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Effect Of E-Bike Use On Route Choice And Bicycle Infrastructure Preference

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EFFECT OF E-BIKE USE ON ROUTE CHOICE AND BICYCLE INFRASTRUCTURE PREFERENCE

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ABSTRACT

As e-bikes become more popular, understanding how e-bikes may affect bicyclist travel behavior and infrastructure preferences can provide useful information to policymakers and bicycle facility designers to address inadequate bicycle facilities and potential safety concerns. We evaluate survey responses about infrastructure preferences of e-bike and conventional bicycle users, including their safety concerns in Chittenden County, Vermont. Generally, we find that conventional bicyclists and e-bike users have similar infrastructure preferences. The study finds that e-bike users tend to travel more frequently than conventional bicyclists, especially for utilitarian purposes. However, e-bike users may be more willing to use roadways with fewer bicycle facilities or higher-speed traffic. Safety perceptions of bicycling are slightly higher among e-bike users than conventional bicyclists.

Furthermore, we use a discrete choice model to analyze bicycle facility preferences from the stated preference responses. Bicyclists prefer buffered bicycle lanes over multi-use paths and bicycle lanes over facility-less roadways. However, the likelihood that a conventional bicyclist will opt for a bicycle facility over a facility-less roadway is higher than that of an e-bike user for the three types of bicycle facilities. Likewise, the perceived speed of vehicles traveling adjacent to the cycling route is also critical in route choice. Conventional bicyclists appear to have a stronger preference for traveling adjacent to vehicles where the posted speed limit is lower than e-bike users. This result may indicate that e-bikes induce confidence in the rider, stemming from a lower speed differential when traveling adjacent to motor vehicles.

E-bikes are rapidly increasing in popularity, and while the needs of e-bike users are important, the needs of every bicyclist need to be considered and accommodated when designing policies and bicycle facilities. Policies to allocate a greater portion of the traveled way to bicycle facilities to allow for buffered or protected bicycle lanes may increase safety perceptions among bicyclists and improve the bicycling mode share in municipalities. Additionally, this study only begins to explore the safety concerns associated with e-bikes. Future research should further explore conventional bicyclists' safety perceptions of e-bikes as they continue to be more prominent on the road.

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INTRODUCTION

Since the early 1900s, the U.S. has spent countless dollars on infrastructure supporting motor vehicle use. Vehicle miles traveled per year by Americans has increased from 7,365 in 1950 to 14,315 in 2016 (Federal Highway Administration, 2018). The significant increase in motor vehicle use has damaged air quality, increased greenhouse gas emissions, depleted non-renewable resources, and increased traffic congestion. The infrastructure to support this travel is costly to build, maintain and operate. On the other hand, bicycle use does not pollute the environment, and the physical activity required to bicycle has significant public health benefits. Because bicycles need a fraction of the road space of a motor vehicle, congestion is less of a concern, and the infrastructure to support bicycling is far less expensive than that for motor vehicles. The potential of bicycling to reduce traffic congestion, improve air quality, mitigate greenhouse gas emissions, and improve public health by increasing physical activity is limited by its meager mode share. Less than 0.5% of all passenger trips in the United States are made by bicycle (U.S. Census Bureau, 2018). E-bikes offer a new opportunity to increase bicycling significantly and its many environmental, public health, and economic benefits.

E-bikes are similar in design and operation to conventional bicycles but offer the rider assistance via an electric motor while still providing similar physical activity and enjoyment (Bourne et al., 2018; Langford, 2013; Popovich et al., 2013). In the last decade, e-bikes have become increasingly popular in the United States. In 2017, e-bike sales in the U.S. increased 91% over 2016 and 800% since 2014 (Bicycle Industry Statistics 2018, 2018), and e-bike sales grew by 240% in 2021 compared to 2019 (The NPD Group/U.S. Retail Tracking Service, 2020). Like bicycles, e-bikes offer low-income commuters and populations underserved by transit an affordable and feasible mode of transportation (Weinert et al., 2006). Additionally, e-bike use can also ameliorate air quality conditions, greenhouse gas emissions (Winslott Hiselius & Svensson, 2017), and energy use because of their low energy requirements per distance traveled (McCarran & Carpenter, 2018; Muetze & Tan, 2007). Moreover, increased e-bike use can minimize traffic congestion and improve public health by replacing motor vehicle trips with active transportation modes (Johnson & Rose, 2013; McCarran & Carpenter, 2018; Weiss, 2015).

Many studies have investigated barriers to bicycling in the U.S.; weather, proximity to destinations, lack of infrastructure, physical ability, and safety (Fowler et al., 2016; Heinen et al., 2010) are the primary deterrents. Recent studies have shown that e-bikes overcome many of these barriers. E-bikes enable people experiencing disabilities, older adults, and people with long commute distances to opt for bicycle use (Dill & Rose, 2012; Langford, 2013; Ling et al., 2017a; MacArthur et al., 2014; Rose, 2012; Shao et al., 2012). E-bikes encourage more bicycle ridership allowing riders to travel more frequently, further distances, and overcome hillier terrain (Dill & Rose, 2012; Haustein & Møller, 2016; Langford et al., 2013). The capabilities afforded to riders by e-bikes encourage their use for utilitarian purposes, such as commuting to work, hauling goods, and children elevating their utility level to motor vehicles for some users (Ling et al., 2017a; Lopez et al., 2017; Popovich et al., 2013). Additionally, e-bike use and ownership are more common in rural and suburban areas, where access to public transit is often more limited than in dense urban areas (Zhang et al., 2013).

While e-bikes address many common barriers to bicycling, safety and a lack of adequate infrastructure remain top concerns (Fyhri et al., 2017). A top barrier to cycling is safety, stemming from the perception of unsafe driver behavior (Fowler et al., 2016; Krizek et al., 2004), yet some e-bike users credit their e-bike with helping them avoid crashes (MacArthur et al., 2018). A recent study found that e-bikes enabled riders to better integrate with motor vehicle traffic flow on shared roadways (Jones et al., 2016; Lopez et al., 2017; MacArthur et al., 2018). Providing suitable infrastructure and developing policies that maximize the potential for e-bikes can further increase bicycle ridership and displace vehicle trips (Buehler & Pucher, 2012; Dill, 2009; Dill & Carr, 2003; Nelson & Allen, 1997; Pucher et al., 2011; Pucher & Buehler, 2011; Rowangould & Tayarani, 2016). Realizing the benefits of increased bicycling will only be possible with informed policies to guide the funding and design of future bicycle infrastructure.

E-bikes allow riders to travel at higher speeds than conventional bicycles (Cherry & He, 2009; Dozza et al., 2016; Langford, 2013; Lin et al., 2008; Lopez et al., 2017; Schleinitz et al., 2017; Vlakveld et al., 2015). The ability to achieve and maintain higher speeds is attractive to many e-bike adopters, but when combined with the increased weight, e-bikes present new safety concerns. Heavier and faster e-bikes can reduce maneuverability and may have different bicycle facility design requirements (Dozza et al., 2016). However, riders tend to feel safe while using an e-bike once they become accustomed to their higher speed capability (Plazier et al., 2017a). Although e-bike riders feel safe, traveling at higher speeds may be perceived as unsafe by conventional cyclists and pedestrians who use the same routes and infrastructure (Popovich et al., 2013). Traffic conflicts with motor vehicles at intersections are common for bicycles. However, studies have found that these conflicts are more common for e-bikes due to the inability of motorists to correctly judge their speed since motorists cannot distinguish them from conventional bicycles (Petzoldt et al., 2017; Popovich et al., 2013). Understanding how e-bikes affect the safety of other infrastructure users and themselves will be essential to design infrastructure and policies that further encourage their adoption and safe use.

In this study, we evaluate the preferences, motivations, and safety perceptions of e-bike and conventional bicycle users with data collected through a stated preference survey distributed to bicyclists in Chittenden County, VT. We use these data to evaluate the question; do e-bike users have different route choice and infrastructure preferences than convention bicyclists? The literature has yet to explore whether e-bike users more comfortable in mixed traffic and more likely to choose routes without bicycle facilities. This research also uses these data to seek an answer to the question; how do e-bike users and conventional bicyclists perceive their safety and the safety of other infrastructure users while bicycling? We aim to understand if the higher speeds and greater acceleration potential of e-bikes provide the rider a greater sense of safety and whether the increased operating speeds, heavier and larger frames of e-bikes decrease the perceived safety of conventional cyclists, pedestrians, or motor vehicles.

LITERATURE REVIEW

E-bikes are similar in design and function to conventional bicycles but include an electric motor and battery to supplement the rider's effort. In the U.S., the Consumer Product Safety Commission (CPSC) defines e-bikes as "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." Furthermore, the Bicycle Product Suppliers Association (BPSA) uses a 3-tier classification system (PeopleForBikes & Bicycle Product Suppliers Association, 2018) for e-bikes. The classes are defined as follows:

- *A "class 1 electric bicycle" is a bicycle equipped with a motor that provides assistance only when the rider is pedaling, and that ceases to provide assistance when the bicycle reaches the speed of 20 miles per hour.*
- *A "class 2 electric bicycle" is a bicycle equipped with a motor that may be used exclusively to propel the bicycle, and that is not capable of providing assistance when the bicycle reaches the speed of 20 miles per hour.*
- *A "class 3 electric bicycle" is a bicycle equipped with a motor that provides assistance only when the rider is pedaling, and that ceases to provide assistance when the bicycle reaches the speed of 28 miles per hour, and is equipped with a speedometer* (PeopleForBikes & Bicycle Product Suppliers Association, 2018*).*

This study focuses on the use of privately-owned e-bikes that are within the scope of the BPSA classification system.

Previous studies find that e-bike trip purposes are primarily to commute to work, run errands, haul goods, and carry children (Engelmoer & Mulder, 2012; Lee et al., 2015; Ling et al., 2017a; Plazier et al., 2017b). The implication is that e-bikes trips are used less for recreational trips but more for utilitarian purposes, suggesting that e-bikes are a viable alternative to other modes of transportation. Prior studies have explored the potential of e-bikes to increase bicycling mode share and understand which mode of transport they are replacing. Intercept surveys in China revealed that trips by e-bike most frequently replaced trips by public transit (An et al., 2013; Cherry & Cervero, 2007). Surveys in the Netherlands found e-bike trips are most frequently replacing conventional bike or motor vehicle trips (Kroesen, 2017; Lee et al., 2015; Sun et al., 2020). These observations differ from that in other parts of Europe, North America, and Australia, where e-bikes most commonly replace motor vehicle trips (Astegiano et al., 2015; Fyhri & Fearnley, 2015; Johnson & Rose, 2013; MacArthur et al., 2014; Plazier et al., 2017b; Winslott Hiselius & Svensson, 2017). These studies indicate that e-bikes are replacing trips that generally would be accomplished by each country's primary modes of transportation. More specifically, the available infrastructure influences mode substitutions by e-bikes. For example, a study of the nation's first e-bike share system found that e-bikes most commonly replaced walking trips on a college campus (Langford et al., 2013). Studies from China and Sweden found trips by e-bike most frequently replaced trips by conventional bicycles and public transit in urban settings (Cherry & Cervero, 2007; Winslott Hiselius & Svensson, 2017). Furthermore, e-bike trips are primarily replacing motor vehicle trips in rural and suburban areas (Sun et al., 2020; Winslott Hiselius & Svensson, 2017).

The effects of this emerging mode of transportation on bicycle infrastructure design are still unknown, especially concerning safety and rider comfort. Prior studies have found evidence that bicycle infrastructure influences riders' decision to bicycle and their route choices (Fitch et al., 2016; Heinen et al., 2010; Krizek, 2006; Winters et al., 2010). However, these studies were primarily focused on conventional bicycles and not on e-bikes. As e-bike use continues to grow, so does the body of literature regarding the influence of infrastructure on e-bike riders. A recent analysis of e-bike commuters found that riders could access preferred routes over shorter, more direct routes (Plazier et al., 2017b). However, this study did not address whether e-bikes enabled commuters to take shorter, more direct routes that may be hillier or lack the rider's preferred infrastructure when riding a conventional bicycle. In the absence of dedicated bicycle facilities, other studies have found that e-bikes enabled riders to feel more comfortable sharing the road with motor vehicles (Jones et al., 2016; Shao et al., 2012). While these studies provide some insight into how e-bike riders use existing transportation infrastructure, little is known about the infrastructure preferences of e-bike riders and how they may differ from conventional bicyclists.

Previous studies have explored conventional bicyclists' route choices and infrastructure preferences. Pucher et al. investigated the impacts of several factors on cycling frequency in seven North American cities (Pucher et al., 1999, 2011). These case studies found that the availability of bicycle facilities was related to increased cycling. Other studies found associations between available bicycle facilities and increased levels of bicycle commuting (Nelson & Allen, 1997). Furthermore, a strong association was observed between bicycle commuting and the density of available off-street bicycles paths (Dill & Carr, 2003).

Additionally, intercept surveys with bicyclists were used to understand if proximity to off-road bicycle trails affects route choice decisions (Shafizadeh & Niemeier, 1997). They found that cyclists were willing to travel for a longer time and distance to use a route that included an off-road bicycle facility. A more recent study utilizing data collected from intercept surveys near an off-street bicycle facility in Minneapolis supported Shafizadeh and Niemeier's findings (Krizek et al., 2007). This study also found that cyclists were willing to travel further to include a bicycle trail as part of their route.

Some studies aiming to ascertain conventional bicyclists' route choice and infrastructure preferences use a revealed preference study design. Revealed preference studies examine individual behavior from past events. Some studies find that bicyclists tend to use routes with bicycle facilities (Dill, 2009; Misra & Watkins, 2018), bicyclists adjust their trips to use existing bicycle facilities (Howard & Burns, 2001), bicyclists make more frequent trips when located near separated paths, and travel distance to desirable destinations are short (Moudon et al., 2005), bicyclists value off-street bicycle paths and bicycle boulevards and commuter bicyclists were more concerned with trip distance than other infrastructure characteristics (Broach et al., 2012). Other revealed preference studies find that bicycle commuters tend to use on-street bicycle facilities, divert minimally from the shortest path between their origin and destination, and avoid routes with inclines (Aultman-Hall, 1996). Another revealed preference study evaluated the travel behavior of e-bike users and found that e-bikes enabled the user to tend to opt for longer routes perceived as safer and more enjoyable (Plazier et al., 2017b). Revealed preference studies are helpful to understand bicyclists' preferences for available bicycling infrastructure in an area. However, this study design is limited in its ability to understand a bicyclist's preference for bicycling infrastructure that exists but is not currently available for their use.

A stated preference study design can glean the influence of bicycle facility attributes on a bicyclist's route choice and infrastructure preferences without being limited to only the infrastructure available to use by the respondent. Stated preference studies ask respondents how they would behave in hypothetical scenarios that they have not previously encountered. An early application of a stated-preference study applied to bicycle route choice preferences found that the stated preference design provided reliable estimates of route characteristics and route utility (Bovy & Bradley, 1985). This study found that routes with lower traffic levels, better surface conditions, and separated facilities provided the most utility to bicycle commuters. In a more recent study, travel time and facility type were significant in estimating a bicyclist's route choice (Stinson & Bhat, 2003). This study also found that cyclists prefer routes on local streets and streets with bicycle facilities over routes on arterial streets with no bicycle facilities. Other stated preference studies find that cyclists are willing to increase their travel time by up to 20 minutes to use an off-road bicycle facility rather than a facility-less roadway; less desirable facilities were associated with less willingness to increase travel time (Krizek et al., 2004; Tilahun et al., 2007). These studies have only been used to gain insight on route choice and infrastructure preferences for conventional bicycle riders but not for e-bike users and their emerging needs. This study uses a stated preference design to allow greater control of the route attributes and bicycle infrastructure to evaluate.

Safety is an essential consideration when choosing routes for bicycling trips. Like conventional bicyclists, concerns over safety and a lack of sensible bicycling infrastructure curb individuals from adopting e-bikes. When comparing the frequency of being involved in a traffic conflict, there was no significant difference between conventional bicycles and e-bikes for most situations (Petzoldt et al., 2017). Low accessibility to bicycle facilities, perceived as safe, was credited as a suppressing factor for the frequency of trips made using e-bikes (Shao et al., 2012). Surveys of e-bike commuters found that rural areas are perceived to be safer than urban areas due to the density of motor vehicle traffic, complex traffic interactions, and discontinuity of bicycle facilities (Plazier et al., 2017b). However, little is known about whether e-bikes affect a rider's perception of safety and how they may differ from a conventional bicyclist.

METHODS

Study Area

We evaluate infrastructure preferences of e-bike and conventional bicycle users, including their safety concerns in Chittenden County, Vermont. The research team is located at the University of Vermont, located in the city of Burlington. Chittenden County is Vermont's most populous county and home to its largest city, Burlington. According to the 2019 American Community Survey (ACS) 2019 1-Year estimates, the population of Chittenden County is estimated to be 163,774, 26% of Vermont's population (United States Census Bureau, 2020). Chittenden County's bicycling mode share made it attractive for engaging a large sample of bicyclists. The 2019 ACS estimates that 1.4% of residents commute to work by bicycle; this figure is twice that of the U.S. (United States Census Bureau, 2020). Chittenden County has several infrastructure types for bicycle use, from streets with sharrows, bicycle lanes, buffered bicycle lanes, protected bicycle lanes to multi-use paths. The topography of the area ranges from flat to hilly. Summers are warm and humid with frequent rain events, while the winters are frigid and drier with regular snow (Runkle et al., 2017).

Survey Development

The research questions identified were evaluated by gathering information through an electronic, stated preference survey. We solicited researchers' input at the University of Vermont (UVM) Transportation Research Center and community bicycle advocacy groups Local Motion and Old Spokes Home. These groups are well integrated and engaged with the bicycle community in Chittenden County. After receiving approval from UVM's Institutional Review Board, a pilot survey was conducted with respondents around the country, more specifically, respondents outside the study area. Upon receiving feedback from the pilot study respondents, the study was revised and prepared for distribution.

Participation in the survey was voluntary and anonymous, and respondents did not receive any compensation for their participation. Potential survey respondents received a link to the survey in their email inboxes thanks to Local Motion and Old Spokes Home; word of mouth distribution was not discouraged. Additionally, the survey received online distribution through Front Porch Forum, a community-building social network in Vermont.

Travel behavior is influenced by many characteristics, including the built and natural environment and the individual's perceptions. An individual's preferences stem from many factors ranging from the type of bicycle used, bicycling experience, type of bicyclist, trip purpose to a respondent's socio-demographics. The survey questionnaire asked respondents to state their preferences for bicycle facilities in different scenarios and poses questions about the type of trips and frequency of the trips a respondent makes to understand how they use their bicycle. We wanted to identify respondents' motivation for bicycling, level of bicycling experience, infrastructure preferences, and safety perceptions when riding an e-bike or conventional bicycle. Additionally, we wanted to identify the type of bicycle or bicycles the respondent uses and how the different bicycles influence the respondents' preferences regarding route characteristics, safety, and bicycle infrastructure types.

One goal of the survey was to measure travel behavior differences between e-bike users and conventional bicyclists. Respondents are asked how frequently they use bicycles for utilitarian (commuting, running errands, accomplishing regular duties, etc.) or recreational (exercise, leisure, etc.) purposes. Then each respondent is asked if they have used an e-bike a few times during the past year. Based on the respondent's response to this question, the following questions will be about their e-bike or conventional bicycle use. The question sets for both types of bicycles are similar. However, the e-bike question set has additional questions specific to the respondent's attitudes and experience concerning e-bikes and their use. Respondents who indicate they have used an e-bike a few times over the last year receive questions about what year they first used an e-bike, whether they own the e-bike they use, and whether the e-bike provides pedal assistance from the rider. Also, these respondents are asked to rate the importance of factors that led to them using an e-bike.

Regardless of bicycle type, respondents are asked how frequently they use their bicycles for different purposes. The survey then asks the respondent to recall a recent trip on their bicycle. The respondent is asked about the trip's purpose, distance, and duration. Also, what other transportation options are available for this trip, the respondent's familiarity with types of bicycle infrastructure, and to rate the importance on a scale from 1 (Not Important) to 5 (Very Important), of route attributes for the route they used.

Next, the respondent is presented with four randomized choice sets, two in an urban setting and two in a rural setting, in which they state their preference for bicycle infrastructure. The respondent decides between two hypothetical routes with varying combinations of bicycle infrastructure, travel time, and posted speed limits for each choice set. Figure 1 and Figure 2 are images of choice set questions from the survey.

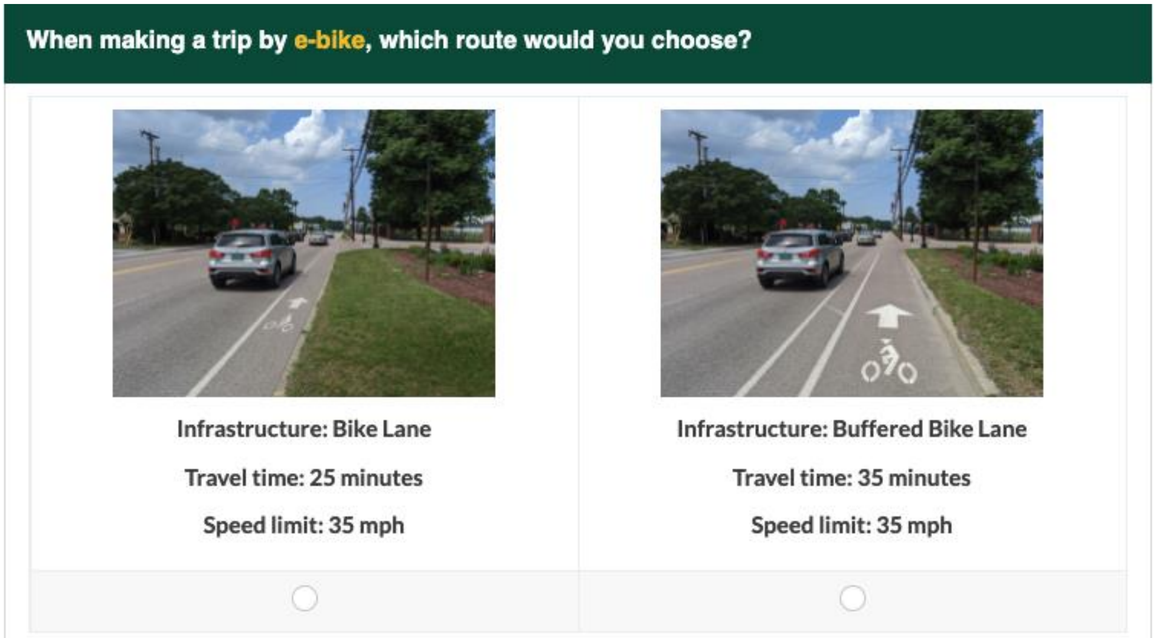


Figure 1: Stated preference choice set for an e-bike rider, urban scenario.

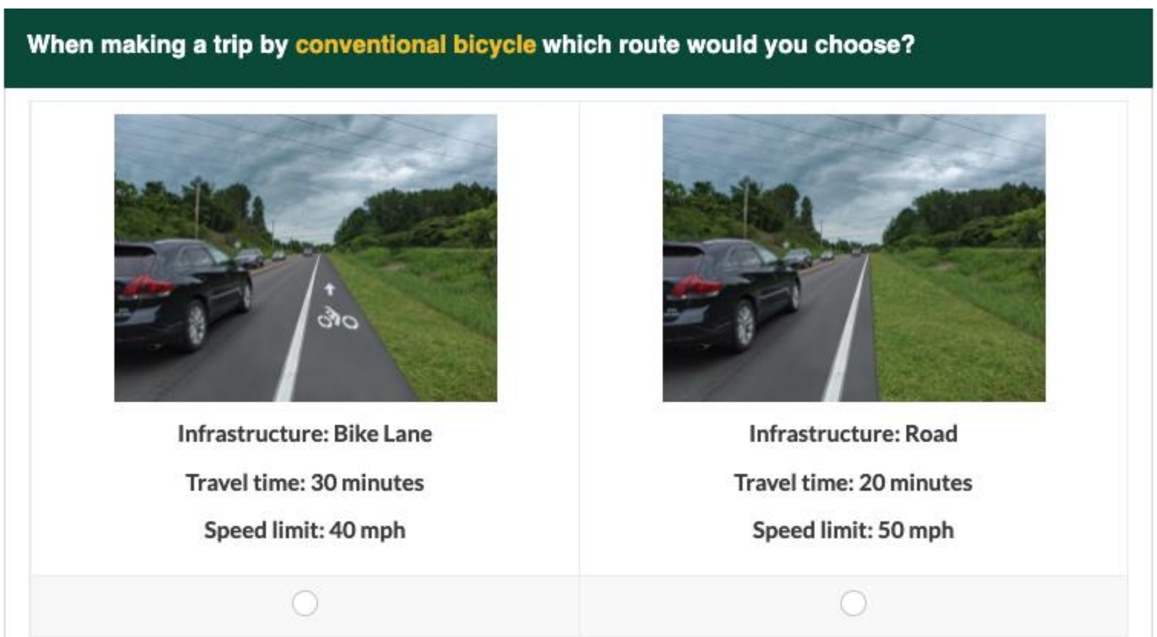


Figure 2: Stated preference set for a conventional bicycle rider, rural scenario.

Figure 3 shows the urban and rural choice set images with possible travel time and posted speed limit combinations.

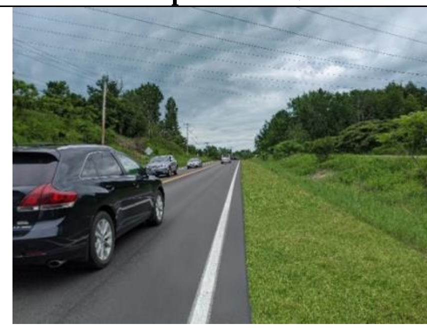
Urban **Posted Speed Limit:** 25 and 35 mph	**Rural** **Posted Speed Limit:** 40 and 50 mph
 **Infrastructure Type:** Road (No bicycle facilities) **Travel Time:** 20 minutes	 **Infrastructure Type:** Road (No bicycle facilities) **Travel Time:** 20 minutes
 **Infrastructure Type:** Bicycle Lane **Travel Time:** 25 and 30 minutes	 **Infrastructure Type:** Bicycle Lane **Travel Time:** 25 and 30 minutes
 **Infrastructure Type:** Buffered Bicycle Lane **Travel Time:** 30 and 35 minutes	 **Infrastructure Type:** Buffered Bicycle Lane **Travel Time:** 30 and 35 minutes
 **Infrastructure Type:** Multi-use Path **Travel Time:** 35 and 40 minutes **Posted Speed Limit:** 0 MPH	 **Infrastructure Type:** Multi-use Path **Travel Time:** 35 and 40 minutes **Posted Speed Limit:** 0 MPH

Figure 3: Choice sets and possible travel time and posted speed limit combinations

Following the stated preference choice set questions, respondents are asked about their perceptions concerning safety. Each respondent is asked about how safe they generally feel when riding their bicycle and to compare how safe they consider riding an e-bike or conventional bicycle compared to driving a motor vehicle. The final safety questions ask the respondent to rate how safe they feel on a scale of 1 (Not Safe) to 5 (Very Safe) when riding at night, in the rain, with snow/ice on the ground, and sharing the roadway with motor vehicles. Also, we ask the respondents to rate how safe they feel on a scale of 1 (Not Safe) to 5 (Very Safe) when passing other users when using a bicycle lane and multi-use path. Respondents are then asked to tell us about their demographics before completing the survey. For e-bike users, they are asked if they also ride a conventional bicycle and if they would be willing to answer the survey from the vantage point of riding a bicycle. Respondents are also asked about how COVID-19 has affected their frequency of bicycle usage.

DESCRIPTION OF SURVEY RESPONDENTS

The survey was administrated during the Fall of 2020. The questionnaire took an average of 16 minutes to complete. The dataset consisted of 821 respondents. However, 154 responses were removed because the respondents started the survey but did not complete it. The final dataset used in the analysis contained 667 survey respondents; 529 were conventional bicycle riders, and 138 were e-bike users. Overall, we collected information on 2,610 choices. Responses to the sociodemographic questions were not required. Respondents' gender was nearly even between females and males; a small percentage of respondents identified as non-binary. The relatively high bicycle mode share in Chittenden County may explain the lack of gender gap among bicyclists in this study; the gender gap is negligible in areas with higher rates of bicycling (Pucher & Buehler, 2008). Table 1 summarizes the sample's respondents and their sociodemographic attributes. The average age of survey respondents was 53 years old. Racially, the sample group was overwhelmingly white, non-Hispanics. Most respondents had a driver's license, lived in a household with a vehicle, and were not students but had a college degree or some college education. In general, our study sample is older, more educated, wealthier, and less racially diverse than the population of Chittenden County.

Table 1: Respondent Socioeconomics

	Description (N)	Sample	Chittenden County
Bicycle Type (667)	Conventional Bicycle (529)	79.3%	-
	E-bike (138)	20.7%	-
Age[1] (642)	Mean	53	-
	Median	55	36.5
	Standard Deviation	15	0.2
Gender[1] (652)	Female (319)	49.1%	50.9%
	Male (322)	49.2%	49.1%
	Nonbinary (11)	1.7%	-
Hispanic, Latino, or Spanish origin[2] (644)	Not of Hispanic, Latino, or Spanish origin (640)	99.4%	97.4%
	Hispanic or Latino (4)	0.6%	2.6%
Race[2] (637)	White (612)	96.4%	87.6%
	Other (13)	2.0%	5.7%
	Asian (6)	0.8%	4.1%
	Native American, American Indian (3)	0.5%	0.2%
	African American, Black (1)	0.2%	2.3%
	Native Hawaiian, Other Pacific Islander	0.0%	0.0%
Driver's License (652)	Yes (642)	98.8%	-
	No (8)	1.2%	-
Student status[1] (655)	No (629)	96.0%	83.4%
	Yes, enrolled in college (26)	4.0%	16.6%
Highest level of school or degree completed[1] (654)	Graduate or Professional Degree (335)	51.4%	16.8%
	Bachelor's Degree (244)	37.4%	28.0%
	Some college/Associates Degree/trade school (66)	10.1%	30.3%
	High School Graduate/GED (5)	0.7%	19.3%
	Some grade school/high school (2)	0.3%	5.6%
Household Size[1] (627)	Mean	2.47	2.31
	Median	2.00	-
	Standard Deviation	1.13	0.02
Household Vehicles[1] (639)	0 (8)	1.3%	2.9%
	1 (183)	28.6%	23.0%
	2 (319)	49.9%	46.3%
	3+ (129)	20.2%	27.8%
Household Income[1] (606)	Less than $10,000 (5)	0.8%	4.8%
	$10,000 to $14,999 (6)	1.0%	3.9%
	$15,000 to $24,999 (14)	2.3%	7.4%
	$25,000 to $34,999 (27)	4.5%	7.3%
	$35,000 to $49,999 (41)	6.8%	10.2%
	$50,000 to $74,999 (92)	15.2%	17.0&
	$75,000 to $99,999 (118)	19.5%	14.5%
	$100,000 to $149,999 (169)	27.9%	18.7%
	$150,000 to $199,999 (66)	10.9%	7.6%
	$200,000 to more (68)	11.2%	8.5%

[1]2019 American Community Survey, 5-year Estimates
[2]2020 Census

Additionally, respondents are disaggregated by their reported bicycle type. Table 2 summarizes the respondent's socioeconomic attributes by bicycle type. E-bike users tended to be slightly older than conventional bicyclists. A greater percentage of males opted for e-bikes than females. A greater proportion of e-bike users did not have a driver's license. Racially, the e-bike users were all white. In general, e-bike users are older, wealthier, and less racially diverse than conventional bicyclists.

Table 2: Respondent Socioeconomics by Bicycle Type

	Description	E-bike User (138)	Conventional Bicyclist (529)
Age[1]	Mean	56	52
	Median	58	54
Gender[1]	Female	47.8%	50.2%
	Male	52.2%	49.8%
Hispanic, Latino, or Spanish origin[2]	Not of Hispanic, Latino, or Spanish origin	98.5%	98.2%
	Hispanic or Latino	1.5%	1.8%
Race[2]	White	100%	96.4%
	Other	0.0%	2.0%
	Asian	0.0%	0.8%
	Native American, American Indian	0.0%	0.6%
	African American, Black	0.0%	0.2%
	Native Hawaiian, Other Pacific Islander	0.0%	0.0%
Driver's License	Yes	97.1%	99.2%
	No	2.9%	0.8%
Student status[1]	No	99.3%	95.2%
	Yes, enrolled in college	0.7%	4.8%
Highest level of school or degree completed[1]	Graduate or Professional Degree	44.2%	53.1%
	Bachelor's Degree	39.1%	37.2%
	Some college/Associates Degree/trade school	15.2%	8.7%
	High School Graduate/GED	1.4%	0.6%
	Some grade school/high school	0.0%	0.4%
Household Size[1]	Mean	2.57	2.44
	Median	2.00	2.00
Household Vehicles[1]	0	2.9%	0.8%
	1	27.0%	29.1%
	2	43.8%	51.6%
	3+	26.3%	18.5%
Household Income[1]	Less than $10,000	0.8%	0.8%
	$10,000 to $14,999	1.6%	0.8%
	$15,000 to $24,999	2.4%	2.3%
	$25,000 to $34,999	3.2%	4.8%
	$35,000 to $49,999	4.8%	7.3%
	$50,000 to $74,999	20.0%	13.9%
	$75,000 to $99,999	14.4%	20.8%
	$100,000 to $149,999	28.0%	27.9%
	$150,000 to $199,999	12.0%	10.6%
	$200,000 to more	12.8%	10.8%

[1]2019 American Community Survey, 5-year Estimates
[2]2020 Census

RESULTS

E-bike Use and Motivations

The survey asks respondents that identified themselves as e-bike users to tell us about their e-bike use. We asked respondents when they first used an e-bike. Figure 4 is a histogram summarizing the responses and shows that e-bike use has grown in Chittenden County almost exponentially in the last decade. At the time of this survey, first time e-bike use in 2020 already outpaced 2018 and may have surpassed 2019 by the end of the year.

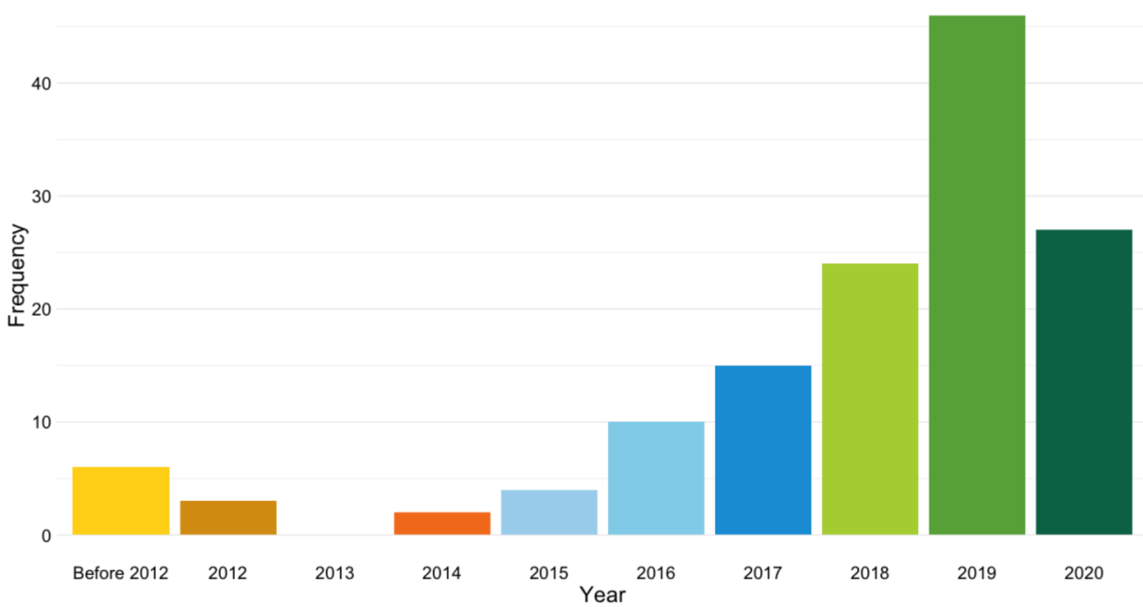


Figure 4: Histogram of the first-year survey respondents reported using an E-Bike.

The survey also asks respondents to rate their primary motivations for purchasing an e-bike. Figure 5 summarizes the responses to this question. The strongest motivator was to aid in overcoming hills, followed by a desire to replace motor vehicle use and travel longer distances by bicycle. The least important motivators were to replace transit trips and using e-bikes to overcome physical limitations.

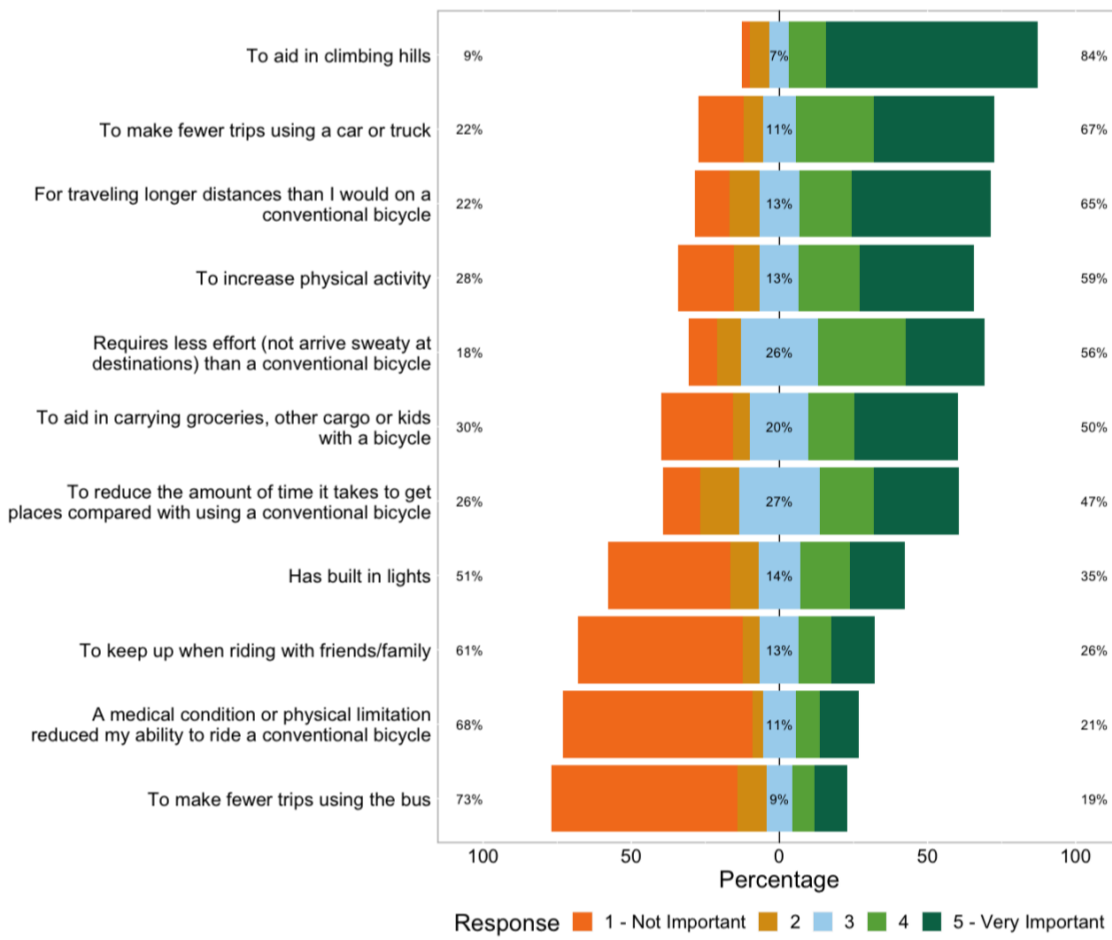


Figure 5: Primary motivations for purchasing an e-bike.

Differences in Travel Behavior

Exploring the differences between conventional bicyclists and e-bike users began by disaggregating respondents' bicycle type responses. Only responses to e-bike questions were evaluated for respondents who answered both the e-bike and conventional bicycle sections of the survey. The following sections illustrate differences in bicycle use between conventional bicyclists and e-bike users. We use the Mann-Whitney-Wilcoxon Test to test whether the distribution of the ordinal responses between the populations are dissimilar and statistically significant. Beginning with trip types and frequency,

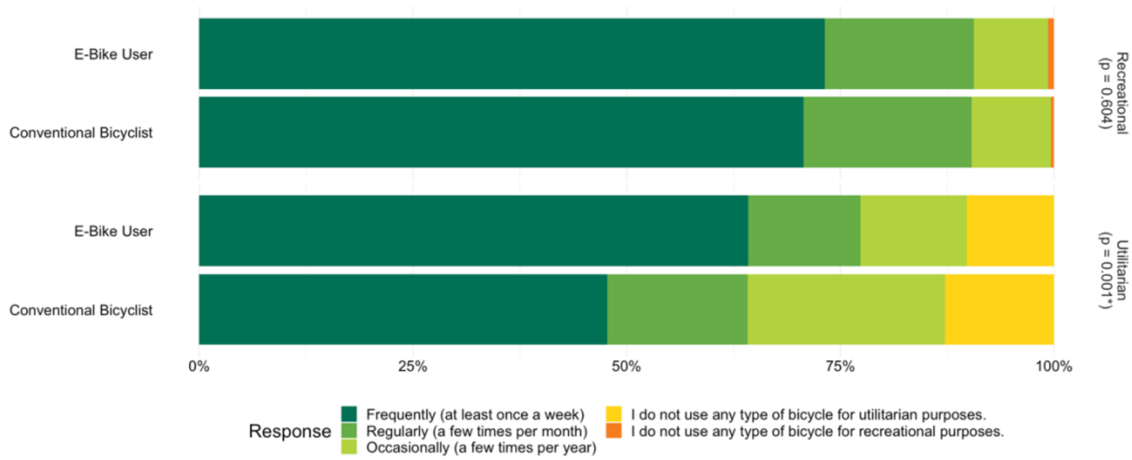


Figure 6 shows that e-bike users make more utilitarian trips than conventional cyclists. Figure 6 also reports the p-value from the Mann-Whitney-Wilcoxon Tests indicating that the distribution in responses between the two groups of bicyclists is statistically significant for utilitarian trips (P = 0.001).

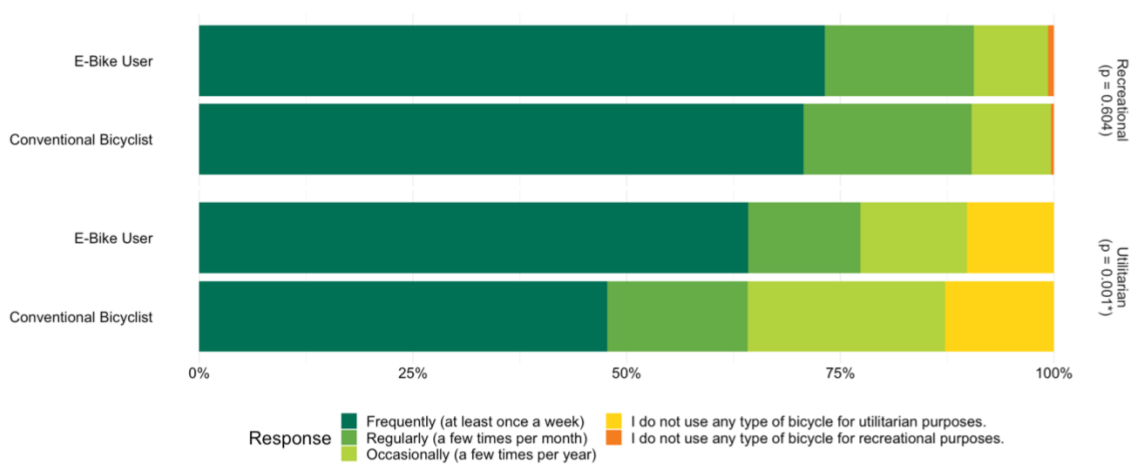


Figure 6: Travel frequency by bicycle type and trip purpose.

Figure 7 summarizes the respondents' experience using different bicycle facilities. Most respondents were familiar with and had previously used bicycle lanes, buffered bicycle lanes, and multi-use paths. While the proportion of conventional bicyclists and e-bike users familiar with bicycle lanes and multi-use paths was similar, fewer e-bike users were familiar with buffered bicycle lanes than conventional bicyclists. Furthermore, only e-bike users indicated no familiarity with any of the three facility types.

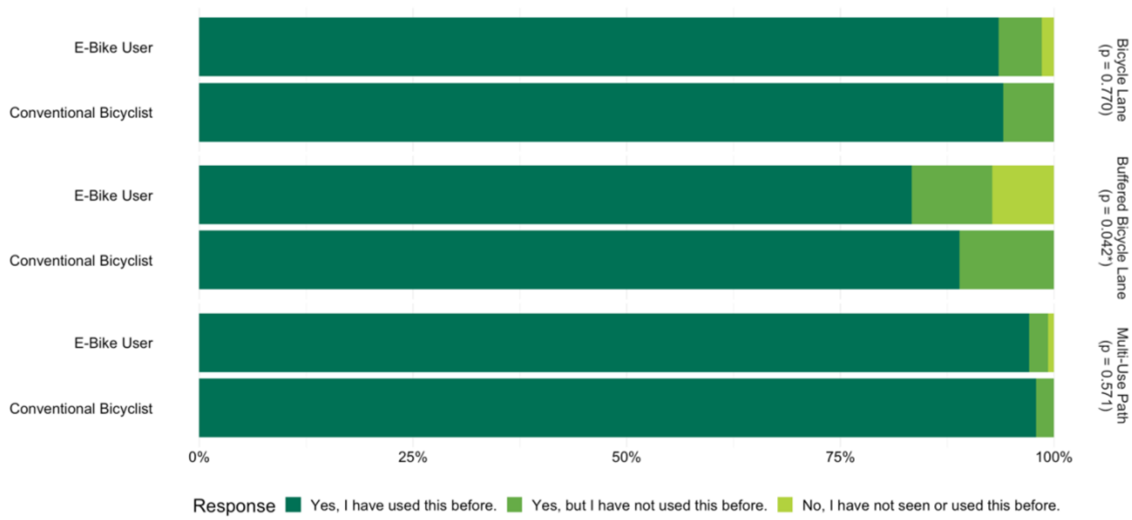


Figure 7: Bicycle facility experience by bicycle type.

Lastly, we asked respondents to estimate their average travel speed using their bicycles. Figure 8 shows the difference in estimated average travel speeds for each bicycle type. E-bike users tend to report traveling at higher speeds than conventional bicyclists. Sixty-two percent of e-bike users report their average travel speed as greater than 13 MPH compared to thirty-eight percent of conventional bicyclists. The distribution in self-reported average travel speed responses between the two groups of bicyclists is statistically significant (P = 5.868e-08) with e-bike users reporting higher travel speeds. Moreover, only e-bike users reported average travel speeds greater than 20 MPH.

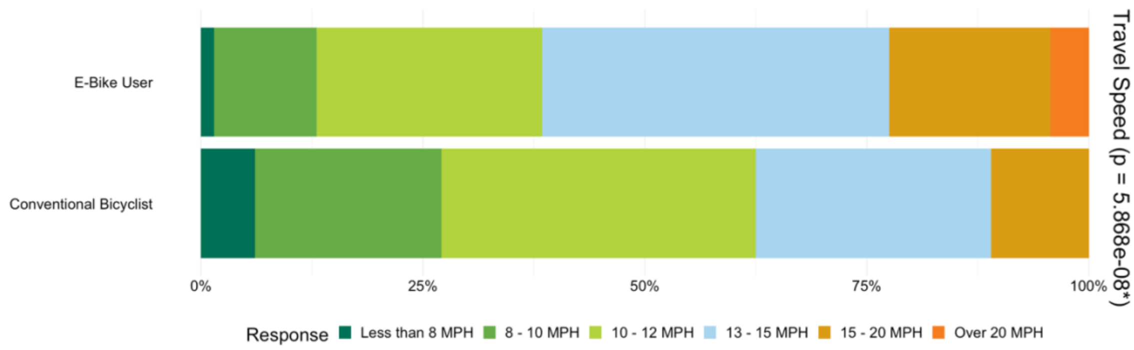


Figure 8: Reported travel speed by bicycle type.

Bicycle use and the COVID-19 pandemic

The COVID-19 pandemic was in full swing when this survey was designed and administered. Many people were looking for physical activities perceived as safe and allowed for proper social distancing. Others were looking for an alternative mode of transportation since public transit was either not operating or was perceived as less safe for COVID exposures (Buehler & Pucher, 2021). We wanted to understand if e-bikes may have influenced travel behavior changes resulting from the COVID-19 pandemic. The survey asked respondents to indicate the frequency of different types of trips they made using their bicycles before and during the pandemic. Figure 9 and Figure 10 show the responses to these questions, disaggregated by bicycle type. The percentage of trips for exercise, recreation, or pleasure was high for both types of bicycles before and during the pandemic. The frequency of these trips increased more so for e-bike users. Furthermore, bicycling increased for utilitarian trips such as commuting to work or school and shopping or to run errands. Like recreational trips, trip frequency increased more for e-bike users than conventional bicyclists.

Figure 9: Trip frequency by trip and bicycle type (Before COVID-19)

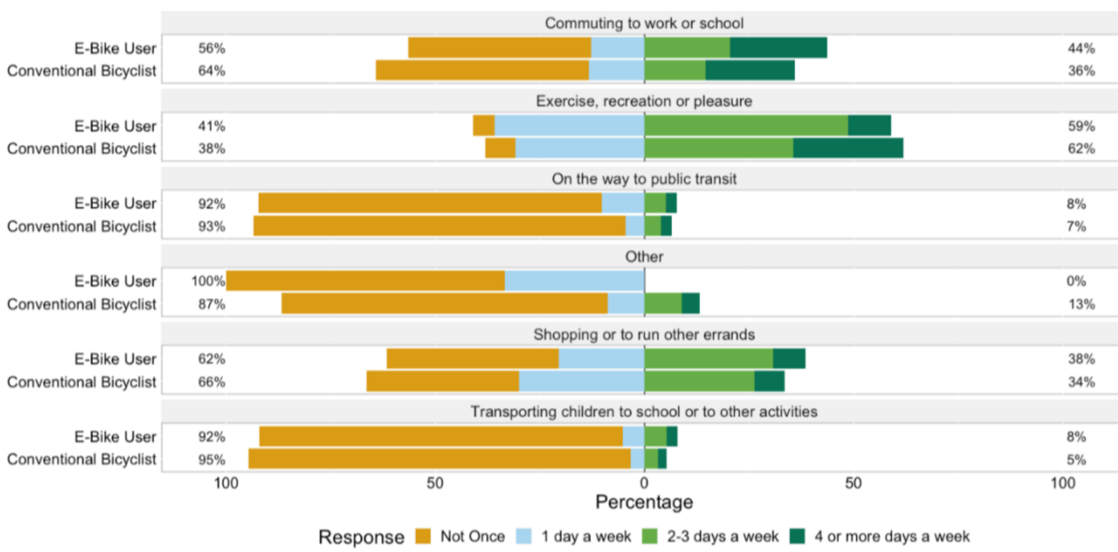


Figure 10: Trip frequency by trip and bicycle type (During COVID-19)

The responses to these questions reveal some differences between trip frequency of conventional bicyclists and e-bike users. Figure 11 and Figure 12 show the response distributions for the frequency of different types of trips made using before and during the pandemic. Regarding trip types before and during COVID-19, only trips for shopping and running errands (P = 0.018) and exercise, recreation, or pleasure (P = 0.034) before COVID-19 were the differences between the median responses statistically significant. These results indicate that before the COVID-19 pandemic, conventional bicyclists reported making more frequent trips for shopping and exercise, recreation, or pleasure.

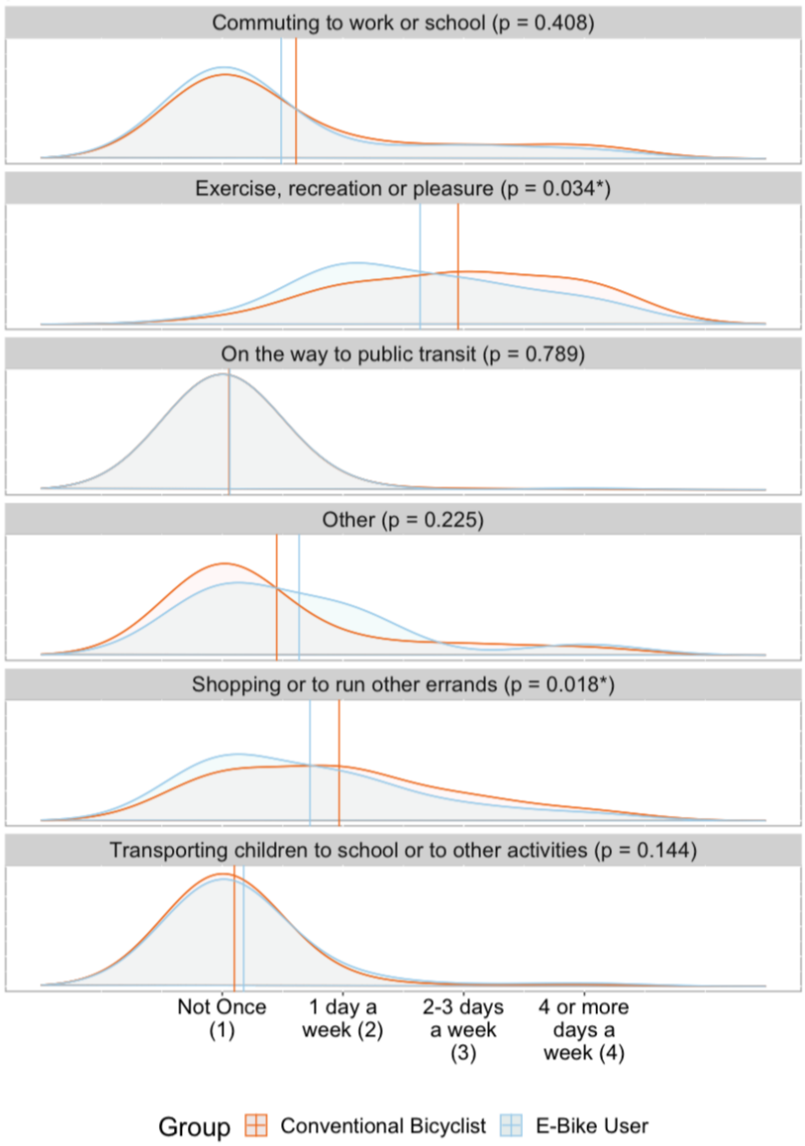


Figure 11: Comparison of responses of trip frequency by trip and bicycle type. (Before COVID-19)

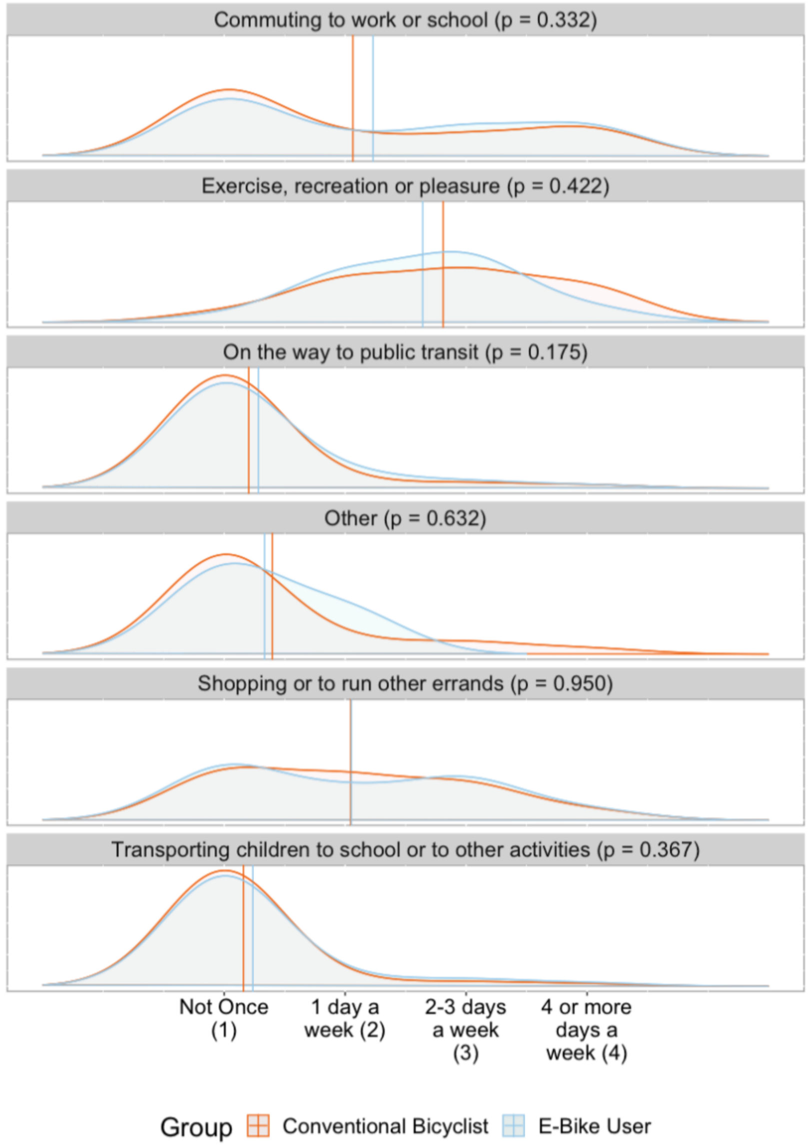


Figure 12: Comparison of responses of trip frequency by trip type. (During COVID-19)

Differences in Route Characteristics and Infrastructure Preferences

We explore the differences in route choice and infrastructure preferences of e-bike users and convention bicyclists by assessing survey responses regarding how important different characteristics are in choosing a route when traveling by bicycle. Respondents rated each characteristic on a scale from 1 to 5, with 1 being Not Important and 5 being Very Important. Figure 13 summarizes the respondent's ratings of route characteristics. We again disaggregate the responses by the type of bicycle the respondent uses. Unexpectedly, a greater percentage of e-bike users than conventional bicyclists indicated that avoiding hills and a route with a shorter distance was important when choosing a route. Additionally, a greater percentage of e-bike users indicated that buffered bicycle lanes were important in their route choice and avoiding roads with high traffic speeds was less critical when compared to the responses of conventional bicyclists.

Once again, we used the Mann-Whitney-Wilcoxon Test to test whether the distribution of responses between the populations is dissimilar and statistically significant. Figure 14 shows the response distributions of the importance of route characteristics. Attributes that were significantly different in importance between the bicyclist types were avoiding hills ($P = 2.08E-06$), avoiding roads with high traffic speeds ($P = 0.038$), routes containing buffered bicycle lanes ($P = 0.035$), and routes shorter in distance ($p= 0.042$). These results show a greater percentage of e-bike users consider routes with shorter distances, buffered bicycle lanes, and free of hilly terrain more important than conventional bicyclists, while routes that avoid roads with higher traffic speeds were more important to a greater percentage of conventional bicyclists than e-bike users.

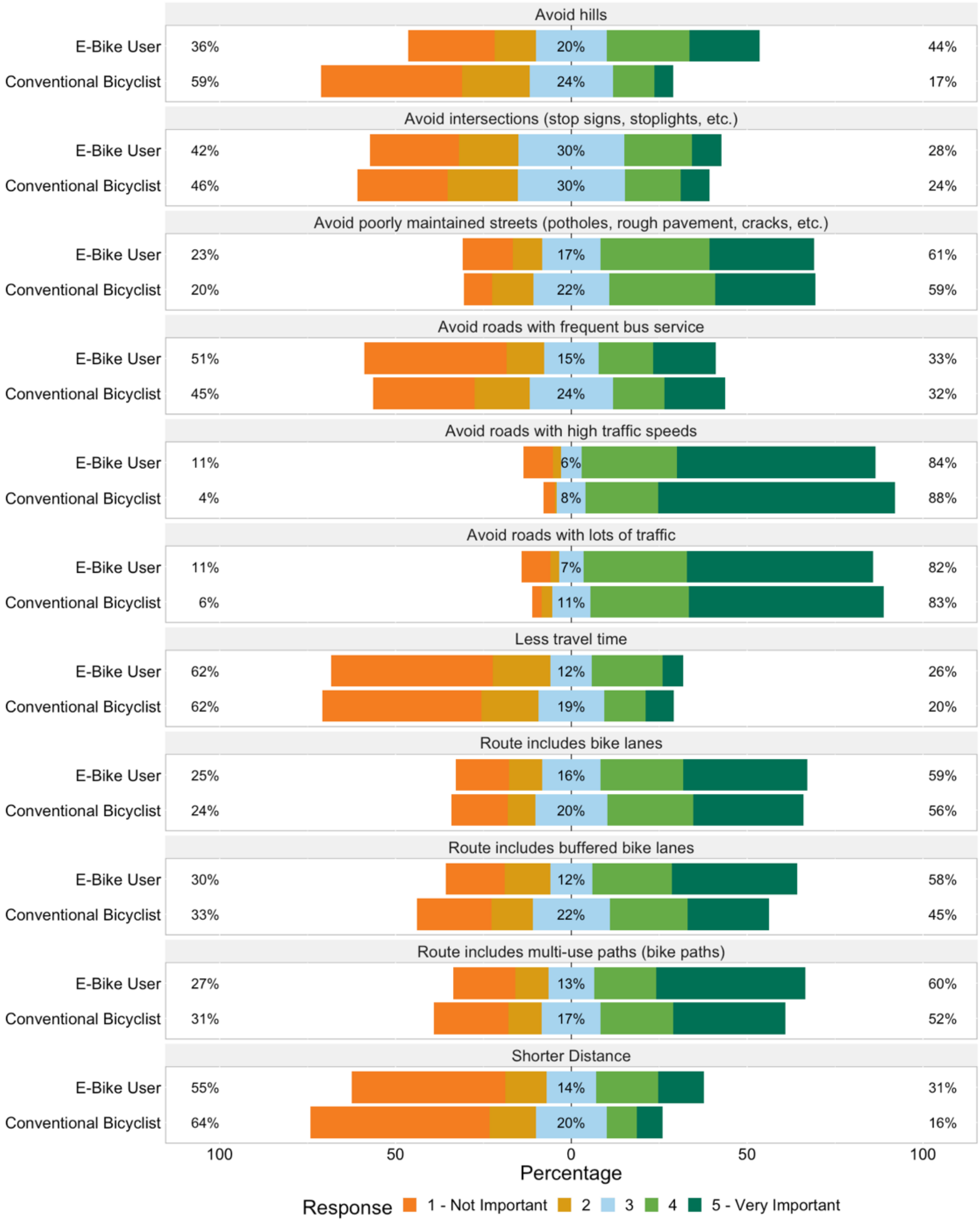


Figure 13: Importance of route characteristics by bicycle type.

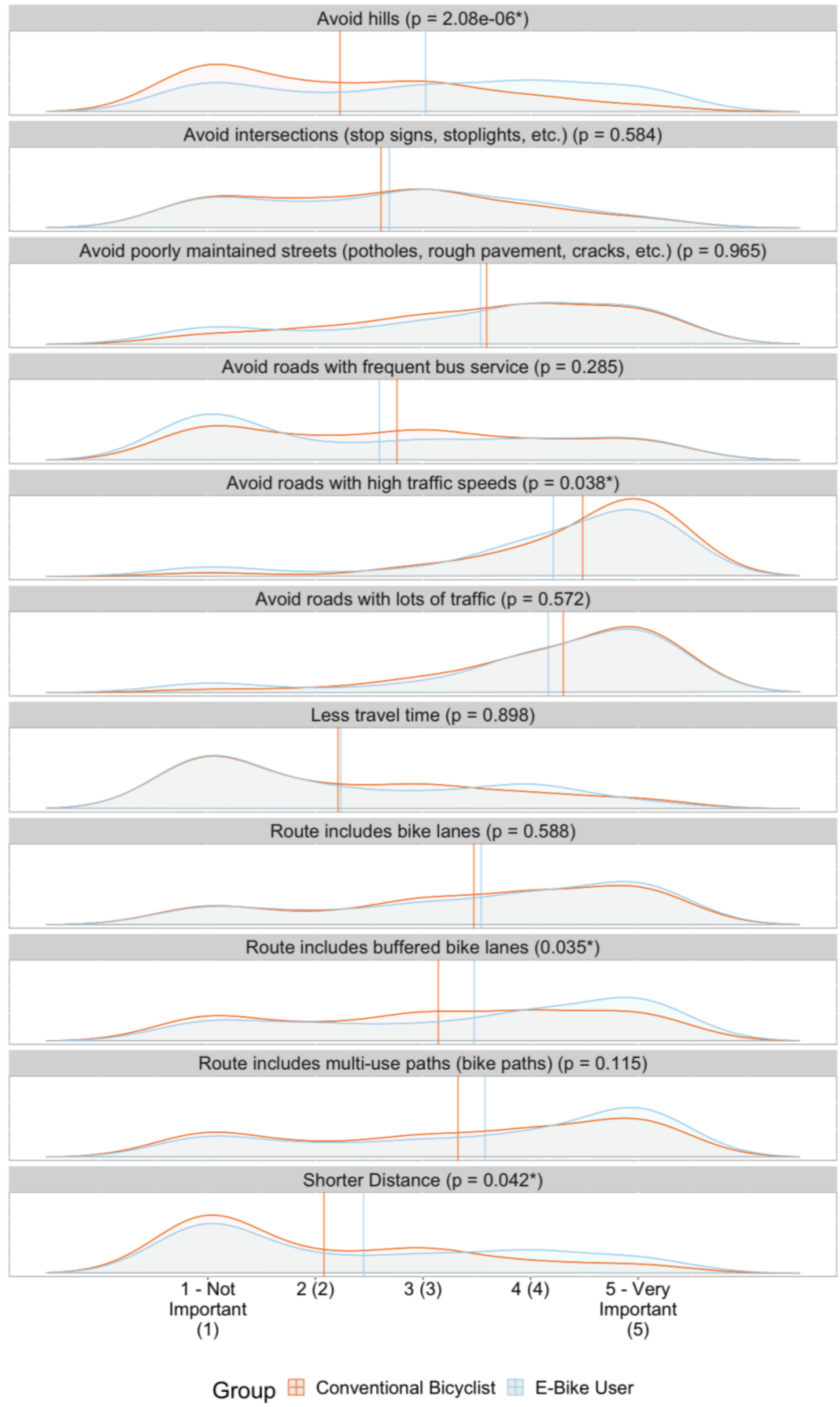


Figure 14: Comparison of response distributions regarding route characteristics by bicycle type.

Perceptions of Safety

Another aim of this study is to discern differences in a bicyclist's perception of safety between e-bike users and conventional bicyclists. Respondents were asked to respond to questions regarding their safety perceptions while riding a bicycle. Most respondents indicated that they generally feel safe when using a bicycle. However, a statistically significant percentage of e-bike users stated they felt safer than conventional bicyclists (P = 0.001). Figure 15 summarizes the respondent's safety perceptions when bicycling, disaggregated by bicycle type. Respondents were asked to compare how safe they feel when bicycling to driving a motor vehicle. Generally, respondents indicated that riding their respective bicycles was less safe than driving a motor vehicle. However, a greater percentage of e-bike users reported perceiving riding an e-bike as safer than driving a motor vehicle than conventional bicyclists. Figure 16 shows the response distributions between e-bike users and conventional bicyclists. The difference between the median response was statistically significant (P = 0.001), with e-bike users indicating that they generally feel safer riding their bicycle than conventional bicyclists.

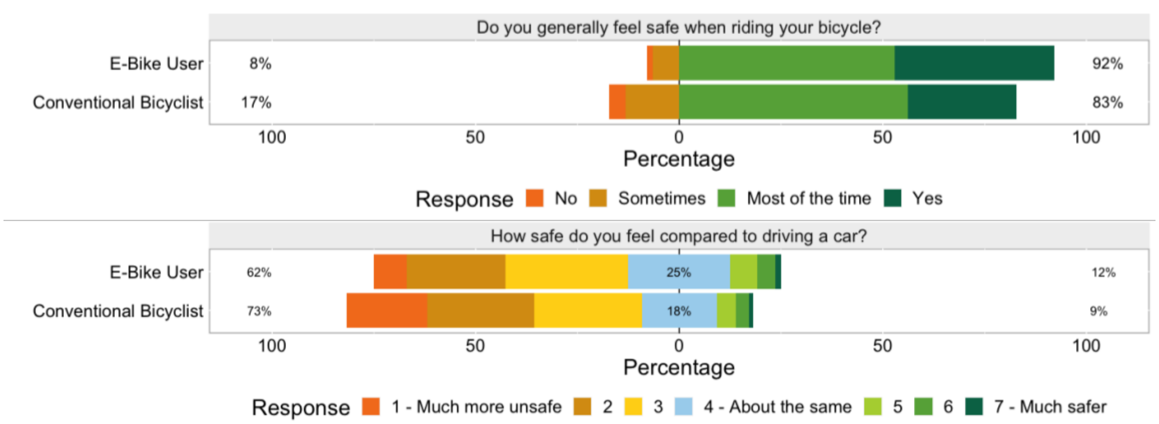


Figure 15: Safety Perceptions by bicycle type.

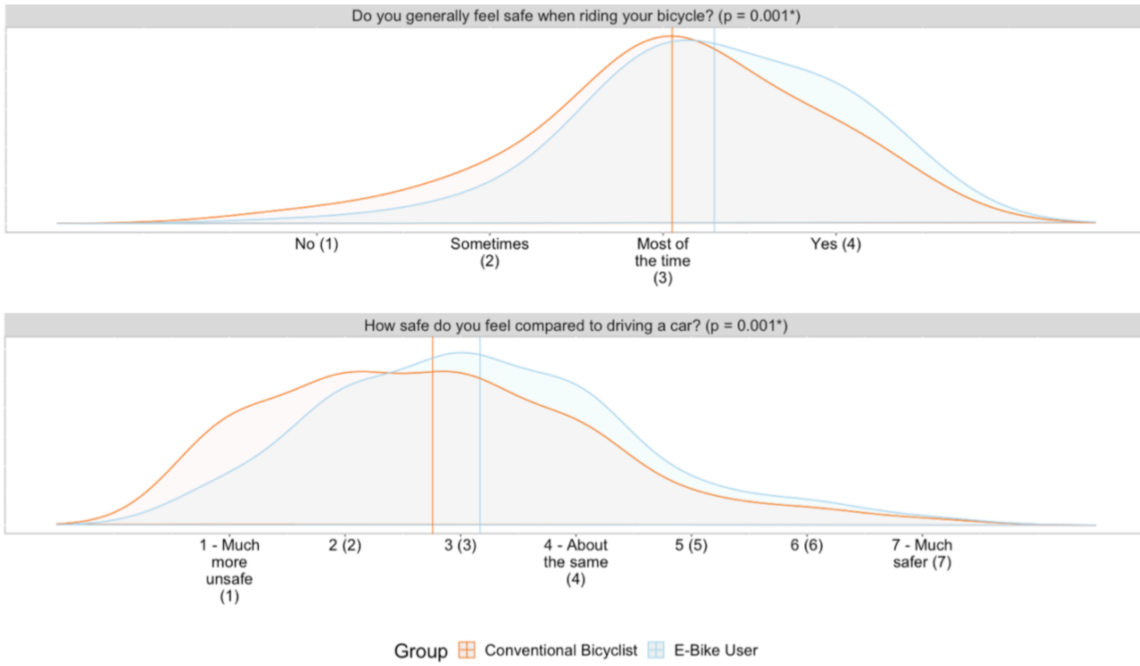


Figure 16: Comparison of response distributions regarding safety perceptions by bicycle type.

Additionally, we asked respondents to tell us about their safety perceptions when riding on a local street in conditions such as at night, in the rain, sharing the road with motor vehicles, and when snow or ice is on the ground; Figure 17 summarizes these responses, disaggregated by bicycle type. A greater percentage of e-bike users stated that they felt safer than conventional bicyclists for all conditions. Figure 18 compares the response distribution between e-bike users and conventional bicyclists. This was statistically significant for the conditions of sharing the road with motor vehicles (P = 0.016) and when snow or ice was on the ground (P = 0.046).

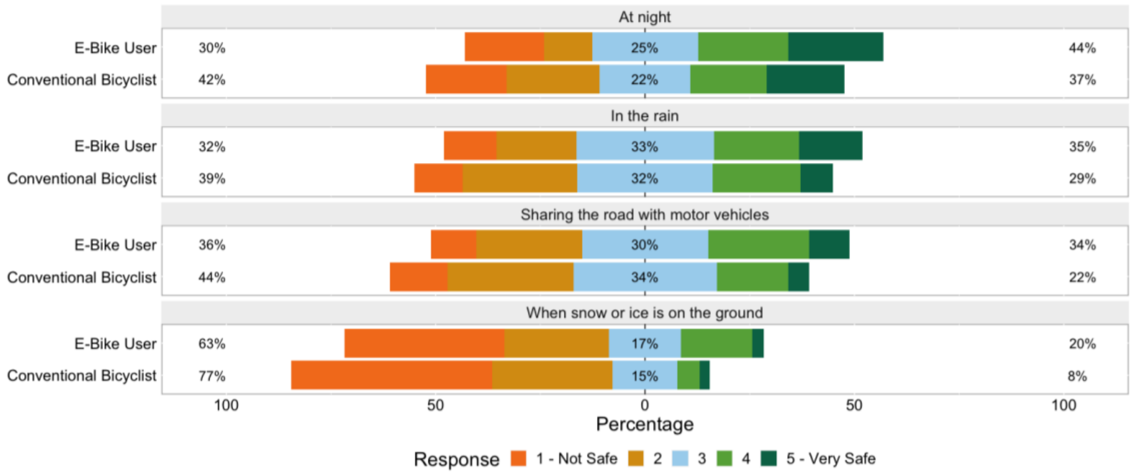


Figure 17: Contextual safety perceptions by bicycle type.

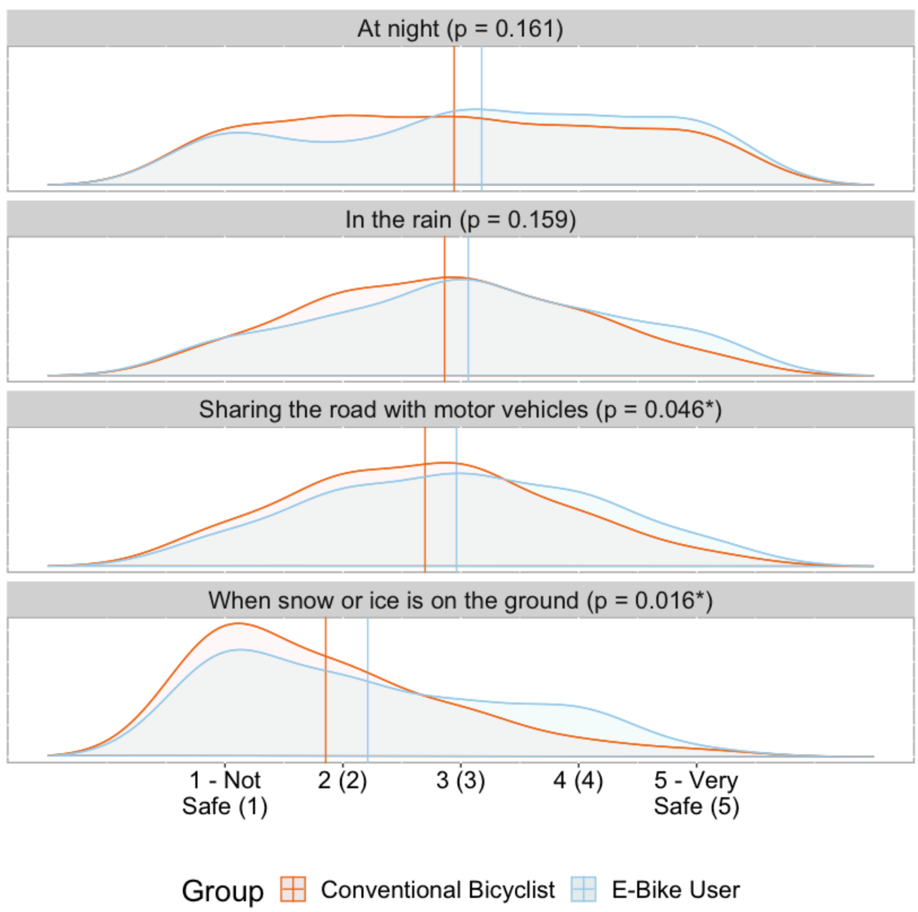


Figure 18: Comparison of response distributions regarding contextual safety perceptions by bicycle type.

Respondents were asked to tell us about their perceived safety of passing other roadway users when using a bicycle lane. The other roadway users were conventional bicycles, e-bikes, and motor vehicles parked in the bicycle lane. Responses to this question are summarized in Figure 19 and Figure 20. Generally, most bicyclists considered passing conventional bicyclists and e-bikes safe, while passing motor vehicles parked in a bike lane was viewed as unsafe. A greater percentage of e-bike users than conventional bicyclists indicated a greater sense of safety when passing any of the three roadway users. The mean difference was only statistically significant for responses regarding passing e-bikes (P = 0.005) and motor vehicles parked in a bicycle lane (P = 0.014).

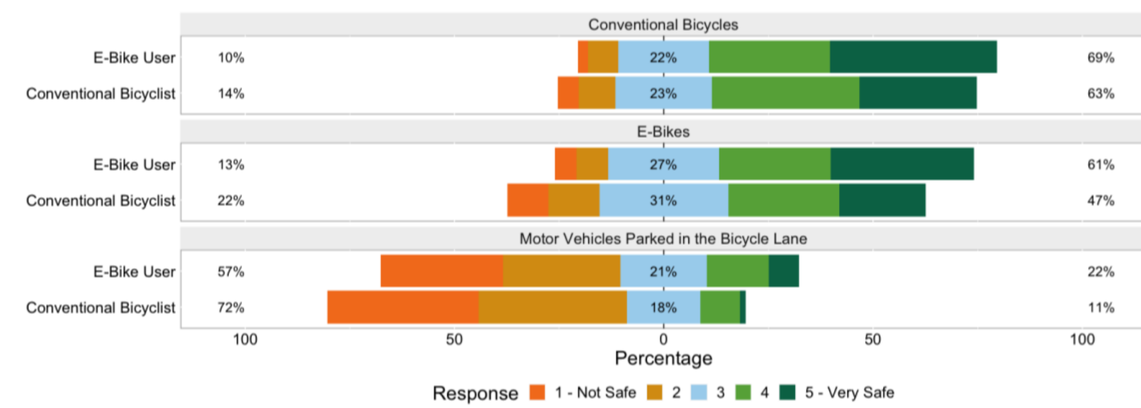


Figure 19: Safety Perceptions when passing others using a bicycle lane by bicycle type.

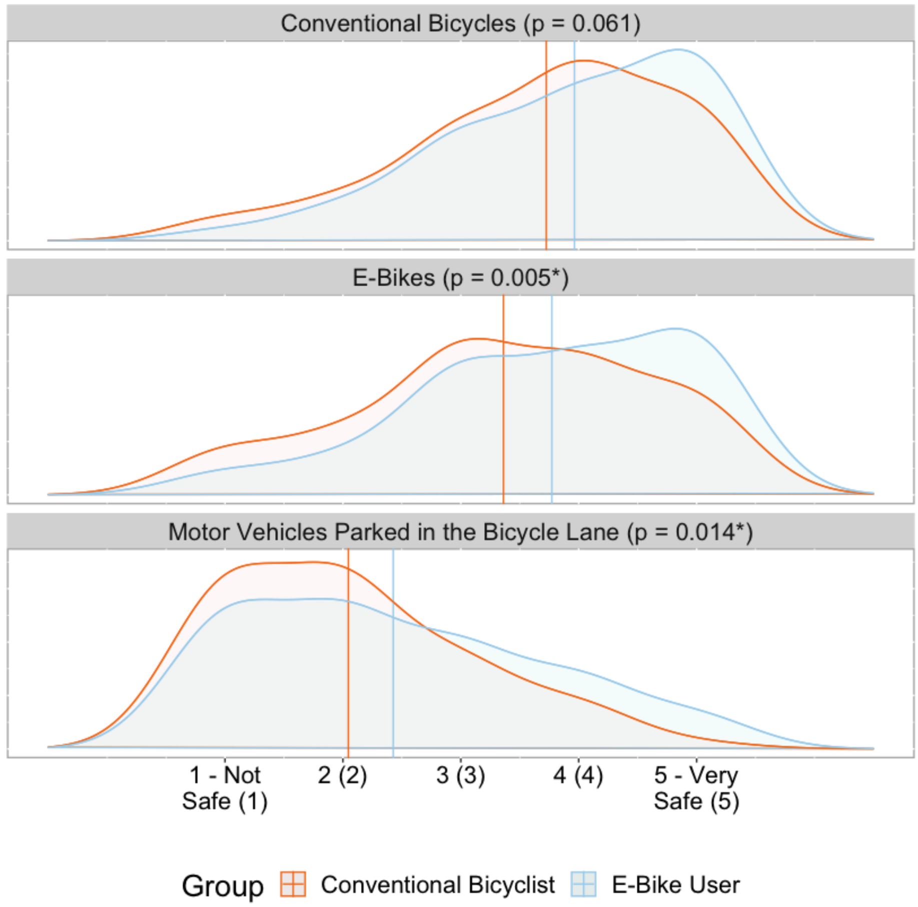


Figure 20: Comparison of response distributions regarding safety perceptions when passing others using a bicycle lane.

We also asked respondents to tell us about their safety perceptions when passing others using a multi-use path; other users were conventional bicycles, pedestrians, and e-bikes. Figure 21 summarizes the responses. Like the bicycle lane scenario responses, most bicyclists considered it safe to pass any of these three users when using a multi-use path. A greater percentage of e-bike users reported a higher level of perceived safety than conventional bicyclists.

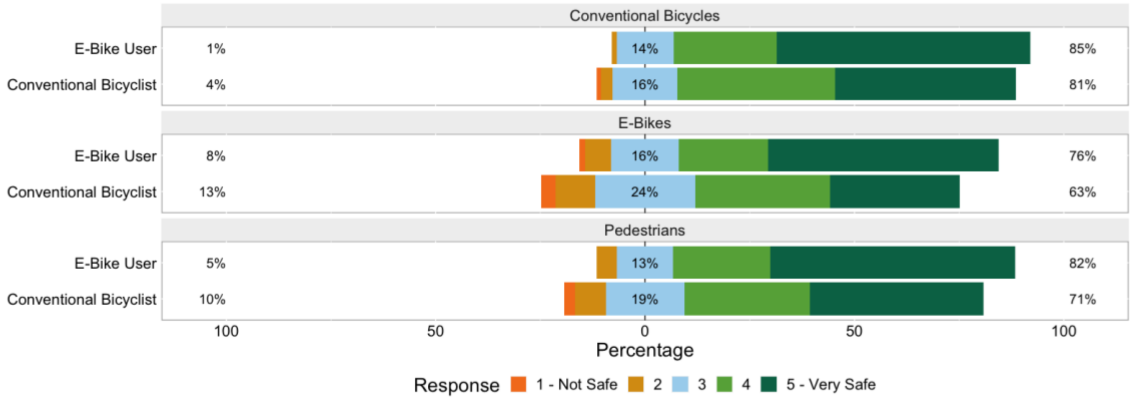


Figure 21: Safety Perceptions when passing others using a multi-use path by bicycle type.

Figure 22 shows the response distributions between e-bike users and conventional bicyclists. The differences between the median responses were statistically significant between e-bike users and conventional bicyclists when passing all other multi-use pathways users. A greater percentage of e-bike users indicated a greater sense of safety when passing conventional bicyclists (P = 0.008), e-bikes (P = 0.000), and pedestrians (P = 0.004).

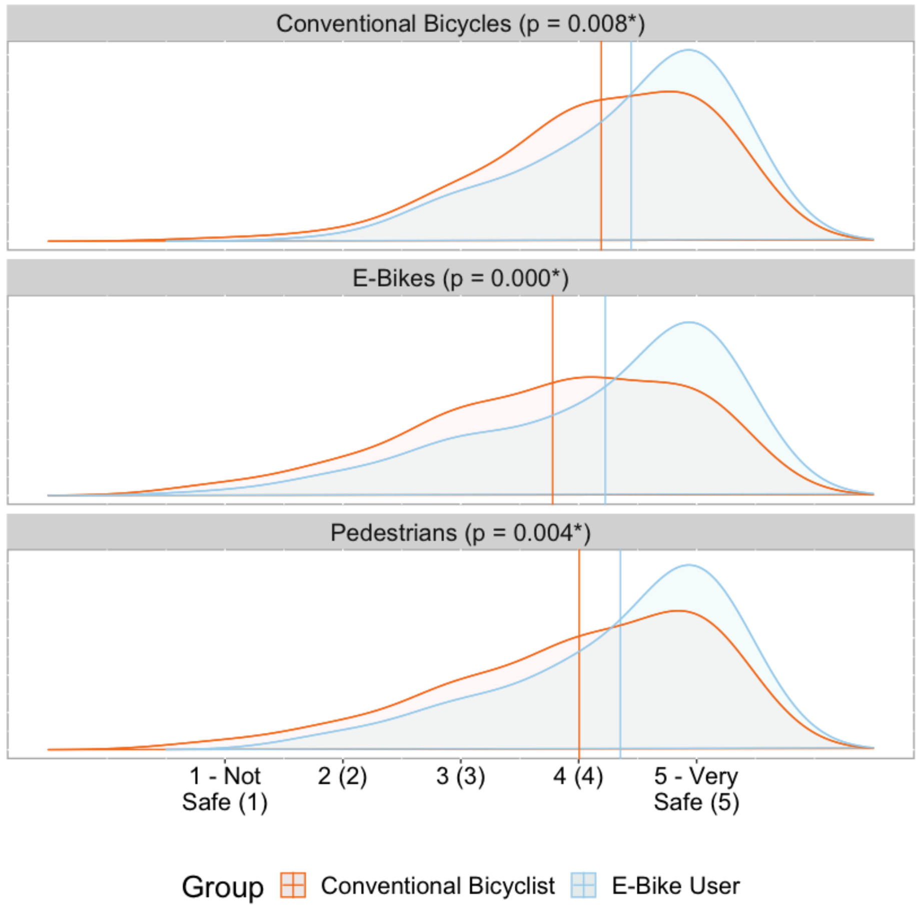


Figure 22: Comparison of response distributions regarding safety perceptions when passing others using a multi-use path.

Route Choices

This section discusses respondents' choices from the randomized choice sets. Respondents stated their route preference when responding to four randomized choice sets, two in an urban setting and two in a rural setting. The respondents chose between two hypothetical routes with varying combinations of bicycle infrastructure, travel time, and posted speed limit for each choice set. Figure 23 summarizes the responses from the urban choice set. Each bar represents the percentage of conventional bicyclists and e-bike users who chose a route comprising the characteristics labeled on the y-axis. As expected, respondents preferred routes with greater separation from motor vehicles indicated by the routes with multi-use paths being the chosen the most, followed by buffered bicycle lanes, bicycle lanes, and facility-less roadways. The overall trend of choices suggests routes with shorter travel times are preferred, followed by routes with lower posted speed limits.

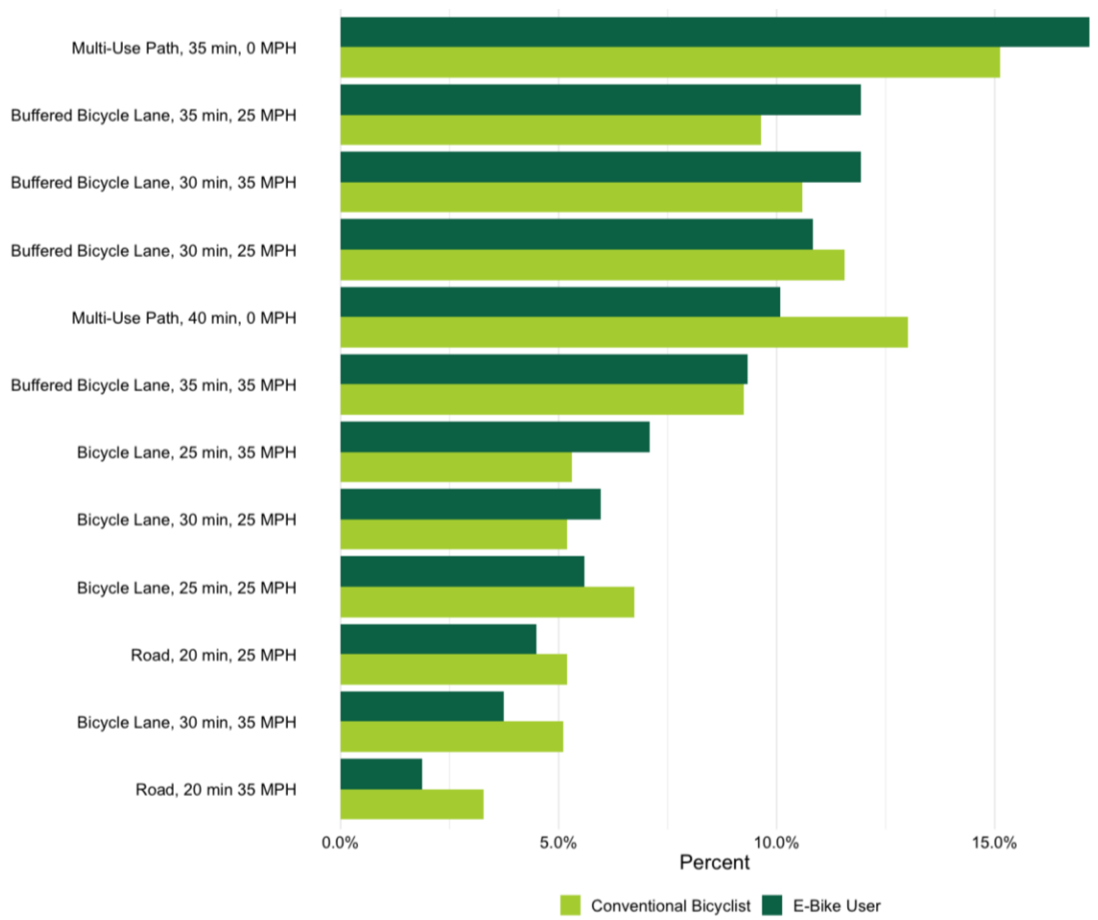


Figure 23: Plot of route choices. (Urban Choice Set)

Figure 24 summarizes the responses from the rural choice set. A similar pattern emerges for bicycle facility preferences in rural settings; respondents prefer routes with greater separation from motor vehicles. However, respondents indicated a stronger preference for multi-use paths and buffered bicycle lanes in rural areas compared to urban ones. Routes with lower posted speed limits appear to be preferred in rural areas where posted speed limits are higher than in urban areas.

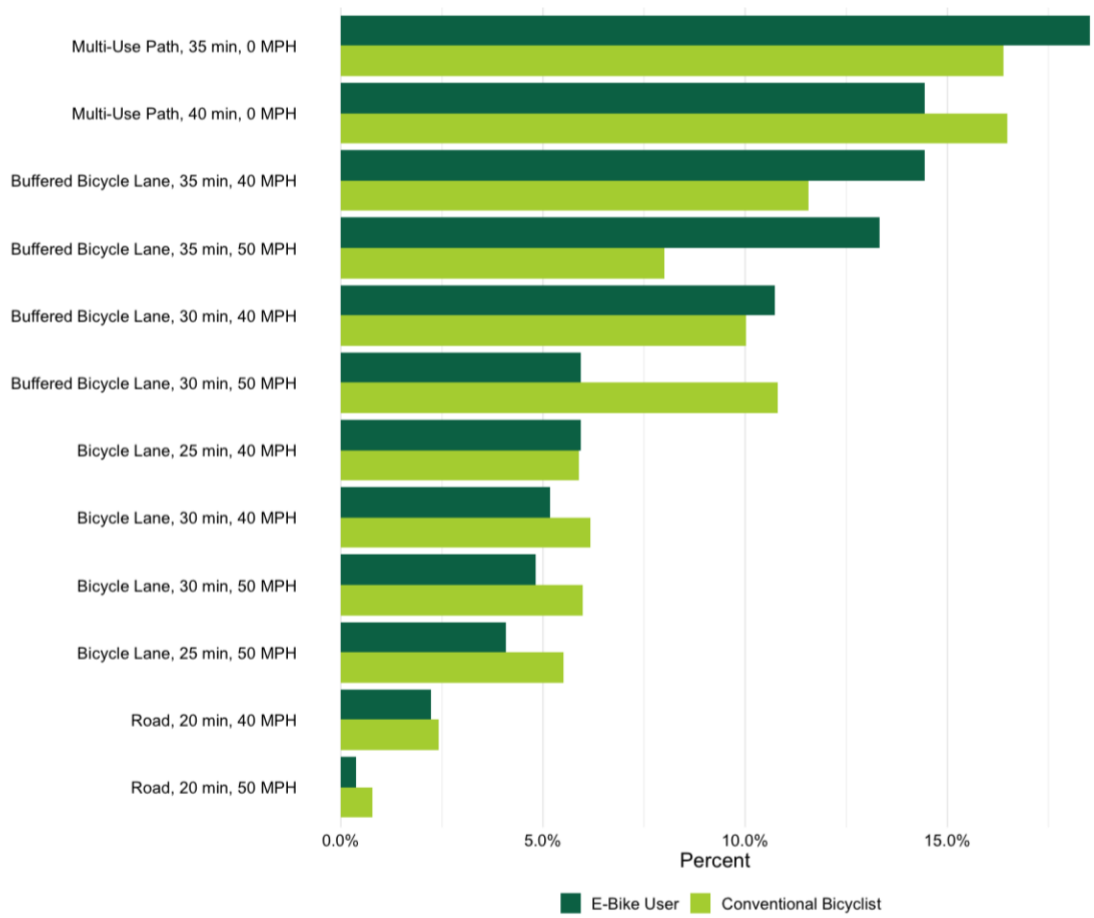


Figure 24: Plot of route choice responses. (Rural Choice Set)

Discrete Choice Modeling

The travel behavior, safety, and route choice responses shed some light on bicyclists' infrastructure preferences. However, this study aims to understand how and if the type of bicycle used by different bicyclists influences their route or facility preferences. A previous study, using a mixed logit model to evaluate the infrastructure preferences of conventional bicyclists, considered both route-related and bicyclist attributes for understanding route choice preferences (Sener et al., 2009). We use a discrete choice model to understand further the different route choices and infrastructure preferences between conventional bicyclists and e-bike users. Here, we discuss the modeling of bicycle route preferences from the stated preference choice experiments.

This study's model, a mixed logit model, is rooted in random utility theory, which can be used to evaluate an individual's utility gained through the consumption of a public good or service. This study considers several bicycle facilities as the public good consumed by bicyclists. The mixed logit model is suitable for analyzing discrete choice responses (Mcfadden & Train, 2000) and transcends the standard logit model (Train, 2009) when analyzing panel data with repeated observations. Additionally, the mixed logit model can account for unobserved factors that arise in repeated observations by not assuming that unobserved factors are new for every respondent's choice (Revelt & Train, 1998). These unobserved factors are individual specific variables such as age, gender, income, and other sociodemographic attributes. The mixed logit model considers the repeated responses and accounts for variations between respondents that indicate individual preference.

The utility function in our discrete choice model contains the attributes of each route choice alternative and the attributes of each decision-maker (conventional bicyclist or e-bike user) bicycle facility type, travel time, the posted speed limit for motor vehicles using the adjacent travel lanes, in addition to personal attributes such as age, gender, household income, trip frequency by trip purpose, and general safety perceptions.

We estimated models for each group of bicyclists, one for respondents who indicated they use an e-bike and another for respondents that only ride a conventional bicycle. Travel Time and Posted Speed Limit are continuous variables. All other variables are dummy variables except for age, which is continuous. Male and Female categorize gender. The sample size of respondents identifying as non-binary was small, and they all reported riding a conventional bicycle. To ensure the model would run for both bicycle subsets, it was necessary to categorize the eleven non-binary responses as Male or Female. The eleven nonbinary responses were randomly distributed to Male or Female based on the proportion of the binary split. Household Income is aggregated in three categories: low, middle, and upper, with low being the base condition. Household Income categories are defined as low (50k and below), middle (50k – 125k), and upper (125k+). Respondents are asked how frequently they use their bicycles for recreational or utilitarian purposes. Dummy variables indicate whether respondents reported riding "Frequently", "Regularly", or "Infrequently" for each trip type; "Infrequently" is the base condition. The last variable used in the model is the respondent's safety perceptions when riding a conventional bicycle or e-bike. For this variable, we aggregated responses to a question asking them how safe they generally feel while riding their bicycle into three categories, "No", "Sometimes", or "Yes"; "No" is the base condition. The utility of an alternative, i, for participant, n, is represented as:

$$U_{ni} = \beta_0 + \beta_1 I_{ni} + \beta_2 T_{ni} + \beta_3 P_{ni} + \beta_4 A_{ni} + \beta_5 G_{ni} + \beta_6 HI_{ni} + \beta_7 FR_{ni} + \beta_8 FU_{ni} + \beta_9 S_{ni} + \epsilon_{ni}$$

Where:

$I = infrastruture\ type$
$(facility - less\ roadway\ (base), bicycle\ lane, buffered\ bicycle\ lane, multi - use\ path)$
$T = travel\ time$
$P = posted\ speed\ limit$
$A = age$
$G = gender\ (female\ (base), male)$
$HI = household\ income\ (low\ (base), middle, upper)$
$FR = frequency\ of\ recreational\ trips\ (infrequently\ (base), regularly, frequently)$
$FU = frequency\ of\ utilitarian\ trips\ (infrequently\ (base), regularly, frequently)$
$S = genral\ safety\ (no\ (base), comestimes, yes)$
$\epsilon_{ni} = iid\ extreme\ value$

The goodness-of-fit for the models is indicated by McFadden's $R^{2,}$ which is 0.31 for conventional bicyclists and 0.39 for the e-bike users. Table 3 summarizes the coefficient estimates and odds ratios resulting from the models. The odds ratios indicate the impact of the choice characteristics (infrastructure type, traffic speed, and travel time) and respondent attributes on the odds of making a particular choice.

The odds ratios for bicycle facilities: bicycle lanes, buffered bicycle lanes, and multi-use paths indicate respondents prefer to use routes with any bicycle facility over a facility-less roadway. This result supports previous findings suggesting bicyclists prefer to use bicycle-specific infrastructure (Dill, 2009). These three variables are highly significant in both models. E-bike users and conventional bicyclists are 16.6 and 25.8 times more likely to choose a route with a buffered bicycle lane over a facility-less roadway. Likewise, this sample's e-bike users and conventional bicyclists are 7.1 and 9.1 times more likely to choose a route with a multi-use path available. Lastly, e-bike users and conventional bicyclists are 4.3 and 6.2 times more likely to choose a route with bicycle lanes than a route with no bicycle facility. This study sample's preference for bicycle facilities seems to agree with previous findings; designated bicycle lanes were more preferred than multi-use paths, with both being preferred to a facility-less roadway (Stinson & Bhat, 2003; Tilahun et al., 2007). The odds of conventional bicyclists choosing any bicycle facility are higher than those of e-bike users for the same facility type. This suggests that bicycle facilities are more important to conventional bicyclists.

Travel Time is a significant variable for conventional bicyclists but not for e-bike users. The odds ratio for conventional bicyclists indicates a lower likelihood of choosing a route with a longer travel time. This result suggests that travel time is a significant disutility to conventional bicyclists but not for e-bike users.

The Posted Speed Limit for motor vehicles influences e-bike users' and conventional bicyclists' route choices. The coefficients are significant, and the odds ratios indicate that e-bike users and conventional bicyclists are less likely to choose routes near vehicles perceived to be traveling at higher speeds. The odds ratios are similar between e-bike users and conventional bicyclists, indicating a shared concern for safety alluding to bicyclists' safety perceptions; the severity of a bicycle and motor vehicle crash increases with motor vehicle speed.

When asked about how safe respondents generally feel when riding their bicycles, most respondents overwhelmingly reported feeling safe. The variable indicating how safe bicyclists generally feel when using a bicycle is not significant in the model despite the prevailing preferences for bicycle-specific facilities with greater separation from motor vehicles and bicycle facilities near vehicles perceived to be traveling at lower speeds. This result is because a small proportion deviated from most respondents who reported feeling safe when riding their bicycle. This small proportion of our sample size is likely too small to be statistically significant.

Lastly, the modeling results suggest that neither bicyclist type nor cycling experience are significant factors for estimating route choice preferences. However, the exception is for utilitarian conventional bicyclists who ride regularly. This bicyclist is 1.58 times more likely to choose a route with enhanced bicycle facilities over a facility-less roadway.

Table 3: Discrete Choice Modeling Estimates and Odds Ratios

Variables	Conventional Bicyclist			E-Bike User		
	Estimate	Pr (>|z|)	Odds Ratio	Estimate	Pr (>|z|)	Odds Ratio
Intercept	-0.342	0.393	0.710	-0.942	0.585	0.390
Bicycle Lane	**1.832**	**<2.2e-16**	**6.248**	**1.453**	**0.000**	**4.278**
Buffered Bicycle Lane	**3.249**	**<2.2e-16**	**25.77**	**2.809**	**4.1e-07**	**16.59**
Multi-Use Path	**2.204**	**3.2e-07**	**9.058**	**1.956**	**0.031**	**7.068**
Travel Time	**-0.076**	**2.3e-05**	**0.927**	-0.012	0.741	0.988
Posted Speed Limit	**-0.054**	**2.1e-12**	**0.947**	**-0.047**	**0.006**	**0.954**
Land Use: Urban	0.116	0.323	1.123	0.021	0.936	1.021
Age	-0.004	0.273	0.996	0.004	0.636	1.004
Male	-0.085	0.483	0.919	0.326	0.210	0.721
Household Income: Middle	-0.122	0.373	1.130	-0.256	0.394	0.774
Household Income: Upper	-0.094	0.580	0.911	-0.357	0.295	0.700
Recreational Bicyclist: Regularly	-0.094	0.687	0.910	0.752	0.191	2.122
Recreational Bicyclist: Frequent	0.085	0.685	1.089	0.120	0.807	1.127
Utilitarian Bicyclist: Regularly	**0.483**	**0.012**	**1.581**	0.215	0.650	1.240
Utilitarian Bicyclist: Frequent	0.112	0.422	1.119	0.250	0.448	1.284
Generally Safe: Sometimes	0.357	0.240	1.429	0.633	0.681	1.884
Generally Safe: Yes	0.116	0.323	1.363	0.640	0.678	1.897
McFadden R^2:	0.307			0.388		

CONCLUSION

This study set out to understand if and how e-bikes may affect bicyclist travel behavior and infrastructure preferences. We used a web-based stated preference survey to gather data from conventional bicyclists and e-bike users in Chittenden County, Vermont. The study sample comprised 667 bicyclists: 529 conventional bicycle riders and 138 e-bike users. We found that many e-bike users had started in the previous five years. Similar to findings of previous e-bike studies, respondents reported their primary motivations for adopting e-bike use was to aid in climbing hills, travel longer distances, and reduce travel time (Dill & Rose, 2012; Haustein & Møller, 2016), replacing vehicle trips and having the ability to carry cargo or transport children were significant motivators (Ling et al., 2017).

E-bike users generally ride their bicycles more frequently for utilitarian purposes (Astegiano et al., 2015; Ling et al., 2017b; MacArthur et al., 2017), as did the e-bike users in our sample. Two-thirds of e-bike users reported using their e-bike weekly for utilitarian purposes compared to almost 50% of conventional bicyclists. Both types of bicyclists preferred routes with few intersections, well-maintained surfaces, slower vehicle speeds, less traffic, less travel time, and dedicated bicycle facilities. However, travel time was a significant variable only for conventional bicyclists when evaluated in the discrete choice model, whereas the posted speed limit and dedicated bicycle facilities were significant variables for both bicyclist types. Additionally, a larger proportion of e-bike users preferred routes that avoided hills but longer in distance than conventional bicyclists.

Safety perceptions between e-bikes users and conventional bicyclists were similar when asked their general perceptions of safety and comparing the safety of riding their bicycle to driving a car. However, in both instances, a larger, non-significant proportion of e-bike users reported greater safety perceptions. When asked about contextual safety perceptions, a larger proportion of e-bike users reported a greater sense of safety than conventional bicyclists when riding at night or in the rain, but e-bike users' sense of safety sharing the road with motor vehicles and riding on snowy or icy surfaces was significantly greater than conventional bicyclists. E-bike users also reported feeling significantly safer when passing other road users using bicycle lanes and multi-use paths than conventional bicyclists. When evaluating general safety perception in the discrete choice model, the safety variable was not significant, presumably because of the large proportion of both bicyclist types reporting a general feeling of safety.

Unsurprisingly, both e-bike users and conventional bicyclists preferred dedicated bicycle facilities over a facility-less roadway, with conventional bicyclists tending to have a higher preference for dedicated bicycle facilities compared to e-bike users. What was surprising, however, was the hierarchy of facilities. The difference in odds ratios between bicycle lanes and multi-use paths was relatively small compared to the difference between multi-use paths and buffered bicycle lanes. This may be because multi-use paths are not as prevalent, i.e., convenient and require more time to access than on-street buffered bicycle lanes.

This study reveals that e-bike users have an elevated perception of safety and exposes the need to provide safer and more accessible routes for bicyclists. The results also shed light on increasing the mileage and connectivity of enhanced on-street bicycle facilities. Designing and striping roads for bicycle lanes only maintains the status quo and does not do enough to attract and encourage more bicycling. Policy changes that allocate more of the traveled way to bicycle facilities to allow for buffered or protected bicycle lanes may improve the bicycling mode share in municipalities. Additionally, considering other bicycle facility designs such as raised cycle tracks can provide bicyclists with safer facilities. While e-bikes are continuing to grow in popularity and have many positive implications, they may be cost-prohibitive for lower-income populations that cannot afford the luxury of owning an e-bike. Planners and policymakers still need to consider conventional bicyclists' needs and safety perceptions. Future policies aiming to increase bicycling could allocate more of the traveled way for dedicated bicycle infrastructure such as buffered bicycle lanes, protected bicycle lanes and intersections, and raised cycle tracks. An ambitious policy such as this may help local, regional, and state transportation systems realize a greater bicycle mode share, improved traffic congestion, and minimize bicyclist fatalities and injuries.

This study provides insights into the different preferences and needs of e-bike users compared to conventional bicyclists. However, there are limitations to consider. First, the sociodemographic make-up of our study sample is not representative of the country. Second, the sample of e-bike users is relatively small and consists of e-bike users who recently began using an e-bike. A larger sample of e-bike users will aid in delving deeper into their emerging needs. Not only a larger sample is desired, but a more diverse sample from different geographical locations, races, income, and education levels. Future research should also consider exploring the differing preferences of bicyclists that ride both a conventional bicycle and an e-bike to isolate the influence of the bicycle type on route and infrastructure preferences.

The study design could also benefit from considering more route attributes such as continuity of facilities, roadway lighting, and the presence of parked vehicles adjacent to the route. Lastly, this study's only measure of preference is the odds ratios from the discrete choice modeling; a measure of bicyclists' willingness-to-pay for enhanced facilities is more meaningful to policymakers. This study attempted to calculate willingness-to-pay; however, we presume the range of travel times was not large enough for respondents to truly consider trading their time to access preferred facilities. Future research should consider more route-specific variables and travel times to establish a more discernable measure of specific route attributes. Additionally, this study merely scratched the surface of the safety concerns associated with e-bikes. Future research should further explore conventional bicyclists' safety perceptions of e-bike users now that e-bikes are more prominent on the road.

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