Changes in Travel Behavior, Attitudes, and Preferences among E-Scooter Riders and Non-Riders: A First Look at Results from Pre and Post E-Scooter System Launch Surveys at Virginia Tech

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ABSTRACT

Shared micromobility such as electric scooters (e-scooters) has potential to enhance the sustainability of urban transport by displacing car trips, providing more mobility options, and improving access to public transit. Most published studies on e-scooter ridership focus on cities and only capture data at one point in time. This study reports results from two cross-sectional surveys deployed before (n=462) and after (n=428) the launch of a fleet of shared e-scooters on Virginia Tech's campus in Blacksburg, VA. This allowed for a pre-post comparison of attitudes and preferences of e-scooter riders and non-users. E-scooter ridership on campus follows patterns identified in other studies, with a greater share of younger riders—in particular undergraduate students. Stated intention to ride prior to system launch was greater than actual ridership after system launch. The drop-off between pre-launch intention to ride and actual riding was strongest for older age groups, women, and university staff. As in city surveys, the main reasons for riding e-scooters on campus were travel speed and fun of riding. About 30% indicated using e-scooters to ride to parking lots or to access public transport service—indicating e-scooters' potential as connector to other modes of transport. Compared to responses prior to system launch, perceptions about the convenience, cost, safety, parking, rider behavior, and usefulness of the e-scooter systems were more positive among non-riders after system launch—indicating that pilot projects may improve public perception of e-scooters. Building more bike lanes or separate spaces for e-scooters to ride could help move e-scooter riders off sidewalks—a desire expressed by both pedestrians and e-scooter users.

Keywords: Micromobility, electric scooter, shared mobility, travel behavior, attitudes, preferences, campus

INTRODUCTION

Shared electric scooters (e-scooters) have been widely introduced in cities and on university campuses in the United States in recent years. The National Association of City Transportation Officials (NACTO) reported that 84 million shared micromobility trips (including both bikesharing and e-scooter sharing systems) were taken in 2018, with e-scooter trips accounting for nearly half of total ridership (NACTO, 2019). About 35% of vehicle trips in the United States are 2 miles or less, an ideal length for e-scooter substitution [1]. Increased use of e-scooters has the potential to enhance the sustainability of urban transport systems by displacing short trips made by passenger cars, SUVs, light trucks, taxis, or transport network company (TNC) vehicles, and by improving access to public transport with a first/last mile connecting service.

Although e-scooters may fit well with city and university transportation planning goals, such as increasing mobility choices and reducing motorized vehicle trips and emissions, there may be strong safety concerns among the public and administrative leadership. Concerns include e-scooter users injuring themselves and pedestrians, as well as creating nuisances by parking e-scooters in the sidewalk or blocking rights-of-way. For this reason, several cities and university campuses have opted to implement e-scooters during a pilot period to closely monitor and evaluate impacts on the community. Successful implementation and political acceptability of e-scooters in the longer term depend on e-scooter usage, rider behavior, and also perceptions and attitudes of non-users during the pilot period.

To date, only a few peer-reviewed studies report on socio-economics and demographics of e-scooter users, rider behavior, and mode shift. Moreover, we found only two published reports on non-rider perceptions about e-scooters—even though this perspective is crucial for political implementation and non-user safety. In addition, virtually all e-scooter studies only report on one point in time and fail to report on changes in usage, behavior, or attitudes over time.

This study reports results from two cross-sectional surveys deployed before and after the launch of a fleet of shared e-scooters on Virginia Tech’s campus in Blacksburg, VA. This allowed for a pre-post comparison of user behavior and attitudes as well as changes in preferences of non-users and users. There were three main goals for this study. First, we add to the body of knowledge about e-scooter usage, rider behavior, and non-user perceptions. Second, we are first (to our knowledge) to trace changes in e-scooter usage, rider behavior, and non-user perceptions over time—using two cross-sectional surveys. Finally, we provide initial informationon what a community (university, city, etc) could do with respect to infrastructure, regulations, and other factors to make an e-scooter system deployment a success, both in terms of achieving accessibility benefits for users and acceptance among non-users.

Several research questions guided the design of our surveys and data analysis, including:

- How often are scooters used, for what trip purpose, why, and what would make riders ride more often and non-riders consider riding at all?
- What barriers and benefits to scooter usage do riders and non-riders perceive?
- Will an e-scooter deployment result in nuisance concerns (e-scooter parking, blocking access)?
- How are e-scooters perceived by users and non-users in terms of safety?
- Where do users ride (in the road, on the sidewalk, in bike lanes, on separate paths)?
- What impacts on travel behavior can be expected as a result of e-scooter deployment on a university campus?

LITERATURE REVIEW

As e-scooters are relatively new to arrive as a shared mobility service, the literature is emerging. User surveys conducted by cities to evaluate pilot e-scooter deployments are one of the primary sources of information about who uses e-scooters, for which kinds of trips, what modes they replace, and how they are perceived by the wider community. The following discussion summarizes what is known about e-scooter use in urban settings, so that we can compare our results from Virginia Tech, assess similarities and differences with other communities, and identify any special issues in the university setting. We found one study conducted in a University campus setting [2], but the majority of e-scooter pilot evaluation surveys have been conducted in cities. We selected city surveys with over 1,000 respondents, including at least 35% of respondents who were e-scooter users.

E-scooter user sociodemographic and travel patterns

City pilot evaluations consistently find that frequent e-scooter users are predominantly male and under 40 years of age [3]–[9]. Atlanta's user survey found that women were more likely to be interested in e-scooters and to have tried an e-scooter [3] while San Francisco's found that men were nearly twice as likely to ride daily [10]. Users span a range of income groups, with more than half of users in some cities reporting income over $75,000 per year, and some systems attracting larger shares of low-income users [3], [4], [9].

A survey at Arizona State University targeted at staff had 1,256 respondents, 32% of whom had used an e-scooter. Users were predominantly 25-34 years of age, and male. Frequent riders (at least once per week) were more likely to use walking or bicycling as their main mode of transportation, and to and frequent e-scooter use, and to have an income between $50,000 and $99,000 [2].

When asked what mode they would have used, if an e-scooter had not been available, users most frequently report they would have walked (39% on average), as shown in Table 1. However, a substantial percentage report that they would have used a car or taxi/TNC, on average 15% and 26%, respectively. This means a significant number of motor vehicle trips are displaced by e-scooters. Some users report they would have otherwise used public transport or a bicycle, on average 8% and 7%, respectively. A roughly equal share of users reported they would not have traveled at all, if an e-scooter had not been available. This indicates latent demand for the mobility service offered by e-scooters. When asked how riding shared e-scooters had changed their use of other modes, users most frequently reported reduced use of taxis/TNCs, for example, 42% of riders in Chicago and 49% in Hoboken. [5], [7] Results from Arizona State University were consistent, with 57% of e-scooter users reporting they would have otherwise walked, 8% biked, and 25% driven in a car or ride hail vehicle. [2]

Table 1 Rider mode choice if an e-scooter had not been available for last trip

Study area	Driving	Taxi or TNC	Public transit	Walk	Bicycle	Would not have traveled
Atlanta, GA [3]	n.a.	42%	2%	48%	4%	n.a.
Arlington, VA [11]	15%	20%	5%	37%	4%	4%
Chicago, IL [5]	11%	32%	14%	30%	8%	3%
Hoboken, NJ [7]	11%	37%	13%	51%	13%	8%
Portland, OR [8]	19%	15%	10%	37%	5%	n.a.
San Francisco, CA [10]	5%	36%	11%	31%	9%	8%
Tucson, AZ [9]	27%	14%	3%	36%	8%	13%
Average	**15%**	**26%**	**8%**	**39%**	**7%**	**7%**

One of the top reasons for using e-scooters is for social and recreational trips, or just for fun. Other top reasons include commuting to work or school, and connecting to transit. A plurality of users (34% to 51%) reported using e-scooters to connect to public transport in some cities [5], [7], [8], [10]. San Francisco reported that scooters induce public transport trips at roughly 4 times the rate that they replace public transport trips [10].

Analyses of e-scooter trip data from city deployments find that trip distances are about 1 mile on average, and trip duration ranges from 5 to 20 minutes [3]–[6], [8]–[11]. Distinct weekday and weekend usage patterns were found in these cities, with nearly twice as many trips made on Saturdays than other days. The temporal distribution showed a single peak at midday, suggesting the e-scooters are used more for trips other than the traditional morning and evening commute. A large percentage of trips were found to start and end near public transport in Chicago and Arlington [5], [11].

Perceptions of users and non-users

In general, city pilot evaluations have found that e-scooters are positively received by the communities where they are introduced. The majority of survey respondents (62% to 81%) supported extending the pilot or replacing it with a permit system in nearly all the reports we reviewed [3], [4], [6]–[9], [12]. Yet they also identified notable differences in how e-scooters are perceived by users and non-users. A majority of users consistently report several benefits of using e-scooters, including that they make it faster and more convenient to get around. Some cities found especially strong support for e-scooters among low-income respondents [3], [4], [8]. Non-users share positive views, but at lower rates.

The majority of non-users report concerns with e-scooters, including safety, incorrect parking, speeding and unsafe riding, especially on sidewalks [13]. Cities that asked survey respondents about their knowledge of e-scooter riding and parking regulations found that only 70% to 75% indicated they knew the rules [4], [7], [12]. This suggests that educational and enforcement efforts could be effective in addressing community concerns.

When asked about barriers to riding e-scooters, riders and non-riders often identified the same issues, but in difference percentages. Riders and non-riders were most likely to agree about a need for safer places to ride and more bike lanes. For example, survey respondents in Tucson were asked to rank the top three changes they would like see, if e-scooters would move beyond the pilot stage [9]. Top responses included better pavement quality on streets (59% riders / 27%

non-riders), more designated scooter parking (53% / 45%), and safer places to ride (protected bike lanes etc.) (51% / 29%).

The Arizona State study found that non-white survey respondents were significantly more likely than white respondents to report both a dissatisfaction with existing transportation options and an intention to try e-scooters [2]. Scooter users' perceptions were found to vary by frequency of use, with more frequent users more likely to report benefits of use such as faster than walking, convenience, better in hot weather than walking, and replacing driving. Occasional riders were more likely to report fun/relaxing as a benefit. Men were significantly more likely to report using an e-scooter as being very safe. Perceptions of non-users were not reported.

STUDY CONTEXT

This study was conducted as part of an 18-month research partnership between the Virginia Tech Transportation Institute (VTTI) and Ford subsidiary Spin, an e-scooter mobility provider. Spin's operating permit allowed deployment of a fleet of 300 e-scooters on the Virginia Tech campus in Blacksburg, Virginia from September 2019 until March 2020, when service was suspended due the COVID19 pandemic.

The Virginia Tech campus is located adjacent to the Town of Blacksburg, Virginia. The campus community consists of 34,000 students (81% undergraduate and 19% graduate) and 7,500 faculty and staff. A GPS-geofence for e-scooter operations was established which bounds the main activity areas, about one square mile, shown in Figure 1. A "no scooter zone" on the drill field may also be seen in Figure 1, as well as designated scooter parking areas and the location of the Virginia Tech Alternative Transportation Department, where riders could request a free helmet from a supply provided by Spin.

Services did not extend into the adjacent Town of Blacksburg, as the town had not yet developed an e-scooter permit program. If a rider crossed the geofenced boundary, the e-scooter provided audible feedback and ceased to operate. This restriction precluded riders from using e-scooters for trips between the campus and residential areas of Blacksburg. Each day, Spin deployed a fleet of up to 200 e-scooters at designated locations in the service area at 7:00 am and collected them for overnight storage and charging 30 minutes after dusk. E-scooters were also removed in advance of high-traffic events (e.g. football games), during winter break, and during inclement weather.

E-scooters were accessed via the Spin app, at a cost of $1 to unlock (start a trip) and $0.15 per minute to ride. Riders were presented with educational information on safe riding practices and parking rules when they signed up via the app, and again each time they unlocked an e-scooter, before they were able to ride.

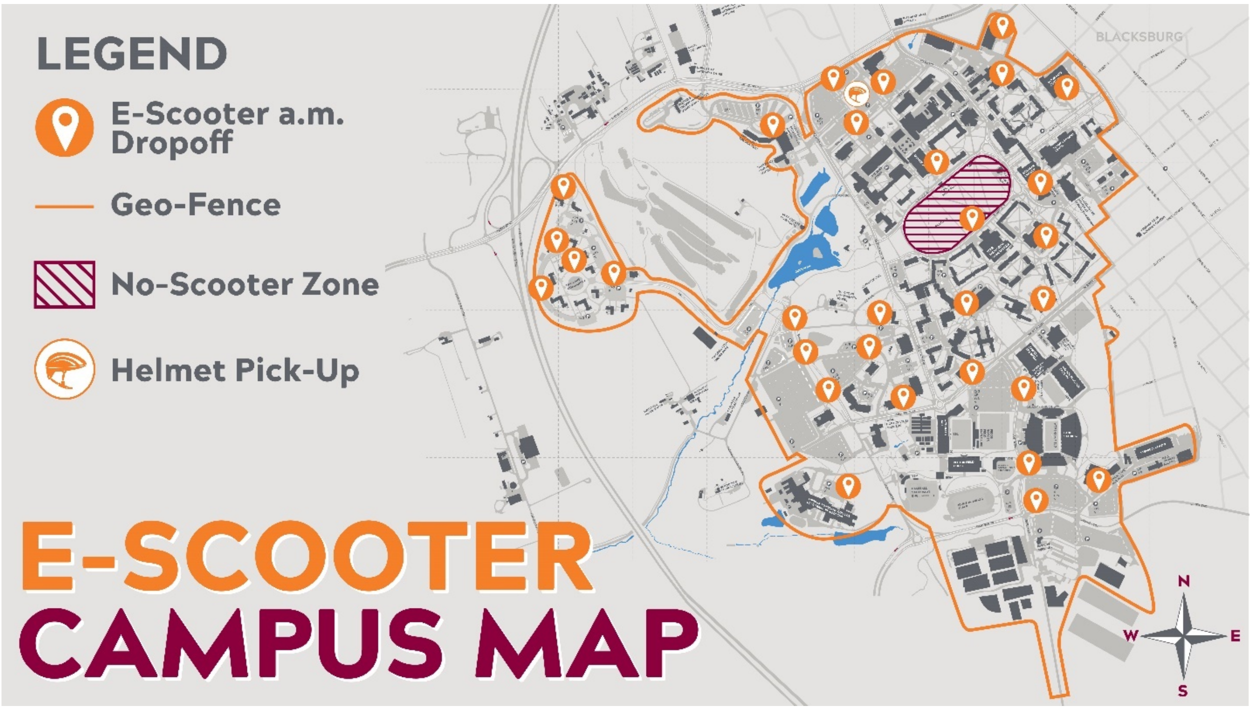

FIGURE 1. Geofence zone for e-scooter operations and no scooter zone [15]

E-scooter deployment was closely monitored by an oversight committee with representation from VTTI, campus Parking and Facilities services, Alternative Transportation, Risk Management, and the Virginia Tech Police Department. The oversight committee met with Spin bi-weekly during the period of deployment to address operational issues as they arose. This was especially important during the early weeks of deployment to review communication plans and adjust deployment locations. Over time, the committee worked with Spin to develop an inclement weather policy and strategies to improve compliance with e-scooter parking regulations. It served as an important conduit of information sharing between the operator and campus leadership, facilities management, and enforcement.

University campus travel patterns at Virginia Tech

We sought to find a baseline of travel patterns on Virginia Tech's campus as a "pre" basis for comparison with travel patterns revealed in our survey and e-scooter trip data. Virginia Tech conducts surveys of commuters to and from campus showing that 35% of campus-related trips are by car, 20% by bicycle, 18% on foot, 17% by bus, and 6% by van pool. However, these travel statistics cannot serve as baseline for our results, because e-scooter use was restricted to the campus only with geofencing not allowing trips beyond the campus. Virginia Tech's campus was part of Virginia's add-on program for the 2009 National Household Travel Survey [14]. The add-on sample was large enough to disaggregate travel patterns for students living on and off campus. Even though somewhat out-of-date, data for students who live on campus show that walking (77% of trips) dominated travel followed by driving (12%), bicycling (6%), and bus (5%). This is the closest "baseline" data we could find for travel on campus—even though it includes trips by campus residents that go beyond campus boundaries. Available modes of transport on campus in fall 2020 included driving, bus (Blacksburg Transit), bicycling, shared bicyles, walking, and e-sooters. Blacksburg Transit buses connect the Virginia Tech campus with the Town of Blacksburg. However, buses serve multiple stops on campus, allowing students to ride buses for trips that originate and end on campus.

METHODS

We designed an online survey to collect attitude and preference data from members of the university community, as well as the usage patterns of e-scooter users. Respondents included students, faculty, and staff recruited by online dissemination to the campus community and by pedestrian intercept using tablets to collect data. We offered a chance to win $50 as an incentive, with 50:1 odds. Data was collected in two cross-sectional surveys, pre and post e-scooter deployment, in late August (428 respondents) and October 2019 (462 respondents). In the post-survey, 129 respondents (28%) had used an e-scooter on campus. In most cases, we tested for statistical significance using chi-square tests. An alternative approach to significance tests of binary data (other than chi-square) is to use t-tests that compare population proportions for subcategories of variables—for example the proportion of respondents reporting the intention to ride e-scooters prior to launch compared to the proportion of respondents riding e-scooters after launch. Chi-square tests for the binary data and t-tests of population proportions (where appropriate) provided consistent results. Results of statistical significance tests are indicated with ($p<0.05$) throughout the text.

In addition, at the end of each ride, e-scooter riders were asked if they would like to answer three quick questions and consent to Spin sharing their anonymized data for research purposes. Therefore, this dataset represents a sample of trips from riders who chose to participate. Over 5,000 unique riders reported data from about 10% of trips (12,014). The three questions were: What was the purpose of your trip? If not by e-scooter, how would you have taken this trip? Why did you choose to ride an e-scooter for this trip? The results of both the general and the post trip surveys were then analyzed for statistically significant correlations and changes over time.

RESULTS

E-scooter Usage Patterns

A total of 120,636 e-scooter trips were made during the study period—794 trips per day. The average trip length was 0.73 miles and the average trip duration was 7.3 minutes. Based on e-scooter GPS trajectory data we calculated travel speed using recorded latitude and longitude of the e-scooter every 5 seconds. We assumed straight-line distances between the trajectory starting and ending points for each 5-second period, assuming the e-scooters did not change directions within this time window. We then divided the moving distance for each GPS record by five seconds. The results suggest that, the moving speed of e-scooters was typically between 6 to 7.5 miles per hour, with an average speed of approximately 6.13 mph. Travel speeds of e-scooters went beyond 10 mph for only a small portion of trips.

We compared the e-scooter Origin-Destination (O-D) matrices for weekdays and weekends (see Figure 2). During weekdays, when classes are in session, more e-scooter trips connected parking lots and residential halls to academic buildings or occurred between academic buildings. On weekends, the majority of e-scooter trips connect students to, from parking lots, and to residential halls. Overall, the results also suggest, that only a limited number of e-scooter trips start or end at campus support facilities and event or athletic venues.

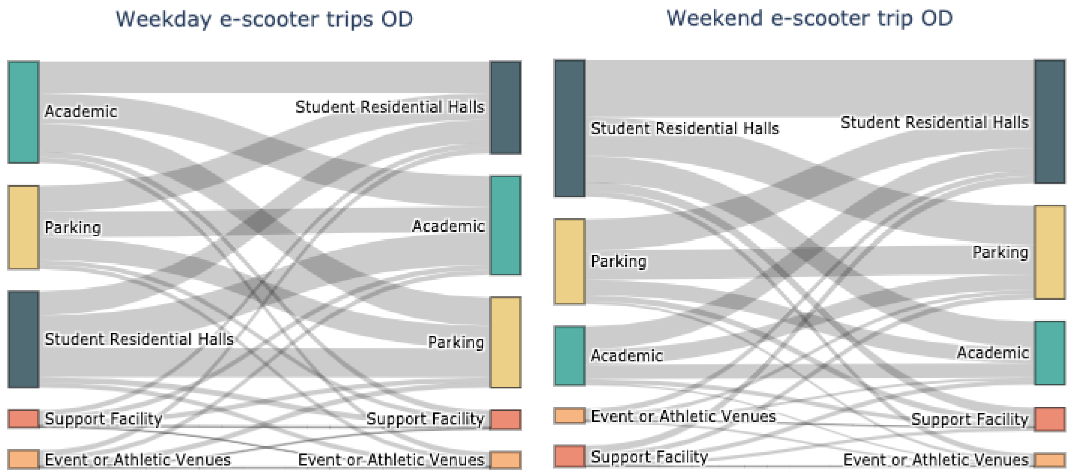

FIGURE 2. E-scooter trip origin and destination (OD) matrix for weekdays and weekends

Pre-Post User Survey

Intention to Ride and Ride Frequency

The vast majority of riders (85%) in our post-launch survey were undergraduate students—who represent 66% of the campus population. Graduate students accounted for only 4% of riders captured in our survey, but represent 16% of the campus population. Faculty and staff, who account for about 18% of the campus population constituted 13% of e-scooter riders in our survey. Almost 6 out of 10 (59%) of riders captured in the survey reported being male, a share close to the percentage of men in the campus population (57%).

Prior to e-scooter launch on campus 66% of respondents stated that they intended to ride e-scooters at least once a week. After the system had launched 29% of respondents to our second survey reported riding at least once a week ($p<0.05$). The discrepancy between the intention to ride weekly and actually riding weekly was smallest for the 18-24 year age group (66% vs. 41%, $p<0.05$) and was largest for those 25-34 (62% vs. 15%; $p<0.05$) and 35-44 (77% vs. 10%; $p<0.05$). Closely related with age, the difference was much greater for Virginia Tech employees (62% intended to ride vs. 9% rode; $p<0.05$) and graduate students (63% vs. 14%; $p<0.05$) than for undergraduate students (64% vs 41%; $p<0.05$). Additionally, the discrepancy was larger for women (61% vs. 23%; $p<0.05$) than for men (66% vs. 37%; $p<0.05$).

Compared to stated intentions prior to system launch, actual frequency of riding e-scooters after system launch was lower for the high intensity usage groups. Compared to stated ride frequency prior to system launch, only 2% reported actually riding daily (vs. 11% who intended to ride daily; $p<0.05$) and 7% stated they rode 4-6 times a week (vs. 14% who intended to do so; $p<0.05$). Roughly, one-third of respondents for each survey planned to or actually rode 1-3 times per week.

Asked about what would motivate current riders to ride more often, they favored expansion of the geographic reach of the system (69%)—and in particular expansion to include the town of Blacksburg (58%). Lower cost for riding (60%), deployment of more scooters (57%), and longer system operating hours (56%) were also among the top motivators for riding more among current riders. Asked about changes that may motivate current non-riders to start riding, the top changes were safer places to ride, such as more bike lanes and paths that are separated from motor vehicles (44%)—a view also shared by one third of riders who indicated they would ride more if there was safer infrastructure. Moreover, about one third (32%) of non-riders said that they would never consider riding.

Reasons for Riding: Travel Speed and Fun

The two top reasons for riding e-scooters were related to the e-scooters themselves: travel speed and fun of riding. Prior to system launch prospective non-riders (38%) and prospective riders (52%) indicated that they anticipated scooters to be the fastest option to travel on campus. After launch, 70% of actual riders reported choosing scooters for that reason (+28% compared to pre-launch; $p<0.05$). Similarly, in the pre-survey, prior to system launch, roughly half of prospective non-riders (48%) and prospective riders (50%) thought that scooters were fun to ride. In the post survey, after system launch, 55% of actual riders reported riding scooters because they are fun. Responses to the post-trip survey align with the findings of the campus surveys discussed in the lieterature review. Respondents for the post-trip survey reported speed or ease of use as the top reason for riding e-scooters (59% of trips). The second top reason e-scooters were chosen in the post-trip survey was that they were considered fun to ride (32%). Riders also reported having chosen e-scooters for some trips because they did not have access to other transport options (4%). Other reasons for riding stated in the post-trip survey were not getting sweaty (30% of pre-launch non-riders and riders said so; as well as 32% of riders after launch).

Trip Purpose

Scooters on Virginia Tech's campus were mainly used to go to class (67% of riders)—similar to the share predicted per-launch by prospective users (see Figure 3). Riding e-scooters for fun without a special trip purpose was the second most popular response category (45% of riders). About a quarter of actual riders reported using e-scooters as a micromobility mode from and to a car parking lot—similar to the share predicted by prospective riders before system launch. Riding e-scooters to connect to public transport was reported by 7% of actual riders—which seems low but is not surprising given that e-scooters are only allowed to operate on campus and only 5% of trips within the campus are made by bus. Again, findings from the post-trip survey reinforce the results from the general surveys: 52% of trips captured in the post-trip app survey were made for an educational purpose, attend a class, or to go study or work on a class assignment. A significant portion (22%) was made for utilitarian purposes (e.g., dining, errands, gym), or to get to or from work. Social and recreational purposes were also frequently reported (21%).

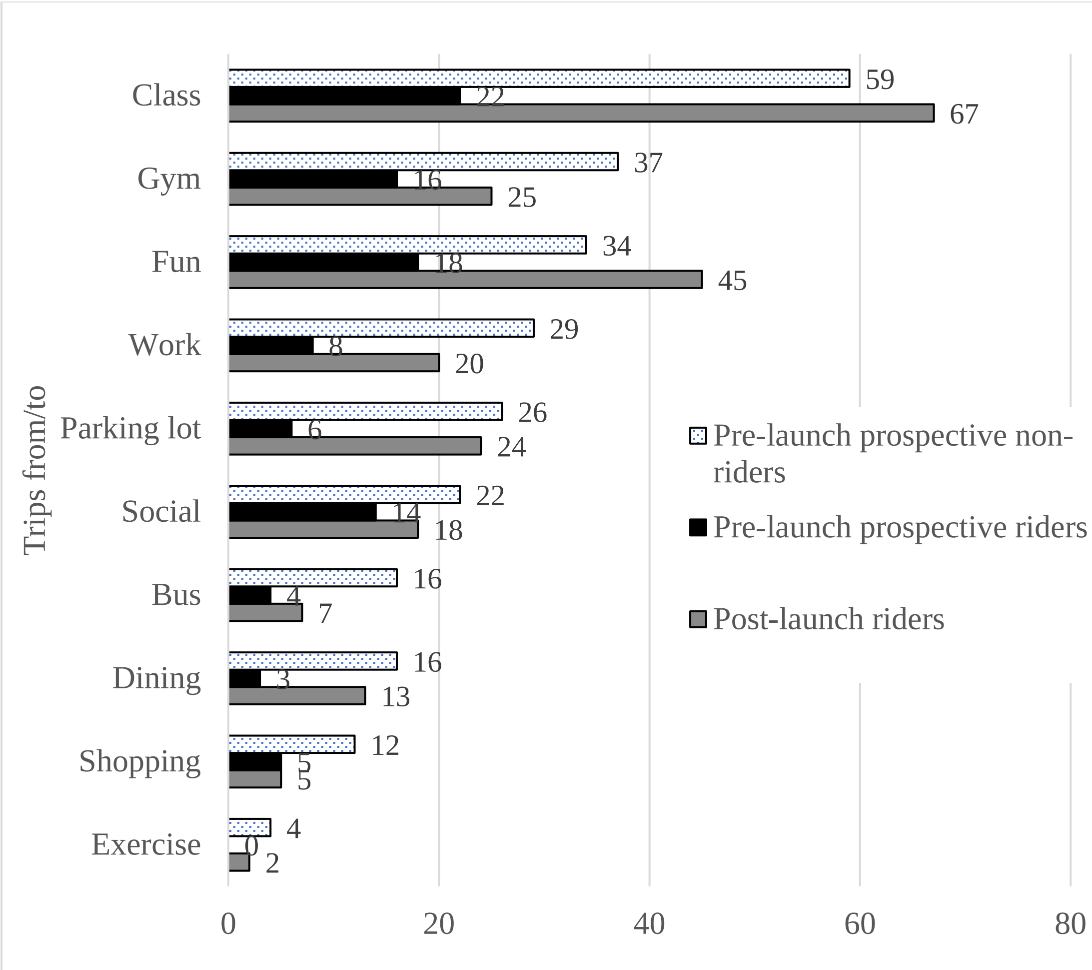

FIGURE 3. Actual and anticipated e-scooter trip purposes (Note: multiple responses were possible per respondent)

Perceptions about Convenience, Cost, Safety, and Usefulness of E-Scooter Systems Improved Among Non-Riders after System Launch

The general perception of the e-scooter system as well as opinions about the systems' usefulness among non-riders was more positive after than before launch of the system. Prior the system launch 42% of prospective non-riders said they thought scooters were not convenient—a perception that dropped to 25% after launch ($p<0.05$). Similarly, 29% thought they would not ride because of cost, but only 19% stated that cost kept them from riding once the system had launched ($p<0.05$). A similar shift occurred concerning safety, with 33% of non-riders stating that the system was not safe prior to launch; a view that dropped to 24% after the system was in operation ($p<0.05$). The share of non-riders who said they do not consider riding because they are happy with the current mode of transport stayed roughly the same pre and post launch (62% vs. 59%).

Prior to system launch 59% of prospecive non-riders stated that a scooter system was useful—compared to 90% of prospective riders. The share of those who considered the system useful increased to 70% among actual non-riders (+11%; $p<0.05$) and to 99% among actual riders (+9%; $p<0.05$) after system launch. Similar trends and general agreement emerged for the perception that scooters were an easy mode of transport to get around campus.

Perceptions of E-Scooter Parking and Rider Behavior Improved Among Non-Riders and Riders

Perceptions about scooter parking and rider behavior improved slightly among non-riders and significantly among riders between the two survey waves. Prior to system launch, one-third (34%) of prospective nonriders expected that e-scooters would be well parked and 30% expected that riders generally would behave well and follow traffic rules. The perception of good parking increased somewhat, but not statistically significantly, after system launch with 38% of actual non-riders reporting a perception of good parking; while the perception or proper riding increased to 36%. Among riders, perceptions shifted more strongly. Prior to system launch, 69% of prospective riders expected good parking and 72% expected good riding behavior. Among actual riders 84% reported good parking and 82% experienced proper rider behavior after system launch ($p<0.05$).

After system launch, 21% of all respondents reported encountering e-scooters blocking sidewalks at least 5 times per week—60% reported experiencing the same once or less than once per week. Reponses differed between riders and non-riders: 26% of non-riders reported experiencing blocked sidewalks more than 5 times per week compared to only 9% of riders. By contrast, 82% of riders reported seeing scooters blocking sidewalks once a week or less vs. 51% of non-riders. This difference did not exist for bikeshare and personal bikes, with over 85% of e-scooter riders and non-riders reporting rarely seeing sidewalks blocked by these modes—likely because bikes are typically locked to bike racks or street furniture for parking. The discrepancy in perception of e-scooter parking and rider behavior between riders and non-riders is similar to a study about e-scooter parking in Rosslyn, Virginia, where non-riders were much more likely to notice poorly parked e-scooters than riders [12].

Compared to Riders, Non-Riders Feel Less Safe Walking and Driving Around E-Scooters

After system launch, we asked riders and non-riders how safe they felt walking around e-scooters, bikeshare bikes, and personal bikes while they were in use (see Figure 4, upper panel). Only one third (31%) of non-riders reported feeling safe when walking around e-scooters, 23% were neutral and 43% felt unsafe. Compared to being a pedestrian around e-scooters, non-riders felt safer walking around bikeshare bikes (43% safe, 38% neutral, and 20% unsafe) and personal bikes (51% safe, 27% neutral, and 21% unsafe). As pedestrians, e-scooter riders, felt safe walking around scooters (64% safe, 23% neutral, 13% unsafe), bikeshare bikes (56% safe, 32% neutral, 11% unsafe), and personal bikes (50% safe, 27% neutral, 18% unsafe).

We also asked respondents how comfortable they were driving around e-scooters (see Figure 4, lower panel). As drivers, only 17% of non-riders felt comfortable driving around e-scooters (51% uncomfortable) compared to almost exactly opposite values for riders (52% comfortable driving around scooters and 15% uncomfortable). These findings are also comparable to the results reported by the e-scooter study from Rosslyn, VA where non-riders felt less safe walking and less comfortable driving around e-scooters [12]. The authors speculate that riders' familiarity with e-scooters and knowledge about their operation increases perceived comfort and safety around e-scooters as pedestrians or drivers.

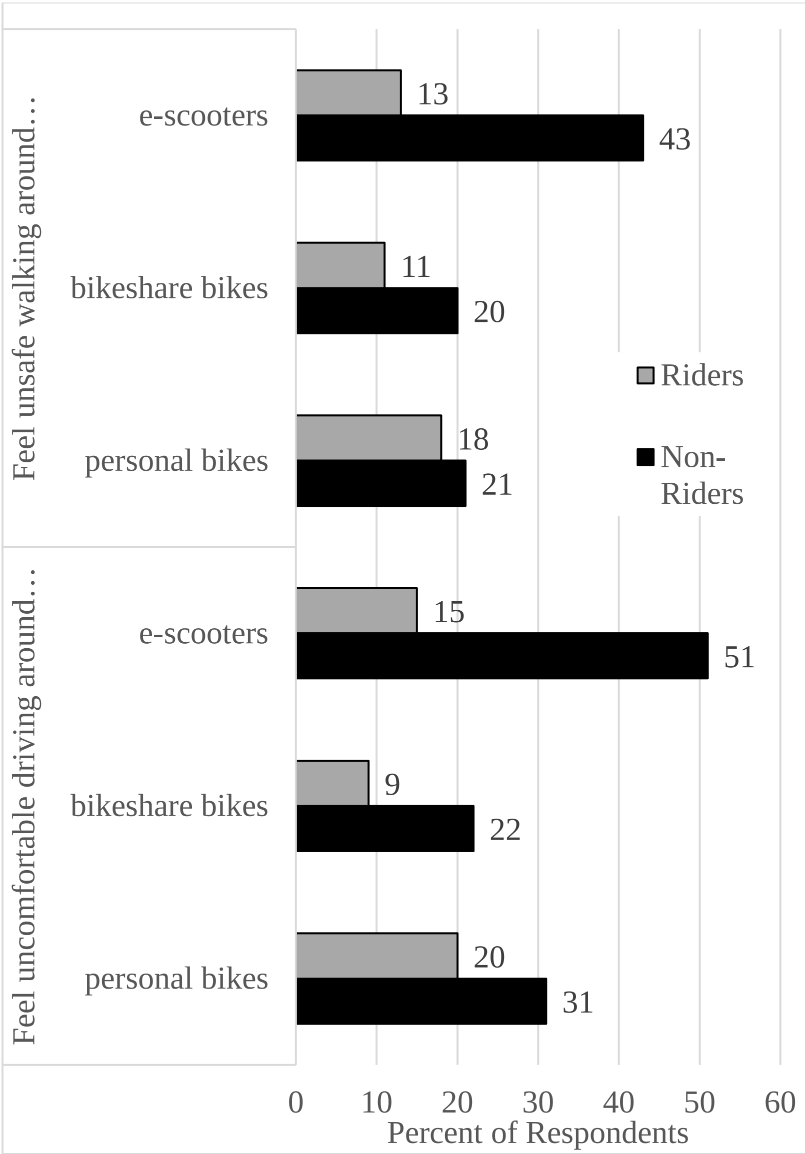

FIGURE 4. Perceived comfort driving around scooter users and perceived safety walking around e-scooters among riders and non-riders.

Where to Ride

Prior to system launch 72% of both prospective riders and prospective non-riders preferred or strongly preferred riding on sidewalks (see Figure 5). After system launch 78% of actual riders reported preferring riding on sidewalks. Prior to system launch 61% of prospective non-riders and prospective riders preferred riding in bike lanes—a share that increased slightly to 66% of actual riders after system launch. Prior to system launch only 14% of non-riders and 20% of prospective riders reported preferring riding in the roadway—with only 16% of actual riders reporting a preference for riding in the roadway. Last, prior to launch 53% of prospective non-riders and 46% of prospective riders stated that they preferred riding on shared-use trails. An opinion shared by 41% of actual riders.

Comparing riding preferences and actual locations for scooter usage shows that 90% of actual riders reported riding on sidewalks even though just 78% preferred riding on sidewalks (see Figure 5). In fact, 80% of those who stated that they did not want to ride on sidewalks, reported riding on sidewalks. Only, 57% reported riding in bike lanes even though 66% would prefer riding there. In fact, 24% of those who stated they wanted to ride in bike lanes did not ride in bike lanes. The share riding in roadways (14%) and on shared-use trails (38%) roughly equals the share of actual riders preferring those locations: 16% for road and 41% for trails.

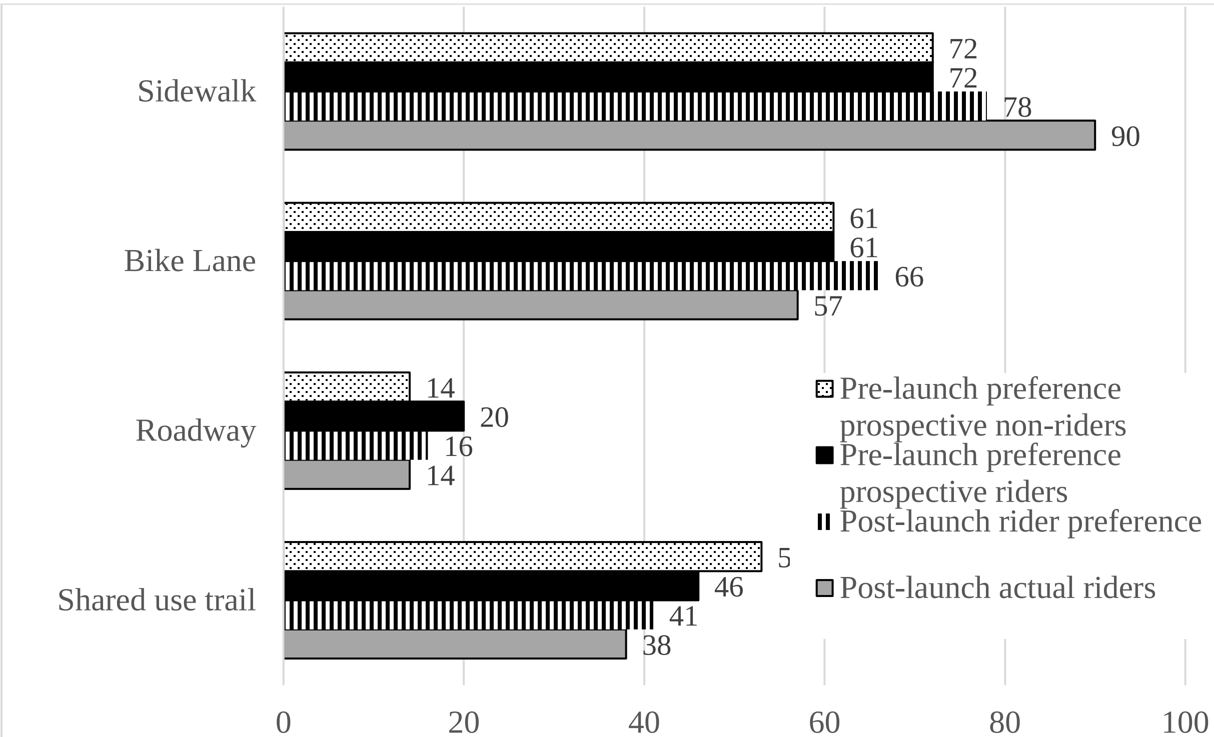

FIGURE 5. Infrastructure preferences for riding e-scooters prior and after system launch compared to actual e-scooter riding locations

Changes in Travel Behavior

Prior to system launch, 70% of prospective riders stated that they agreed with the statement that riding scooters would reduce car driving. After system launch 78% of actual riders agreed with this statement. One in four (27%) of non-riders agreed that scooters reduce driving—both before and after system launch.

Four in five (81%) e-scooter riders reported that their most recent e-scooter trip replaced a walk trip, followed by 9% reporting replacement of a bus trip. These replacement rates are roughly in line with reported mode shares of travel by campus residents in a 2009 travel survey: 77% of trips on foot and 5% by bus. In our survey, only 2% reported e-scooters to replace a car trip—lower than the share of car trips reported by campus residents (12%). The share of e-scooter trips replacing former walk trips is greater than both riders and non-riders had expected prior to system launch. Prior to system launch 56% of non-riders expected e-scooters to replace walk trips, 16% transit trips, 10% bike trips, and 8% car trips. Those who intended to ride prior to system launch also expected to replace walk trips (70%), transit (10%), bike (10%), and car trips (8%).

Again, results from our in-app post-trip survey, asking the question *If not by e-scooter, how would you have taken this trip?* were similar to the findings of the general survey. In contrast to our online survey, and the city pilot evaluation surveys we reviewed, which asked respondents to recall their last e-scooter trip, riders responded immediately upon completing their ride, which means they are less prone to recall error. The majority of trips (77%) captured in the post-trip survey would have otherwise been made by walking (not shown). E-scooter trips captured in the post trip-survey replaced 1,353 motorized vehicle trips, including 627 car trips (see Figure 6). Given the average e-scooter trip distance of .73 miles, this indicates that e-scooters displaced 458 vehicle miles travelled. Roughly equal shares of bus (7%) and car (6%) trips were also replaced. Interestingly, 6% of trips would not have been made at all, perhaps indicating pent-up demand.

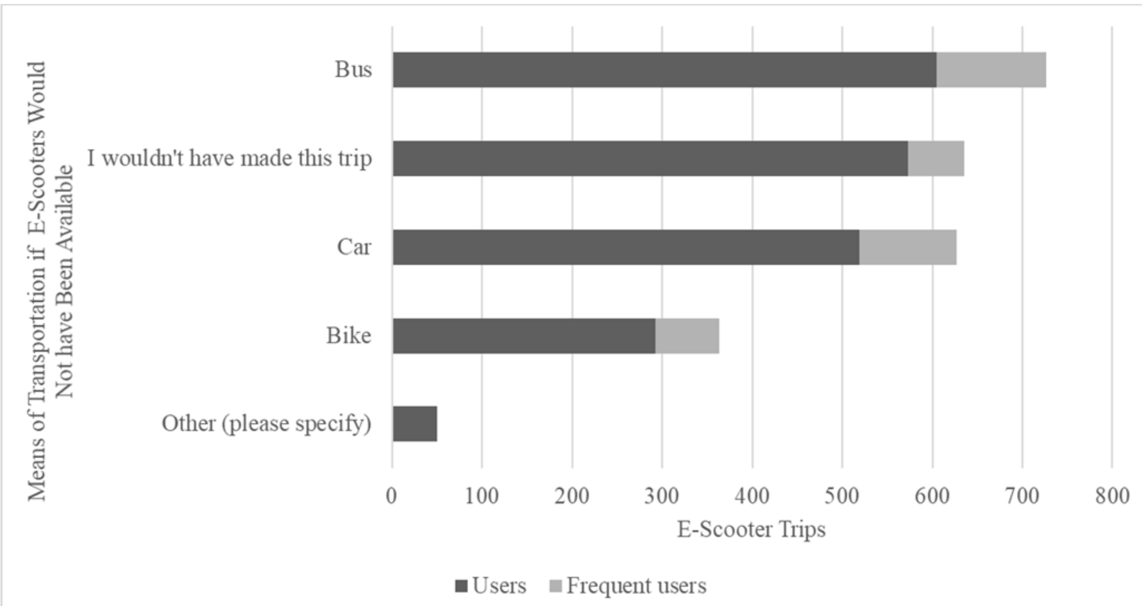

FIGURE 6. Modes of transortation replaced by e-scooter riders for the trip recorded by the post-ride in-app survey. *(Note: walking not shown, see text for details).*

In contrast to the small reductions in driving for a specific e-scooter trip, respondents reported larger reductions in overall car use when asked about general changes in travel behavior since system launch. Prior to system launch riders expected less walking (-37%), riding buses (-13%), driving (-14%), and cycling (-5% bikeshare; -5% personal bike). Prospective riders expected less walking (-61%), bus use (-42%), driving (-34%), and cycling (-21% bikeshare; -22% personal bike). Actual reductions in walking (-30%), bus use (-15%), and cycling (-7% bikeshare; -7% personal bike) where smaller than anticipated ($p<0.05$). However, the reduction in driving was almost the same as expected: 30% or e-scooter riders reported to drive less since the launch of the e-scooter system.

Knowledge about Scooter Laws and Regulations

Before and after system launch we asked respondents how they intended to learn and how they learned about e-scooter rules and laws. Before and after the scooter launch sizable shares of respondents admitted not knowing about e-scooter laws and regulations on campus: 57% before and 40% after launch ($p<0.05$). This share was lower among riders (31%) than non-riders (44%). A plurality learned about e-scooter laws from social media (35%), electronic university newsletters (19%), and the university e-scooter website (13%). For virtually all modes of learning about e-scooter laws and regulations, expected access of information was greater than actual usage of the medium. For example, before system launch 48% stated that they expected to use the google search engine to find information about e-scooter regulations on campus. After launch only 6% reported actually doing so ($p<0.05$).

Helmets

Prior to system launch 21% of prospective riders said they would always wear a helmet while another 25% stated that they would wear one often (9%) or sometimes (16%). About one third indicated that they were not planning to wear a helmet. After launch less than 10% of actual riders reported wearing helmets at least sometimes (4% always, 1% often, and 5% sometimes) ($p<0.05$). One in ten (9%) actual riders reported rarely wearing a helmet and the vast majority (82%) never wore a helmet. The main reason stated for not wearing a helmet was lack of access to a helmet (84%), followed by perceived inconvenience of a helmet (32%); while 10% said they already felt safe riding without a helmet.

DISCUSSION AND CONCLUSIONS

This study showed that socio-demographics of e-scooter riders on Virginia Tech's campus follows patterns identified in city surveys, with a greater share of younger riders—in particular undergraduate students [5], [8]. While males (59%) accounted for a larger share of e-scooter trips than females (41%), those rates reflect the gender distribution on campus (57% male). Based on these initial results, stated intention to ride was greater than actual ridership for all user groups analyzed in this paper. The drop-off between pre-launch intention to ride and actual riding found in this study was strongest for older individuals, women, and university staff. More marketing and outreach specifically tailored to older individuals, women, and university staff may help attract those who are potentially interested to ride e-scooters—as they indicated the intention to ride in the pre-survey responses. In particular, current non-riders indicated that they would prefer more separate infrastructure, such as bike lanes, to ride scooters. This is similar to the four groups of cyclists, identified by Roger Geller and Jennifer Dill [16] where a significant share of current non-bicyclists would ride more if they had safer facilities to ride. Also similar to the Geller and Dill typology where about one third of the U.S. population would never consider riding a bike, 32% of our respondents indicated that they would never consider riding an e-scooter.

As in many city surveys, the main reasons for riding e-scooters were travel speed and the fun of riding. Going to class was the main trip purpose (67%) which was expected for a university campus. About one quarter of users (24%) rode e-scooters to and from university parking lots and 7% used e-scooters to access public transport, showing that e-scooters can be a viable micromobility mode for the first or last mile for both cars and public transport.

Perceptions about the convenience, cost, safety, and usefulness of the e-scooter system improved among non-riders after system launch. This may indicate that public hesitation about e-scooter systems could be mitigated by pilot projects where the community gets to experience e-scooters. However, even though non-rider perceptions about e-scooter parking and rider behavior were slightly more positive after system launch, they still lagged perceptions by riders. This may indicate that e-scooter companies, university administration, and local governments could design incentives and supportive infrastructure such as racks, marked parking areas, and charging stations to increase proper parking to help promote the general positive trend in community perceptions about e-scooters.

Our study suggests a mismatch between preferences for riding on sidewalks and actual sidewalk riding: 78% wanted to ride on sidewalks, while 90% did. Similarly, a greater share wanted to ride in bike lanes (66%) than actually did (57%). Providing more bike lanes or separate spaces for e-scooters to ride could help move riders off sidewalks. This may increase satisfaction among riders, attract more riders, and improve perceptions by non-rider pedestrians—of whom 43% reported feeling unsafe walking around scooters.

In terms of mode replacement for their last trips, e-scooters mainly replaced walking trips (81%) and did not replace many automobile trips (only 2% in the online survey and 6% in the post-trip in-app survey)—a lower share for car replacement than found in most surveys of systems in cities. The geofenced restriction of e-scooters to travel only within the pedestrian-oriented campus likely explains this. A prior survey found that students living on campus made 77% of their trips on foot and only 12% of their trips by car. Most of these car trips reported by students living on campus were likely to reach off-campus locations—where e-scooters are not allowed to go. When asked about overall changes in their travel behavior, 30% of riders reported that they were driving less since system launch. It is often argued that e-scooters contribute to a “car-lite" lifestyle where automobile ownership and use become less necessary.

Last, our surveys suggests that e-scooter riders and non-riders do not have good knowledge about rules and laws of e-scooter usage. While the university used many different channels of communication to reach riders and non-riders, one third of riders and 40% of non-riders reported not knowing e-scooter rules after system launch. Lack of knowledge about rules is likely larger, because even those who indicated they knew e-scooter rules, failed to identify e-scooter rules on campus correctly when prompted. The two most promising ways of communication were social media and the e-scooter user app. However, the app mainly reaches riders and will likely not reach non-riders.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: RB, AB, MM; survey administration and data collection: EW, TS; analysis and interpretation of results: RB, AB. draft manuscript preparation: RB, AB, TS, WZ. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

[1] NHTS, “National Household Travel Survey,” *National Household Transportation Survey*, 2017. https://nhts.ornl.gov/vehicle-trips (accessed Jul. 11, 2020).

[2] R. L. Sanders, M. Branion-Calles, and T. A. Nelson, “To scoot or not to scoot: Findings from a recent survey about the benefits and barriers of using E-scooters for riders and non-riders,” *Transportation Research Part A: Policy and Practice*, vol. 139, pp. 217–227, Sep. 2020, doi: 10.1016/j.tra.2020.07.009.

[3] ATLDOT, “Atlanta E-scooter Survey Results,” Altalnta Department of Transportation, Atlanta, GA, 2019. [Online]. Available: https://www.atlantaga.gov/home/showdocument?id=45981.

[4] BCDOT, “Baltimore City Dockless Vehicle Program Annual Evaluation Report: Permit Year 1,” Baltimore City Dept of Transportation, Baltimore, MD, 2020. [Online]. Available: https://transportation.baltimorecity.gov/sites/default/files/Year%202%20evaluation%20Report%20APPENDIX%202%20FINAL.pdf.

[5] CDOT, “E-Scooter Pilot Evaluation,” Chicago Department of Transportation, Chicago, IL, 2020. [Online]. Available: https://www.chicago.gov/content/dam/city/depts/cdot/Misc/EScooters/E-Scooter_Pilot_Evaluation_2.17.20.pdf.

[6] DPW, “Denver Dockless Mobility Program Pilot Interim Report,” Denver Public Works, Denver, CO, 2019. [Online]. Available: https://www.denvergov.org/content/dam/denvergov/Portals/705/documents/permits/Denver-dockless-mobility-pilot-update-Feb2019.pdf.

[7] HDOTP, “Hoboken Shared E-Scooter Program End-of-Pilot Survey,” City of Hoboken Dept of Transportation and Parking, Hoboken, NJ, 2019. [Online]. Available: https://assets.website-files.com/58407e2ebca0e34c30a2d39c/5dd570e833006067e38907ca_e-scooter%20survey.pdf.

[8] PBOT, “2018 E-Scooter Findings Report,” Portland Bureau of Transportation, Portland, OR, 2018. [Online]. Available: https://www.portlandoregon.gov/transportation/article/709719.

[9] TDOT, “Tucson E-scooter Pilot Program Evaluation,” City of Tuscson Department of Transportation and Mobility, Tucson, AZ, 2020. [Online]. Available: https://www.tucsonaz.gov/files/bicycle/documents/E-Scooter_Pilot_Evaluation.pdf.

[10] SFMTA, “Car sharing policy and pilot project,” San Francisco Municipal Transportation Agency, San Francisco, 2013. [Online]. Available: https://www.sfmta.com/sites/default/files/projects/2017/Carshare_eval_final.pdf.

[11] Mobility Lab, “Arlington County Shared Mobility (SMD) Pilot Evaluation Report,” Mobility Lab, Arlington County Commuter Services (ACCS), Arlington, VA, 2019. [Online]. Available: https://1105am3mju9f3st1xn20q6ek-wpengine.netdna-ssl.com/wp-content/uploads/2019/11/ARL_SMD_Evaluation-Final-Report-1112-vff-2.pdf.

[12] SMPCD, “Shared Mobility Pilot Program Summary Report,” City of Santa Monica Planning and Community Development Department, Santa Monica, CA, 2019. [Online]. Available: https://www.smgov.net/uploadedFiles/Departments/PCD/Transportation/SantaMonicaSharedMobilityEvaluation_Final_110419.pdf.

[13] O. James, J. Swiderski, J. Hicks, D. Teoman, and R. Buehler, "Pedestrians and E-Scooters: An Initial Look at E-Scooter Parking and Perceptions by Riders and Non-Riders," *Sustainability*, vol. 11, no. 20, p. 5591, Oct. 2019, doi: 10.3390/su11205591.
[14] A. Khattak, X. Wang, S. Son, and P. Agnello, "Travel by University Students in Virginia: Is This Travel Different from Travel by the General Population?," *Transportation Research Record*, vol. 2255, no. 1, pp. 137–145, Jan. 2011, doi: 10.3141/2255-15.
[15] Virginia Tech, "E-Scooter Campus Map," *Scooters on Campus: FAQs*, 2020. https://parking.vt.edu/content/dam/parking_vt_edu/alternative-transportation/Escooter%20map-01%20090419.jpg (accessed Jul. 10, 2020).
[16] J. Dill and N. McNeil, "Revisiting the Four Types of Cyclists: Findings from a National Survey:," *Transportation Research Record*, Jan. 2016, doi: 10.3141/2587-11.