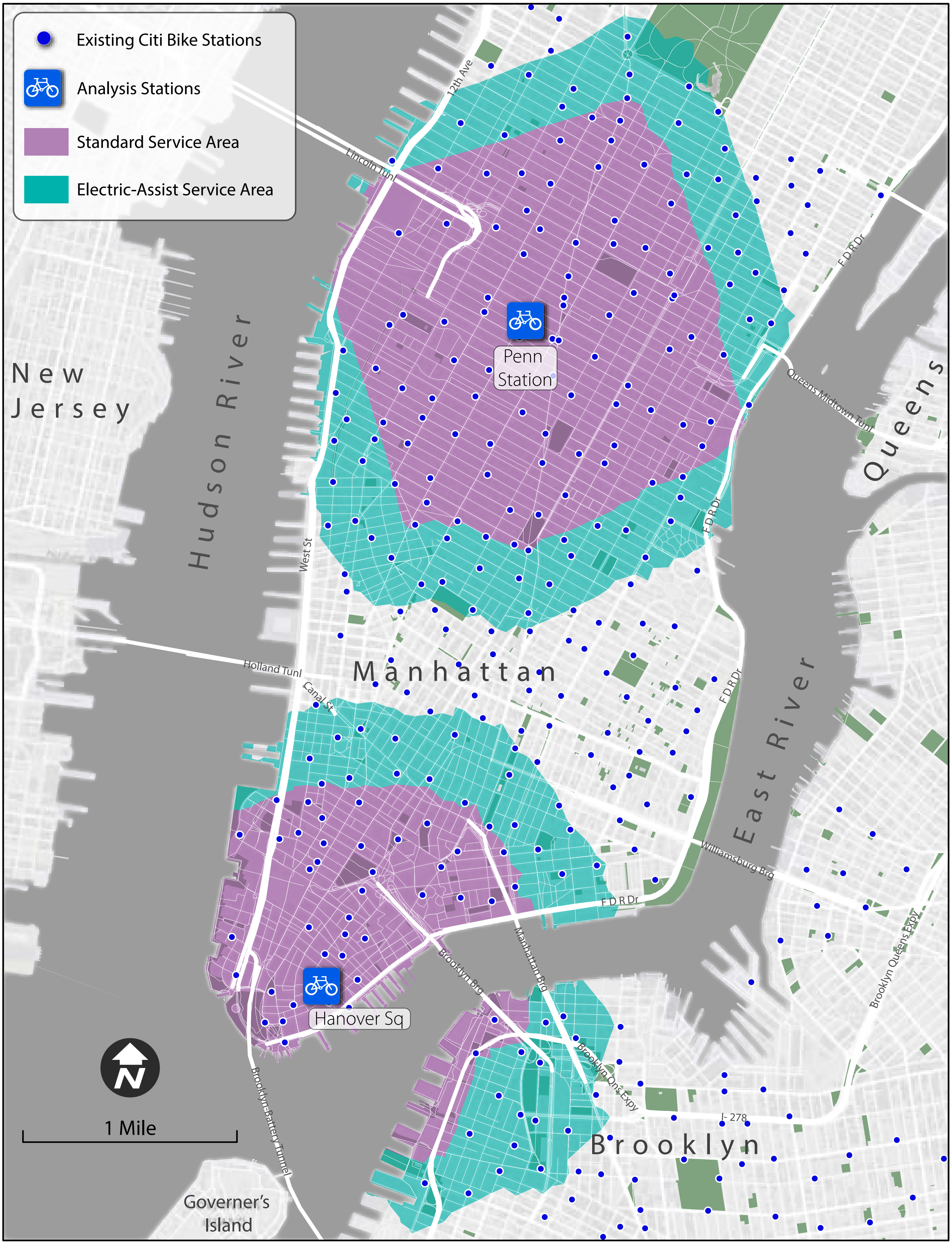
Station	Standard Coverage	Electric-Assist Coverage	Difference
Hanover Square (at Pearl St)	41 stations	76 stations	+85%
Penn Station (7th Ave & 33rd St)	79 stations	129 stations	+63%

7th Ave & 33rd St (Source: citibike.com)



Hanover Square (Source: citibike.com)

56 "Rebalancing" is a bicycle share industry term that denotes the process of manually redistributing bicycles from one station to another within the same system. This is primarily done to replenish bicycle availability at certain stations to correct inventory imbalances that arise from uneven trip distribution, and is usually a significant cost in the operation of a bicycle sharing system.


Existing Citi Bike Stations
Analysis Stations
Standard Service Area
Electric-Assist Service Area
New Jersey
Hudson River
Manhattan
East River
Queens
Brooklyn
Governer's Island
Penn Station
Hanover Sq
12th Ave
Lincoln Tunl
West St
Holland Tunl
Canal St
F D R Dr
Queens Midtown Tunl
Williamsburg Brg
Manhattan Brg
Brooklyn Brg
Brooklyn Qns Expy
Brooklyn Queens Expy
Brooklyn-Battery Tunnel
I- 278
1 Mile

Small/Newly-Launched Systems (Upstate New York)

The benefits that electric-assist bicycles could offer a major system like Citi Bike are clear. However, the majority of cities throughout the US do not currently have any sort of bicycle sharing system at all, and are unlikely to be able to support a tightly-woven network of fixed stations like those found in the nation's largest cities.

How, then, could the demonstrated service area benefits of an electric-assist bicycle system actually be of use to a smaller city with an emerging bicycle share market? One of the keys could lie in harnessing electric-assist bicycle and station technology to enable a system launch that capitalizes on some of the most cutting-edge practices in the sharing economy.

Systems like Citi Bike have shown that a tight station network is indeed important in maximizing coverage and preventing user frustration. For example, if a station that a member was planning to return his or her bicycle to in New York City unexpectedly reaches capacity, it is very likely that there would be another station with a few blocks that could be utilized as an alternative. If those stations were placed further apart, however, then the user might have to travel an unacceptable distance just to complete the trip - perhaps even further than the original trip.

This emerging rule of functionality presents a problem for smaller cities like Albany, Buffalo, Syracuse, and Rochester that may aspire to a highly visible and static station-based system, yet lack the resources and population density to justify launching a system with a tight enough station network to make it user-friendly under the existing typical bicycle share business model.

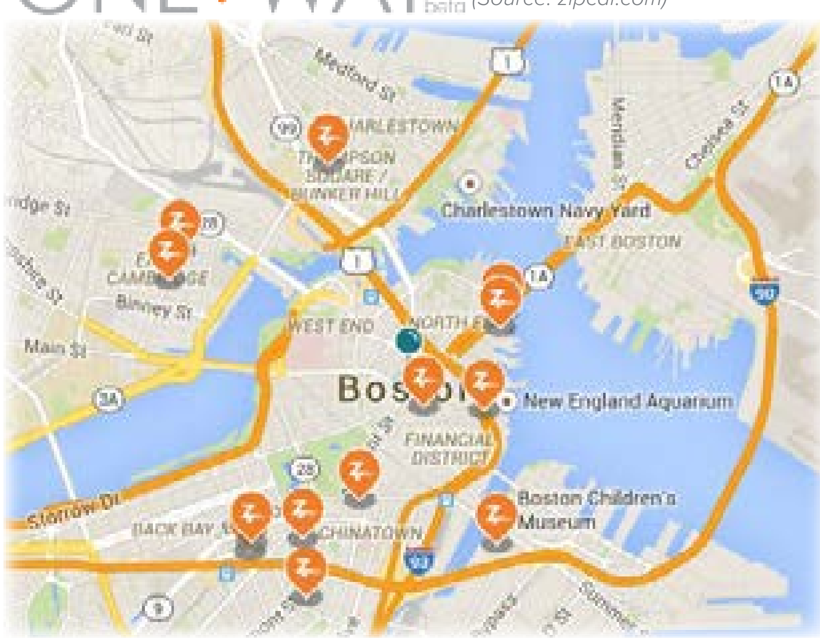
Electric-assist bicycles could help bridge this impasse. Since more distance could be covered from a given station, the stations could be placed further apart and would be more financially and operationally sustainable. In order to avoid member dissatisfaction and limited system utility resulting from stations that become full without an alternative within a reasonable walking distance, methods currently employed at the world's leading car share companies could be incorporated into a low-density electric-assist bicycle sharing system.

Practices at Zipcar's One->Way beta test in Boston and and Car2Go are the most relevant to this study. Car2Go offers one-way car sharing in cities across the world, and members are billed by the minute to encourage short trips within "home areas" that allow members to park in specified, generally on-street, parking zones. In addition, reservations can only be made as much as 30 minutes in advance, making the system fluid yet ensuring that the car one chooses does not disappear by the time one reaches it. Parking at one's destination is not guaranteed, however, which can result in frustration and time spent circling the block while charges to your credit card rack up. Zipcar's One->Way beta attempts to eliminate this frustration by not only allowing users to reserve a car in advance, but also to reserve a destination parking spot in advance. This reduces overall flexibility, but as a trade-off ensures that a member is able to park quickly and easily at his or her desired destination.

If a combination of these practices were to be employed in an electric-assist bicycle sharing system in a smaller city with a dispersed station structure that prioritizes major generators and residential centers, then the system may have a better chance of success. There would be technological and logistical issues to contend with, but grid-connected, reliably-powered stations inherent to an electric-assist bicycle share system would be the first step in providing this sort of functionality. A notable drawback, however, would be that customers may be faced with a longer walk between a station and their final destination.

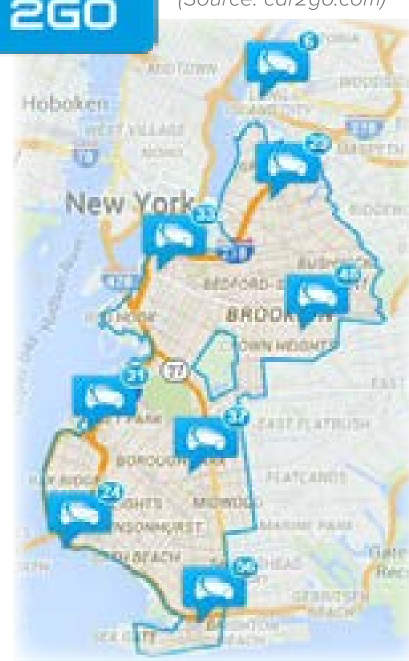
The maps on pages 42 to 44 will analyze some potential service areas of each selected Upstate New York cities, using two theoretical bicycle share stations within each city.

ONE>WAY beta



Zipcar One->Way Beta's locations (Source: zipcar.com)

CAR 2GO



Car2Go's Brooklyn "home area" (Source: car2go.com)

Albany

As a city of almost 100,000 people with a relatively high concentration of political, medical, and educational activity centers, potential for bicycle share exists and was documented in a June 2013 feasibility study. One of the recommendations in the feasibility study was to use a phased approach to station deployment, with phase 2 expanding beyond the most densely populated downtown areas.

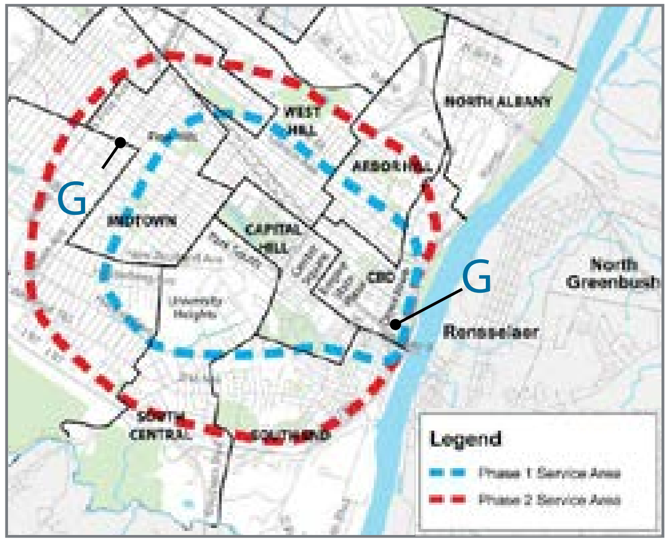
With this phasing in mind, the following theoretical stations were chosen for the Albany analysis:

- Broadway & State Street (downtown)
- Madison & Western (commercial hub)

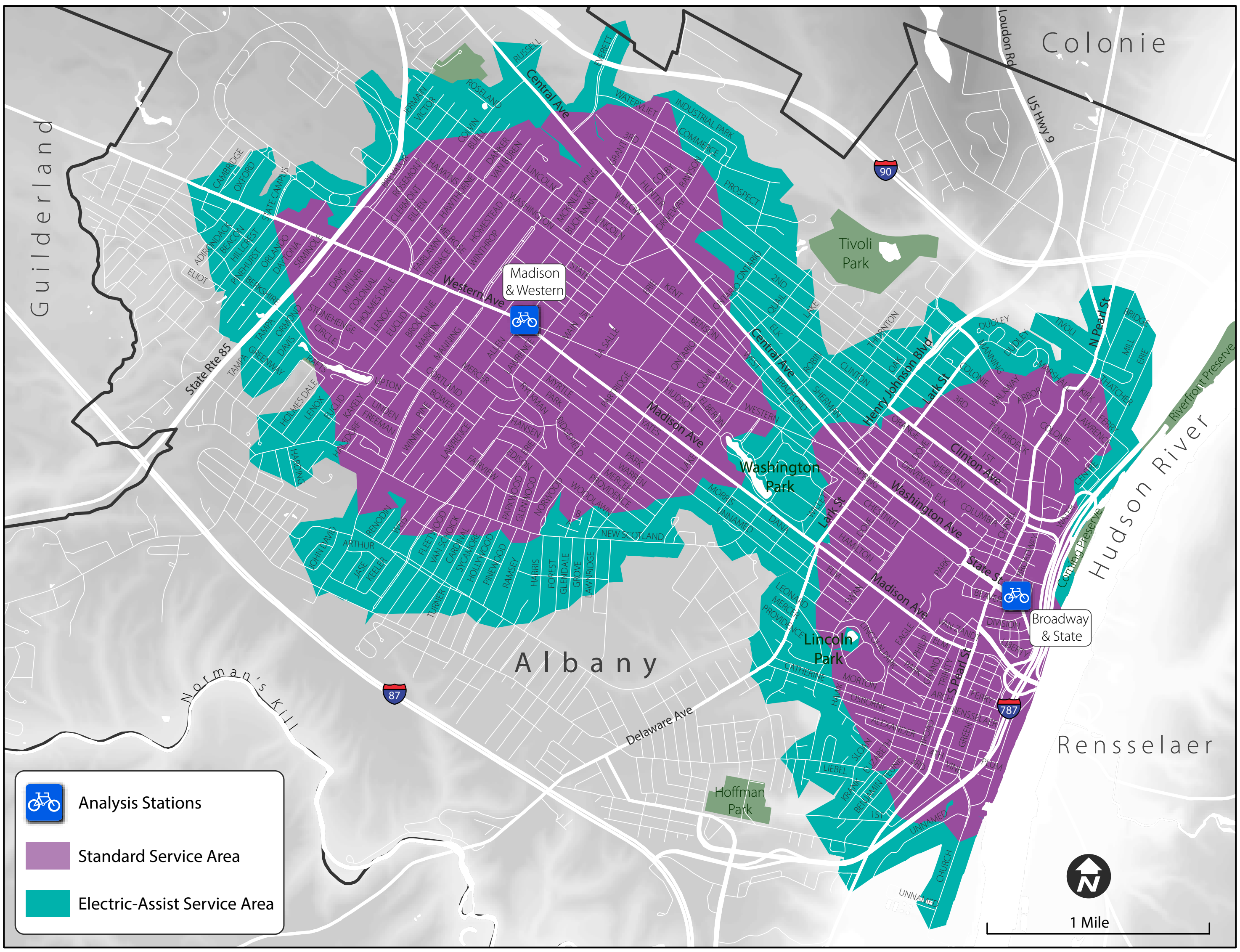
The downtown station lies at the foot of a sizeable hill, which is a considerable obstacle to bicyclists in Albany. The "flattening" of that hill with an electric-assist bicycle shows that many more destinations are reachable from Albany's downtown core.

The potential station at Madison & Western is a recently revitalized hub of activity, from which an electric-assist bicycle could reach many parts of the city. Indeed, the service areas of the two stations converge under an electric-assist scenario, and the increased range could be one of the keys in bringing together otherwise disparate parts of what could very well emerge as a regional Albany-Schenectady-Troy bicycle sharing system.

City of Albany Bike Share Feasibility Study phasing plan (2013)



Service Area Analysis - City of Albany



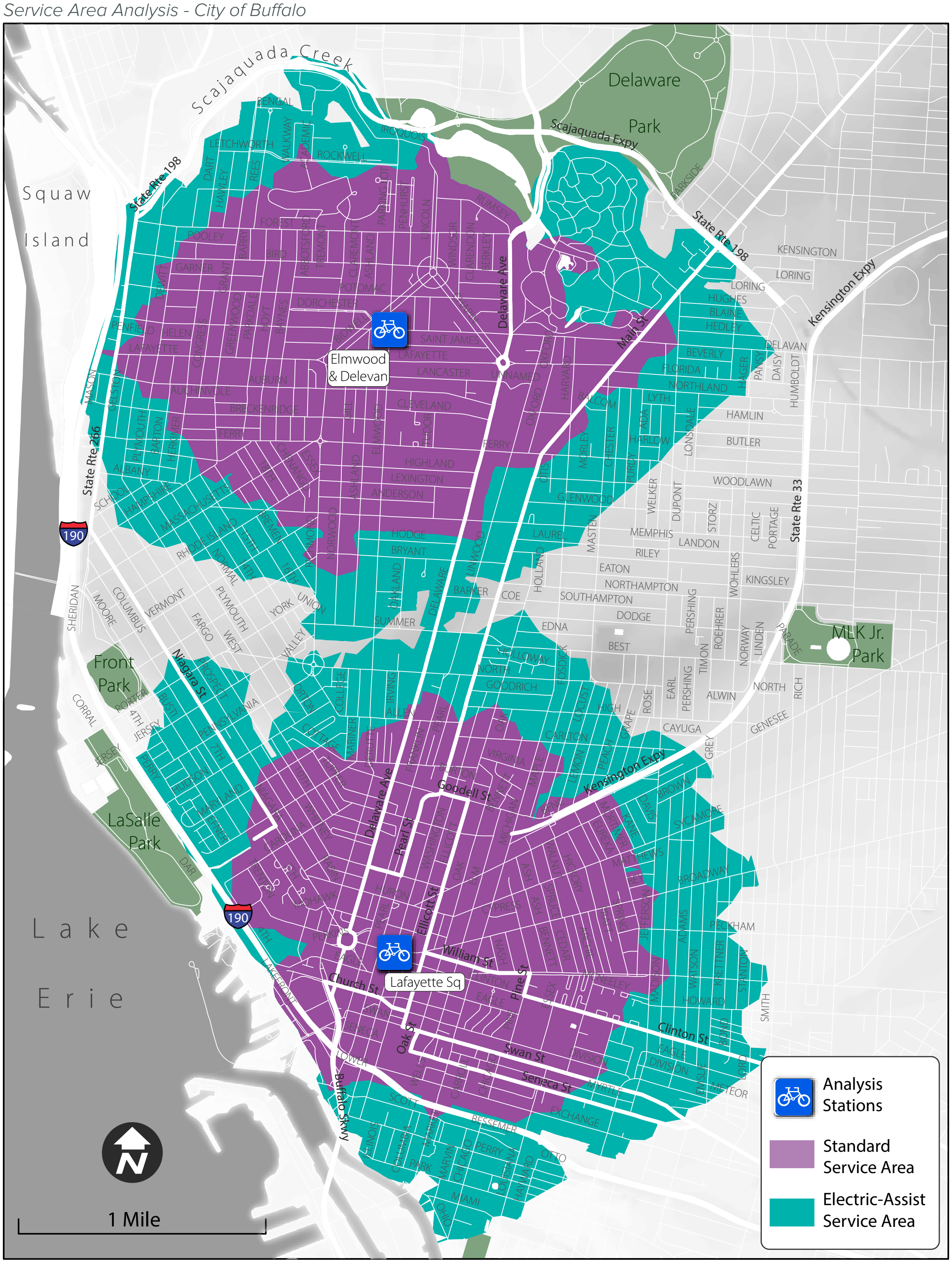
Buffalo

Of the Upstate cities highlighted in this chapter, Buffalo is the largest at about 260,000 residents. It is also the only city in Upstate New York that currently has a formal bicycle sharing system, although it is limited to free-floating Sobi bicycles. For the analysis, these potential stations were chosen:

- Lafayette Square (downtown)
- Elmwood & Delevan (commercial hub)

The electric-assist bicycles again cover quite a large area in comparison to the standard bicycle coverage. Given Buffalo's relatively large land area and diversity of neighborhoods, the electric-assist service area is important and could be used as to justify a fixed-station network that is more widely spaced than in other cities.

Service Area Analysis - City of Buffalo



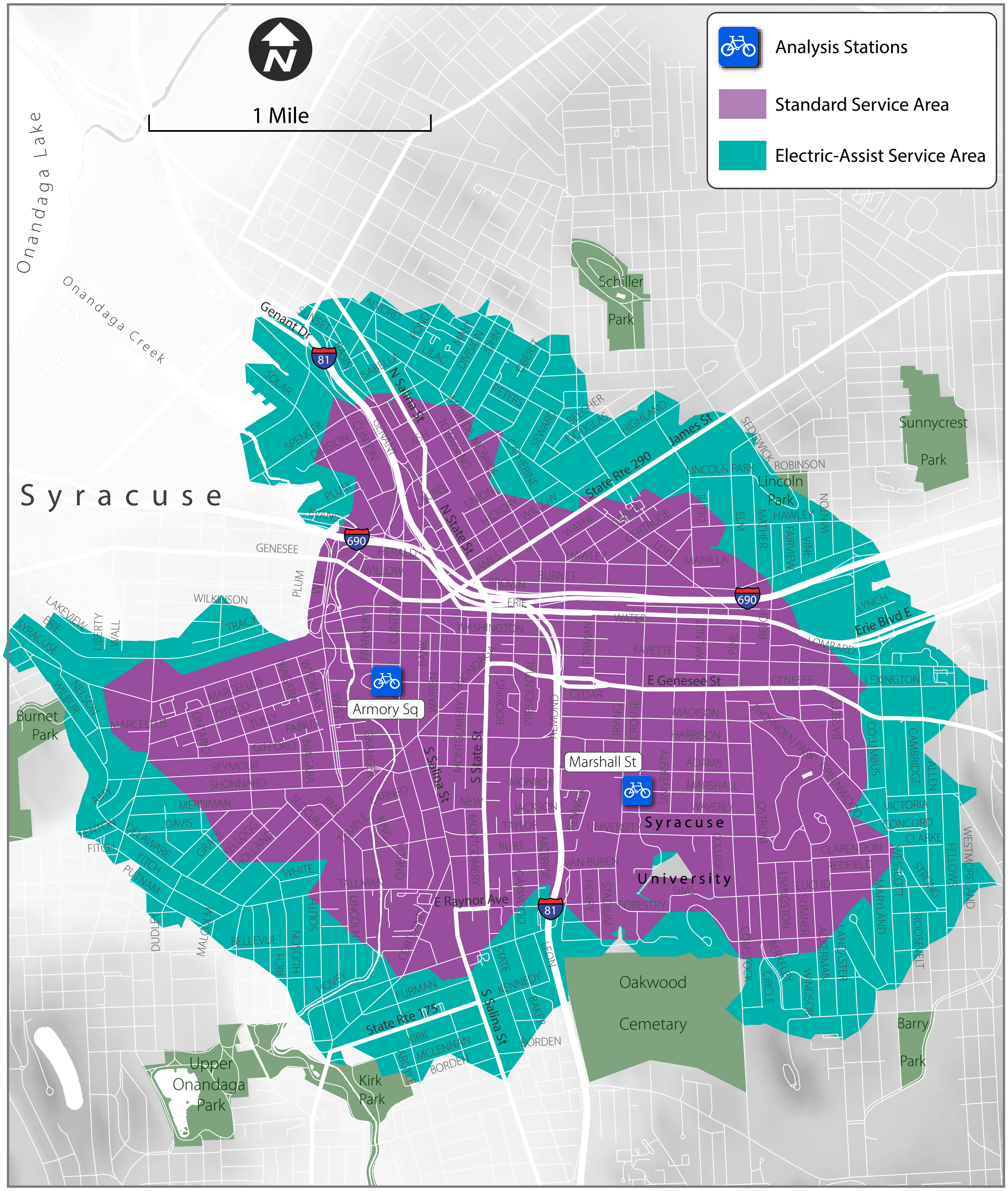
Syracuse

In comparison to Albany and Buffalo, Syracuse's downtown area is very compact, with major hubs of commercial, residential, student activity occuring relatively close together. For the Syracuse service area analysis, the following theoretical stations were selected:

- Armory Square (downtown hub)
- Marshall Street (student hub - Syracuse University)

The results of the analysis show that both standard and electric-assist service areas for the two stations converge quite a bit, although the electric-assist service area is again larger by a good margin. For a potential electric-assist bicycle system in Syracuse, one of the primary benefits of a larger service area would be the ability to locate more widely-dispersed stations in some of the city's residential areas that might not receive as much (if any) service under a standard bicycle share system.

Service Area Analysis - City of Syracuse



BATTERY LIFE

While the potential benefits of electric-assist bicycle sharing are clear, the way that a bicycle's battery life could affect operational concerns and the customer experience needs to be examined closely.

For the purpose of this analysis, a large battery on an electric-assist bicycle share bike operating on a single charge at 48V/20 Ah is expected to provide up to about 6 hours of electric-assist before depleting, and is also expected to be charged primarily overnight. With this in mind, the key question becomes: about how long would each bicycle be ridden per day? To answer this question, the study again examines data from Citi Bike's system.

Median Daily Usage per Bicycle

Looking at Citi Bike data available for September 2013,[57] out of all bicycles that experienced at least one use, the median total daily use of each single bicycle was 1.6 hours. Of all examined bicycles:

- 50% were used for 1.6 hours per day or less.
- 80% were used for 2.6 hours per day or less.
- 95% were used for 3.9 hours per day or less.
- 99% were used for 5.6 hours per day or less.

The most important statistic here is that, during the period examined, 99% of bicycles that were used at least once experienced less than 5.6 hours of usage per day.

This data suggests that, given a 6 hour charge, nearly all bicycles in an electric-assist fleet would have enough charge to get through the day without needing to be recharged during its time spent at stations between uses.

While per-bicycle daily usage could increase if an electric-assist system with fewer bicycles and longer distances between stations was introduced, it appears unlikely that most bicycles would be used for more than 6 hours per day. If that somehow became the case, then trickle-charging at stations between uses could be used to help support demands on battery life. In addition, although a depleted battery is not desirable in any case, low-battery notifications could be provided both on the bicycles and on computers or mobile devices as measures to prevent a customer from taking out a bicycle with a charge that may be too low to support his or her trip. The computer/mobile device notification method would be particularly helpful in a system that employed the one-way reservation system described on page 41.

If all else were to fail, the bicycles are still designed to be ridden without a charge, so a depleted battery would not result in the sort of stranded customer situation that might arise in the case of an electric car.

Median Daily Rest Time per Bicycle

If trickle-charging is to be an option, then the question of how long each bicycle typically rests at given station becomes important.

Examining Citi Bike usage data for the same month (September 2013), the following numbers emerge:

- ***Median Rest - 15 hours***
- 10% = 8 hours of rest per day
- 5% = 7 hours of rest per day
- 1% = 5 hours of rest per day

The median rest of 15 hours suggests that, even on the busiest days, most bicycles still get quite a bit of rest time at stations. However, in the previous section we saw that the busiest 1% experience a median usage of about 5.6 hours. With that in mind, this rest time data appears to tell us that as the day gets busier, the proportion of rest that comes from smaller intervals grows dramatically. This high turnover effect may be mitigated in smaller systems with stations that are further apart, but would likely remain consistent in large, high-density systems like Citi Bike.

All of this means that trickle-charging would be limited during the busiest 1%, but would be a viable option for the majority of cases, since the even the busiest 10% experience a rest time of 8 hours per day.

Overall Effect of Battery Life

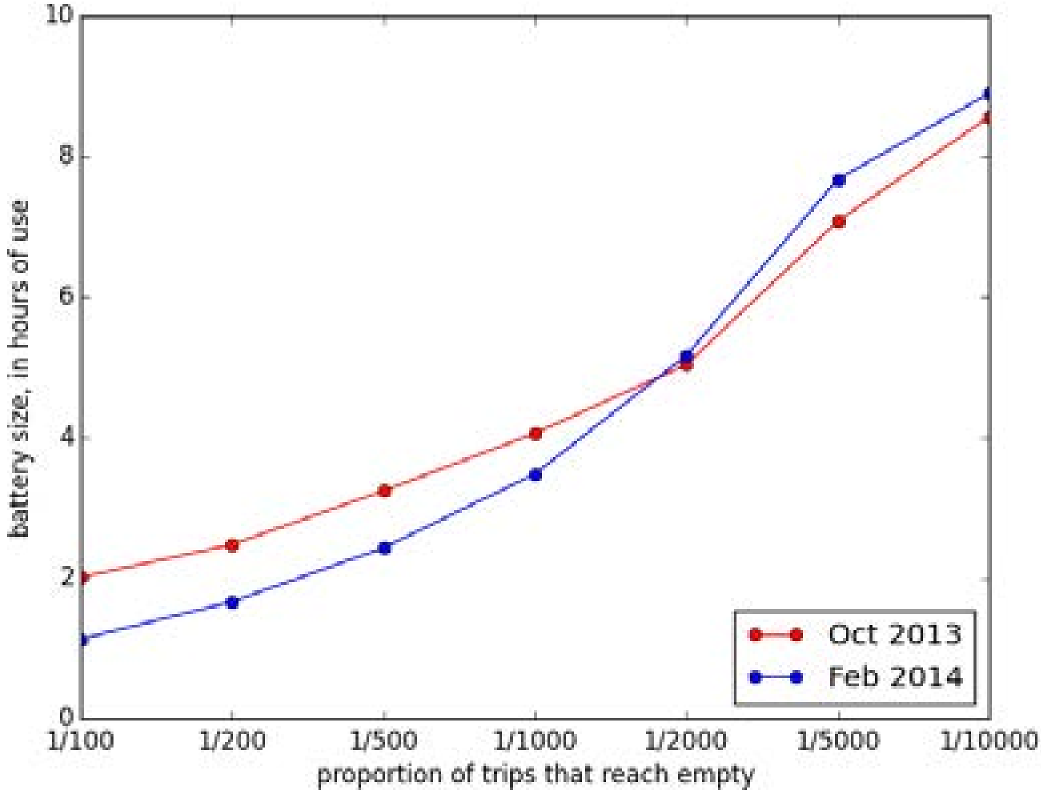
In the end, what would battery life as a constraint actually mean for the customer experience? Citi Bike data from October 2013 and February 2014 was analyzed in light of the conclusions from the previous two sections. October 2013 was chosen because it was the busiest month at an average of 180 trips per bicycle, and February 2014 was chosen for comparison since it was the slowest month at an average of 40 trips per bicycle.

The graph on page 46 shows about how many trips per month would potentially reach empty given a certain battery charge. At 6 hours of charge, only about 1 in 3,500 bicycles would be projected to reach empty per month. One would expect that October needs a much bigger battery and/or a faster recharge rate to accommodate the increased demand. It should be noted, of course, that these results do not take proactive customer action into account (i.e., avoiding a low-battery bicycle when notified of the situation).

However, it appears that at after roughly 6 hours of charge, the effect of several unusually long trips becomes much more important. In February 2014, there were both fewer long trips and fewer overall trips than October 2013, but the proportion of long trips is much higher. In sum, 0.4% of trips were over 2 hours in February 2014, vs. 0.2% in October 2013. These longer trips cause problems, and a higher proportion of trips run out of charge.

57 September 2013 was chosen because it was found to be most representative of the available data.

Daily battery charge vs. number of trips that experience a dead battery



What this tells us is that, given a daily battery charge that is in line with the upper bounds of per-day usage, the effect of bicycle supply and demand is very small compared to the effect of a few users making unusually long trips that deplete the battery. This is very good news, in the sense that neither a potential increase in usage (demand) caused by electric-assist bicycles, nor a decrease in rest time, is likely to negatively impact the customer experience, particularly in light of the benefits that electric-assist bicycles confer.

Also, if the main instances in which a battery is depleted result from a few unusually long trips, then the customer can be easily made aware of the low battery before he or she even checks out the bicycle, minimizing user frustration related to battery life issues. This also means that very few bicycles would be anticipated to be "off the grid"[58] on a given day.

In conclusion, a 6 hour daily battery charge would provide enough battery life for normal bicycle share operations on the majority of days and in the majority of situations, and would not be expected to negatively impact the overall customer experience.

58 Having as many bicycles "on the grid" (available for customer use) as possible at all times is important in netting as many trips and as much revenue as possible.

POTENTIAL DRAWBACKS OF ELECTRIC-ASSIST BICYCLES

The benefits of an electric-assist bicycle sharing fleet are expected to outweigh any negative factors, and such systems have already been shown to be successful in a variety of settings. Nevertheless, it is important to outline some of the drawbacks that occur in the context of an electric-assist system.

Technological & Operational Complexity

Wherever a new technology is applied to an existing paradigm, the potential for technological and/or operational failures are increased. However, electric-assist technology has already reached a point at which the parts and components are fairly user-friendly, and this trend is expected to continue. In addition, there are existing electric-assist bicycle sharing systems that have already contended with this dynamic, and none have experienced major setbacks due to the technology.

Operationally, new practices would have to be introduced to safeguard the user experience in the face of e-problems specific to e-bikes, particularly the dead battery issue. As noted, the occurrence of dead batteries is expected to be small and manageable. Still, this will require the cultivation of a proactive approach to troubleshooting to avoid member frustration before it is allowed to happen, rather than reacting solely to member complaints. This could take the form of ensuring a dynamic battery monitoring system that alerts existing staff to low battery events, in conjunction with a software mechanism that prevents low-battery bicycles from being checked out or reserved.

Technological complexity may also induce the need for explicit instructions regarding how the electric-assist bicycles function. This could be accomplished both on-site at stations and electronically via the system's web site and mobile app. The most important drawback of this complexity may be the inadvertent creation of a barrier to entry for unnecessarily intimidated consumers, but is nothing that proactive online/offline member education efforts and clear kiosk directions would be unable to solve. In small systems, new members could even be invited to an in-person orientation, as is the practice at smaller car sharing organizations like Albany's Capital Carshare.

Pricing

At present, bicycle sharing systems generally offer an outstanding bargain to consumers. At a rate like $149 per year, the Citi Bike system is very affordable and even modest price increases would be unlikely to drive away those that value the service. An electric-assist system would entail higher prices than a standard fleet, but the value-added for consumers that the electric-assist bicycles bring to the table are expected to more than justify this increase. Furthermore, there is actually the chance that pricing could be more sustainable in some smaller cities when compared to a standard fleet, assuming a scenario in which fewer electric-assist stations are able to serve the same (or greater) number of customers. System finances will be discussed in the next chapter.

Perceived Safety Concerns

Although there are no documented cases where electric-assist bicycles have presented any safety concerns that are more severe than those found within the operation of a standard bicycle share fleet, public perception may still lag behind industry knowledge and standards. For example, residents of New York City may be apprehensive about a fleet of electric-assist bicycles if they (erroneously) associate those bicycles with powered bicycles, scooter-style electric bicycles, or even mopeds and motorcycles. In some cases, public agencies may also be wary of electric-assist bicycles.

The perception of e-bikes has been moderating dramatically in recent years, and more and more states are recognizing the legal status and true operational safety of low-powered e-bikes. Therefore, an awareness of these perceptions and an attempt to meet them head-on when planning for an electric-assist system should be enough to assure interested groups that electric-assist bicycles will not pose any new threats to safety.

NEXT STEPS & FUTURE RESEARCH

7 NEXT STEPS & FUTURE RESEARCH

As this study has demonstrated, electric-assist bicycle share will be feasible in New York State as soon as the legal situation is resolved. Other cities are also recognizing the potential for electric-assist bicyles in a bicycle sharing context. In addition to Birmingham, Alabama's upcoming partial electric-assist system rollout, Seattle's recent TIGER[59] grant application seeks funding to "launch a 250-station, citywide electric-assist bikeshare expansion to provide first-mile/last mile access to the region's light rail and Rapid Ride system."[60]

Following this trend, electric bicycle technology has seen rapid improvements over the past couple of years, with at least one North American manufacturer (Bewegen) working on bicycle share applications of electric-assist technology for use in Birmingham, AL.[61]

Implementing an electric-assist bicycle share system in New York State will hinge upon the right technology that can accommodate the State's unique range of urban environments and grid connection requirements. A locally manufactured system would also promote efficiencies and maximize local benefits. The technological specifications outlined in this study will also need to be more thoroughly tested and investigated.

In addition to the right technology, it will be important to engage corporate, municipal, and state partners early on in the development process. Partnerships with these entities will help boost chances for productive sponsorship arrangements, while providing opportunities to engage New York State cities in a conversation about their interest in hosting an electric-assist bicycle share system. Additionally, working with existing bicycle share operators like Motivate and Shared Mobility will be essential in ensuring that the electric-assist bicycle share technology that emerges from this project is not only viable for use in new markets, but also that is able to be incorporated into existing markets. In sum, the following items are recommended for further action:

Engage municipalities

Successful deployment of electric-assist technology will hinge upon the willingness of local governments to help support an electric-assist bicycle share system. At minimum, cities need to be amenable to providing space on public right-of-way for bicycle share stations. At best, host cities could also participate in funding a system. All engagement efforts should use each city's experience with bicycle share planning and operation to date (outlined in chapter 1) as a starting point.

Cultivate private and non-profit partnerships

A significant amount of funding for an electric-assist system may spring from the private sector, and a non-profit operations arrangement is a distinct possibility, particularly for new and smaller bicycle share markets.

Coordinate with existing bicycle share operators

To the extent possible, it will be important to coordinate product/technology development with existing bicycle share operators - particularly Shared Mobility in Buffalo and Motivate in New York City. This would help ensure that this project's electric-assist bicycle technology remains compatible with existing operational structures, while also beginning conversations and relationships that could lead to targeted field testing and eventual sales.

Continue technological development

While the technological specifications outlined here constitute a proof-of-concept and demonstrate the feasibility of an electric-assist bicycle share system, the technology will be taken to the next level during prototype design and deployment in Phase 2. During this next stage, the project team will further consider dynamics like the system software implications of battery charging and discharging rates, the effects of ambient temperature on battery performance, and the possible effects of wear-and-tear on the new electric-assist components.

59 Administered by USDOT, Tran Transportation Investment Generating Economic Recovery (TIGER) grants are a competitive funding source that provide millions of dollars in funding for local transportation projects.

60 "Northgate Non-Motorized Access to Transit and Education." City of Seattle FY 2015 TIGER Grant Application.

61 Bewegen Technologies. "https://www.bewegen.com" Accessed 6-8-2015

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