BUILDING A BRIDGE WHEN NOBODY IS SWIMMING ACROSS THE RIVER: ASSESSING THE POTENTIAL FOR SHARED ELECTRIC BICYCLES TO CONNECT OUTER SUBURBS IN CHITTENDEN COUNTY, VERMONT

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ABSTRACT

In central Chittenden County, Vermont (the cities of Burlington and Winooski and some parts of the city of South Burlington), Greenride Bikeshare, via Gotcha Bikes, has operated a small (105 conventional bikes) bicycle share program for the last two years. In the fall of 2019, in anticipation of replacing the conventional bicycles with 200 e-bikes, the Chittenden County Regional Planning Commission (CCRPC) performed an assessment of the future of shared mobility within the existing bikeshare service area (*1*). This assessment includes a demand analysis that considers multiple factors and generates a "demand score" for each census block in the existing service area.

This paper examines the feasibility of providing bicycle share hubs in areas outside of the existing service area by using shared electric bicycles. Existing research about the differences between conventional and e-bike use patterns and perceptions is used to propose a new assessment tool. This tool adapts the methodology used by the demand analysis in the 2019 *Chittenden County Shared Mobility Analysis* (*1*) to account for the use of e-bikes and to focus on system expansion rather than equitable distribution of hubs within an existing system. Census blocks within 5 kilometers of the existing service area boundary and particularly those in and adjacent to a state-designated Growth Center and Village Center in the suburban community of Williston, Vermont are examined in greater detail to provide examples of how electric bicycle share might work in outlying communities beyond the boundaries of the existing service area.

Keywords: bike share, e-bike, suburban

INTRODUCTION

> "Remember, when asked to prove that #bikelanes would be well used, it's hard to justify a bridge by the # of people swimming across a river." - Brent Toderian, 2014 (*2*)

Burlington, Vermont, and the adjacent cities of South Burlington and Winooski host a recently-established bicycle share program, consisting of 105 conventional bicycles at 15 hubs (*1*). A planned expansion, originally hoped to replace the conventional fleet with 200 electric-assist bicycles (e-bikes), was temporarily shelved in fall 2019 due to difficulties related to increased tariffs on goods imported from China, (3) and has been further delayed due to the impact of the COVID-19 pandemic on exports from that country. In anticipation of this eventual near-doubling of the share system and simultaneous total conversion of the fleet to e-bikes, the operators of the system have begun to consider how to distribute the additional bicycles within the existing service area.

If the expansion does take place eventually, the extended range, speed, and hill-climbing capability of e-bikes could be considered in determining how to grow the bike share system geographically beyond the current system boundary. The lower level of perceived and actual physical effort necessary to propel an e-bike (especially compared to relatively heavy conventional bikeshare bikes), the ease with which hills can be climbed and deficiencies in infrastructure navigated, and the added speed with which greater distances can be traversed, all suggest that e-bike use in a bicycle share context should be modeled differently than conventional bicycles. Further, because e-bikes can go farther and faster than conventional ones, it may be possible to consider a more geographically dispersed expansion of a bicycle share system boundaries when e-bikes are substituted into an existing system. Compared to an assessment of how to distribute additional bikes and hubs within an existing, urban system, expanding into the suburbs could be evaluated using a modified method that de-emphasizes geographic proximity of bike eshare hubs to one another.

A recent assessment (*1*) of the future of shared mobility within the existing bicycle share service area around Burlington, intended to inform the placement of new bicycle share hubs and the distribution of the 200 proposed new e-bikes, includes a demand analysis that considers multiple factors and generates a "demand score" for each census block in the existing service area. The existing analysis, in addition to being geographically limited to the existing system boundary within the three cities of Chittenden County, considered population density by census block while also factoring in equity, car ownership, proximity to "attractions," and proximity to existing bike share hubs. Based on this score, 18 new station hubs and 19 new "virtual hub" locations are recommended to be added to the existing service area (*1*). An expansion of the service area was not considered in the analysis.

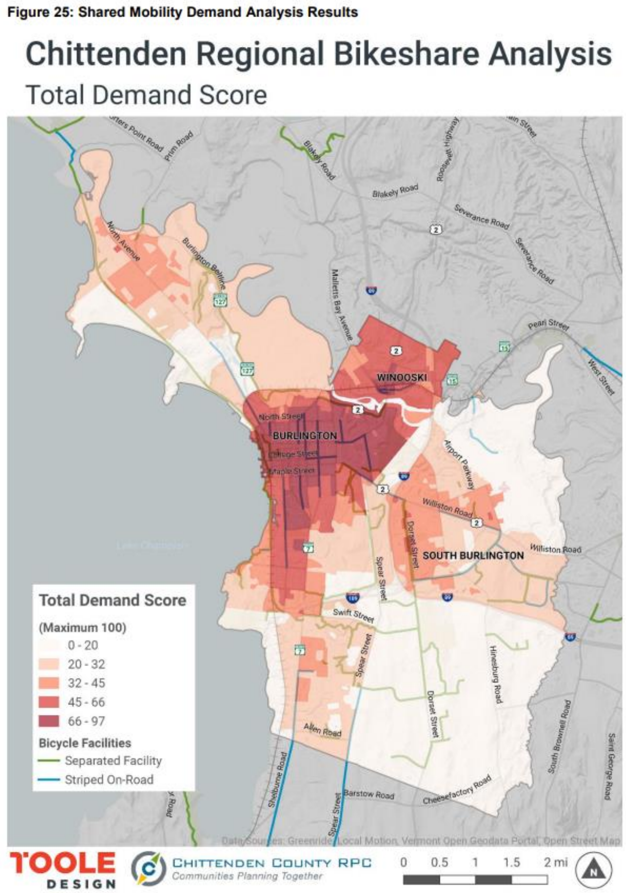
FIGURE 1. Scoring Matrix Used in the *Shared Mobility Regional Analysis* (*1*)

Table 1: Demand Scoring

Data Item	Factors	Proximity Factor 0.25 Mi	Proximity Factor 0.5 Mi	Total Points
Intersection Density	**12.5**			12.5
Population Density	**12.5**			12.5
Employment Density	**20**			20
Attractions		**17.5**	8.75	17.5
Universities		10	5	
Points of Interest (Church St, Waterfront, Hospitals)		5	2.5	
Existing Greenride Hubs		2.5	1.25	
Bus Stop Boardings and Alightings		**5**	2.5	5
Alternative Commuters	**10**			10
Bicycle Commuters	5			
Pedestrian Commuters	5			
Equity	**22.5**			22.5
Minority	8.75			
Low-Income Households	8.75			
Zero-Car Ownership	5			
Total Score				100

These metrics may disadvantage an analysis of suburban Chittenden County beyond the current service area boundary, where few people can walk to work or get by without owning a car, existing bicycle share hubs are nonexistent, and “attractions” are limited. While equity is an important consideration within the service boundary and may be important outside of it, the population of minority, low-income, and car-free households in the suburbs may not be the best indicator of potential bicycle share usage. Deployment of e-bikes in an expanded system might make the number of existing pedestrian and bicycle commuters in a census block less relevant to the analysis because e-bikes allow people to ride routes and distances that conventional bikes may not, sometimes at travel times that are comparable to a transit ride. E-bikes are typically able to achieve pedal-assisted speeds of up to 20 miles per hour and can climb hills with steep (8-10%) grades at half that speed with less effort than it would take to ride a conventional bike the same speed on flat ground(*4*). Following existing patterns of bike commuters without considering the enhanced capabilities of e-bikes could amount to “not building the bridge because nobody is swimming across the river.”

FIGURE 2. The Existing GreenRide Bikeshare Service Area, Demand Score Map from the *Shared Mobility Regional Analysis* (*1*)



The possible substitution of conventional bicycles with e-bikes warrants consideration of expanding the system geographically. Researchers have noted that, in contrast to users of conventional bicycles, e-bike users report that they are better able to navigate hills and can use e-bikes to commute to work without sweating excessively, such that they do not need to shower upon arrival (*5*).

This possible uptick in system use due to e-bikes has been noted in two recent examples. In Madison, Wisconsin, the recent conversion of its bike share system to e-bikes was in part informed by pilots performed by Bcycle, its vendor. In those pilot programs, introducing e-bikes resulted in increases in ridership ranging from double to five times the ridership the system had with conventional bicycles(*6*). According to Bcycle, ridership in Madison since the change has also more than doubled (*7*). Cobb County, Georgia is also considering the use of shared e-bikes in an expansion of its regional bike-share system, which would connect several suburban centers to one another, as opposed to a more traditional urban downtown-centered system(*8*).

Much of the existing research on e-bike adoption and usage has been related to e-bike ownership and the reported experiences of those new e-bike owners. A bicycle share program that provides e-bikes presents an opportunity for people to experience the difference between conventional bikes and e-bikes without committing to a purchase.

LITERATURE REVIEW

Existing research that is helpful in understanding how e-bikes might work in a suburban bikeshare system covers a range of topics, from use patterns by e-bike owners and pilot study participants, to tests of actual physical or perceived exertion, to assessments of the utilization of existing conventional bikeshare systems, to the relationship between recreational and utility use of e-bikes. A few researchers have noted the particular circumstances in which e-bikes might have applicability in a sharing system. For example, Ji et. al. (*4*) discussed the suitability of e-bikes for a “spread out,” hilly environment in their modeling of a potential e-bike share system for the University of Tennessee, Knoxville while also noting that the availability of e-bikes through a bike share model could overcome cost barriers associated with the purchase of an e-bike (*4*). The combination of reduced actual and perceived effort, increased ride distance and willingness to ride, lower cost barriers, and suitability in hillier and more geographically dispersed areas all suggest that the addition of e-bikes to a bicycle share system should be evaluated using different metrics from those that are more applicable to conventional bicycles.

E-Bikes and Physical Exertion

Langford (*9*) found a 24% difference in energy expenditure between e-bikes and conventional bicycles on a closed course in Nashville, Tennessee that included a hill. Participants also rated their perception of exertion and perceived a lower level of exertion when using the e-bikes. Finally, participants reported a higher need to shower after the trial when navigating the course by walking or with a conventional bicycle as compared to using an e-bike. Gojanovic et. al. (*10*) compared groups of otherwise sedentary pedestrians, conventional bicycle riders, and e-bike riders on a hilly course in Switzerland. The authors found that while e-bike users still had to make a physical effort that was likely to meet minimum requirements for exercise, they reported a significantly lower desire to shower after completing their trip on a e-bike compared to riding a conventional bicycle or walking. Both the real and perceived differences in effort and need to recover or shower after an e-bike trip could encourage riders to take them for longer trips than conventional bikeshare bicycles, which are often quite heavy and limited in their gearing.

E-Bikes and Perceived Effort

Fishman and Cherry (*11*) noted that e-bike users across multiple studies report that they ride more frequently and for longer distances than with conventional bicycles. The authors noted that the existing research did not suggest whether riders were riding longer because they had e-bikes, or had chosen to purchase e-bikes because they had longer trips to make- this may be a less relevant distinction when the goal is to determine whether e-bikes in a bike share system could be used over a larger service area.

E-Bikes and Utility Travel

Kroesen et. al. (*12*) found that e-bike owners in the Netherlands substituted significantly more of their car travel with e-bike travel than those who substituted car travel with conventional bicycle travel, suggesting that e-bikes can be used to substitute for more trips, longer trips, or more challenging trips. Fyri and Fearnley (*13*), in a study in Norway, found that providing e-bikes to test subjects increased both the number of commute trips they took by bike as well as the total mileage ridden, as compared to subjects who received the use of conventional bicycles. The authors also found that as users grew accustomed to the e-bikes, they used them more, suggesting that any pilot of an e-bike share system expansion should be in place for a length of time that allows for users in the service area to “learn” what trips they are capable of making on the e-bikes. Popovich et. al found that e-bike users they interviewed reported using the bikes they had purchased 80% for transportation (as opposed to recreational riding) (*14*). Thus, adding e-bikes to a bicycle share system might increase the amount of transportation cycling the system is used for. In a study that used GPS tracking on personally-owned e-bikes, Lopez et. al found that users of e-bikes took longer journeys and traveled more frequently on work days than users of conventional bicycles (*15*).

The availability of E-Bikes and Willingness to Ride

The availability of e-bikes has been shown to incentivize biking to work, even along corridors where commuting by conventional bicycle was not previously desirable for riders. Page and Nilson (*16*) studied an active travel intervention where employees at a campus located five hilly kilometers from the nearest transit stop were provided with access to e-bikes. Most used the bikes 1-2 days out of the work week. The median travel time spent on the bikes was 21-30 minutes, which was notably the same median travel time for the control group who continued to commute by car. Participants were allowed to keep the bikes as long as they wanted to, with a median time period of six weeks. The authors noted that the flexibility of the program- that users could ride the bikes when they wanted to, as often as they wanted to, and as much as they wanted to, contributed to their willingness to continue riding. The authors found that the provision of e-bikes in a workplace also resulted in statistically significant positive changes to workplace well-being and organizational behavior (*16*). The findings in this study could be relevant to an analysis of the potential to add e-bikes to a suburban bikeshare program in Chittenden County because bikeshare offers similarly low levels of commitment and high amounts of flexibility for users. In addition, this study specifically involved a workplace that was located on a route that most users perceived as undesirable to ride with a conventional bicycle, due to the hills along the route and the lack of bicycle infrastructure. Parallels might be drawn between the geographic context in this study and suburban Chittenden County, where bicycle infrastructure is somewhat incomplete and hills are regularly encountered along major commuting routes.

Peterman et. al. (*17*), in a study of activity levels and physical health related to the adoption of e-bikes by sedentary commuters, noted that study participants, in addition to riding their mandatory work commute with the e-bike, reported that they began to substitute other trips (such as grocery shopping) they previously made by car with e-bike trips, suggesting that e-bikes availability can impact transportation mode choice over routes or for purposes that participants previously chose to use a car for.

The availability of e-bikes through a bike share model can also overcome cost barriers associated with the purchase of an e-bike. In 2017, Ji et. al noted that users in their pilot simulation of an e-bike share system, when surveyed, identified the low cost commitment of the share system as an advantage over the high cost and commitment associated with purchasing a personal e-bike. (*4*).

Bikeshare Expansion and Equity

If the goal is more bikeshare rides, emphasizing equity in hub placement or system expansion may not result in greater usage. Caspi and Noland (*18*) found that hubs in lower-income areas in Indego, the Philadelphia, Pennsylvania bicycle share system, did not generate as many trips as hubs in higher income areas (hubs in higher income areas generated 141% more trips than those in lower income areas), though they also noted a geographic correlation between higher-income parts of the city and the presence and density of bicycle lanes and other bicycle infrastructure. Others have noted (*19*), however, that the provision of bike lanes and other infrastructure alone is not likely to influence greater ridership, while lower prices for bicycles (and possibly by extension bicycle share) may be a more effective strategy to encourage ridership than infrastructure alone.

Factors in Bicycle Share Use

A recent study of BIXI, the Montreal, Quebec bikeshare system by Bachand et. al.(*20*), found that the proximity of docking stations to home locations was more important than proximity to work locations, that drivers (as measured by licensure, not car ownership) were more likely to use the system than nondrivers, and that proximity to transit stations was also important. Bicycle ownership and year-round bicycle commuting (biking to work) were found to decrease the chances that a rider used BIXI. These findings suggest that more emphasis on areas with residential density and proximity to transit and less emphasis on existing bicycle use for commuting could be warranted in determining how to expand an existing bicycle share system.

While saturation of the service area with hubs (spacing between hubs of 250-300 meters is recommended) (*21*), this advice has generally been based on the experience of large cities with defined central downtowns, as opposed to small polycentric regions like suburban Chittenden County. The 250-300 meter hub spacing may be convenient for short walks between hubs and destinations, but does not necessarily account for the greater speed and distance that e-bikes can cover.

E-bikes for Bikeshare, Specifically

How e-bikes are different from conventional bicycles and their applicability to bike-share has been directly studied in at least one instance. Liu and Suzuki (*22*) , in an assessment of e-bike “applicability” (meaning that they could be considered a valid mode of transportation) in four cities in Japan, found that e-bikes were “applicable” for short trips in those cities both in areas with good transit coverage and for longer trips that extended beyond places that were well-served by transit. Liu and Suzuki examined factors including travel distance and elevation change, determining that e-bikes were “applicable,” in areas that were significantly steeper than those where conventional bicycles were applicable, the e-bikes were applicable for trips of up to 65 minutes. In the suburbs of Chittenden County, hillier terrain and sparse transit coverage are both present.

E-bikes have different capabilities and are used differently by those who ride them. Some of that difference is likely to carry over into their use in a bike share system. A review of the literature supports some key insights that are applicable to planning for an e-bike share system: perceived and actual physical effort is lower with e-bikes, and people who use e-bikes ride more, sometimes even riding distances and places they would not ride with a conventional bicycles. Bike share systems that have added e-bikes have seen increases in ridership. E-bikes are generally more expensive to purchase than conventional bicycles, but not much more expensive to use as part of a bike-share system, overcoming cost barriers associated with ownership. Bike share use is not well-predicted by zero car households or by the presence of existing bicycle commuters, and a sparser network of hubs may be served when the e-bikes themselves can be ridden faster.

GEOGRAPHIC CONTEXT

Of the estimated 164,000 people in Chittenden County, approximately 69,700 live in the communities covered by the CCRPC study, another 57,000 live in the adjacent suburban communities, and the remaining 37,800 live in the outlying towns beyond those suburbs. Vermont’s population is urbanizing into Chittenden County (*23*), and much of the new dwelling unit construction is happening in compact mixed-use developments in the suburban communities adjacent to the cities covered by the bike share system.

Williston, a suburb of Burlington located eight miles to its east with an estimated population of 9,800 is a good example of the new form of polycentric growth taking place in Chittenden County. Since 2010, over 533 new dwelling units have been constructed within the Town’s Growth Center, which is 2.7 miles from the nearest existing bike share hub. The road between the closest hub, at the Burlington International Airport and the Growth Center, was completely retrofitted with bike lanes over the last the last two years. While the infrastructure along the corridor has become more bike-friendly, there are still topographical challenges. Within that 2.7 mile ride, there is a short, but very steep, (9% grade, 0.4 mile) hill that makes biking a challenge. On an e-bike, the impact of the hill is greatly reduced. At a steady 15 miles/hour (achievable on an e-bike that is limited to assist up to 20mph), that ride is just under 11 sweat-free minutes. At 10mph on a conventional bicycle, the same ride is closer to 17 minutes and may require a shower at its conclusion. Extending further into the expanded study area, Williston Village, a historic and state-designated Village Center, is another two miles east of the town’s Growth Center. The Village Center is separated from the Growth Center by another significant climb: 0.5 mile at 8% grade. E-bikes, available in an integrated bikeshare program, could reduce the distance and topographic barriers that users of conventional bicycles face. Planning for shared e-bikes should be done in a way that considers this reduction in barriers.

GEOGRAPHIC INFORMATION SYSTEMS (GIS) ANALYSIS

Based on some of the findings in this paper's literature review, new suburban census blocks within Chittenden County not contained within the existing service area were added to a modified scoring comparison. The 867 blocks in the existing analysis were considered along with 948 new census blocks. This selection represents census blocks within 5 kilometers of the boundary of the existing service area. These new blocks include two additional state-designated Growth Centers (Williston and Colchester) a New Town Center (Colchester) and two Village Centers (Williston and Shelburne), as well as a densely developed corridor along Route 7 between South Burlington and Shelburne Village.

The existing study weighted factors including intersection density, intensity of transit boardings and alightings, population and employment density, percentage of low-income, minority, and zero car households, and well as proximity of points of interest and existing bikeshare hubs. The geographically-expanded study conducted by the author is simpler, examining only population and intersection density, address density, and proximity of existing transit stops. This simplified analysis, however, produces very similar results within the existing service area while also revealing similar patterns of high and low scores among census blocks outside of the boundary.

Because the goal of this paper is to examine the potential for a service area expansion, rather than the placement of new hubs within an existing service area, some factors from the 2019 demand analysis were not considered. The proximity of "attractions," like the University of Vermont, Lake Champlain Waterfront, and Church Street Marketplace were not considered because similar attractions do not exist in suburban parts of the county, where bike share trips are more likely to be for purposes other than tourism, like home, work, shopping, and social trips. While employment density, an element of the 2019 analysis, was not used, an address point file was used to capture nonresidential address density- this captures places of employment as well as retail and other service sites that may generate significant customer traffic. Existing bicycle and pedestrian commuters and zero-car households are not part of the proposed analysis, as the literature review conducted in this paper suggests that these factors are not likely predictors of greater bicycle share utilization.

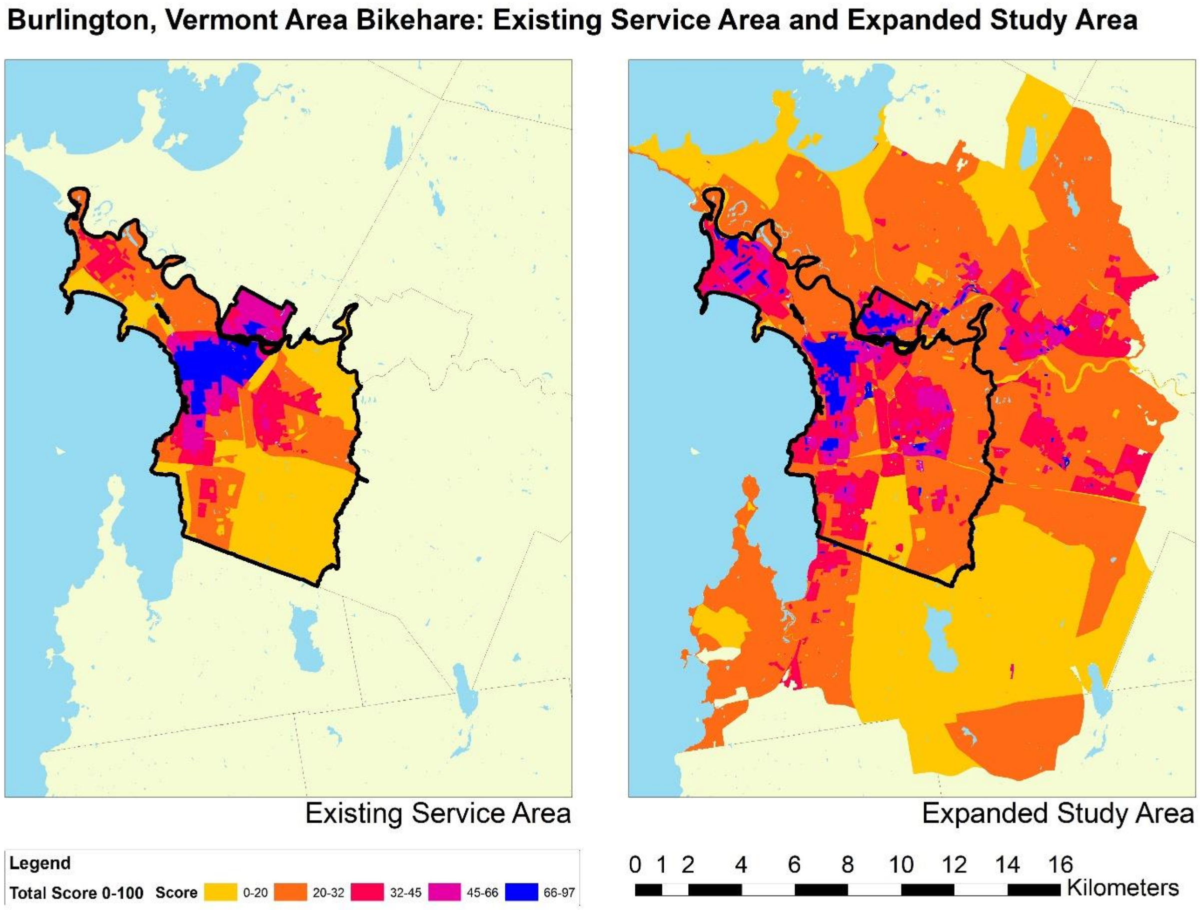
Table 1 compares the old and new scoring criteria. Both analyses used intersection and population density, but in the new analysis, these two metrics each account for 25 points on the 100-point scoring scale, instead of 12.5 points each originally. The new analysis adds address density as a component, to account for areas that are dense with commercial locations and in part to substitute for the "attractions" metric used in the original study. Finally, the expanded analysis uses the proximity of transit stops as a scoring metric, rather than boardings and alightings. Transit service is sparsely-used in the expanded service area, but the existence of transit stops do help identify prominent nodes in the existing transportation network that would be relevant to e-bike use.

TABLE 1. COMPARING EXISTING AND PROPOSED ANALYSES

	Existing CCRPC Study- 100 point rating scale				Proposed E-bike Criteria- 100 point rating scale			
Attribute	**Factors**	**Proximity Factor**		**Total Points**	**Factors**	**Proximity Factor**		**Total Points**
		0.25 Miles	**0.5 Miles**			**0.25 Miles**	**0.5 Miles**	
Intersection Density	12.5	n/a	n/a	12.5	25	n/a	n/a	25
Population Density	12.5	n/a	n/a	12.5	25	n/a	n/a	25
Employment Density	20	n/a	n/a	20	Not used			
Attractions	17.5	8.5	17.5	17.5	Not used			
Universities		10	5					
Points of Interest		5	2.5					
Existing GreenRide Hubs		2.5	1.25					
Alternative Commuters				10	Not used			
Bicycle Commuters	5							
Pedestrian Commuters	5							
Address Density	n/a				25	n/a	n/a	25
Transit Boardings and Alightings	5	5	2.5	5	Not Used			
Transit Stops Proximity						12.5	25	25
Equity				22.5	Not used			
Minority	8.75							
Low-Income Households	8.75							
Zero-Car Ownership Households	5							
Total Score	**-**			**100**				**100**
Key								
Criterion Not used in Proposed Analysis	**Criterion Modified in Proposed Analysis**				**New Criterion in Proposed Analysis**			

This new set of scoring criteria, accounting only for address density, population density, transit stop proximity, and intersection density, generates fairly similar results within the existing service area, while revealing opportunities to serve census blocks that are beyond its boundaries. In the following map comparison, the existing rating system scores, divided into quintiles, are shown for the area within the service boundary only, while the expanded analysis is shown both inside and outside the existing boundaries. With the equity, attractions, and alternative commuter criteria removed (fully 50% of the original scoring criteria), the maps and relative ratings of the census blocks are still similar.

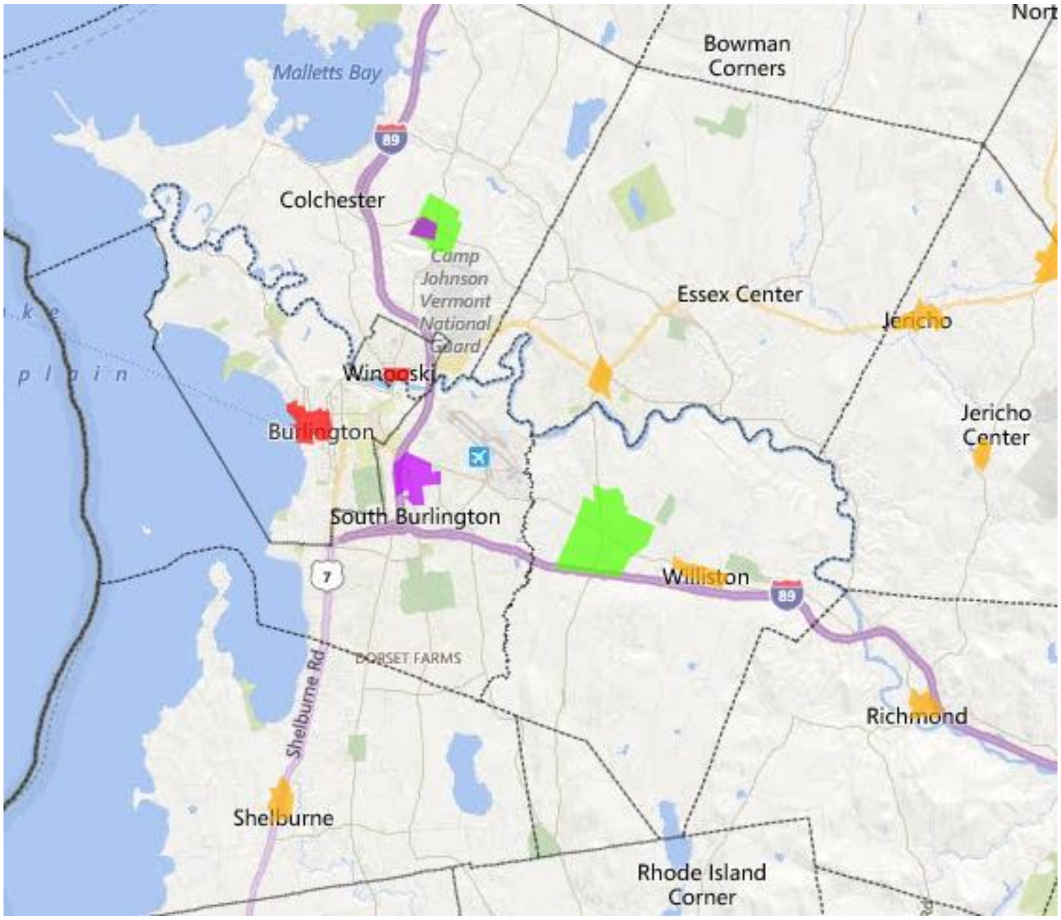
FIGURE 3. COMPARISON MAPS OF EXISTING AND PROPOSED ANALYSIS AREAS



WILLISTON VILLAGE AND THE WILLISTON GROWTH CENTER

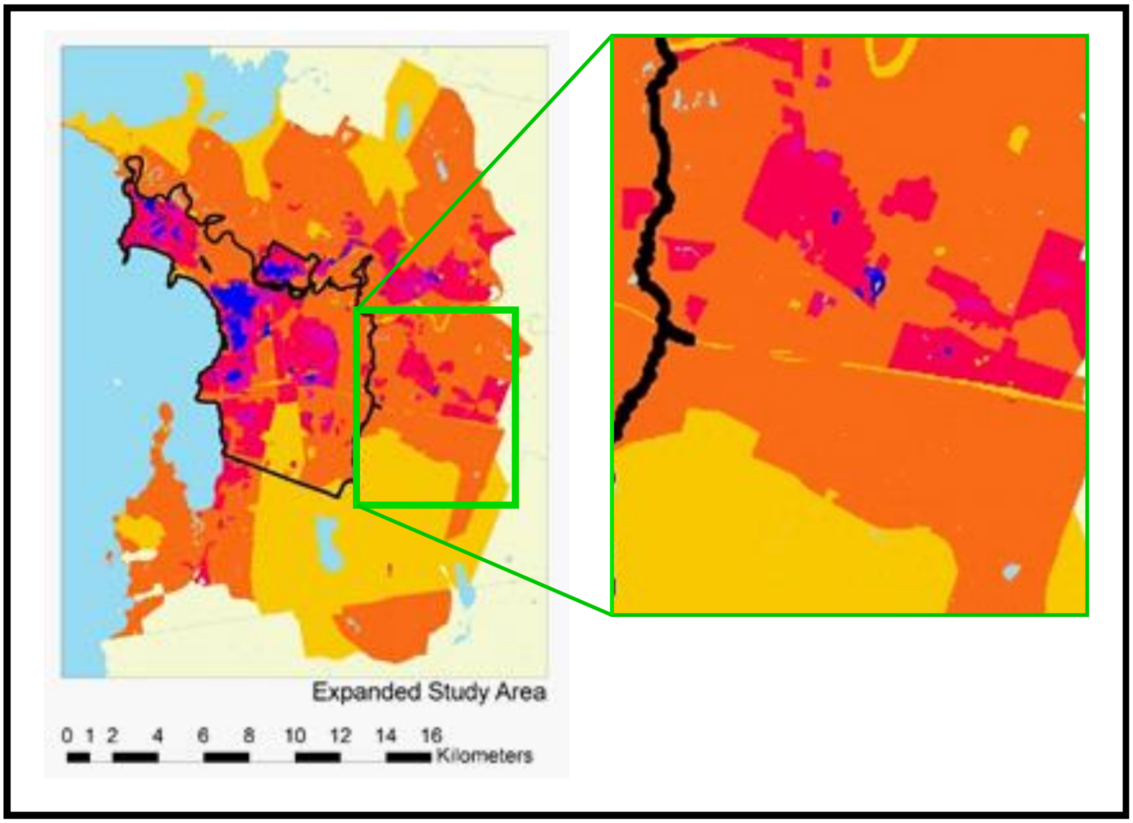
The expanded study area takes in both a state designated Growth Center and Village Center in the town of Williston. These areas, designated for growth and redevelopment through state incentive programs, could be enhanced with multimodal connections to other centers within the region as well as denser areas within the exiting bikeshare service area. While the analysis in this project uses 2010 census blocks and populations, densities have increased since then, with over 600 homes added to the Williston Growth Center since 2011, with another 233 units planned and permitted over the next decade.

FIGURE 4. Growth Centers, Designated Downtowns, Village Centers, New Town Centers, and Neighborhood Development Areas in the Study Area (*24*).



Williston's Growth Center and Village Center, even as scored by their 2010 metrics, show small pockets of high-scoring census blocks (in blue, indicating ratings in the top quintile of scores) to which the additional constructed and planned growth is adjacent. A single census block in the Growth Center with a population of 222 people in 2010 now contains an additional 550 dwelling units and has also added a 100-room hotel and a bank. A grocery store and restaurant are under construction and a brewpub has been proposed.

FIGURE 5. WILLISTON'S GROWTH CENTER AND VILLAGE CENTER, SHOWING POCKETS OF DENSITY (BLUE) IN 2010, WITH MORE TO COME.



NEXT STEPS

Once e-bikes are introduced in Burlington, performance and use could be evaluated against the existing census block analysis performed by Toole in 2019. The existing service area contains some low-rated, “suburban” blocks that are similar to blocks in the proposed expanded study area, but for their proximity to existing bikeshare hubs. If the performance of some of those lower-rated blocks exceeds the demand ratings predicted by the 2019 study, this could be an indicator that other, more suburban blocks should be considered.

Another possible way an expanded tool could be used would be to consider a suburban bikeshare pilot, focusing new hubs and e-bike availability within state-designated centers along corridors with good bicycle infrastructure, like the Williston Growth Center. A refreshed analysis should update census blocks in growing places with on-the-ground information from planners and developers in those communities to ensure that ratings systems do not fall behind in times of rapid change.

While there are few zero-car or pedestrian or transit commuter households in places like Williston today, there may be more in the future, especially if an e-bike share option is available to them. Perhaps some of the residents of theses denser places won’t “swim across the river,” but would use a “bridge” if it existed.

CONCLUSIONS

E-bikes have been shown to take less physical effort to move riders faster, further, and up steeper hills more easily than conventional bicycles. Along with less difficulty and less sweat, riders of e-bikes report using them more frequently, often to traverse areas beyond the reach of transit with less favorable infrastructure for bicycling. Adding e-bikes to bike share systems has been shown to increase ridership. Riders of e-bikes report replacing more car trips with bike trips than riders of conventional bicycles.

The addition of e-bikes to a conventional bike share system warrants consideration of these differences between e-bikes and conventional bicycles and the opportunities they present. In regions where significant portions of the population live and travel outside of the traditional downtown core, there may be significant opportunities to offer bike share as an additional mode of transportation, even where hills are steeper, distances between destinations are greater, and transit use is less.

When the attributes that make e-bikes different from conventional bicycles are considered in an analysis of geographic areas that are suitable for an expanded bikeshare system, opportunities for e-bike hubs are revealed that correlate to emerging areas of higher commercial, and residential density. While these areas may be somewhat distant from one another and the traditional downtown core, they still may be able to be served by an expanded bicycle share system that uses e-bikes.

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