E-Scooter Safety Assessment and Campus Deployment Planning

May 2023 | Final Report

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Abstract

E-scooters are a popular new service providing last-mile transportation, but there are reports of safety concerns for riders and impingement on other users' of rights of way. Little formal research has been conducted on E-scooter safety or the optimal approach to deployment to decrease nuisance issues. To address this, the Virginia Tech Transportation Institute and Spin deployed a fleet of E-Scooters on the Virginia Tech campus through an exclusive, controlled research program. Through on-scooter data acquisition systems, fixed infrastructure cameras, anecdotal injury reports, and surveys, data was collected to assess safety impact and to understand user behaviors and patterns for subsequent countermeasure development and deployment. The resulting naturalistic dataset includes over 9,000 miles of riding data. Overall, the E-Scooter deployment on the Virginia Tech campus was safer than other deployments. The operational constraints that were put in place were largely effective and, with the additional results from this study, some additional constraints and expanded outreach programs may make future deployments even safer. The campus community largely considered the deployment of E-Scooters a clean alternative transportation option and viewed the service favorably.

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Introduction

Through an exclusive research partnership aimed at creating a living laboratory on the Virginia Tech campus in Blacksburg, Virginia, the Virginia Tech Transportation Institute (VTTI) and Spin deployed a fleet of about 200 shared e-scooters from September of 2019 through May of 2022. Fifty-two of the e-scooters were equipped with VTTI's proprietary onboard data acquisition system (DAS), the MicroDAS. The data collection and deployment effort occurred in three phases, each aligning with a change in scooter model, resulting in the largest naturalistic e-scooter dataset collected to date. The project was originally intended to span the 2019-2020 academic year only, but due to the COVID-19 pandemic, data collection was suspended in March 2020 when campus activities became remote, leaving little, if any, demand for e-scooters on campus. The project team wanted to ensure that the resulting dataset would support answering research questions pertaining to riding preferences and behaviors over time, and spanning the multiple seasons encompassed by an academic year, so an additional academic year of data collection was added. Table 1 summarizes the e-scooter operational phases.

Table 1. E-Scooter Operations Summary

	Dates	E-scooter model	Wheels	Weight	Braking system
Phase 1	September 1, 2019 – November 5, 2019	Segway Ninebot ES4	8" non-pneumatic tires	31 lbs	Front electric brake and rear fender brake
Phase 2	November 6, 2019 – March 21, 2020	Segway Ninebot Max	10" pneumatic tires	43 lbs	Front mechanical drum brake and rear regenerative electronic brake
Phase 3	August 16, 2021 – May 24, 2022	Segway S-100 (7th edition)	10" pneumatic tires	63 lbs	Double braking system: Front and rear wheel drum brakes, and rear wheel electronic brake

Background

E-scooters are a popular new service providing last-mile transportation and can potentially make transit more user-friendly. According to a survey of 7,000 people in six major cities where e-scooters have been deployed, 70% of survey participants viewed scooters positively (Richter, 2018). In San Francisco, for example, in the first 30 days of e-scooter deployment, 1,600 scooters were deployed, resulting in 95,000 rides by 32,000 different people (Richter, 2018). E-scooters offer dockless operation and are replacing car trips, resulting in benefits such as increased availability of car parking and reduction in carbon emissions. According to the US Department of Energy, short trips make up the majority of trips taken; almost 60% of trips taken in 2017 encompassed less than 6 miles. These statistics show that e-scooters are a viable option for our country's current transportation needs and are likely to be deployed in more and more communities over time.

Along with the benefits, however, there are also some negatives associated with e-scooter deployments. In areas where e-scooters are already deployed, there are reports of safety concerns for riders and impingement of e-scooters on other users' rights of way. According to a Journal of the American Medical Association (JAMA) study in Southern California that monitored the University of California, Los Angeles (UCLA) and the UCLA Santa Monica Emergency Room for a 1-year period, there were 249 emergency room visits for scooter users, compared to 195 visits for bicyclists and 181 visits for pedestrians in the same time period (Trivedi, 2019). Among the scooter-related emergency room visits, most were due to minor injuries, but in 6% of cases, at least one of the injured parties was admitted for more serious injuries (Trivedi, 2019). In spite of these findings, very little formal research has been conducted on the safety of e-scooters and the optimal approach to deployment to decrease nuisance issues.

Motivated by these issues, VTTI partnered with Spin to deploy a fleet of e-scooters on the Virginia Tech (VT) campus through an exclusive, controlled research program. VTTI added a DAS to a subset of scooters to collect data to assess safety impact, rider behavior, and ways in which kinematic and/or other data may be used to predict risky behavior and develop countermeasures. In addition, fixed cameras were deployed around campus to evaluate a variety of behavioral measures through a classification system developed as part of the project. The resulting data was used to assess safety, nuisance, and mobility; identify unique countermeasures to problems associated with e-scooter deployments; and generate deployment requirements and guidelines for VT to leverage if they decide to deploy e-scooters on the campus again in the future.

Methods

Task 1: Project Management

Under Task 1, the team managed the overall technical program to ensure that the project achieved its objectives within the designated timeframe and allocated resources. VTTI also performed several administrative and financial supporting tasks under Task 1. VTTI led a project kickoff meeting with relevant project stakeholders, where the research objectives, research and deployment plan, the work plan tasks, and issues related to program governance were discussed. VTTI conducted regular project status meetings with the sponsors and also held biweekly project status meetings with campus stakeholders during the e-scooter deployments on campus to discuss and resolve any safety or logistical concerns.

VTTI also facilitated all necessary approvals and buy-in from all local governing bodies, including VT, the Town of Blacksburg, and the VT Institutional Review Board. Leading up to deployment, VTTI convened a stakeholder group that included members from the VT police, legal, risk management, communications, parking and transportation, alternative transportation, and operations departments. During these meetings, many operational constraints were discussed and agreed upon with the ultimate goal of a safe e-scooter deployment on the VT campus. Operational constraints included:

- Geofencing
  - Scooters were restricted to the limits of the VT campus, with certain campus areas remaining off limits (e.g., the Drillfield in the middle of the campus, which connects the academic side of campus to the residential side of campus).
  - Scooters were not allowed in the Town of Blacksburg (which borders areas of the VT campus).
- Scooter speed limits
  - Scooter speeds were governed to 12 mph; reduced speeds of 4 mph were enforced in certain high-pedestrian traffic areas.
- Weather
  - During service hours, **IF** more than 50% of the hourly predictions exceeded 50% probability of precipitation **AND** (total forecast accumulation of rain during the hours of operation was expected to exceed 0.5 inches **OR** the forecast precipitation was snow/ice) according to the National Weather Service, the day's deployment was cancelled.
  - Deployment and operations were suspended while observed winds were greater than 30 mph.
  - Deployment and operations were suspended while there was observable snow and ice coverage on campus sidewalks and streets.
- Special events on campus
  - Deployment would not occur on VT football game days with the exception of evening games where deployment could be conducted up until 1 p.m. on the day of the game.
  - Deployment would not occur on dates where significantly high volumes of traffic were expected on campus such as move-in, move-out, and commencement.
- Time of service
  - Scooter service started at 7 a.m. and ended at civil twilight (i.e., 30 minutes after dusk).

In another attempt to ensure the safest deployment possible, free helmets (provided by VTTI and Spin) were given away in various locations on campus to anyone who wanted one.

Task 2: Develop DAS and Instrument Scooters

VTTI developed a DAS specifically for the Spin e-scooter platform, the MicroDAS (Figure 1). This MicroDAS was encapsulated in a custom waterproof enclosure mounted on the scooter's Internet of Things box installed on the stalk of the scooter. VTTI modified 52 of Spin's e-scooters to facilitate such instrumentation.

Figure 1. Photo. MicroDAS installed on a Spin scooter.

The MicroDAS collected several data elements, all at 10 Hz, including:

- Video stream – high-definition video of the area in front of the rider.
- Accelerometers – A multi-axis (x, y, z) accelerometer collected kinematic behavior, including hard stops, starts, and turns. When combined with the video data, it enabled analysis of riding behaviors that may be associated with risky outcomes.
- GPS – A GPS sensor collected speed and high-precision positioning of the scooter to enable analysis of trip-level rider behavior and usage patterns.

VTTI also developed a fixed observation video system package to complement the data collected by the MicroDAS. VTTI managed to procure and install 14 stationary video cameras on the VT campus at strategically placed, public locations to facilitate the collection of aggregate data on rider/pedestrian interactions and rider behavior in general that could not be captured by the MicroDAS's forward video alone.

Task 3: Develop Rider and Pedestrian Survey Instruments

VTTI developed a series of subjective surveys (summarized in Table 2) to obtain opinion and preference data from scooter users and non-users in the university community.

Table 2. Subjective Survey Summary

Survey Name	Timing	Deployment Phase	Modality
Pre-deployment	August 2019	1	Qualtrics
In-app Survey	2019-2020	1 and 2	Spin app
Post-deployment	October 2019	1	Qualtrics
Redeployment Survey	Fall 2021	3	Qualtrics
Panel Survey	Spring 2022	3	Qualtrics

The pre- and post-deployment Qualtrics surveys focused on opinions about e-scooters in general, the specific implementation associated with this project, and ways that riders and non-riders could envision improvements in safety, distribution, and/or usefulness of a deployment. The project team referenced a similar survey conducted by a team member in Arlington, Virginia, when developing the survey instruments (Buehler, 2019). Surveys were administered online and in person via tablets at various high-traffic campus locations. One out of 50 survey respondents were randomly chosen to receive a $50 check for their participation.

VTTI also designed a short three-question survey to be presented to every Spin e-scooter rider at the conclusion of their ride within the Spin application during Phases 1 and 2. This optional survey allowed more e-scooter riders to be reached and to understand changes over time during Phases 1 and 2. The three questions that were included in this survey were:

1. What was the purpose of your trip?
2. If not by e-scooter, how would you have taken this trip?
3. Why did you choose to ride an e-scooter for this trip?

Another online survey was developed for administration at the beginning of the Phase 3 redeployment of the scooter fleet on campus in August of 2021. This short survey was sent to any individual who had created a Spin user account in Blacksburg during the initial deployment during 2019-2020, regardless of whether the user had actually taken an e-scooter trip. This survey collected basic demographic information and asked the respondents if they would be willing to participate in a follow-on panel survey that consisted of two in-depth surveys about e-scooters on the VT campus. One out of 20 survey respondents were randomly chosen to receive a $50 check for their participation. The objective of the panel survey was to understand shifts in ridership and/or perceptions of the e-scooter service over time.

Task 4: Data Collection

VTTI led the effort to gather a comprehensive dataset about the e-scooter deployment on the VT campus. This dataset included five main data sources:

1. Naturalistic data collected from e-scooters equipped with VTTI's MicroDAS;
2. Observational data collected by external cameras installed in high-traffic areas around the VT campus;
3. Subjective data collected by surveys;
4. Photographs taken at the conclusion of each e-scooter ride using the SPIN smartphone application; and
5. De-identified injury information from the Schiffert Health Center, Virginia Tech Police Department, and Spin.

1. **On-scooter MicroDAS –** See section Task 2: Develop DAS and Instrument Scooters.

2. **Fixed Cameras –** During the first deployment from 2019 to 2020, 14 stationary cameras were mounted in strategic locations throughout the VT campus to capture observational e-scooter data of public areas. During the second deployment from 2021 to 2022, six of those cameras were reactivated. The cameras were configured to stream video to enable remote storage on secure servers and to record during hours of scooter deployment (approximately 6 a.m. to 8 p.m. daily). Across both the 2019 and 2021 deployments, VTTI's data reduction team evaluated a total of 1,657 fixed camera baseline samples encompassing 1,737 individual riders.

3. **Perception Surveys –** See section Task 3: Develop Rider and Pedestrian Survey Instruments.

4. **Spin Application Data Collection –** Spin collected location data throughout all phases of the deployment using their typical onboard systems at 5 Hz (i.e., half the resolution of VTTI's MicroDAS) and through their mobile application that all riders must use to lock and unlock a Spin e-scooter. Spin provided start and stop times and locations of each ride to VTTI for analysis purposes, which totaled almost 160,000 rides across all three phases. This data did not include personally identifiable information since all Spin e-scooters were geofenced to the VT campus boundaries wherein all campus buildings host a large number of students/employees.

   During Phase 1 and Phase 2, Spin riders were presented with a screen in the Spin application at the end of each ride asking if they wanted to consent to sharing their full trip GPS data and take a short survey. Approximately 12,000 rides resulted in the rider choosing to consent to share their trip data and approximately 11,000 of those completed the in-application survey questions. Spin de-identified the responses to these surveys and provided the data to researchers, along with the full GPS position traces of rides where users agreed to data sharing.

   Lastly, as part of Spin's normal processes, riders were required to upload a picture of the parked e-scooter to end their ride within the mobile application. Spin shared approximately 67,000 final parking photos with VTTI from Phase 1 and 2 to analyze parking compliance over time.

5. **Injury Data –** Throughout deployment, VTTI gathered deidentified information on known e-scooter injuries from Virginia Tech's Schiffert Health Center, the Virginia Tech Police Department, and Spin.

Task 5: Data Analysis

Develop Conflict Trigger Algorithms

VTTI created algorithms to detect certain riding behaviors and events. Three main trigger algorithms were developed, based on the reduced forward video and kinematic data, to detect fall-over events, forward-impact events, and near-miss events. These algorithms were run across the MicroDAS data to identify behaviors and events of interest. The specifics of these algorithms have been marked as intellectual property and, therefore, details are not included within this report.

Develop Conflict/Behavior Classification Schemes

During this task, VTTI developed a classification scheme to systematically identify and categorize the types of behaviors that e-scooter riders engaged in relative to the infrastructure, trafficway, environmental factors, and other road users. This classification scheme included two data reduction protocols: one for on-scooter MicroDAS analyses (see Appendix B) and one for the fixed-camera analyses (see Appendix C). Both variants defined events of interest as (1) crashes or (2) near-crashes. The definitions of each event type are included in Appendix A. In addition to crashes and near-crashes, the classification schemes also considered baseline events, which are epochs randomly selected from the entire dataset where neither a crash nor a near-crash occurred.

The inclusion of baseline event reduction allowed the research team to draw conclusions during analyses about the prevalence of certain behaviors and the level of risk associated with those behaviors. The data reduction protocols were modeled after existing schemes, particularly the Researcher Dictionary for Safety Critical Event Video Reduction Data (Virginia Tech Transportation Institute, 2015), but were altered to account for behaviors unique to scooter riders.

Develop Parking Classification Scheme

Similarly, the team developed a classification scheme to analyze e-scooter parking compliance and behaviors. The data reduction protocol included only four questions focusing on parking compliance, further classification of the e-scooter parking location, and whether the scooter was blocking access to anything in a way that would be considered a nuisance (e.g., ADA ramps, sidewalks, stairs, sidewalk furniture). The full classification scheme is included in Appendix D.

Data Sampling and Reduction

VTTI's statisticians completed power analyses to determine adequate baseline sample sizes to answer the study's main research questions. For the MicroDAS dataset, the baseline analysis found that a sample size of 800 events per phase of deployment would sufficiently detect a 15% to 20% difference in the prevalence of key behaviors/elements. The fixed camera data was used to answer two main research questions and, therefore, had a different sampling strategy. To answer questions on the prevalence of certain behaviors, the cameras were sampled evenly. To answer questions related to specific infrastructure elements, the research team oversampled a portion of the cameras with high to moderate exposure to vehicle interactions and the following infrastructure elements of interest: shared lanes, bike lanes, intersections, roundabouts, and crosswalks.

Once the data reduction protocols and sampling plans were finalized, VTTI's Data Reduction team integrated the MicroDAS and fixed camera protocol questions and response options into their toolsets to code the video and inertial measurement unit data. The sampled events of interest that were identified by the triggers (i.e., fall-overs, forward impacts, and near misses) were reviewed by trained human data reductionists and confirmed as either a near-crash or crash event as defined in Appendix A. The behaviors and elements that were present in the video during the selected timeframe were coded for valid events. In parallel, the data reduction team used standard quality control practices to ensure consistency among the reductionist coding to the extent possible.

Parking Photos

To understand e-scooter parking patterns and prevalence, a sample of 826 parking photos from Phase 1 and 2 were analyzed, stratified proportionally to the number of rides taken by week during those phases. As this dataset included still photos rather than video, a simpler reduction process was followed. The parking photos were imported into a VTTI tool that allowed reductionists to quickly scroll through the photos and answer the applicable reduction protocol questions.

Analyze Data

Analyses were performed upon the reduced/coded data, which allowed the research team to address the questions motivating the study, including rider behavior, factors associated with risk, riding and parking patterns, and other issues surrounding the safe deployment of a fleet of e-scooters on college campuses. Summary statistics were compiled for each of the four datasets. Prevalence and odds ratios (ORs) were calculated for the MicroDAS data to inform the level of risk associated with various factors encountered during e-scooter rides on campus. To compute these ORs, the frequencies of certain factors encountered during e-scooter conflicts (crashes, crash-relevant conflicts, and near misses) were compared to the frequencies of those same factors being present during baseline events. The results of all analyses are discussed in detail in the Results section.

Task 6: Final Report and Deployment Recommendations

Upon completion of the data analysis, the team prepared this final report as well as a results briefing and deployment recommendation for VT stakeholders.

Results

Table 3 summarizes the number of trips, mean trips per day, mean trip length, mean trip duration, mean travel speed, number of MicroDAS trips, and the total duration of the MicroDAS trips taken by scooters in this study. The resulting naturalistic dataset includes over 9,000 miles of riding data. As can be seen, the mean trip duration for DAS trips is lower than the duration Spin provided for all trips. This can likely be attributed to (1) the time it took for the DAS to boot up at the beginning of a ride, and/or (2) multiple shorter DAS trips may make up a longer Spin trip if the rider was idle for a 30-second period during the middle of the trip, causing the DAS to end the prior trip.

Table 3. Trip Information by Deployment Phase

Scooter Fleet	Data Description	Phase 1	Phase 2	Phase 3	Total
Spin	# Spin recorded Trips	72,315	48,321	81,700	202,336
Spin	Mean trips per day	1,417	582	371	790
Spin	Mean trip duration (mins)	7.8	6.5	7.7	7.3
DAS-equipped	# MicroDAS recorded Trips	3,106	5,981	7,271	16,358
DAS-equipped	Mean trip duration (mins)	6.1	4.0	7.6	4.8

In rides taken with the VTTI-instrumented scooters, there were a total 132 crashes out of 16,358 trips, for an overall crash rate of 0.81%. Table 4 details the safety-critical events (SCEs) per phase.

Table 4. SCEs by Deployment Phase

DAS Results	Phase 1	Phase 2	Phase 3	Total
Crashes	51	34	47	132
Crash Rate	1.64%	0.57%	0.65%	0.81%

DAS Results	Phase 1	Phase 2	Phase 3	Total
Near-crashes	52	17	42	111
Total SCEs	103	51	89	243
Total SCE Rate	3.32%	0.85%	1.22%	1.49%

Crashes were characterized as either being a simple fall-over/bailout (where the scooter made contact with the ground), which was the most common crash type (73%), or an impact event (where the scooter made contact with another object), which accounted for 27% of crashes.

Assessing Risk Factors

The prevalence and ORs associated with various risk factors were evaluated in three broad categories: infrastructure, behavioral, and environmental factors. The prevalence of precipitating factors observed in the MicroDAS data prior to crashes can be seen in Table 5. Per the Researcher Dictionary for Safety Critical Event Video Reduction Data (Virginia Tech Transportation Institute, 2015), only one precipitating factor can be noted for each SCE, and reductionists are instructed to choose the event that imparted the greatest effect on the crash or near-crash.

Table 5. Prevalence of Precipitating Factors Prior to Safety Critical Events (Phases 1– 3)

Precipitating Factor Category	Precipitating Factor Details	Crashes Count	Near-crash Count	Total SCE Count	Proportion of Total SCEs
Infrastructure	Loss of control related to infrastructure	66	38	104	43%
Infrastructure	Conflict with fixed infrastructure element	29	9	38	16%
Infrastructure	Conflict with plant	2	1	3	1%
Infrastructure	Subtotal	97	48	145	60%
Presence of other road users	Conflict with pedestrian	1	16	17	7%
Presence of other road users	Conflict with another e-scooter	4	9	13	5%
Presence of other road users	Conflict with vehicle	1	2	3	1%
Presence of other road users	Conflict with bicycle	0	3	3	1%
Presence of other road users	Subtotal	6	30	36	15%
Rider behavior	Loss of control related to riding behavior	23	22	45	19%
Rider behavior	Loss of control related to excessive speed	5	10	15	6%
Rider behavior	Loss of control unknown factor	1	1	2	1%
Rider behavior	Subtotal	29	33	62	26%
Total		**132**	**111**	**243**	**100%**

Infrastructure Risk Factors

MicroDAS

Infrastructure-related factors were the most prevalent precipitating factors, accounting for nearly 60% of all SCEs. Loss of control related to infrastructure was the most frequent infrastructure-related precipitating factor (43% of all SCEs). This precipitating factor was coded when observed infrastructure factors seemingly related to the rider's loss of control, resulting in a crash or near-crash. These infrastructure factors included the riding surface type, surface condition, and surface features, including transitions from one surface type to another. Conflict with a fixed infrastructure element was the second most prevalent infrastructure-related precipitating factor (16% of the SCEs). This was coded when the e-scooter rider impacted the raised edge of a paved surface, curb, or other proximate hazard such as a building or a short stone pillar. The prevalence of crashes and near-crashes where infrastructure was noted as a precipitating factor across all three phases was 61%, 71%, and 48%, respectively. The lower rate in Phase 3 could be attributed to various features of the new scooter model and/or a training effect as riders improved with more experience.

Because of the large prevalence of infrastructure factors, the overall risk associated with various infrastructure elements was examined in additional detail. In particular, the riding surface was found to be a key factor affecting e-scooter riding safety. The impact of riding surface was evaluated from two aspects: the type of riding surface (Table 6) and transitions between different surface types (Table 7). E-scooters are designed to operate on flat pavement, and riding on all other surface types introduces various levels of risk. As shown in the charts below, the riskiest infrastructure factors include transitioning between gravel/dirt and grass surfaces (OR of 67.64), transitioning between pavement and grass (OR of 39.1), riding on loose surfaces such as gravel, dirt, mulch, or sand (OR of 32.23), riding on grass (OR of 30.97), and riding over curbs (OR of 29.87). Other infrastructure factors such as riding on rough or degraded surfaces and riding over curb cutouts and on shoulders also introduced additional risk to the rider.

Table 6. Prevalence and Relative Risk by Surface Type

Riding Surface Type	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
S0	-	126	-	2215	52%	93%	-	-
S1 vs. S0	20	126	108	2215	8%	4%	3.25	[1.95, 5.42]
S2 vs. S0	22	126	12	2215	9%	0.50%	32.23	[15.59, 66.61]
S3 vs. S0	74	126	42	2215	30%	1.80%	30.97	[20.37, 47.10]
S0: Asphalt or concrete; S1: Aggregate/brick/cobblestone/wood planks/decorative tile; S2: Loose gravel/dirt/mulch/sand; S3: Grass								

Table 7. Prevalence and Relative Risk by Surface Transition Type

Riding Surface Transition	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
No transition	-	77	-	1488	32%	62%	-	-
Gravel/dirt to/from grass	21	77	6	1488	21%	0.40%	67.64	[26.53, 172.42]
Pavement to/from grass	89	77	44	1488	54%	2.90%	39.1	[25.49, 59.95]
Sidewalk to/from curb	17	77	11	1488	18%	0.70%	29.87	[13.52, 65.95]
Sidewalk to/from road cutout	36	77	257	1488	32%	15%	2.71	[1.78, 4.11]
Uneven/degraded surface	60	77	670	1488	44%	31%	1.73	[1.22, 2.45]

Behavioral Risk Factors

Riding behavior was analyzed using both the MicroDAS data, which showed the forward video only, and the fixed camera data, which included video of the area immediately around the rider.

MicroDAS

As previously shown in Table 5, conflicts between e-scooters and other road users, including pedestrians (9%), other e-scooters (7%), bicycles (2%), and parked vehicles (1%) accounted for 19% of the SCEs. E-scooter riders exhibited abnormal riding behavior in 10% of all SCEs. These behaviors included hard braking, trick riding, aggressive riding, or riding at an excessive speed. Excessive speed was a riding behavior observed in only 1% of the SCEs.

As seen in Table 8, the behavioral risk factors that were found to increase risk to e-scooter riders the most were responding to other nearby actors (OR of 13.2), riding e-scooters aggressively (defined as risky weaving or speeding, creating an unsafe proximity to other road users, or operating the e-scooter at a speed unsafe for the conditions) (OR of 9.50), and riding with risky behavior (defined as trick riding or aggressive riding) (OR of 9.02).

Table 8. Prevalence and Relative Risk of Behavioral Risk Factors

Environmental Factors	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
Other actor behavior: Irregular vs. Normal	40	203	35	2345	16%	1.50%	13.2	[8.20, 21.25]
Riding behavior: aggressive vs. Normal	91	104	191	2073	37%	8%	9.5	[6.91, 13.05]
Riding behavior: Risky vs. Normal	139	104	307	2073	57%	13%	9.02	[6.81, 11.95]

Environmental Factors	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
Grouping: Group riding vs. Riding alone	56	187	281	2099	23%	12%	2.24	[1.62, 3.09]

Fixed Camera

Analyses of the fixed camera video showed that most riders (93%) rode in a normal manner, followed by some aggressive riding (4%), trick riding (1%), sign/signal violation (1%), and double riding (1%), where more than one person was riding on the same scooter. In comparison, analysis of the MicroDAS video suggested that e-scooter riders rode in a normal manner only 87% of the time, with the remainder of riders displaying trick riding, aggressive riding, or riding too fast.

Riding stance was another behavioral factor of interest captured by the fixed cameras. A rider's center of gravity was determined by looking at their hip location relative to the scooter's handlebars. In the first deployment, it was seen that 36% of riders had their center of gravity more toward the front of the scooter, and 62% had their center of gravity toward the center or back of the scooter. Foot placement was also examined. Seventy-two percent (72%) of riders had their feet placed in the fore and aft of the scooter, 23% rode with their feet side to side, and 4% rode with one foot on and one foot off. Additional results from the fixed camera dataset are in Appendix F.

Environmental Risk Factors

MicroDAS

Environmental factors had less of an impact on SCEs than infrastructure and behavioral factors, which could be attributed to the operational constraints. While the e-scooter service at VT was limited to 7 a.m. to civil twilight (which ranged from 5 to 7 p.m. during the study), low-light conditions early in the morning or in the evening or during inclement weather were observed in 5% of baseline events and were associated with almost 3 times higher risk (Table 9) compared to riding during full daylight, suggesting that visibility plays a crucial role in e-scooter safety. Further, riding on non-dry surfaces was almost twice as risky as riding on dry surfaces.

Table 9. Prevalence and Relative Risk of Environmental Risk Factors

Environmental Factors	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
Lighting: Non-daylight vs. Daylight	32	211	117	2263	13%	5%	2.93	[1.94, 4.45]
Direction of traffic flow: NA vs. In traffic flow	191	52	1453	927	79%	61%	2.34	[1.71, 3.22]
Surface condition: Dry vs. Others	194	49	1660	720	80%	70%	1.72	[1.24, 2.38]

Environmental Factors	SCE: Risk Factor	SCE: Ref. Level	Control: Risk Factor	Control: Ref. Level	SCE Prevalence	Control Prevalence	OR	95% CI
Level of demand: Others vs. LOD A	102	141	1182	1198	42%	50%	0.73	[0.56, 0.96]

Surveys

A series of subjective surveys were administered over the course of deployment to obtain opinion and preference data from scooter users and non-users in the university community. High-level results are included in this section, with a focus on the overall perceptions of the deployment, mode replacement, and parking corral perceptions. Additional results are included in Appendix G, Appendix H, and Appendix I.

Pre- and Post-deployment Survey Results (Phase 1)

Of the nearly 900 pre- and post-deployment survey responses received, which included both e-scooter riders and non-riders present on the VT campus, 60% of the respondents viewed the deployment as favorable to moderately favorable (Figure 2).

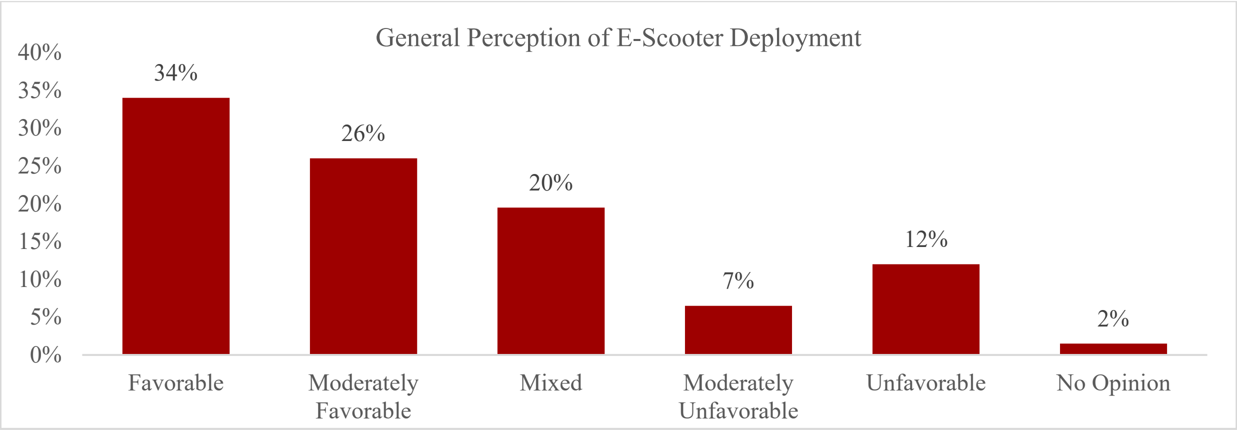

Figure 2. Chart. Pre- and post-deployment survey – overall perception.

In-app Survey (Phases 1 and 2)

The vast majority of respondents to the 12,050 post-ride in-app surveys received during Phases 1 and 2 indicated that their trips replaced walking trips (Figure 3). The largest proportion of e-scooter riders who completed the post-ride surveys indicated that they chose an e-scooter to get to or from class (47%).

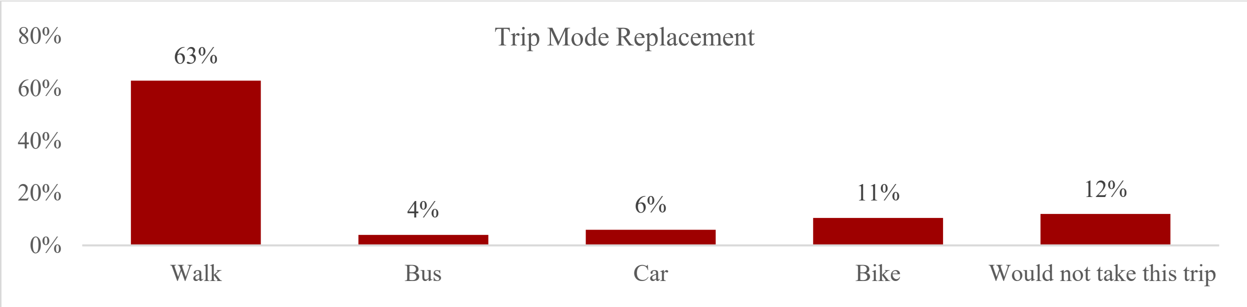

Figure 3. Chart. Post-ride survey results – trip mode replacement.

Redeployment and Panel Surveys (Phase 3)

The surveys administered in Phase 3 asked questions similar to the pre- and post-deployment surveys, in addition to specific questions pertaining to the parking corrals that were deployed in Phase 3. After the introduction of parking corrals in Spring 2022, the number of panel respondents still riding e-scooters declined by nearly half. Respondents were asked about their perceptions of e-scooter parking corrals before and after implementation, and the majority of respondents reported experiencing trouble with the corrals. One quarter indicated that corrals were not located where the user needed them, 20% claimed they were difficult to find, 19% indicated that corrals took too much extra time to use when parking, 13% reported having trouble ending the trip within the app, and 4% indicated the corrals were fully occupied when the user needed to park (Buehler R. B., 2022). Several riders made comments about their trouble ending rides, for example, taking the scooter to the corral location but not being able to end the ride due to the app not recognizing the scooter's correct location and/or not acknowledging the connection to the permitted geofence.

E-scooter Parking Results

Prior to the deployment, VT stakeholders modified the Bicycle and Personal Transportation Devices Policy (No. 5005) to include e-scooters. According to that policy, "E-Scooters must be parked within 5 feet of an approved bicycle rack or at designated zones on campus. E-Scooters cannot block ADA pathways, ADA ramps, or building entrances or exits." Of the parking photos analyzed, 39% were parked according to the VT policy, and VTTI classified an additional 46% as being parked "acceptably" (i.e., not blocking access to pedestrian or vehicle rights-of-way). Thus, a total of 86% were parked acceptably while 14% were blocking access to something and would likely be considered a "nuisance." E-scooters parked acceptably increased from an average of 80% to 90% over the course of the 20-week deployment. Only 8% of all the parking photos were classified as blocking access to either a sidewalk (n = 64; 7.7%) or ADA ramp (n = 2; 0.2%). Detailed parking photo results are included in Appendix H.

Injury Results

Table 10 shows the injuries recorded by Schiffert Health Center, the VT Police Department, and Spin during each phase of deployment. Across all three phases, the overall injury rate was 17 injuries per 100,000 trips, with zero fatalities. It is important to note that the majority of the injuries noted below could have occurred on either Spin scooters or personally owned scooters, as this information was not noted by Schiffert Health Center.

Table 10. Injuries Recorded During Deployment

	Phase 1	Phase 2	Phase 3	Total
Total Injuries	17	9	8	34
Injuries per 100,000 Trips	24	19	10	17

Discussion

E-scooters are a relatively new mode of transportation, and there have been reports of safety concerns for e-scooter riders and other road users. The data collected during this study provides a comprehensive look at e-scooter utilization patterns, as well as safety and nuisance concerns, to inform best practices for future deployments.

Overall Safety

The overall observed crash rate was 0.81% (807 crashes per 100,000 trips). Other e-scooter safety studies published to date have been based on hospital records alone and therefore cannot be used to compare to the crash rate reported in this study. The dataset captured during this study is much more comprehensive, capturing crashes ranging from very minor in severity or potential for injury (e.g., a scooter brushed against a plant) to more severe crashes that were likely to result in an injury. Crash rates were observed to decrease from 1.64% in Phase 1 to 0.57% in Phase 2 but increased slightly in Phase 3 to 0.65%. This decrease in crash rate between Phase 1 and 2 could be the result of a training effect assuming that most riders using e-scooters during Phase 2 had already ridden one during Phase 1. Conversely, Phase 3 spanned the entire academic year with over a year between Phase 2 and Phase 3, so the training effect may have been present within Phase 3 but cannot be quantified. Additionally, there were scooter design changes seen during the shift from the ES4 scooter model in Phase 1 to the Max model in Phase 2 and the S-100 in Phase 3. The ES4 had smaller, non-pneumatic tires and weighed 31 lbs. The Max and S-100 models had larger pneumatic tires and weighed upwards of 42 lbs., likely providing better stability and handling. These design changes could have resulted in added safety benefits.

The injury rate observed during the deployment was slightly higher than the recently published national average of 11.5 e-scooter injuries per 100,000 trips (Ioannides, 2022). This may be attributed to the presence of a health center on campus that is easily accessible to those with even minor injuries. These people may not have pursued medical attention for those same minor injuries outside the campus environment. In addition, it is unclear whether all the injuries seen by Schiffert Health Center occurred on Spin scooters versus personally owned scooters, so this injury rate may also overestimate the actual rate with the specific deployment of interest. Despite the high injury risk, severe injuries were not commonly observed. Only 14 of the 132 crashes resulted in riders completely ending their ride, an outcome likely indicative of more severe injuries. This also likely indicates that in the rest of the crash cases, riders were either unharmed or did not sustain an injury that was severe enough to limit their ability to ride an e-scooter. Overall, this demonstrates that while e-scooter riders can be at risk to sustain serious injuries, severe injuries tend to occur less often. Many of the injured riders reported that they were not wearing a helmet at the time of the crash, indicating a need to encourage helmet use. The fixed camera results reinforce this observation, as 99% of the observed riders were not wearing helmets. Therefore, it is apparent that new solutions need to be implemented to increase helmet use.

Risk Factors

Several factors were identified to increase risk levels for e-scooter riders: infrastructure, riding behavior, and environmental factors.

Infrastructure factors were the most prevalent precipitating factor for SCEs. Riding on non-solid surfaces such as grass, gravel, dirt, sand, and mulch were seen to result in a higher SCE risk than riding on smooth surfaces. Most e-scooters are designed for travel on flat pavement, and perhaps due to the selection or design of tires, they do not handle well on off-road surfaces. To reduce the number of conflicts, either more rider outreach is needed regarding e-scooters' appropriate operating domains or tires designed for off-roading should be added to the e-scooter design.

Riding behaviors such as aggressive riding, excessive speed, and trick riding had large effects on SCE risk. Of the 243 SCEs, 140 (57.6%) involved one of these. Ninety-one of those events involved aggressive riding, resulting in a 9.5 times higher risk of an SCE compared to normal riding. However, e-scooter fleet services present a unique opportunity such that algorithms can be developed and incorporated into the scooter software that can detect aggressive riding and either give feedback or limit services for users that continue to ride in a dangerous manner. Other road user actions that were characterized as aggressive, distracted, or unexpected also affected risk. There was a 13.2 times higher risk of an SCE occurrence when other road users acted in any of these manners. Interactions with other road users continue to be a major safety concern, signifying the importance for all road users to be educated on traffic laws and for educational campaigns to reinforce the need to be attentive while operating an e-scooter and all other transportation modes.

One environmental factor that impacted risk was lighting. Riding during non-daylight conditions had a 2.93 greater risk of an SCE when compared to riding during daylight conditions. Spin e-scooters are equipped with headlights, yet several crashes and near-crashes occurred during low-light conditions, indicating the need for either improved headlights or additional road lighting to help riders detect hazards that may not be easily visible. Limiting operations to daylight hours appears to be an effective policy for improving safety but it does limit the utility of the service.

Parking

E-Scooters parked acceptably increased from an average of 80% to 90% over the course of the 20 weeks that spanned Phases 1 and 2. Of the unacceptably parked scooters, only 8% were blocking access to either a sidewalk or ADA ramp. As a comparison, an observational study conducted in

Rosslyn, Virginia, characterized 606 parked e-scooters and found that 16% were not parked properly and 6% were blocking pedestrian rights-of-way (James, 2019) .

During Phase 3, Spin implemented geofenced parking corrals in certain areas on campus to encourage parking in desired locations. The parking corrals were not well received and reduced ridership levels significantly. While about a third of survey respondents felt that the corrals kept e-scooters from blocking sidewalks and provided a reliable location to find e-scooters, the issues that riders experienced (e.g., corrals not being located in the right locations, being difficult to find, and the app not allowing the trip to end appropriately) likely outweighed these benefits, and thus reduced overall ridership. If geofenced parking corrals are implemented again, VTTI recommends testing their effectiveness and accuracy in advance and initiating the parking corrals at the beginning of any new deployment rather than potentially introducing confusion later on.

Conclusions and Recommendations

Overall, the e-scooter deployment on the VT campus was well received, with 60% of survey respondents viewing the deployment as favorable to moderately favorable, and over 200,000 total e-scooter trips taken across all three phases. Based on the data collected from DAS-equipped scooters, there were a total of 132 crashes (of all severities). Other e-scooter studies published to date have been based on hospital records alone, and therefore cannot be used to compare to the crash rate determined in this study. While the injury rate observed during the VT deployment is slightly higher than the national average, this higher rate may be attributed to the presence of a health center on campus that is easily accessible to those with even minor injuries who may not have pursued medical attention for those same minor injuries outside of the campus environment.

The operational constraints that were put in place were largely effective. With the results from this study, some additional constraints and expanded outreach programs may make future deployments even safer. The campus community largely saw the deployment of e-scooters as a clean alternative transportation option and viewed the service favorably. One open issue that remains is parking. Spin tried a number of technological solutions to improve this, but those were not well-received because the technology just was not mature or capable enough. These issues can be somewhat alleviated by controlling the size of the scooter fleet and working with the operator to address individual issues, but the acceptance of mis-parked scooters and other personal transportation devices is ultimately up to the university community. Based upon the results, the following recommendations have been made to VT for consideration in future e-scooter operations.

Stakeholder Committee. VTTI recommends that a cross-functional committee of campus officials be reconvened to remain actively involved in the operations, educational outreach, and safety monitoring of the program and work through any issues with the e-scooter service or other personal mobility device provider.

Operational Constraints. VTTI recommends retaining similar operational constraints as those listed above on future deployments to maintain the safety levels observed during this deployment.

Campus Outreach and Educational Campaigns. Education and helmet giveaway programs did not appear to positively impact helmet utilization on campus. While lack of helmet usage among e-scooter riders, especially those using shared e-scooters, may be difficult to improve, VTTI recommends continuing such education and helmet giveaway programs to raise general awareness of risk of injury and ensure helmet availability for those who do want one.

VTTI recommends enhancing educational outreach programs by quantifying and presenting the significant risks associated with riding on and transitioning between unrecommended riding surfaces (i.e., loose surfaces and grass) and encouraging riders to select safer riding surfaces.

The prevalence of abnormal riding behavior remained level across the phases of the deployment. These results suggest that it is crucial to influence e-scooter riders' behavior and the behavior of all other trafficway users through safety campaigns, educational outreach, and proper training and orientation programs.

Policy Updates. VTTI recommends updating Policy 5005, section 2.1.1, to ban e-scooter riding on grass surfaces.

Infrastructure Maintenance. VTTI recommends developing a targeted infrastructure maintenance approach that will identify the most critical infrastructure elements that may need attention by the university (e.g., uneven pavement, deep cracks, loose gravel on concrete). Identification of these elements could potentially be crowdsourced from a mobile application.

Contractual Agreements. Anecdotal evidence suggests that the larger pneumatic tires and heavier weights of the scooter models used in Phases 2 and 3 were able to better handle the various infrastructure elements found on the VT campus. VTTI recommends that future deployments include similar scooters with larger pneumatic tires and that future e-scooter service contracts include a provision for VT to approve the e-scooter model being used on campus.

VTTI also recommends that operational constraints, including those listed below, remain in place for future deployments, and that the e-scooter operator should be able to demonstrate positive past performance of complying with and proactively managing such constraints under a tight deadline.

- Geofencing
- Reduced scooter speed limits
- No-deploy times/days (e.g., inclement weather, special events on campus)
- Time of service limited to daylight

VTTI recommends that future e-scooter deployment contracts on campus have a provision to allow VT to increase or decrease the size of the scooter fleet in collaboration with the operator based on nuisance levels associated with congestion and parking issues, which are directly influenced by a number of factors, including the geographical area, effectiveness of outreach campaigns, and number of users.

Additional Products

The Education and Workforce Development and Technology Transfer products are available for download at the following link: https://safed.vtti.vt.edu/projects/e-scooter-safety-assessment-and-campus-deployment-planning/

Education and Workforce Development Products

Over the course of this project, multiple VT students were involved at varying levels of responsibility. Adam Novotny was the primary student researcher involved in this program. He started out as a Graduate Research Assistant and was hired as a full-time employee of VTTI in 2022. Adam assisted primarily with data analyses and deliverable development. As a result of Adam's participation in this program and a related effort, he wrote and presented his doctoral dissertation in 2022 (see citation below).

Novotny, A. J. (2022). Improving E-Scooter Safety: Deployment Policy Recommendations, Design Optimization, and Training Development (Doctoral dissertation, Virginia Tech).

Multiple undergraduate students also worked on this project in varying roles. Multiple students assisted with the dissemination of the pre- and post-deployment subjective surveys, MicroDAS field testing prior to deployment, and various other miscellaneous tasks throughout the program. Two undergraduate students from VT's Computational Modeling and Data Analytics program contributed significantly to the first iteration of the data mining algorithms that were used in Phase 1 and Phase 2 to identify SCEs from the full dataset collected by the MicroDAS.

VTTI also developed materials for two outreach events that were held on the VT campus that targeted students and other potential users of the e-scooters to ensure they were educated on safe riding habits. Additionally, VTTI worked with various groups on campus to develop a social media outreach campaign that showcased safe riding habits and provided additional information as to where riders could find additional safe riding materials.

Lastly, an overview of the program was provided during Career Day at Auburn Elementary School in Riner, Virginia, to an audience of about 100 second graders.

Technology Transfer Products

To date, three journal articles have been written using the results from this study:

1. White, E., Guo, F., Han, S., et al. (2023). What factors contribute to E-Scooter crashes: a first look using a naturalistic riding approach. Journal of Safety Research. https://doi.org/10.1016/j.jsr.2023.02.002.
2. Buehler, R., Broaddus, A., White, E., Sweeney, T., & Evans, C. (2022). An Exploration of the Decline in E-Scooter Ridership after the Introduction of Mandatory E-Scooter

Parking Corrals on Virginia Tech’s Campus in Blacksburg, VA. Sustainability 2023, 15(1), 226; https://doi.org/10.3390/su15010226.
3. Buehler, R., Broaddus, A., Sweeney, T., Zhang, W., White, E., & Mollenhauer, M. (2021). Changes in Travel Behavior, Attitudes, and Preferences among E-Scooter Riders and Non-Riders: Results from Pre and Post E-Scooter System Launch Surveys at Virginia Tech. Transportation Research Record Journal of the Transportation Research Board. http://dx.doi.org/10.1177/03611981211002213

In addition to the journal articles, the results of this program were shared with around 20 VT stakeholders on December 8, 2022, through a video conference call. Following that meeting, a briefing document, including future deployment guidelines and recommendations, was shared with the stakeholders for their consideration when determining whether to deploy another fleet of shared e-scooters on the VT campus in the future.

Lastly, multiple news articles and/or websites featured the VT e-scooter research program, seven of which can be found at the links below:

- https://vtx.vt.edu/articles/2021/08/escooters-return-VirginiaTech.html
- https://vtx.vt.edu/articles/2019/08/VTTI-ScooterResearch.html
- https://vtx.vt.edu/notices/adm-evergreens/escooter-safety.html
- https://vtx.vt.edu/art/2021/09/doodle-september-20-2021.html
- https://vtx.vt.edu/notices/scootersustainability.html
- https://augustafreepress.com/E-Scooters-return-to-virginia-tech-providing-opportunities-for-research/
- https://theroanokestar.com/2021/08/17/use-safety-data-to-be-collected-as-E-Scooters-return-to-va-tech/

Data Products

A copy of the annotated MicroDAS baseline data as well as SCE data is available on Dataverse.

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Appendices

Appendix A. Video Reduction Data Definitions

Event severity definitions used in the data reduction process are defined below, and are listed in order of event severity.

1. **Crash** - Any contact that the subject scooter has with an object (including curbs), either moving or fixed, at any speed. This also includes any contact between the ground and the scooter (other than tires) or ground and rider (other than foot).
2. **Near Crash -** Any circumstance that requires an evasive maneuver by the subject vehicle or any other vehicle, pedestrian, cyclist, or animal to avoid a crash. Near Crashes must meet the following four criteria:
    a. Not a Crash. The scooter must not make contact with any object, moving or fixed, and the maneuver must not result in a road departure.
    b. Not pre-meditated. The maneuver performed by the subject must not be pre-meditated. This criterion does not rule out Near Crashes caused by unexpected events experienced during a pre-meditated maneuver (e.g., a premeditated aggressive lane change resulting in a conflict with an unseen vehicle in the adjacent lane that requires a rapid evasive maneuver by one of the vehicles).
    c. Evasion required. An evasive maneuver to avoid a crash was required by either the subject or another vehicle, pedestrian, animal, etc. An evasive maneuver is defined as steering, braking, accelerating, or combination of control inputs that is performed to avoid a potential crash.
    d. Rapidity required. The required evasive maneuver must also require rapidity. Rapidity refers to the swiftness of the response required given the amount of time from the beginning of the subject's reaction and the potential time of impact.
3. **Crash relevant** - Any circumstance that requires an evasive maneuver on the part of the subject vehicle or any other vehicle, pedestrian, cyclist, or animal that is less urgent than a rapid evasive maneuver (as defined in Near Crash), but greater in urgency than a "normal maneuver" to avoid a crash. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. Crash Relevant Conflicts must meet the following four criteria
    a. Not a Crash.
    b. Not pre-meditated.
    c. Evasion required.
    d. Rapidity NOT required. The evasive maneuver must not be required to be rapid.

Appendix B. MicroDAS Data Reduction Protocol

Spin Data Reduction
MicroDAS on Scooters
(last updated 6/17/2020)

In this document, the term "anchor point" means the point at which a specified variable is to be assessed:

- For conflicts, this is the Conflict Begin timestamp.
- For Baselines, this is the timestamp one second before the end of the event window.

There will be two separate reduction tasks, both of which are covered in this document. Each section may be accessed by clicking on the numbered item below. The tasks are as follows:

I. MicroDAS Baseline reduction (from scooter MicroDAS data)
   a. These will be sampled by the research team, likely stratified by time of day and day of week, and deployment period (time since deployment began).
   b. Baselines will be 4 seconds long, with an anchor point defined as above.
   c. Potential sampling plan: 2,000

II. MicroDAS Conflict reduction (from scooter MicroDAS data)
   a. This will require pre-reduction, separate reduction task to validate the conflict triggers.
   b. Conflict reduction will include all of the baseline variables, plus additional variables to characterize the conflict and its causes/outcomes
   c. Conflict related variables will include:
      i. Some questions about/around the precipitating event
      ii. Reduction will cover ~3 seconds before Conflict Begin through the Conflict End)
   d. Some questions answered about time between the precipitating event and the actual fall or crash

MicroDAS Baseline reduction

Infrastructure:

1. AnchorPoint. Anchor Point Timestamp. The point (timestamp) that is 1 second (1000 ms) prior to the end of the baseline event window. For dynamically coded variables (the 'event window'), the assessment window starts 3 seconds prior to this timestamp and ends 1 second after. For conflicts, this question is replaced by the "Conflict Begin" variable.

- Timestamp (text box)

2. ConflictSeverity. Conflict Presence/Severity. Continue reduction regardless of response. If event to be coded is a baseline that contains a conflict, additional reduction may be completed later, but the responses provided here would still be useful.

- No Conflict

- Crash - If a baseline event, continue reduction and leave a note in log. This event will need to be switched to the conflict type and queued up for a different (longer) annotation set.
- Non-Crash Conflict - If a baseline event, continue reduction and leave a note in log. This event will need to be switched to the conflict type and queued up for a different (longer) annotation set.
- Unable to determine

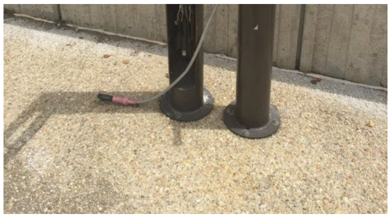
3. Intersection. What types of intersection(s) did the subject rider cross or traverse during the event window? (Check all that apply)
    - None - no junction present
    - Unpaved path – path not surfaced with a hard, durable material such as asphalt or cement concrete
    - Sidewalk – that portion of a street or highway right-of-way, adjacent to a roadway, beyond the curb or edge of roadway pavement, which is intended for use by pedestrians. Includes stairway if adjacent to a roadway. Sidewalks are, by definition, adjacent to a roadway. If not adjacent to a roadway, consider the "Shared use path" category.
    - Shared use path – a dedicated pathway that is physically separated from motor vehicle traffic by an open space or barrier (i.e., not directly adjacent to a roadway) and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. Most shared use paths are designed for two-way travel. Shared use paths are paved (asphalt or concrete) paths for pedestrians, bikes, etc., without vehicular traffic immediately adjacent. A local example would be the Huckleberry Trail, Duck Pond trail, or paved paths between residence halls and other campus buildings that are not adjacent to a road way.
    - Driveway – entrance or exit to roadway (from non-roadway) for vehicles (includes parking lot entrances)
    - Roadway, Uncontrolled – Crossing, without a traffic control applicable to the subject, a roadway or roadway intersection, including shoulders, intended for vehicular use. May or may not be on a crosswalk (use of crosswalk is included in RidingLocation variable).
    - Roadway, Stop Sign – Crossing, with a stop sign applicable to the subject, a roadway intersection. May or may not be on a crosswalk (use of crosswalk is included in RidingLocation variable).
    - Roadway, Traffic Signal – Crossing, with a traffic signal present applicable to the subject (regardless of signal phase) a roadway intersection. May or may not be on a crosswalk (use of crosswalk is included in RidingLocation variable).
    - Crosswalk - subject is on roadway crossing a crosswalk (not crossing a roadway using a crosswalk) (area for crossing a roadway designated by pavement markings and, if used, signs.)
    - Other – leave a note

- Unable to determine – leave a note

4. RidingLocation. What roadway designs were encountered (traversed or traveled on) by the subject rider during the event window? (Check all that apply)
    - Roadway – a lane of a traveled way that is ***open to both bicycle and motor vehicle*** travel. If crosswalk also present, either crossing over or traveling on, code that as well.
    - Bike lane – a portion of roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane.
    - Shoulder - the paved or unpaved (e.g., soft) portion of roadway contiguous with the traveled way that accommodates stopped vehicles, emergency use. Shoulders, where paved, are often used by bicyclists but would not be marked as dedicated to bicyclists. Should be separated from dedicated vehicle lane by painted line, crosshatching, or change in surface type (e.g., a soft shoulder).
    - Parking lane – in a roadway designated for vehicular traffic, but within a designated parallel or street-side perpendicular parking area (not to be confused with parking lot below)
    - Parking lot – within the boundaries of a designated parking lot
    - Sidewalk – the portion of a street or highway right-of-way, adjacent to a roadway, beyond the curb or edge of roadway pavement, which is paved and intended for use by pedestrians. Paved (asphalt or concrete). Includes stairway if adjacent to a roadway.
    - Crosswalk - area for crossing a roadway designated by pavement markings and, if used, signs. Also code Roadway if crosswalk is on a roadway (either traveling on or crossing over).
    - ADA access ramp – wheelchair accessible
    - Shared-use path – a dedicated pathway that is physically separated from motor vehicle traffic by an open space or barrier (i.e., not directly adjacent to a roadway) and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. Most shared use paths are designed for two-way travel. Shared use paths are paved (asphalt or concrete) paths for pedestrians, bikes, etc., without vehicular traffic immediately adjacent. A local example would be the Huckleberry Trail, Duck Pond trail, or paved paths between residence halls and other campus buildings that are not adjacent to a road way.
    - Unpaved path – A path maintained for use, but not surfaced with a hard, durable material such as asphalt or cement concrete. Includes dirt/gravel trails.
    - No designated path (Off-road) – grass, sand, dirt, or artificial turf with no intentionally designated path. ***Includes paths worn in by use, but not paths maintained for that purpose.***
    - Other - leave a note (may include trick riding surfaces)

5. SharedLane. If “Roadway” is coded above, describe the relation of other traffic in the roadway to the subject rider at the anchor point. (Check all that apply) If not a roadway, no traffic is ahead, or subject if just crossing a roadway rather than riding on a roadway, use the applicable NA option.
    - Vehicle ahead: Medium/Far - a motor vehicle directly ahead (same direction, same lane), greater than 1 car length ahead longitudinally
    - Vehicle ahead: Short - a motor vehicle directly ahead (same direction, same lane), less than 1 car length ahead longitudinally
    - Vehicle adjacent: Medium/Far – a motor vehicle adjacent ahead (same direction, adjacent lane), greater than 1 car length ahead longitudinally
    - Vehicle adjacent: Short – a motor vehicle adjacent ahead (same direction, adjacent lane), less than 1 car length ahead longitudinally
    - Vehicle passing: unsafe distance - subject rider is passed by a motor vehicle (same direction) with 3 feet or less lateral distance between them based on vehicle’s estimated trajectory when in view of forward camera
    - Vehicle passing: safe distance - subject rider is passed by a motor vehicle (same direction) with more than 3 feet lateral distance between them based on vehicle’s estimated trajectory when in view of forward camera
    - Scooter passing vehicle: unsafe distance - subject rider passes a motor vehicle (same direction) with 3 feet or less lateral distance between them based on vehicle’s estimated trajectory when in view of forward camera
    - Scooter passing vehicle: safe distance - subject rider passes a motor vehicle (same direction) with more than 3 feet lateral distance between them based on vehicle’s estimated trajectory when in view of forward camera
    - Oncoming vehicle: unsafe distance - subject rider passes an oncoming motor vehicle (opposite direction) with 3 feet or less lateral distance between them
    - Oncoming vehicle: safe distance - subject rider passes an oncoming motor vehicle (opposite direction) with greater than 3 feet lateral distance between them
    - Parked vehicle: unsafe distance - subject rider passes a parked motor vehicle on the roadway with 3 feet or less lateral distance between them
    - NA – Not a Roadway – Either roadway is not coded above, or roadway is not the riding the riding location at the anchor point.
    - NA – No traffic ahead/adjacent - at anchor point
    - NA – Just crossing – just crossing the Roadway, not traveling longitudinally in it

6. SurfaceType. What surface types were encountered (traversed or traveled on) by the subject rider during the event window? (Check all that apply)
    - Asphalt
    - Concrete
    - Rough aggregate surface- small pebbles in hard/compact aggregate, rougher than concrete, but still ‘paved’ (e.g., sidewalks in front of Squires Student Center)



- Brick/cobblestone – e.g., pavers, large stones set in sand or mortar
- Loose Gravel
- Grass
- Dirt
- Mulch
- Wood planks
- Artificial turf – is seen on many athletic fields, such as VT baseball field
- Sand – may be seen, for example, on volleyball courts
- Other - leave a note

Surface Features:

For this series of questions, indicate which surface features were encountered (traversed, traveled on) by the subject rider during the event window. Include features that are passed within ~3 feet on the right or left. Do not include features that remain ahead and are never reached within the assessment window. (Check all that apply)

Choices for all of the surface feature variables below (Q7-Q18), unless otherwise noted:

- None (includes not present, passed by without ridden on/through, and/or passed by without by trajectory change)
- Ridden through/on (May or may not have altered trajectory to do so)
- Failed avoidance (Rider attempted to avoid the surface feature, but that attempt failed. This option assumes that the failed attempt resulted in some degree of "ridden through/on" as well, no need to check both unless two different encounters of that feature were encountered and dealt with differently.)
- Avoided (Requires deviation from intended/expected trajectory in order to avoid, which may have occurred prior to the event window and requires review of additional lead-up time. If unclear whether trajectory change is a specific response to the coded feature or not, then do not consider as "avoided" (most likely "None").)
- Unable to determine (leave a note)

7. Stairs. Stairs
8. ADARamp. ADA ramp
9. Manhole. Manhole cover
10. Grate. Grate (e.g., storm drain)
11. SteelPlate. Steel Plate

12. TactilePaving. Tactile paving (e.g., textured surface often installed at the ends of sidewalks before crossing into the road)
13. UnevenDegraded. Uneven surface, degraded/needs maintenance (may include potholes, cracked/shifted pavement, etc. on either sidewalks or roadways; does not include simply riding on dirt, grass, gravel unless unexpected holes or similar are encountered. Does not include surfaces that are uneven by design, such as gravel or textured surfaces). 'Avoided' option must include a deviation from intended trajectory rather than a planned turn.
14. PavementToGrass. Transition - pavement to/from unpaved surface (Pavement may be any type of durable surface. Only consider what would potentially be in the rider's path. So, if just riding parallel to grass without risk of going over the edge, code as None.) 'Avoided' option must include a deviation from intended trajectory rather than a planned turn.
15. SidewalkToRoadCutout. Transition - sidewalk to/from road, curb cutout 'Avoided' option must include a deviation from intended trajectory rather than a planned turn.
16. SidewalkToRoadCurb. Transition - sidewalk to/from road, no curb cutout (i.e., jumped the curb) 'Avoided' option must include a deviation from intended trajectory rather than a planned turn.
17. GravelDirtGrass. Transition – between different unpaved surfaces 'Avoided' option must include a deviation from intended trajectory rather than a planned turn.
18. SurfaceFeatureOther. Other surface features - leave a note if not "None"
19. SurfaceCondition. What conditions were encountered (traversed or travelled on) by the subject rider during the event window? (Check all that apply)
    - Dry
    - Wet
    - Snow/Ice
    - Standing water
    - Loose material/debris (e.g., from degraded paving, mulch/rocks/leaves that have been scattered over an otherwise paved sidewalk/road. Do not use this category if Surface Type is already coded as a loose material such as dirt, gravel, grass, sand, etc.; Code as wet/dry/standing water/etc. as appropriate instead.)
    - Other - leave a note

20. ProximateHazards. To what features or hazards does the rider react (i.e., changed trajectory and/or speed in response) during the event window? (Check all that apply) These are in addition to any surface features coded above.)
    - None
    - Sidewalk furniture - benches, flowerpots/planters, mailboxes, etc. that appear to have been purposefully placed as part of the infrastructure.
    - Parked car: doors closed
    - Parked car: door(s) not closed – door(s) are already open or in the process of opening/closing as people are loading/unloading, etc.
    - Parked bikes

- Handrails - includes the series of chains between posts that line many campus sidewalks
- Bollards/pylons – e.g., concrete, plastic, or metal posts that separate different areas of the road and/or sidewalk to prevent certain types of traffic from passing through.
- Construction – temporary traffic controls (cones, barrels, etc.)
- Landscaping – something planted or installed in the ground (other than typical, mowed grass); does not include bare mulch (which should instead be coded under Surface Type).
- Sign/Sign post
- Parking meter
- Utility pole
- Buildings – includes opening doors
- Vehicle – not parked
- Pedestrian
- Bicyclist
- Scooter rider
- Dog/Animal
- Other - leave a note

Behavior:

21. GroupRiding. Does the subject rider appear to be riding with or as part of a group during the event window? If yes, indicate the group size AND the type of group members. (Check all that apply) This does not include being near others in passing or just because all are going in the same direction; this refers to people intentionally travelling together for a defined time period. May need to examine additional video to confirm.
    - None, rider is independent
    - 1 other
    - 2 others
    - 3+ others
    - Other scooters
    - Bicycles
    - Pedestrians
    - Skateboarders
    - Other – leave a note
    - Unsure - leave a note

22. RidingBehavior. What type of behavior do you suspect the subject rider is engaged in during the event window (for baselines) or just prior (within ~3 seconds) to the start of the conflict (for conflicts)?
    - Normal riding

- Trick riding - includes donuts, wheelies, slalom or weaving just for fun (not aggressively with other users)
- Aggressive riding – includes risky/aggressive/dangerous weaving or speeding, intentionally causing close/unsafe proximity to other users, riding in non-traditional situations in a way generally considered non conducive to scooters, etc.
- Excessive speed (>6.7 m/s) – code if the GPS-Speed exceeds 15 mph (6.7 m/s). Do not code if the GPS.Speed seems unrealistic (e.g., due to poor satellite signal). (For reference, 1 m/s = ~2 mph)

23. OtherActorBehavior. To what type of behaviors from other actors does the subject rider appear to respond? (Check all that apply) Other actors may be other vehicles as well as other scooters, pedestrians, skateboarders, etc. Only code behaviors to which the subject rider appears to respond, whether or not a response is actually needed.
    - None/Normal
    - Vehicle: Aggressive – aggressive motor vehicle behavior. Examples may include (but are not limited to) excessive speed or attempts to inappropriately overtake or cut in front of the subject scooter
    - Vehicle: Possibly Distracted/Inattentive – possibly distracted motor vehicle behavior. Examples may include (but are not limited to) other actors appearing to not look before pulling out of a driveway or turning a corner, failing to stop at a stop sign, encroaching inappropriately into bike lane, or observed texting/talking on phone while driving.
    - Vehicle: Unexpected movements – unexpected motor vehicle movement that do not appear intentionally aggressive. Examples include sudden braking, etc.
    - Other: Aggressive – aggressive behavior by other type of actor (e.g., scooter, pedestrian). Examples may include (but are not limited to) excessive speed or attempts to inappropriately overtake or cut in front of the subject scooter
    - Other: Possibly Distracted/Inattentive – possibly distracted or inattentive behavior by other type of actor (e.g., scooter, pedestrian). Examples may include (but are not limited to) other actors appearing to not look before pulling out of a driveway or turning a corner, failing to stop at a stop sign, encroaching inappropriately into bike lane, or texting/talking on phone while riding/walking.
    - Other: Unexpected movements – unexpected movements by other type of actor (e.g., scooter, pedestrian) that do not appear intentionally aggressive. Examples include pedestrian side-stepping, sudden bicyclist or scooter braking, being cut off by another cyclist, etc.

Trafficway Description:

24. LevelOfDemand. What is the level of traffic demand encountered by the subject rider at the anchor point? Assessment of demand should include all actors that are present and relevant to the subject rider's trajectory (e.g., scooters, pedestrians, vehicles, etc.). (Of note, the example images below all show "shared use paths" as defined under the

Intersection and Riding Location categories, although the level of traffic demand should be coded in all scenarios using these a guide.)

- LOD A – No other users or very distance users. Subject rider is likely unaffected by surrounding actors
- LOD B – One or two other user(s) nearby. Subject rider is required to moderate speed and or steering maneuvers to navigate as a result of other users being present.
- LOD C – Moderate number of other users. Subject rider must maintain close speed and steering control and heightened awareness of numerous users.
- LOD D – Many other users in close proximity. Traffic demand likely exceeds the amount of actors that can be serviced efficiently. Similar to “stop-and-go” conditions found in other types of traffic ways.

25. FlowDirection. What is the intended type of traffic at the anchor point, and is the subject rider’s direction and location correct according to regulations/conventions? Location refers to the correct side of the road, sidewalk, or parking lot. Note that this variable does not require the subject rider to match speeds with other traffic.
    - Pedestrian traffic, with flow, slower – sidewalk or other area meant for pedestrians (or similar), subject is going in same direction but going slower than traffic moving in the same direction

- Pedestrian traffic, with flow, matched speed – sidewalk or other area meant for pedestrians (or similar), subject is going in same direction and matching speed to the other traffic in the same direction
- Pedestrian traffic, with flow, faster – sidewalk or other area meant for pedestrians (or similar), subject is going in same direction but going faster than traffic moving in the same direction
- Pedestrian traffic, against flow – sidewalk or other area meant for pedestrians (or similar), subject is going in opposite direction (e.g., likely weaving in/out or requiring pedestrians to give way)
- Shared vehicle lane, correct direction – same lane used by cars, on the correct side of the road for the direction being traveled
- Shared vehicle lane, incorrect direction – same lane used by cars, on the wrong side of the road for the direction being traveled
- Bike lane, correct direction – designated bike lane, on the correct side of the road for the direction being traveled
- Bike lane, incorrect direction – designated bike lane, on the wrong side of the road for the direction being traveled
- Not Applicable – riding in an area where no flow is expected or (for pedestrian traffic areas) where either no flow exists or flow direction is commingled (not side-of-path specific) or unclear
- Other – leave a note

26. Lighting. Lighting at anchor point.
    - Daylight
    - Partial light (Dawn/Dusk)
    - Darkness, lighted
    - Darkness, not lighted
    - Other

27. PathWidth. Estimate the width of the path on which the subject rider is traveling at the anchor point (sidewalks and shared use paths only).
    - Narrow - 3 feet wide or less (estimating room for no more than 2 side-by-side pedestrians)
    - Moderate - between 3 and 5 feet wide (estimating room for 3 side-by-side pedestrians)
    - Wide - 5 feet wide or more (estimating room for 4 or more side-by-side pedestrians, including wide walking areas and all areas designed for vehicular travel)
    - Unsure – leave a note
    - Not applicable – not a sidewalk or shared use path

28. PathPosition. Location of subject rider on current path at anchor point (sidewalks and shared use paths only).
    - Left side of path
    - Middle of path
    - Right side of path
    - Not applicable – not a sidewalk or shared-use path

29. Notes. Leave notes for any "unknown" or "other" categories or for anything notable not covered under other variables. If a conflict occurs within a baseline, describe it here as well.

MicroDAS Conflict reduction

For conflicts, all MicroDAS baseline variables are to be coded (those in section I above) in addition to the variables listed in this section.

Incident Description:

30. ConflictBegin. Conflict Begin Timestamp. The point (timestamp) in the video when the sequence of events defining the conflict begins. The timestamp at which the Precipitating Event begins. This timestamp is then used as the "anchor point" for all variables that reference the anchor point. For dynamically coded variables, the assessment window starts 3 seconds prior to this timestamp. This question replaces the baseline "Anchor Point" question for conflicts.
    - Timestamp (text box)

31. ConflictEnd. Conflict End Timestamp. The point (timestamp) in the video when the sequence of events defining the conflict ends. The timestamp at which final evasive maneuvers have been completed and all conflict partners have either stopped or resumed normal patterns of travel, whichever occurs first. For dynamically coded variables, the assessment window ends at this timestamp.
    - Timestamp (text box)

32. ConflictMaxSpeed. Max Conflict Scooter Speed (m/s). The maximum speed of the subject scooter starting 3 seconds before Conflict Begin through Conflict End, using GPS.Speed, in m/s. If the GPS.Speed is unavailable or seems unrealistic (e.g., due to poor satellite signal), enter -99. (For reference to determine if realistic, 1 m/s = ~2 mph. The maximum realistic scooter speed can be assumed to be ~7 m/s or ~15mph.)
    - Speed Value rounded to the nearest hundredth (two decimal places) (text box)

33. PrecipitatingEvent. Precipitating Event, if determinable

- Subject loss of control due to infrastructure – may include causes or a combination of causes due to surface type, surface features, surface conditions coded above; subject loses control due to an infrastructure element (e.g., surface type, surface feature, surface condition) but doesn't actually impact an infrastructure element (other than the ground)
- Subject loss of control due to excessive speed
- Subject loss of control, other - leave a note
- Subject loss of control, unknown- leave a note
- Conflict with vehicle
- Conflict with pedestrian
- Conflict with bicycle
- Conflict with other scooter
- Conflict with animal
- Conflict with non-fixed object – building, trash can, rock, banana peel
- Conflict with fixed infrastructure element – "conflict with…" entails actually making impact with an infrastructure element (e.g. impacting the edge of the sidewalk/curb when attempting to ride over it)
- Conflict resulting from carried cargo - if known
- Other – leave a note
- Unable to determine - leave a note

34. ConflictType. What type of crash occurred?
    - No impact or fall
    - Simple fall over/bailout –no other conflict partner or impact present
    - Impact with vehicle
    - Impact with pedestrian – includes pedestrian walking a bicycle
    - Impact with bicycle
    - Impact with other scooter
    - Impact with animal
    - Impact with non-fixed object – e.g., litter, other non-fixed items that are not part of the infrastructural design
    - Impact with infrastructure element – e.g., fixed aspects of the infrastructure such as buildings, sign posts, mailboxes, curb/raised sidewalk, etc.
    - Other – leave a note

35. ConflictRole. What role did the subject rider play in the conflict?
    - Struck (or would have struck)
    - Struck by (or would have been struck by)
    - Non-striking scenario
    - Unknown – leave a note

36. ConflictOutcome. How did the scooter fall as a result of the conflict?
    - Fell to the left - making impact with the ground

- Fell to the right - making impact with the ground
- Fell forward – rear wheel up or fell over handlebars, making impact with the ground
- Fell backward – front wheel up or fell over rear wheel, making impact with the ground
- Combination of above – leave a note
- Did not fall/remained on scooter

37. ConflictFault. Which conflict partner is at fault? Indicates which conflict partner (scooter, bicycle, pedestrian, vehicle, etc.), if any, committed an error that led to the conflict. Only code a fault if there is observable evidence. Note: Objects and animals cannot be assigned fault; such events are coded as 'subject at fault' or 'no fault'.
    - Subject rider - The rider of the subject scooter committed the error that led to the event. Use this option for loss of control scenarios.
    - Other conflict partner – Another conflict partner (other vehicle, pedestrian, scooter, etc.) committed the error that led to the event.
    - Shared fault - More than one conflict partner committed errors that contributed to the event.
    - No fault - No user errors were committed any errors that led to the event. This is often (but not always) true for animal-related conflicts and objects in the roadway, especially if the conflict cannot be reasonably anticipated or that does not allow for sufficient reaction time given safe riding patterns.
    - Unable to determine - Cannot determine the fault due to limitations in video views, lighting, visual obstructions, or limited perspective, or cannot make a judgment as to whether one user was completely at fault.

Behavior:

38. RideStatus. What did the subject rider do just after the conflict ended?
    - Continued riding, no stop – scooter did not fall and did not come to a stop
    - Stopped briefly, resumed – scooter may or may not have fallen, but does come to a stop and resumes riding prior to the end of the video
    - Stopped altogether – video ends
    - Other - leave a note

39. FinalNarrative. Provide a brief description of the conflict, and leave notes for any "unknown" or "other" categories or for anything notable not covered under other variables.

Appendix C. Fixed Camera Data Reduction Protocol

Spin Data Reduction

(last updated 7/17/2020)

In this document, the term "anchor point" means the point at which a specified variable is to be assessed:

- For conflicts, this is the Conflict Begin timestamp.
- For Baselines, this is the timestamp one second before the end of the event window.

There will be four separate reduction tasks, all of which are covered in this document. Each section may be accessed by clicking on the numbered item below. The tasks are as follows:

III. Fixed camera Baseline reduction
(from stationary cameras affixed at key locations on VT campus)
   a. These will be sampled by the research team and imported into a Hawkeye-accessible format by the IT Developer team. Likely stratified by camera and representative of frequency of scooter trips through each camera FOV, time of day, day of week, and deployment period (time since deployment began).
   b. Baselines will be 4 seconds long with an anchor point defined as above. In the case where the referenced rider is not in the fixed camera view for the entire 4s window, then the referenced rider will be assessed for the duration that it is visible within the assessment window (up to 4s maximum)
   c. Potential sampling plan: 1,200

IV. Fixed camera Conflict reduction
(from stationary cameras affixed at key locations on VT campus)
   a. This will require first that conflicts be identified during the baseline reduction (above). Then, identified conflicts will undergo a separate conflict reduction task.
      i. This will include crashes and non-crash conflicts
      ii. It is unknown how many of these conflicts will be identified, and the number assessed may need to be determined based on how many are identified
   b. Because the baseline reduction codes information for up to 6 riders, the conflict reduction will be performed on a separate event ID, using the conflict bounds to define the conflict assessment window.

Fixed Camera Baseline Reduction

First answer Q1, and then answer questions 2-7 for all scooters in view. (If there are 4 scooters in view during the assessment window, Q1 will be answered once, and Qs 2-7 will each be answered 4 times.)

1. ScooterCount. How many scooters are seen in the video during the 4 second event window? (Enter number, user -99 if unable to determine)
   - Integer (text box)

For the questions that follow, number the scooters as defined here: in the first frame of video in the assessment window (i.e., at the start of the 4 seconds), number the visible scooters from a clockwise fashion starting from the 12:00, outermost position. Then, number any additional scooters as they come into the video view during the event window. Code the first 6 scooters that are numbered using this system.

2. Rider(1-6)Gender. What is the gender of the referenced scooter rider?
   - Male
   - Female
   - Unable to determine

3. Rider(1-6)Age. What is the estimated age of the referenced scooter rider?
   - Typical college student
   - Older – appears to be older than typical college student
   - Younger – appears to be younger than typical college student
   - Unable to determine

4. Rider(1-6)WearingHelmet. Is the referenced scooter rider wearing a helmet?
   - Yes
   - No
   - Unable to determine

5. Rider(1-6)WearingBag. Is the referenced scooter rider wearing a backpack or other type of bag? Includes purse, sidebag, etc., that is hanging on one or more shoulder or in some way strapped to the rider's body (e.g., around waist).
   - Yes
   - No
   - Unable to determine

6. Rider(1-6)HandheldItem. Is the referenced scooter rider carrying a hand held item? Includes phone, grocery bag, water bottle, etc., that is held in hand or similar (e.g,, supported by wrist or lower arm).
   - Yes
   - No
   - Unable to determine

7. Rider(1-6)HandlebarItem. Does the referenced scooter rider have an item hanging from or otherwise supported by the handlebars?
   - Yes, hanging from one handlebar
   - Yes, hanging from both handlebars
   - Yes, balanced on top of handlebars
   - Yes, Other - leave note
   - No
   - Unable to determine

8. Rider(1-6)Hands. How many hands does the referenced scooter rider have on the handlebars at the anchor point?
   - None
   - One
   - Two
   - Unable to determine

9. Rider(1-6)RidingStance. How are the feet and body positioned on the scooter at the anchor point? (check all that apply) Must check at least one center of gravity location (Front vs Center/Back) AND one foot position (fore/aft vs side to side) option, or if one of these is unknown, code the one that is known plus the unable to determine option.
   - Front – the rider's center of gravity is towards the front of the scooter (2" of space or less between the rider's hips and the scooter stalk)
   - Center/Back - the rider's center of gravity is in the center or rear part of the scooter (more than 2" of space between the rider's hips and the scooter stalk)
   - Feet fore/aft – one foot is placed in front and one in back on the scooter footboard
   - Feet side to side – both feet are placed next to each other on the scooter footboard
   - Unable to determine

10. Rider(1-6)RidingBehavior. Is the referenced scooter rider participating in the following behaviors during the assessment window? (check all that apply)
    - None
    - 2+ riders/scooter – if this is the case, other questions should consider the rider in control only or the lead rider if control is unclear
    - Trick riding - includes donuts, wheelies, slalom or weaving just for fun (not aggressively with other users)
    - Aggressive riding – includes aggressive/dangerous weaving or speeding, intentionally causing close/unsafe proximity to other users, etc.
    - Sign/Signal violation(s) – referenced rider violates at least one stop sign or traffic signal during the assessment window

11. Rider(1-6)RidingLocation. Where is the referenced scooter rider operating the scooter during the assessment window? (check all that apply)
    - Roadway – a lane of a traveled way that is ***open to both bicycle and motor vehicle*** travel. If crosswalk also present, either crossing over or traveling on, code that as well.
    - Bike lane – a portion of roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane.
    - Shoulder - the portion of roadway contiguous with the traveled way that accommodates stopped vehicles, emergency use. Shoulders, where paved, are

often used by bicyclists but would not be marked as dedicated to bicyclists. Should be separated from dedicated vehicle lane by painted line, crosshatching, or change in surface type (e.g., a soft shoulder).

- Parking lane – in a roadway designated for vehicular traffic, but within a designated parallel or street-side perpendicular parking area (not to be confused with parking lot below)
- Parking lot – within the boundaries of a designated parking lot
- Sidewalk – the portion of a street or highway right-of-way, adjacent to a roadway, beyond the curb or edge of roadway pavement, which is paved and intended for use by pedestrians. Paved (asphalt or concrete). Includes stairway if adjacent to a roadway.
- Crosswalk - area for crossing a roadway designated by pavement markings and, if used, signs. Also code Roadway if crosswalk is on a roadway (either traveling on or crossing over).
- ADA access ramp – wheelchair accessible
- Shared-use path – a dedicated pathway that is physically separated from motor vehicle traffic by an open space or barrier (i.e., not directly adjacent to a roadway) and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. Most shared use paths are designed for two-way travel. Shared use paths are paved (asphalt or concrete) paths for pedestrians, bikes, etc., without vehicular traffic immediately adjacent. A local example would be the Huckleberry Trail, Duck Pond trail, or paved paths between residence halls and other campus buildings that are not adjacent to a road way.
- Unpaved path – A path maintained for use, but not surfaced with a hard, durable material such as asphalt or cement concrete. Includes dirt/gravel trails.
- No designated path (Off-road) – grass, sand, dirt, or artificial turf with no intentionally designated path. Includes paths worn in by use, but not paths maintained for that purpose.
- Other - leave a note (may include trick riding surfaces)

12. Rider(1-6)VehicleInteraction. How is the referenced rider interacting with motorized vehicles in the roadway during the assessment window? (check all that apply) (this question applies only if roadway, bike lane, shoulder, parking lane, or parking lot are coded above.)
    - Scooter passes parked cars – referenced rider is at risk of being hit by vehicle driver opening a car door or pulling out
    - Scooter overtakes vehicle – referenced rider goes around a slow or stopped motorized vehicle (e.g. bus at bus stop, car waiting to park or make a turn, etc)
    - Scooter crosses in front of vehicle – referenced rider crosses in front of a non-parked motorized vehicle, at a crosswalk, at a driveway, while making a turn, or otherwise

- Vehicle passes moving scooter, different lane initially – a motorized vehicle drives past the referenced rider while the scooter is in motion in the bike lane or parking lane
- Vehicle overtakes moving scooter, same lane initially – a motorized vehicle goes around the referenced scooter while the scooter is in motion using a shared travel lane (i.e. to go faster)
- Vehicle passes standing scooter – a motorized vehicle drives past the referenced rider while scooter is standing still (e.g. waiting to cross road, looking at phone, etc)
- Vehicle crosses in front of scooter – a motorized vehicle crosses in front of the scooter, at a crosswalk, at a driveway, while making a turn, or otherwise
- Other - leave a note
- Unable to determine
- NA – Location type not applicable to motorized vehicles – rider is not riding on a roadway, bike lane, shoulder, parking lane, or parking lot.

13. Rider(1-6)RidingMode. What operating rules is the scooter rider following during the assessment window? (check all that apply) (this question applies only if roadway, bike lane, shoulder, parking lane, parking lot, sidewalk, crosswalk, access ramp, or shared use path are coded above.)
    - Behaving like a car – scooter is in a lane with cars and following the rules of the road like a car driver
    - Behaving like a bike – scooter is using a bike lane, parking lane, or shoulder, and traveling in the same direction as cars, and behaving as one would expect for that location
    - Behaving like a pedestrian – scooter is using the sidewalk, crosswalks, access ramps or shared use path, and behaving as one would expect for that location
    - Behaving unexpectedly or mixed – not following expected behaviors of the mode currently in use (e.g. cutting across lanes of traffic, jumping over curbs, doing U-turn in the middle of the road, etc.) or shifting between behavior modes.
    - Other – leave note
    - Unable to determine
    - NA – Not subject to specific rules– rider is not riding on a roadway, bike lane, shoulder, parking lane, or parking lot.
14. Rider(1-6)ConflictSeverity. Conflict Presence/Severity (for referenced rider). Was the referenced rider involved in a conflict during the assessment window?
    - No Conflict
    - Crash – includes falling over or making contact with any object, vehicle, or person. This will be further processed and the variables under “Fixed camera Conflict reduction” will be coded accordingly.
    - Non-Crash Conflict – includes nearly falling over, swerving or stopping abruptly to avoid a crash, or causing another vehicle/pedestrian/scooter to swerve or stop abruptly to avoid a crash. This will be further processed and the variables under “Fixed camera Conflict reduction” will be coded accordingly.

- Unable to determine

15. Rider(1-6)ConflictEvent. If a conflict is coded as present above, then once the conflict is reduced, come back and enter the new Event_ID of the conflict here. (Note, this will be left blank until the new conflict event is created and reduced, but will be populated once the conflict has been fully processed.)
1. Event_ID of conflict (text box), leave null if referenced rider is not involved in a conflict

16. Notes. Leave notes for any "unable to determine" or "other" categories or for anything notable not covered under other variables. If a conflict occurs within a baseline, describe it here as well.

Fixed Camera Conflict Reduction

For conflicts seen in the fixed camera baseline reduction, the variables in this section will also coded during separate conflict reduction task. Because a new Event_ID will be assigned to each conflict, the first couple of variables are used to link the baseline event where the conflict was seen to the conflict event coded here.

Conflicts includes both crashes and near misses (non-crash conflicts). These are incidents where the scooter rider

- Falls or nearly falls over
- Swerves or stops abruptly to avoid a crash
- Causes another vehicle or pedestrian to swerve or stop abruptly to avoid a crash
- Has contact with any object, vehicle, or person

Incident Description:

17. FixedBaselineEvent. Enter the Event_ID of the baseline event where this conflict was coded to a referenced rider.
- Event_ID of corresponding fixed cam baseline (text box)

18. RiderReference. Enter the Referenced Rider number(s) involved in the conflict. If two riders from the referenced baselines were involved in the conflict, then enter both numbers separated by a comma but not space (e.g., "2,3")
- Rider reference number(s) (text box)

19. ConflictBegin. Conflict Begin Timestamp. The point (timestamp) in the video when the sequence of events defining the conflict begins. The timestamp at which the Precipitating Event begins. This timestamp is then used as the "anchor point" for all variables that reference the anchor point. For dynamically coded variables, the assessment window starts 3 seconds prior to this timestamp. This question replaces the baseline "Anchor Point" question for conflicts.

- Timestamp (text box)

20. ConflictEnd. Conflict End Timestamp. The point (timestamp) in the video when the sequence of events defining the conflict ends. The timestamp at which final evasive maneuvers have been completed and all conflict partners have either stopped or resumed normal patterns of travel, whichever occurs first. For dynamically coded variables, the assessment window ends at this timestamp.
    - Timestamp (text box)

21. PrecipitatingEvent. Precipitating Event, if determinable

- Subject loss of control due to infrastructure – may include causes or a combination of causes due to surface type, surface features, surface conditions coded above
- Subject loss of control due to excessive speed
- Subject loss of control, other - leave a note
- Subject loss of control, unknown- leave a note
- Conflict with vehicle
- Conflict with pedestrian
- Conflict with bicycle
- Conflict with other scooter
- Conflict with animal
- Conflict with non-fixed object - trash can, rock, banana peel
- Conflict with fixed infrastructure element
- Conflict resulting from carried cargo - if known
- Other – leave a note
- Unable to determine - leave a note

22. ConflictType. What type of crash occurred (or would have occurred if non-crash)?
    - No impact or fall
    - Simple fall over/bailout –no other conflict partner present
    - Impact with vehicle
    - Impact with pedestrian – includes pedestrian walking a bicycle
    - Impact with bicycle
    - Impact with other scooter
    - Impact with animal
    - Impact with object – e.g., litter, other non-fixed items that are not part of the infrastructural design
    - Impact with infrastructure element – e.g., items listed under the Proximate Hazards variable.
    - Other – leave a note
    - NA – Not a crash

23. ConflictEvasion. Which conflict partner(s) performed evasive maneuvers in attempt to avoid a crash? (check all that apply)?
    - One referenced scooter – select only if only one referenced scooter performed evasive maneuver
    - More than one referenced scooter – select if both conflict partners are referenced scooters and both performed evasive maneuvers.
    - Non-referenced scooter – select if the other conflict partner is a scooter not referenced in the baseline reduction (or RiderReference variable above) and performed an evasive maneuver
    - Pedestrian – select if conflict partner is a pedestrian and performed an evasive maneuver
    - Motorized vehicle – select if conflict partner is a motorized vehicle and performed an evasive maneuver
    - Non-motorized vehicle – select if conflict partner is a non-motorized vehicle such as a bicycle, skateboard, etc. and performs an evasive maneuver
    - NA – Conflict is a crash

24. ConflictRole. What role did the referenced rider(s) play in the conflict?
    - Struck (or would have struck)
    - Struck by (or would have been struck by)
    - Both struck and struck by (or would have been) – only if both conflict partners are riders referenced in the baseline reduction
    - Non-striking scenario
    - Unknown – leave a note

25. ConflictOutcome. How did the referenced scooter(s) fall as a result of the conflict?
    - Fell to the left - making impact with the ground
    - Fell to the right - making impact with the ground
    - Fell forward – rear wheel up or fell over handlebars, making impact with the ground
    - Fell backward – front wheel up or fell over rear wheel, making impact with the ground
    - Combination of above – leave a note, includes when two referenced scooters are involved and have different outcomes.
    - Did not fall/remained on scooter

26. ConflictFault. Which conflict partner is at fault? Indicates which conflict partner (scooter, bicycle, pedestrian, vehicle, etc.), if any, committed an error that led to the conflict. Only code a fault if there is observable evidence. Note: Objects and animals cannot be assigned fault; such events are coded as ‘subject at fault’ or ‘no fault’.
    - Referenced rider - The rider of the subject scooter committed the error that led to the event. (If both conflict partners are riders referenced in the baseline reduction, reference the corresponding rider at fault in the final narrative.)

- Other conflict partner – Another conflict partner (other vehicle, pedestrian, non-referenced scooter, etc.) committed the error that led to the event.
- Shared fault - More than one conflict partner committed errors that contributed to the event.
- No fault - No user errors were committed any errors that led to the event. This is often (but not always) true for animal-related conflicts and objects in the roadway, especially if the conflict cannot be reasonably anticipated or that does not allow for sufficient reaction time given safe riding patterns.
- Unable to determine - Cannot determine the fault due to limitations in video views, lighting, visual obstructions, or limited perspective, or cannot make a judgment as to whether one user was completely at fault.

27. FinalNarrative. Provide a brief description of the conflict, and leave notes for any “unable to determine” or “other” categories or for anything notable not covered under other variables.

Appendix D. Parking Photo Reduction Protocol

The following protocol was incorporated into VTTI's photo reduction tool for assisting with the reduction of Spin scooter parking photos. It consists of a set of questions that will be answered by the reviewer. Multiple responses can be selected for each of the questions.

1. Select the following that describe the quality of the parking photo. Choose all that apply. [If either option is selected, move onto the next photo without answering questions 2-4].

☐ The scooter is not in view in the picture

☐ There is not enough information in the picture to describe other aspects regarding its location

2. Was the scooter parked according to VT policy?

☐ Yes (skip to question 4)

☐ No

3. Which of the following describe the location of the incorrectly parked scooter? Choose all that apply.

☐ Sidewalk – blocking ADA access

☐ Sidewalk – NOT blocking ADA access

☐ Sidewalk – blocking ADA ramp

☐ Sidewalk – blocking stairs

☐ Sidewalk – blocking building entrance/exit

☐ Sidewalk – blocking other

☐ Parking lot – blocking vehicle right of way

☐ Parking lot – blocking pedestrian right of way

☐ In building

☐ Other (roadway, landscaped area, driveway, loading zone, etc.)

- Text box will be available to leave note

4. Select the following additional notes regarding the parked scooter. Choose all that apply:

☐ Laying down

☐ Touching vegetation (i.e. leaning on tree or bush, lying on grass)

☐ Damaging property (i.e. crushing vegetation, other)

☐ Obstructing access to sidewalk furniture (e.g. benches, bus stops, etc.)

☐ Obstructing access to fire hydrant or valve

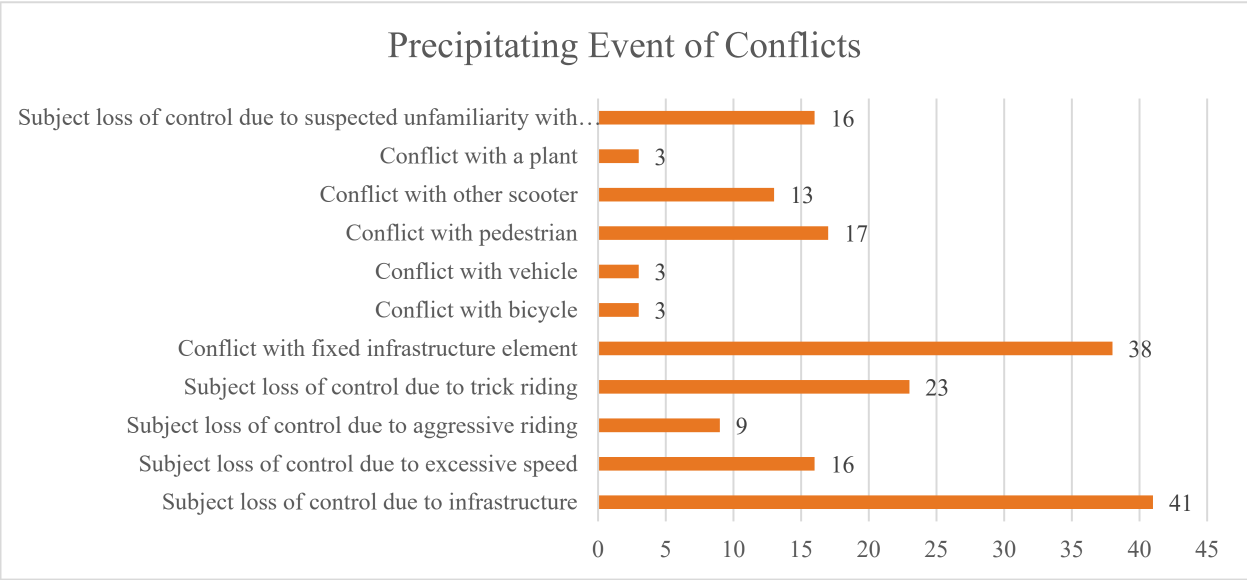
☐ Obstructing access to driveway or loading zone

Appendix E. On-Scooter MicroDAS Results

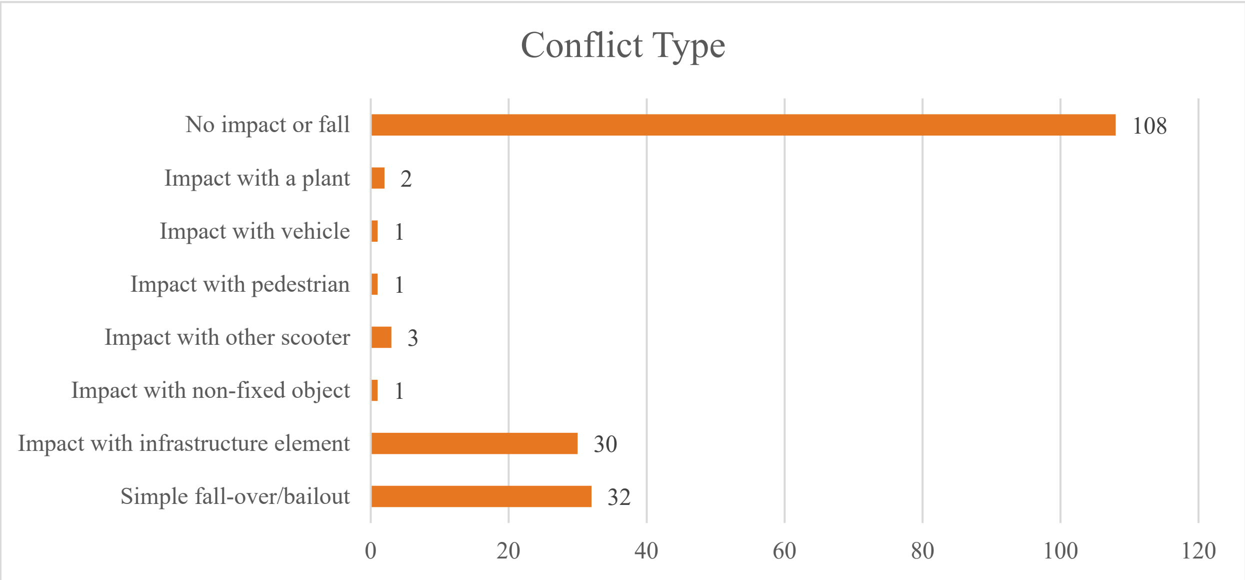
Conflict Results

The following graphs provide additional details of the identified conflicts (crashes and near crashes) based on the annotations from the MicroDAS Data Reduction Protocol. The x-axis for each graph is the count of conflict events.

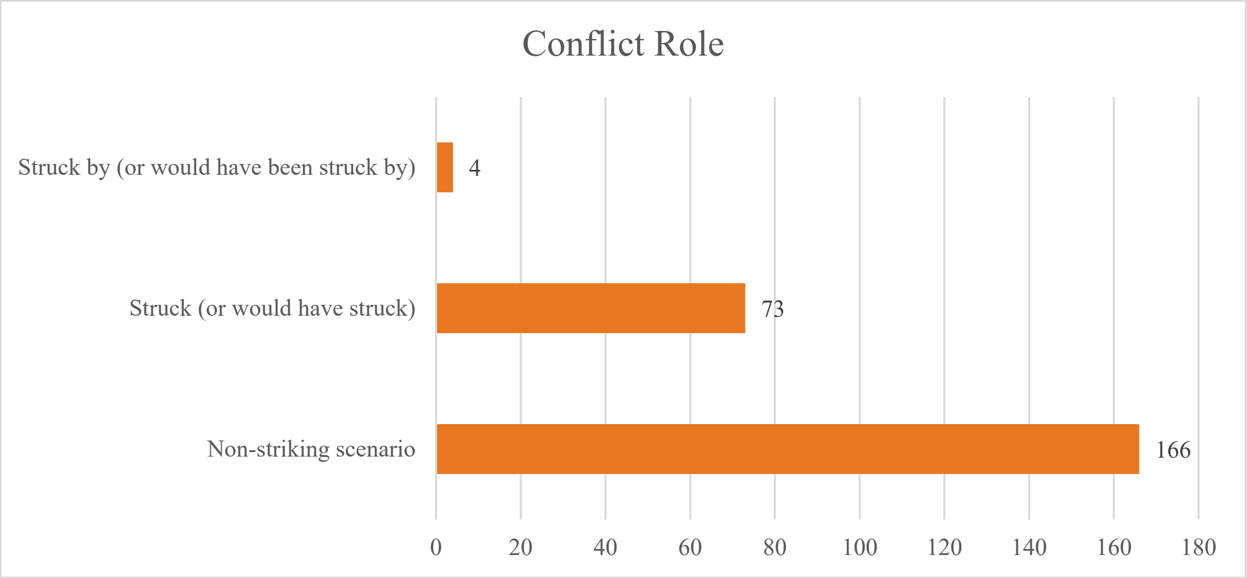
Precipitating Event of Conflicts



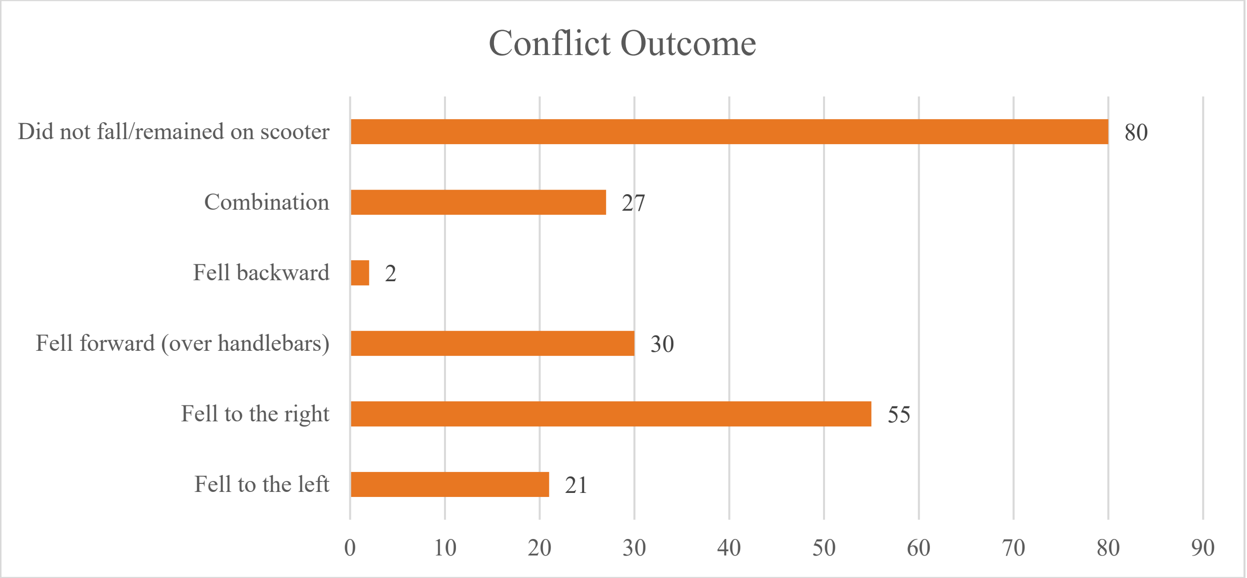
Crash Type



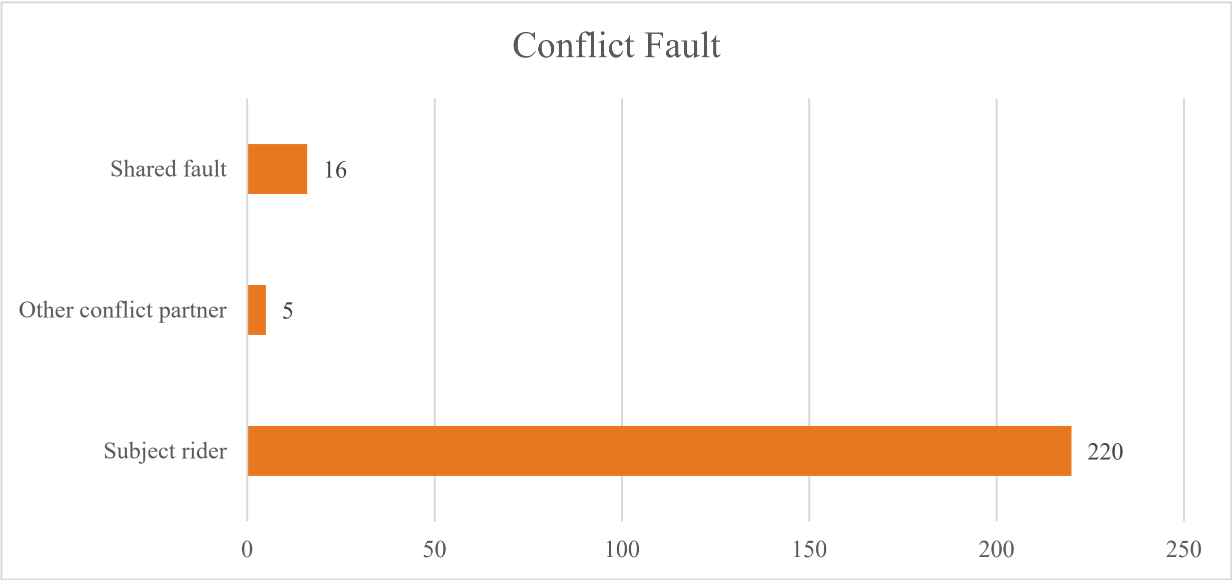
Conflict Role



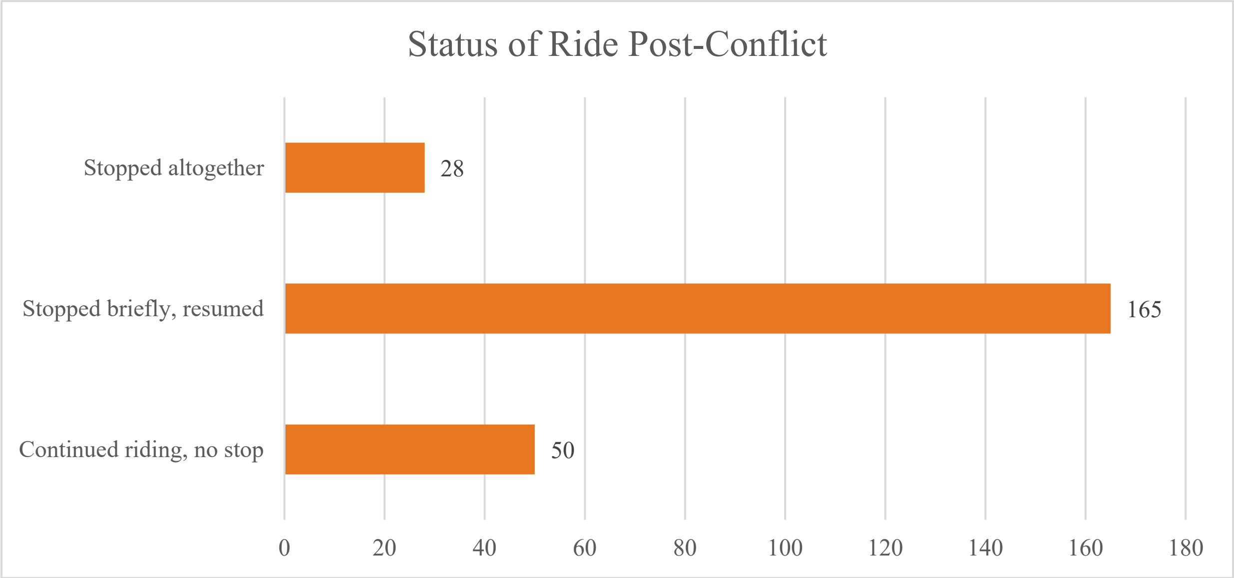
Conflict Outcome



Conflict Fault

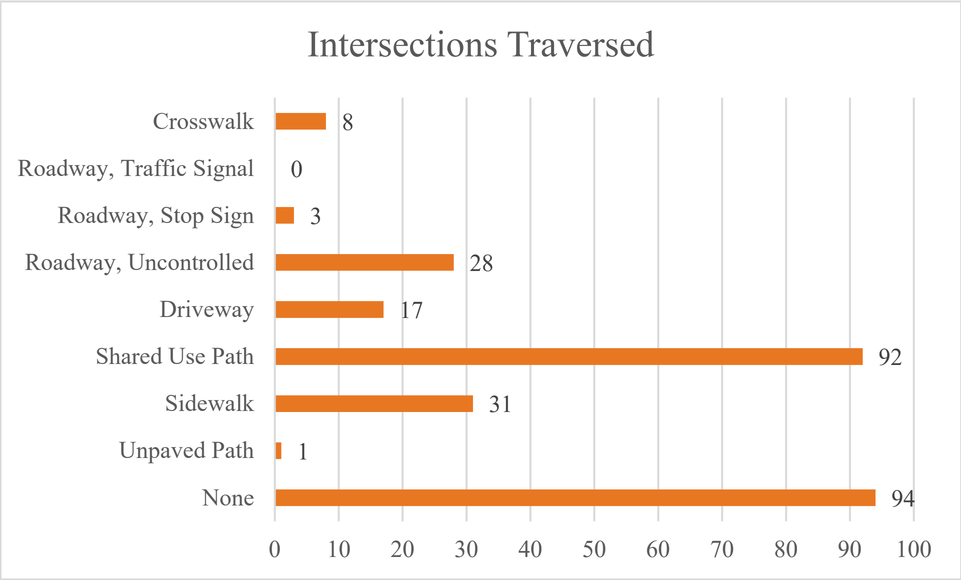


Status of Ride Post-Conflict

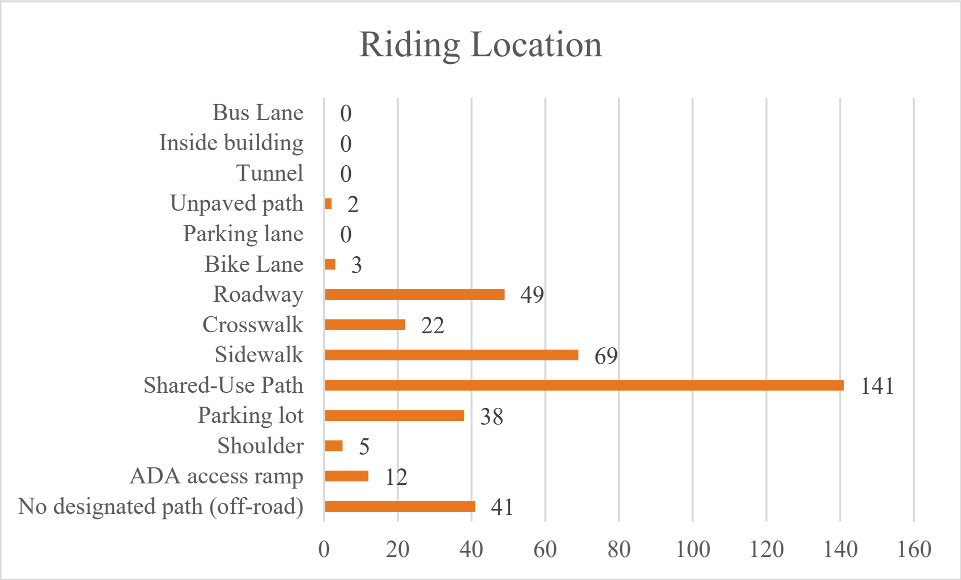


Trafficway/Infrastructure Factor Results

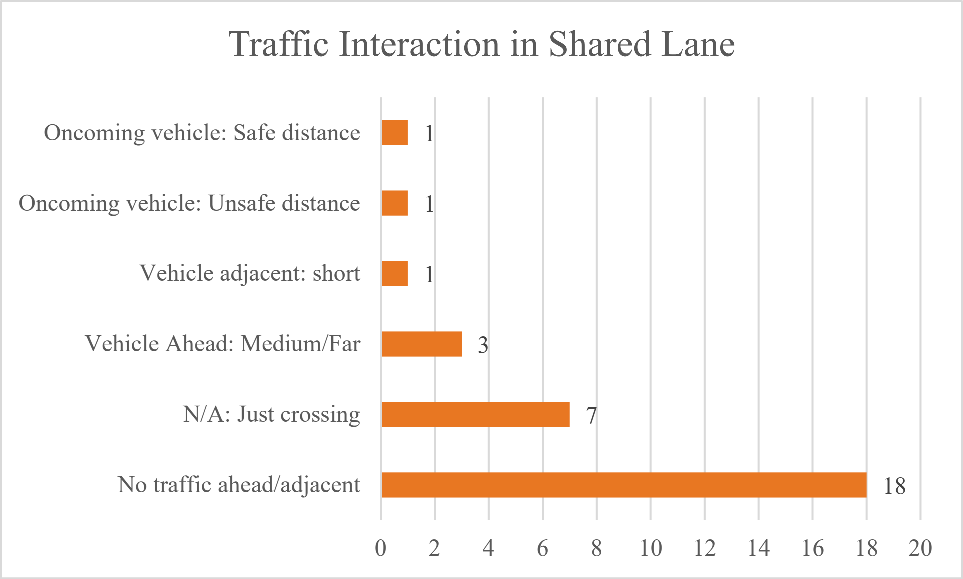
Intersections Traversed during Conflict and Baseline Events



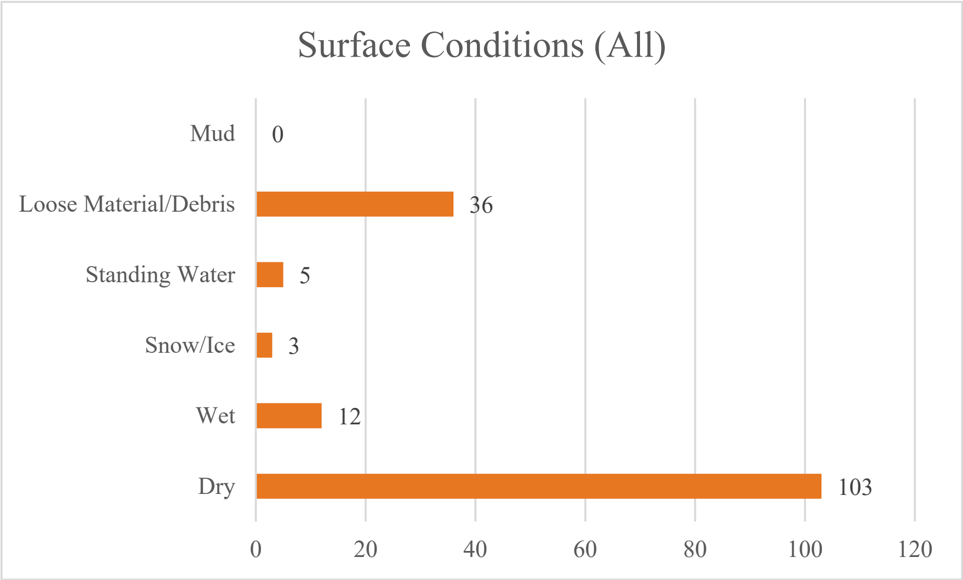
Riding Location during Conflicts and Baselines



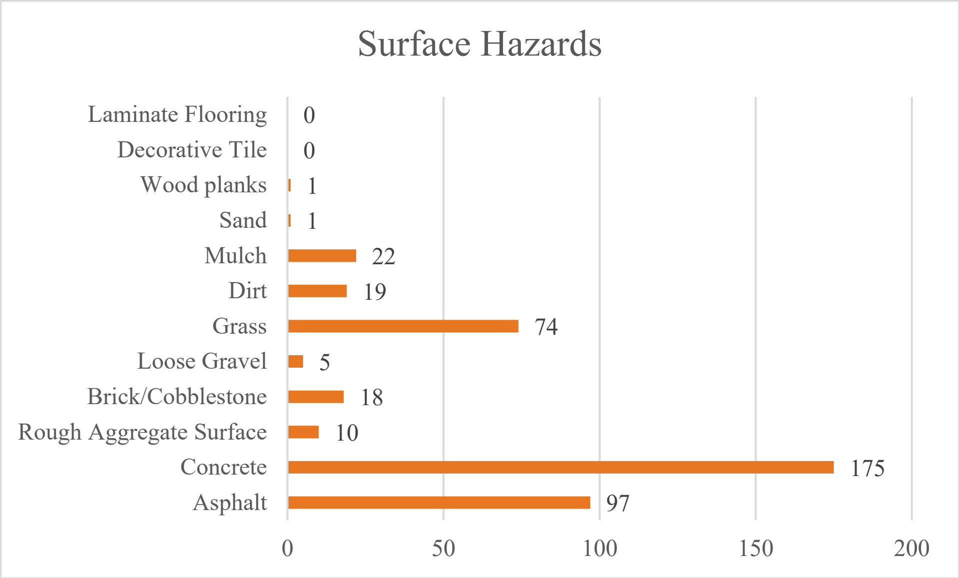
Traffic Interaction when Riding in Shared Lane/Roadway



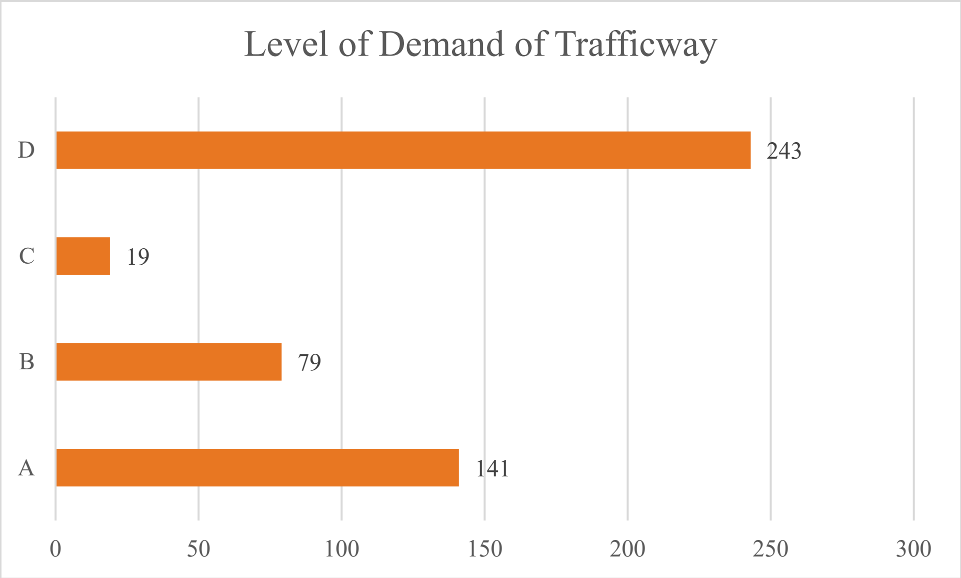
Surface Conditions (all)



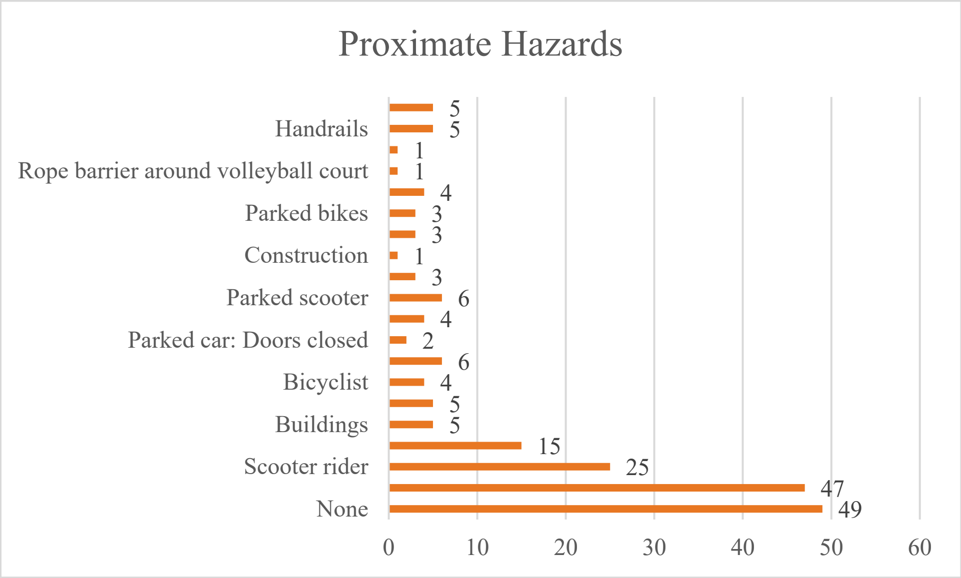
Surface Features Encountered During Conflicts



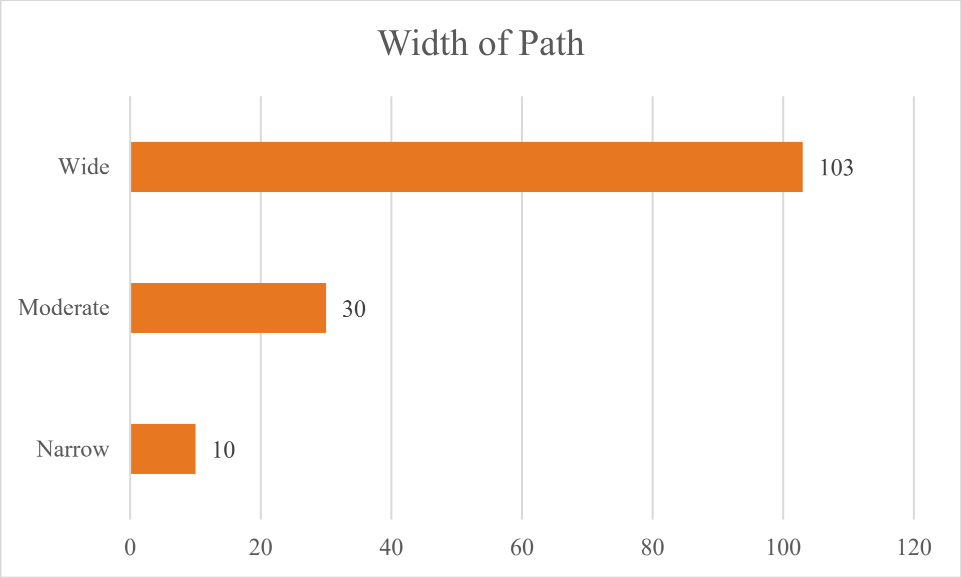
Level of Demand of Trafficway



Proximate Hazards to Scooter Rider

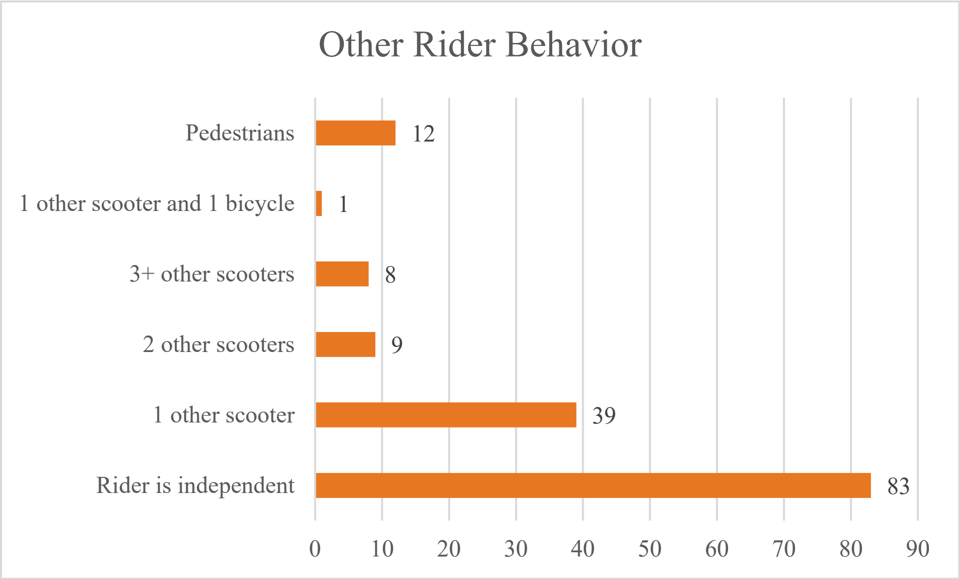


Width of Path being Traversed by E-Scooter Rider

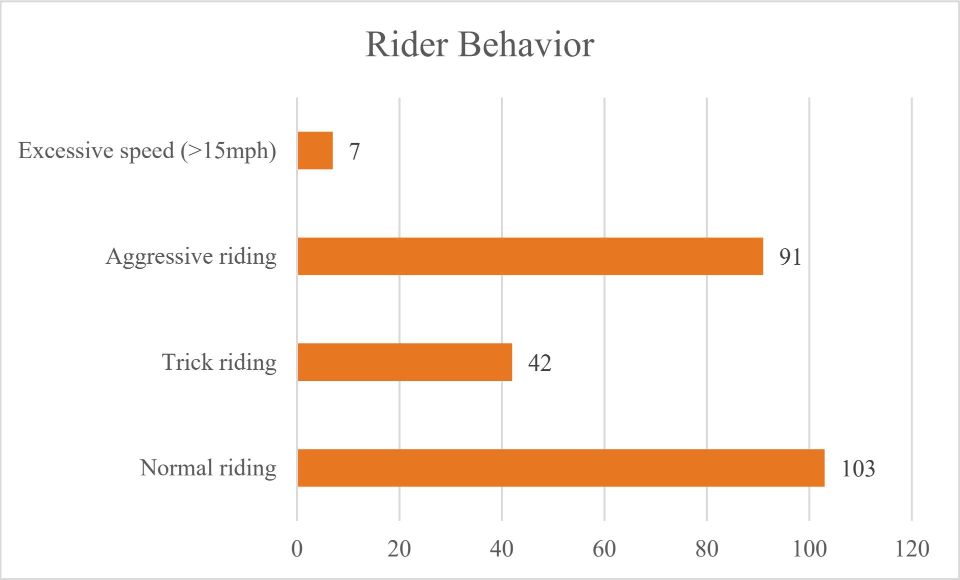


Behavioral Factor Results

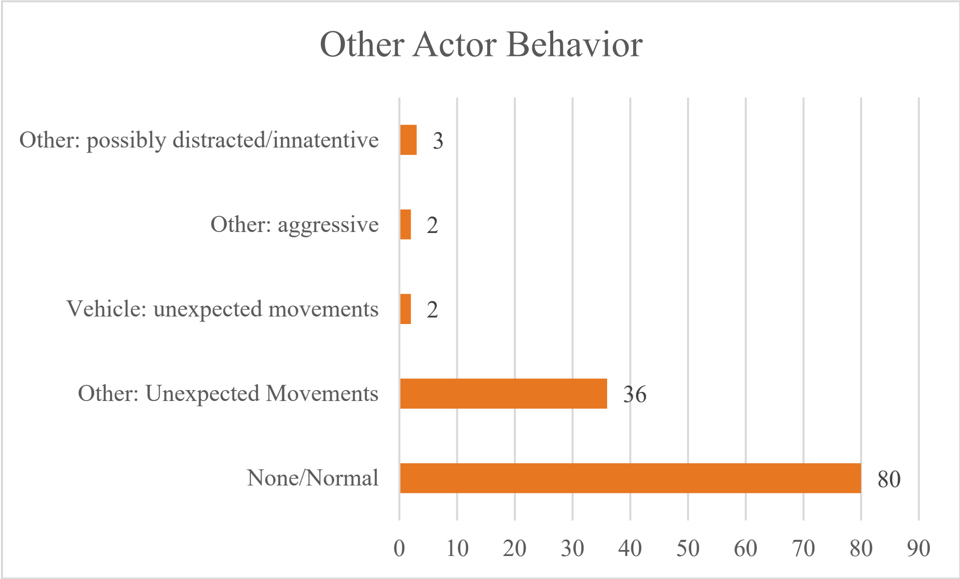
Group Riding



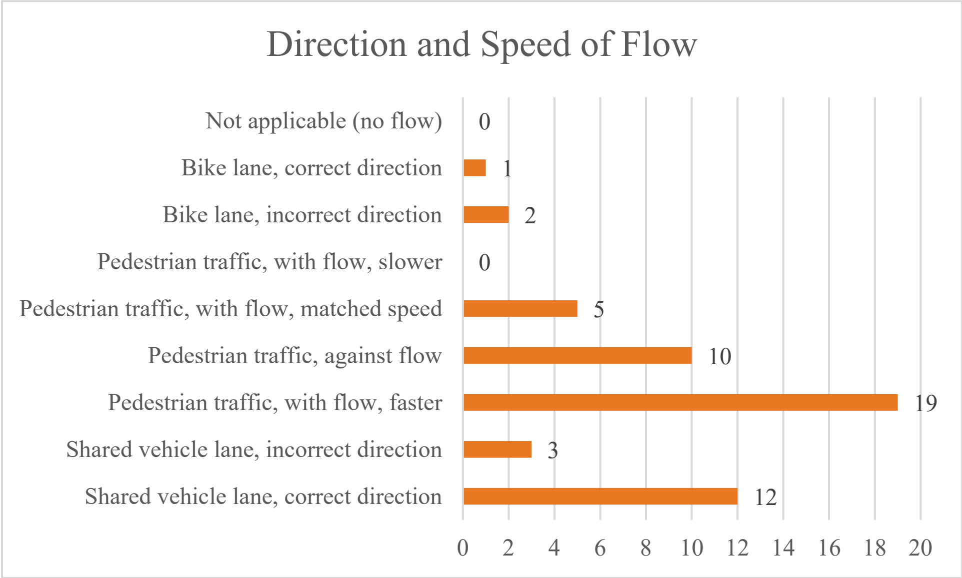
Characterization of E-Scooter Rider Behavior



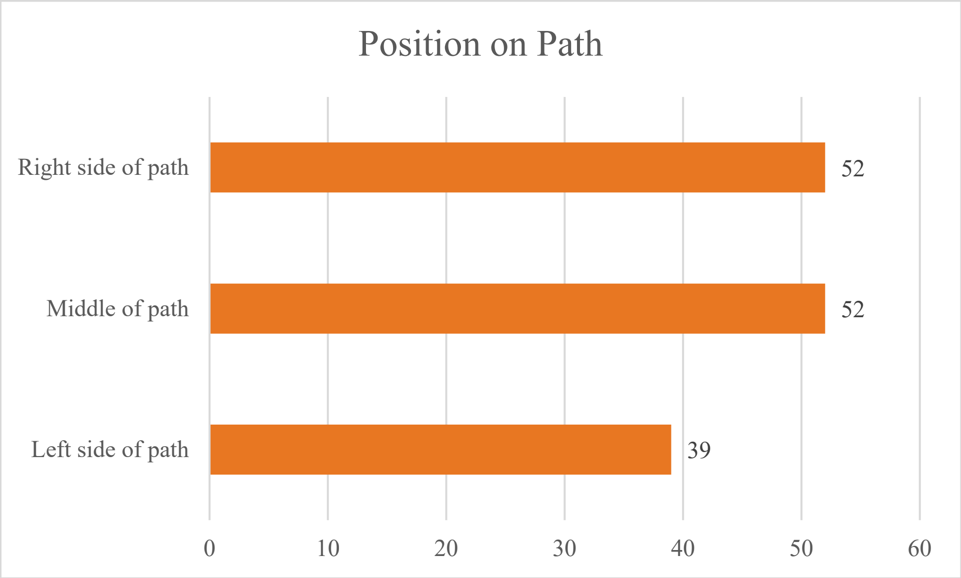
Characterization of Behaviors of Other Trafficway Users



Direction and Speed of Flow Relative to E-Scooter Rider

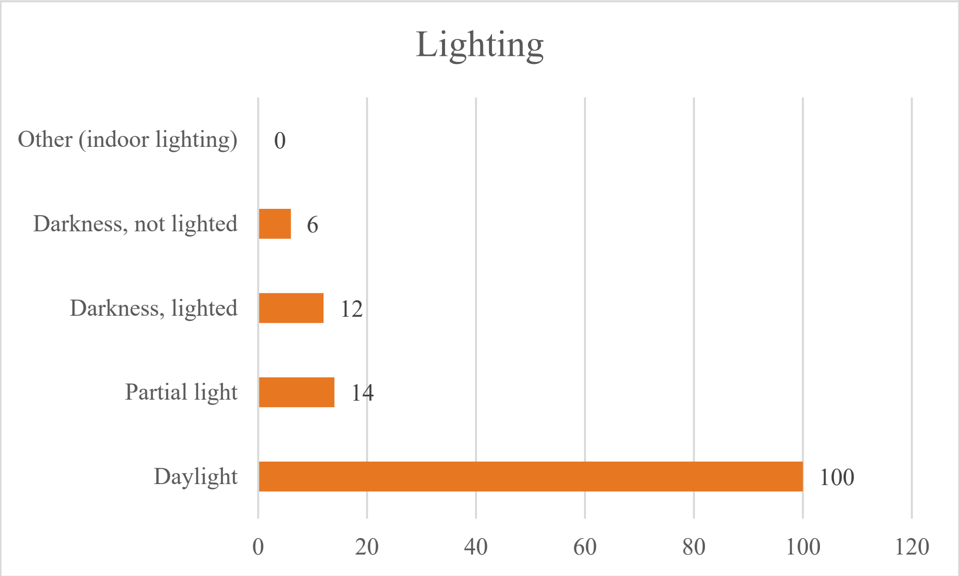


Position of E-Scooter Rider on Path



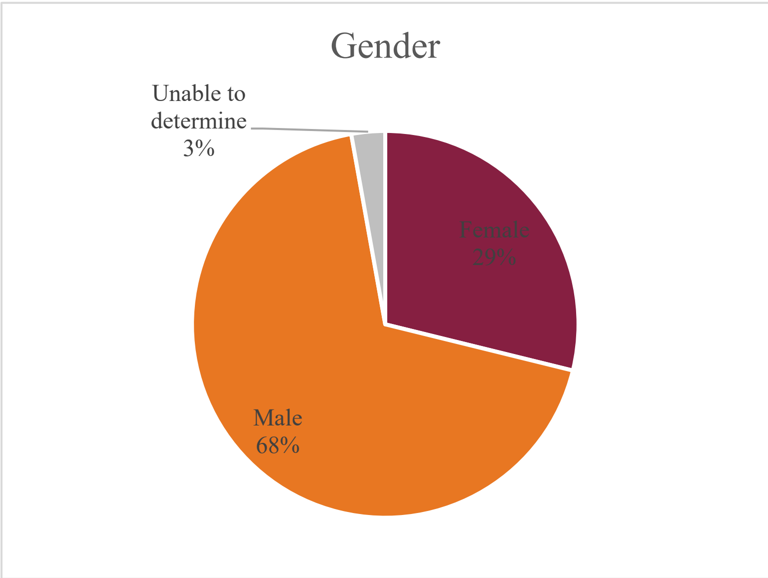
Environmental Factors

Lighting

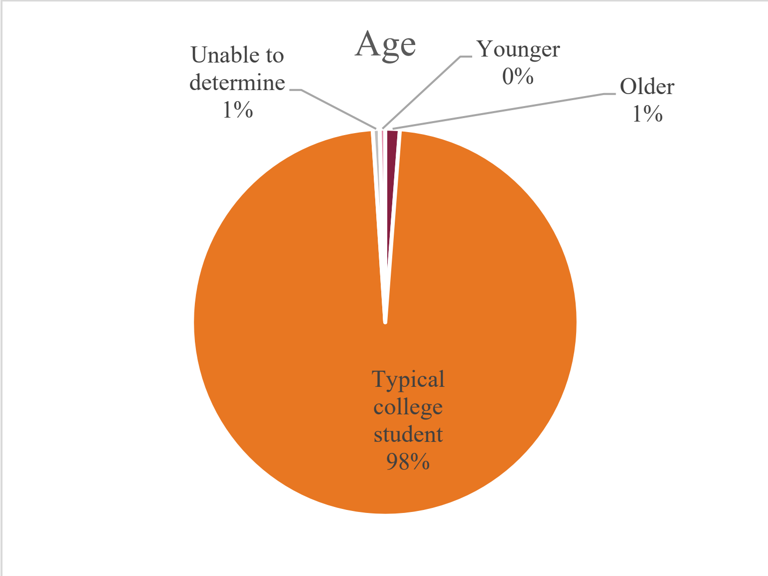


Appendix F. Fixed Camera Results

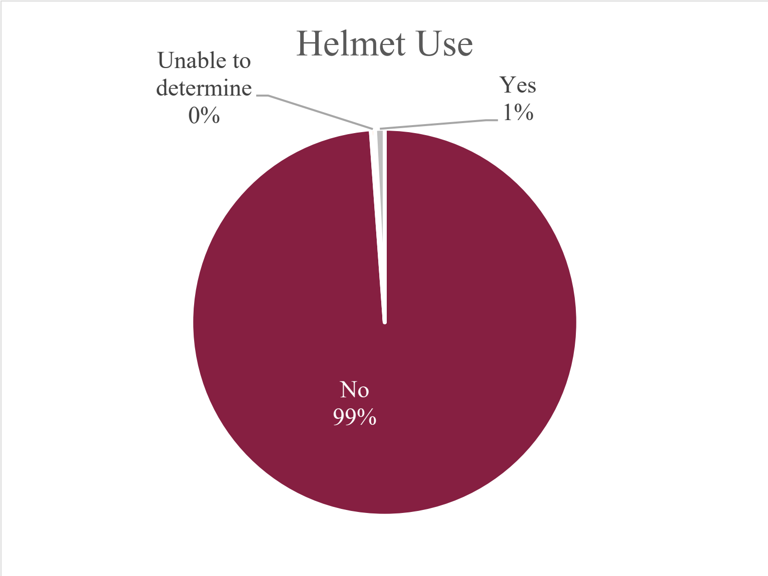
Combined Deployment Results



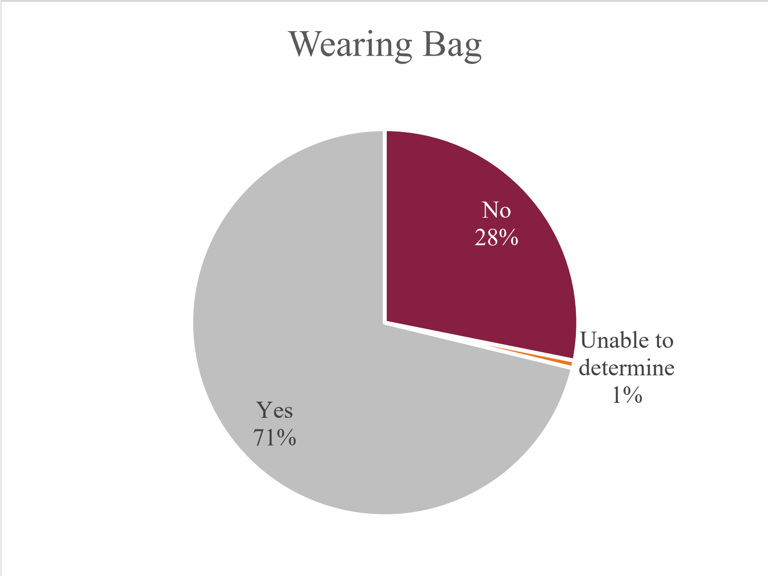
Categories	Count
Female	501
Male	1187
Unable to determine	49
Grand Total	1737



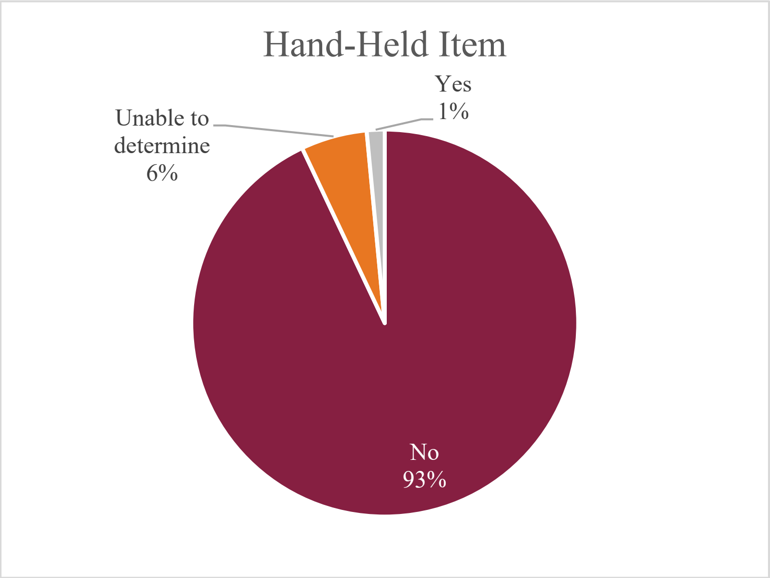
Categories	Count
Older	21
Typical college student	1698
Unable to determine	10
Younger	8
Grand Total	1737



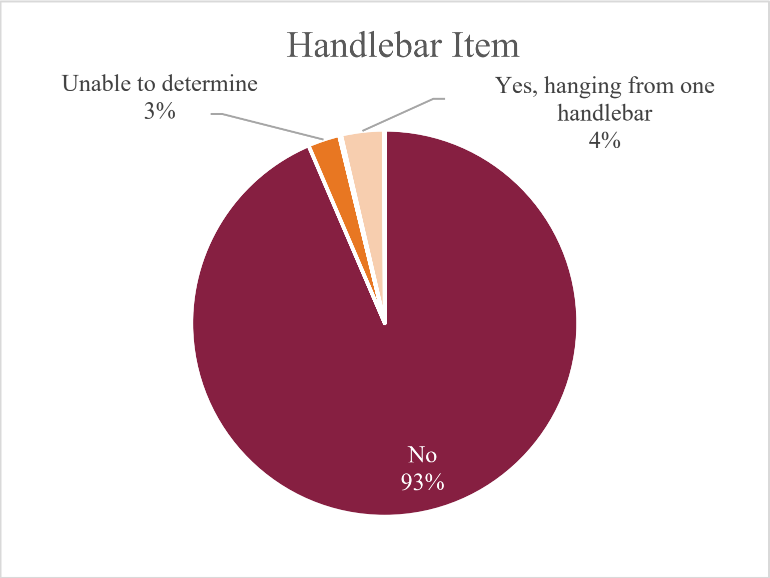
Categories	Count
No	1717
Unable to determine	6
Yes	14
Grand Total	1737



Categories	Count
No	489
Unable to determine	11
Yes	1237
Grand Total	1737

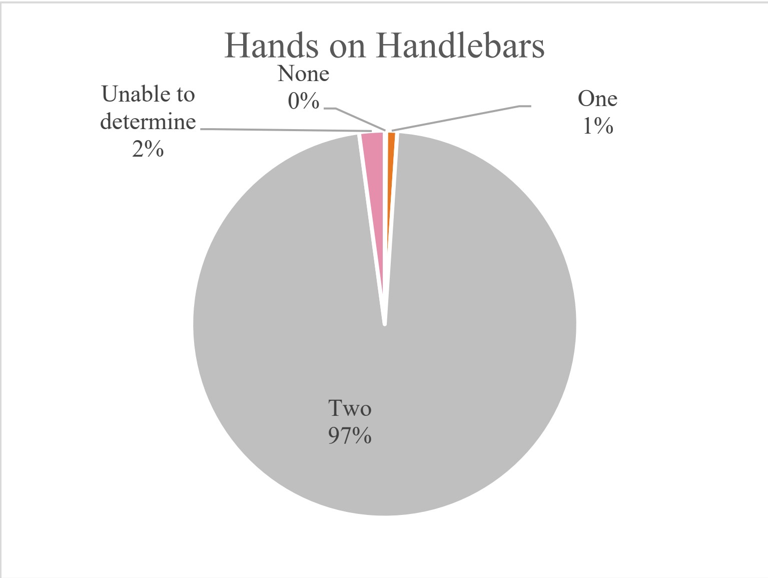


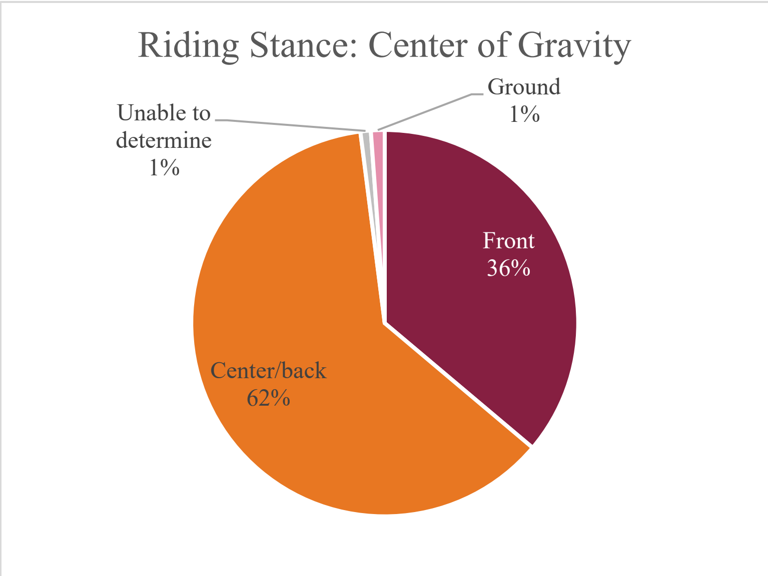
Categories	Count
No	1615
Unable to determine	96
Yes	26
Grand Total	1737



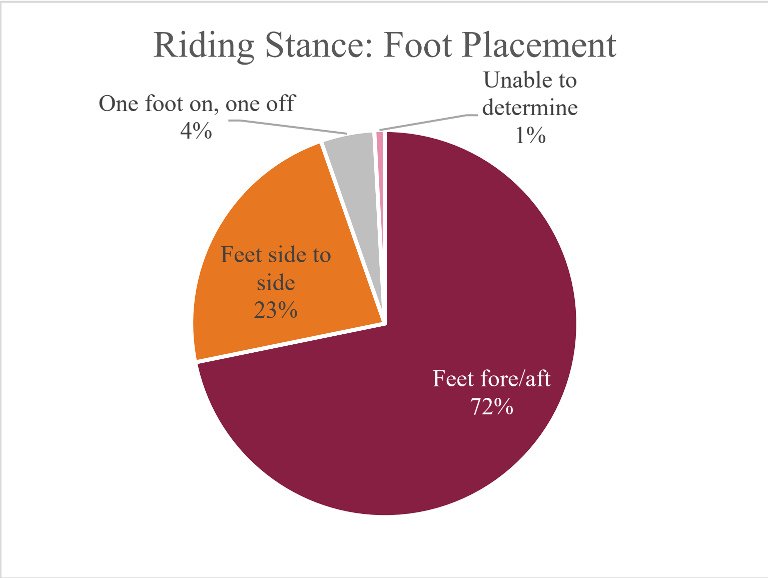
Categories	Counts
No	1625
Unable to determine	46
Yes, balanced on top of handlebars	2
Yes, hanging from both handlebars	1
Yes, hanging from one handlebar	62
Yes, Other	1
Grand Total	1737

Categories	Count
None	2
One	16
Two	1682
Unable to determine	37
Grand Total	1737

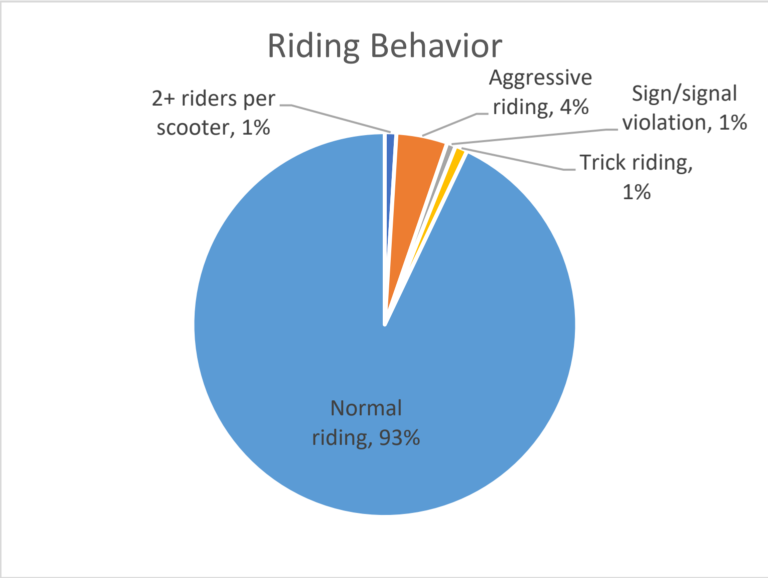




Categories	Count
Front	628
Center/back	1074
Unable to determine	15
Ground	20
Grand Total	1737

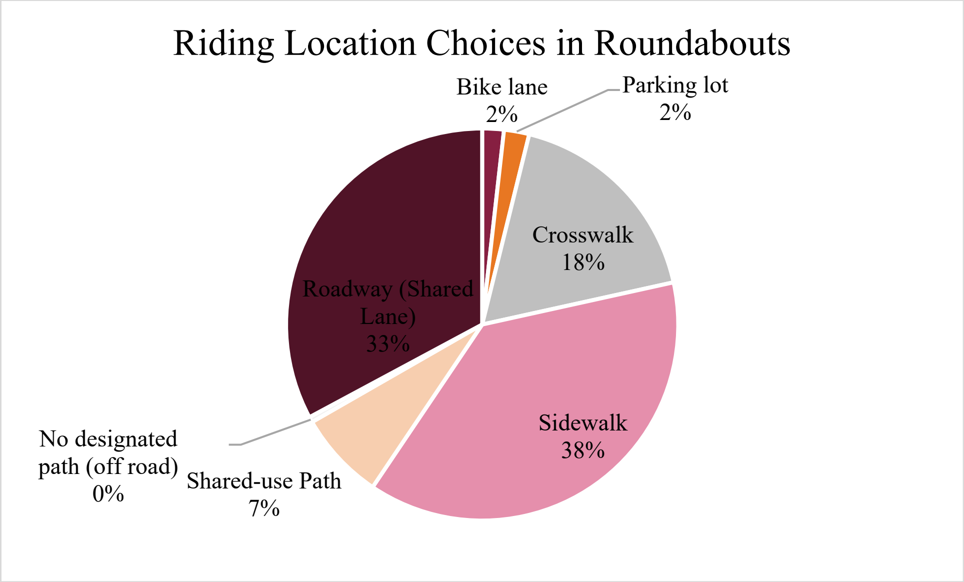


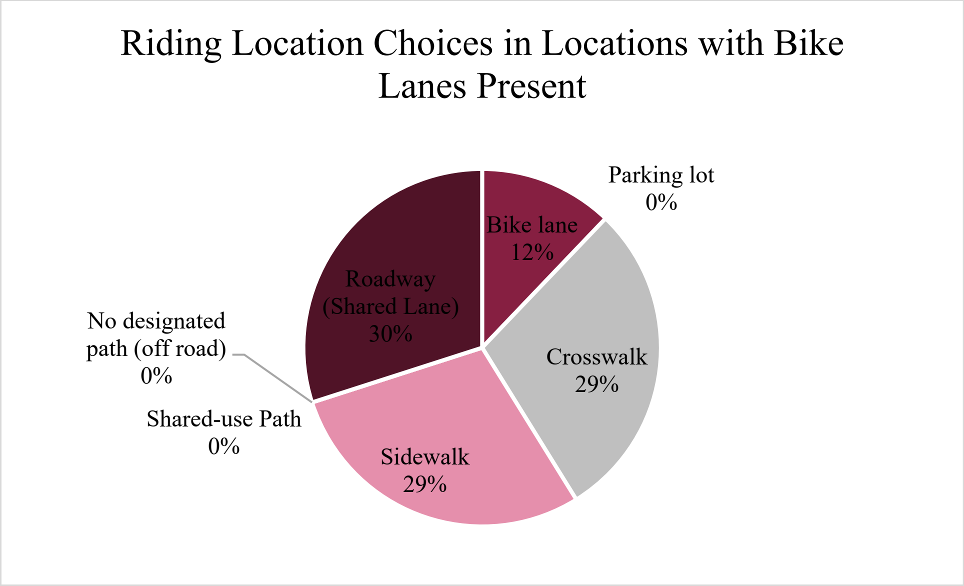
Categories	Count
Feet fore/aft	1247
Feet side to side	397
One foot on, one off	78
Unable to determine	15
Grand Total	1737

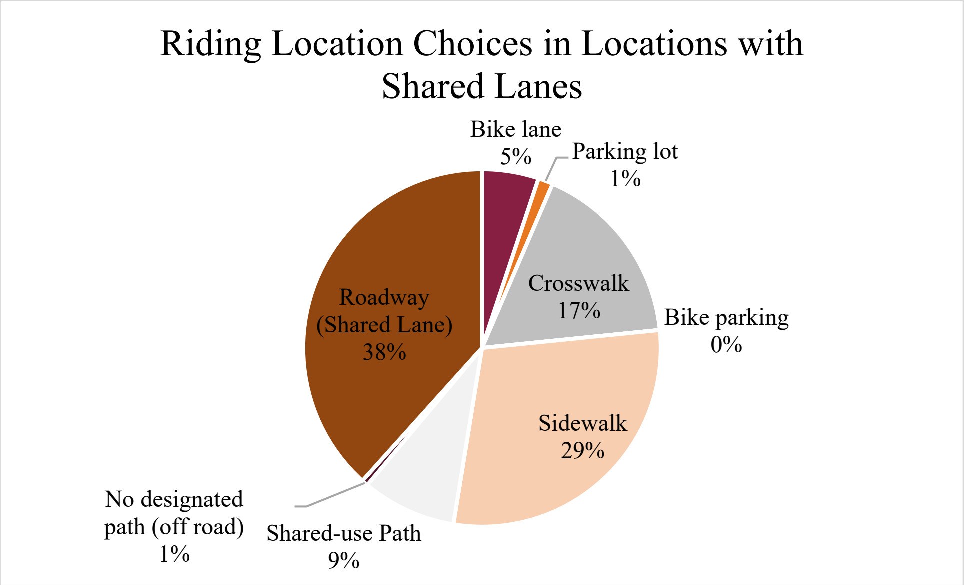


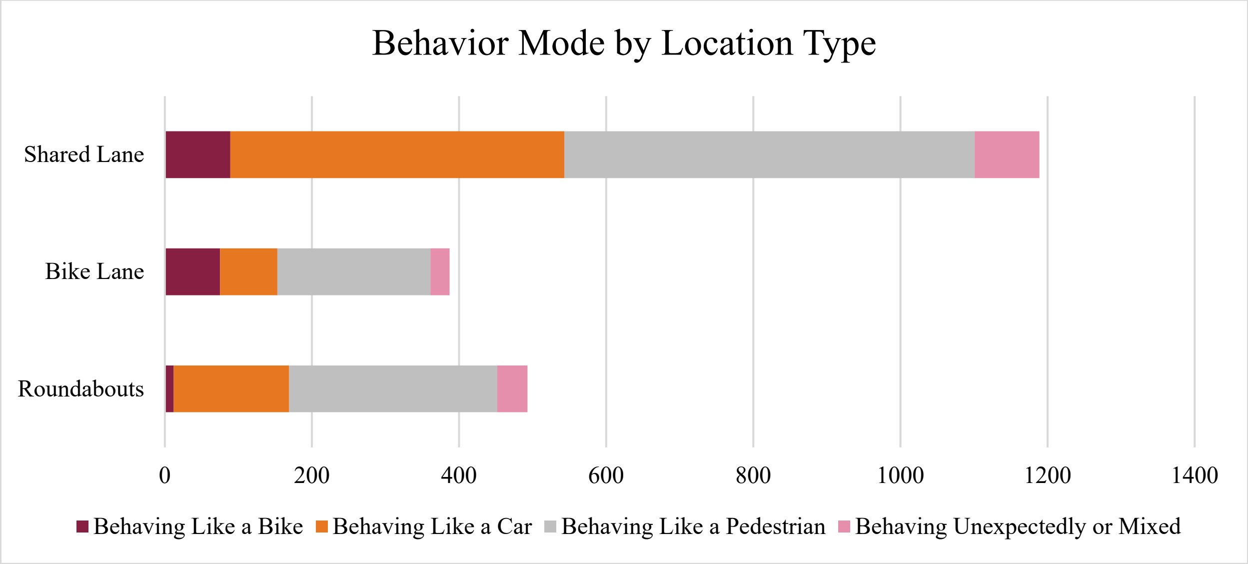
Categories	Count
2+ riders per scooter	17
Aggressive ridding	75
Sign/signal violation	13
Trick riding	18
Normal riding	1621

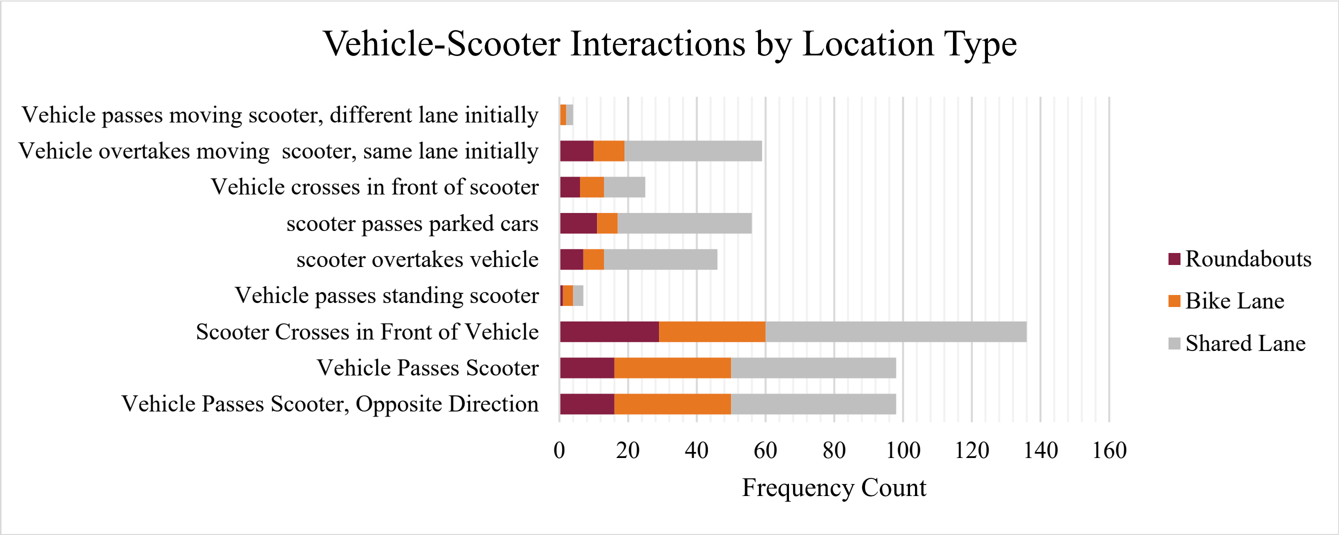
First Deployment Results



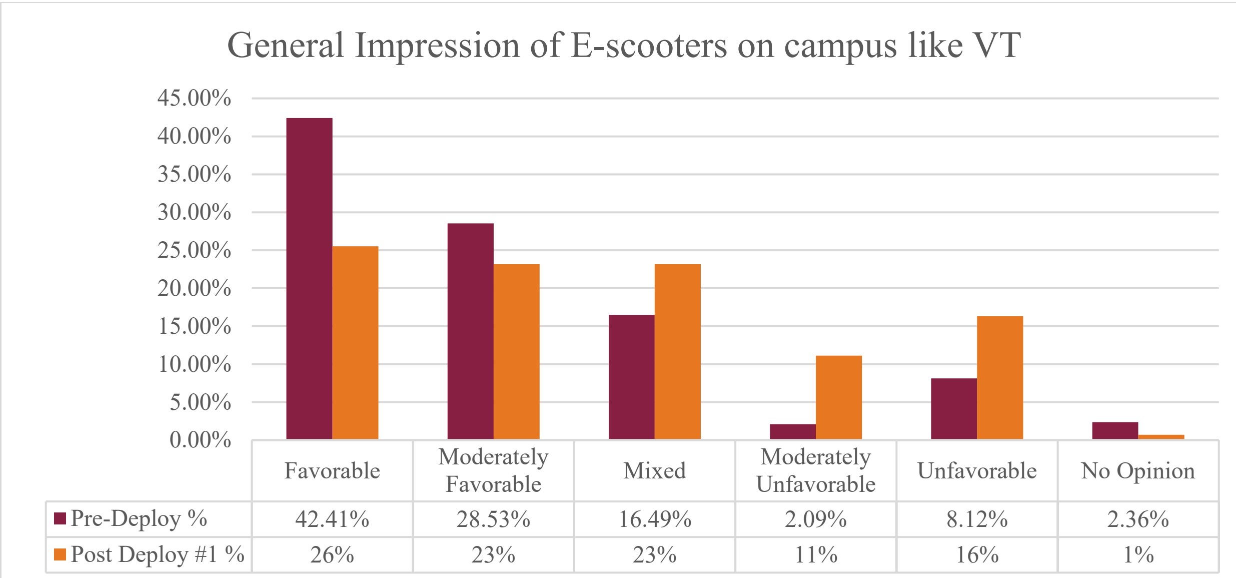



Riding Location Choices in Locations with Shared Lanes
Bike lane 5%
Parking lot 1%
Crosswalk 17%
Bike parking 0%
Sidewalk 29%
Shared-use Path 9%
No designated path (off road) 1%
Roadway (Shared Lane) 38%


Behavior Mode by Location Type
Shared Lane
Bike Lane
Roundabouts
0
200
400
600
800
1000
1200
1400
Behaving Like a Bike
Behaving Like a Car
Behaving Like a Pedestrian
Behaving Unexpectedly or Mixed

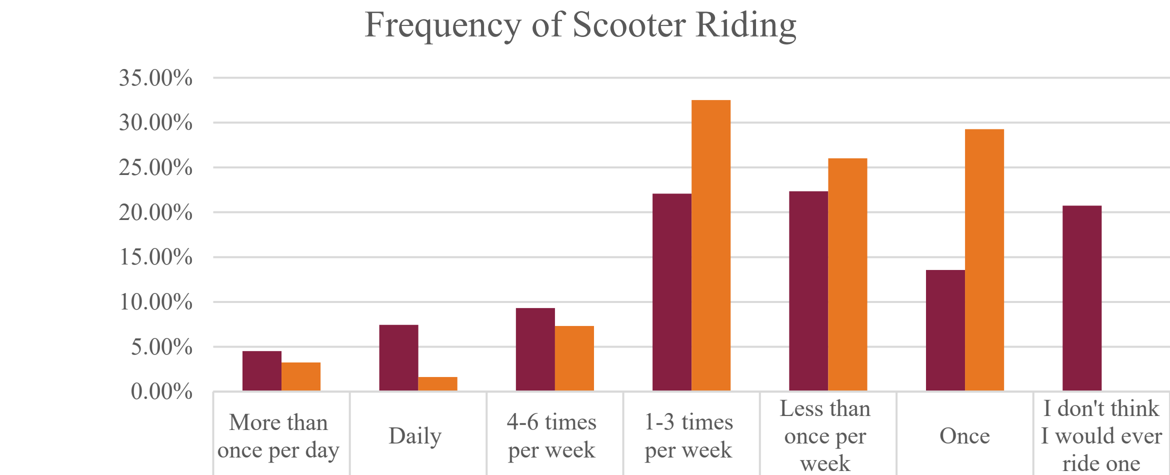

Vehicle-Scooter Interactions by Location Type
Vehicle passes moving scooter, different lane initially
Vehicle overtakes moving scooter, same lane initially
Vehicle crosses in front of scooter
scooter passes parked cars
scooter overtakes vehicle
Vehicle passes standing scooter
Scooter Crosses in Front of Vehicle
Vehicle Passes Scooter
Vehicle Passes Scooter, Opposite Direction
0
20
40
60
80
100
120
140
160
Frequency Count
Roundabouts
Bike Lane
Shared Lane

Appendix G. Long-Form Phase 1 Perception Survey Results



E-Scooter Perceptions (scale of 1 [strongly disagree] to 6 [strongly agree])

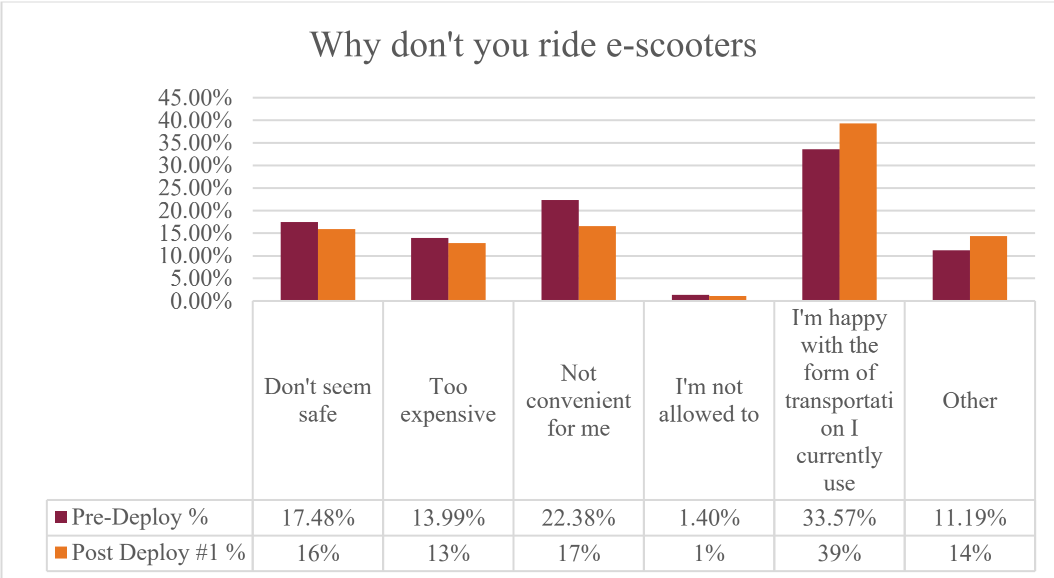
	Pre-Deployment	Post-Deployment
Provide a useful mobility option	4.59	4.43
Make it easier to get around	4.62	4.47
Are generally well-parked and won't block sidewalks or doorways	3.73	3.32
Are ridden in a safe manner	3.56	3.14
I would be more likely to not drive around campus if I know an E-Scooter would be available (leave blank if not applicable)	3.61	3.01
I am in favor of E-Scooters becoming available for rent in the Town of Blacksburg in addition to VT campus	4.38	3.71

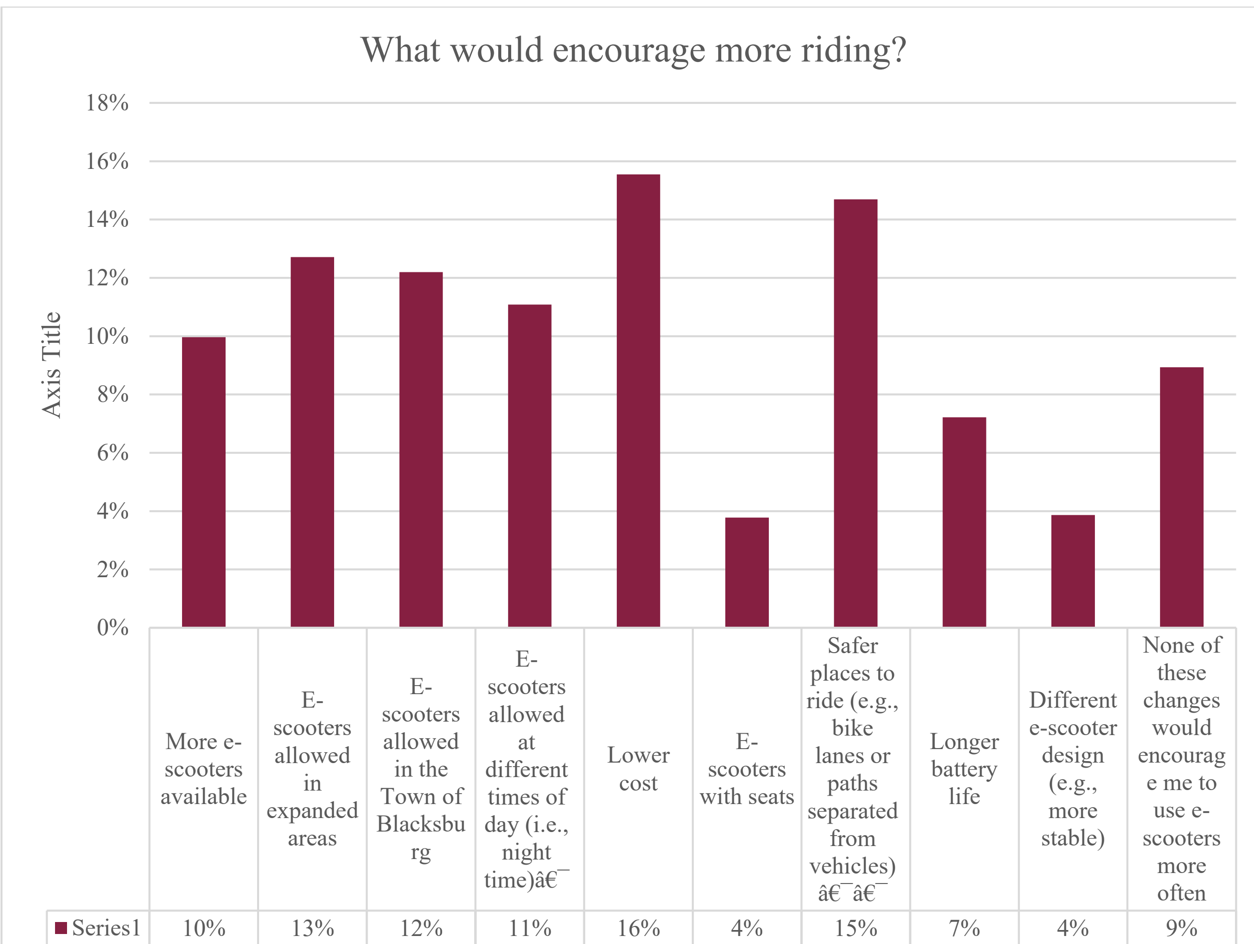


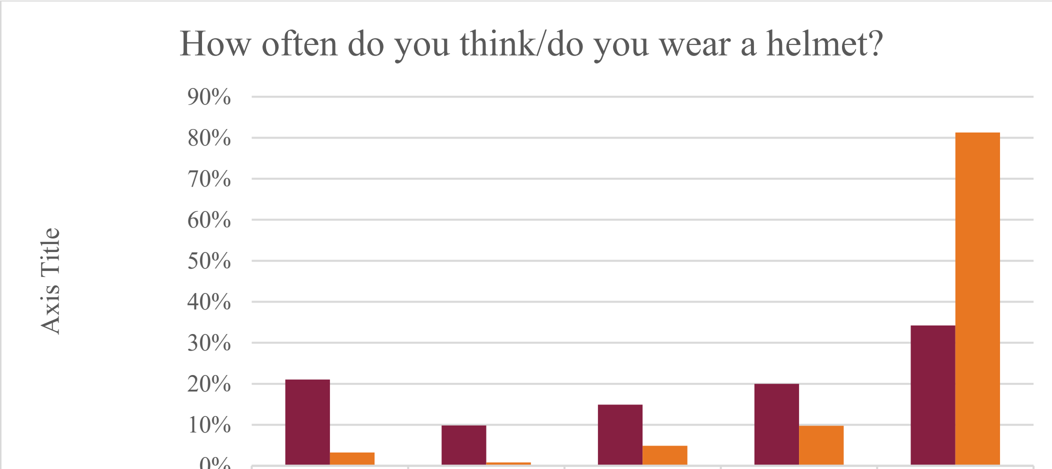
	More than once per day	Daily	4-6 times per week	1-3 times per week	Less than once per week	Once	I don't think I would ever ride one
Pre-Deploy %	4.52%	7.45%	9.31%	22.07%	22.34%	13.56%	20.74%
Post Deploy #1 %	3%	2%	7%	33%	26%	29%	0%

Riding Preference (scale of 1 [strongly disagree] to 4 [strongly agree])

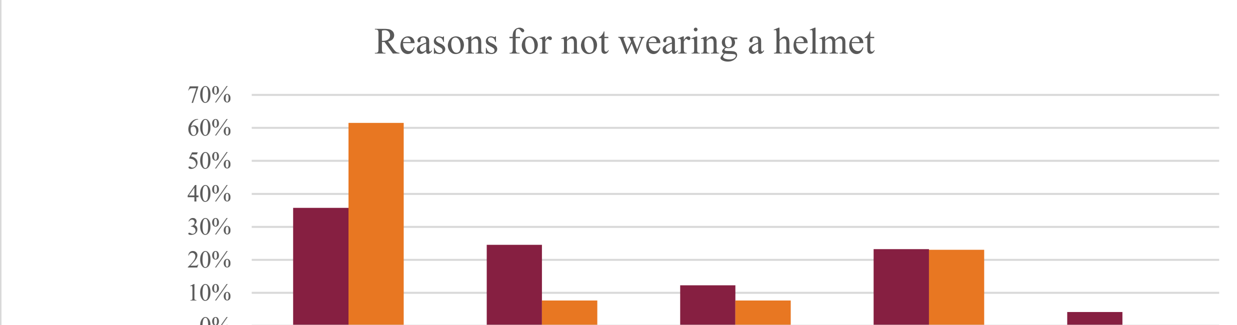
Preferred Riding Location	Pre-Deployment	Post-Deployment
Sidewalk	1.91	1.88
Bike lane in street	2.12	1.94
Shared travel lane	3.4	3.4
Campus trail/footpath	2.57	2.78


Why don't you ride e-scooters
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Don't seem safe
Too expensive
Not convenient for me
I'm not allowed to
I'm happy with the form of transportation I currently use
Other
Pre-Deploy %: 17.48% | 13.99% | 22.38% | 1.40% | 33.57% | 11.19%
Post Deploy #1 %: 16% | 13% | 17% | 1% | 39% | 14%


What would encourage more riding?
Axis Title
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
More e-scooters available
E-scooters allowed in expanded areas
E-scooters allowed in the Town of Blacksburg
E-scooters allowed at different times of day (i.e., night time)â€¯
Lower cost
E-scooters with seats
Safer places to ride (e.g., bike lanes or paths separated from vehicles) â€¯â€¯
Longer battery life
Different e-scooter design (e.g., more stable)
None of these changes would encourage me to use e-scooters more often
Series1: 10% | 13% | 12% | 11% | 16% | 4% | 15% | 7% | 4% | 9%

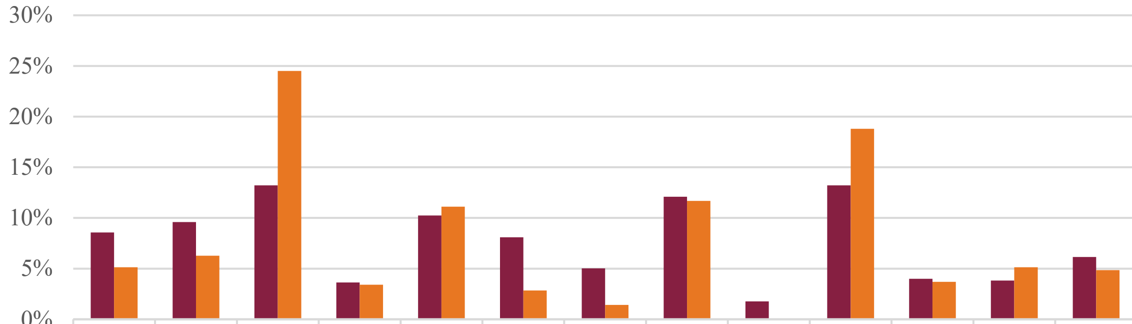


	Always	Often	Sometimes	Rarely	Never
Pre-Deploy %	21%	10%	15%	20%	34%
Post Deploy #1 %	3%	1%	5%	10%	81%



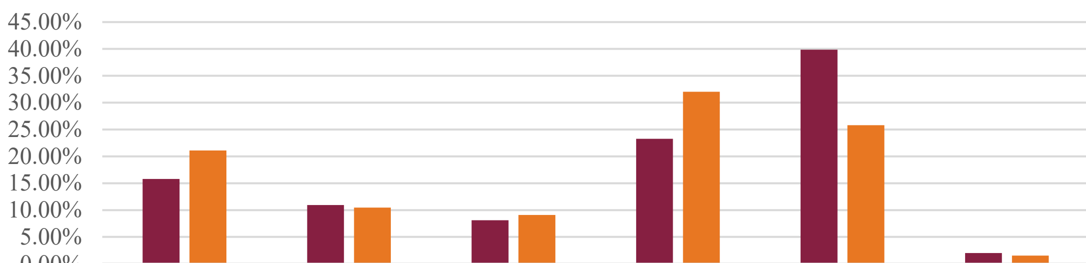
	I don't have one	I don't like wearing helmets	I don't feel that I need a helmet to keep me safe	Helmets are inconvenient to have on campus	Other
Pre-Deploy %	36%	25%	12%	23%	4%
Post Deploy #1 %	62%	8%	8%	23%	0%

Reasons for wanting to ride a scooter



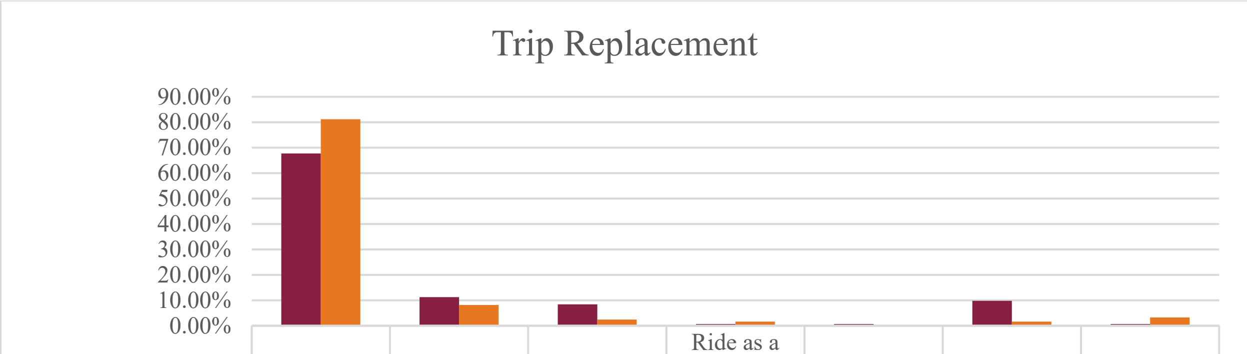
	No access to a car	Car parking is difficult	It is the fastest option	It is the most reliable option	Don't want to get sweaty	It's less polluting/more environmentally friendly	It's less expensive than other ways to get there	It's new and I wanted to try one out	No bikeshare available where/ when I need them	It's fun	No buses available at the time/destination I need them	My friends would want to ride it	Hills make walking difficult or I hate walking up hills
Pre-Deploy %	9%	10%	13%	4%	10%	8%	5%	12%	2%	13%	4%	4%	6%
Post Deploy %	5%	6%	25%	3%	11%	3%	1%	12%	0%	19%	4%	5%	5%

Which are laws/VT Policies regarding e-scooters?

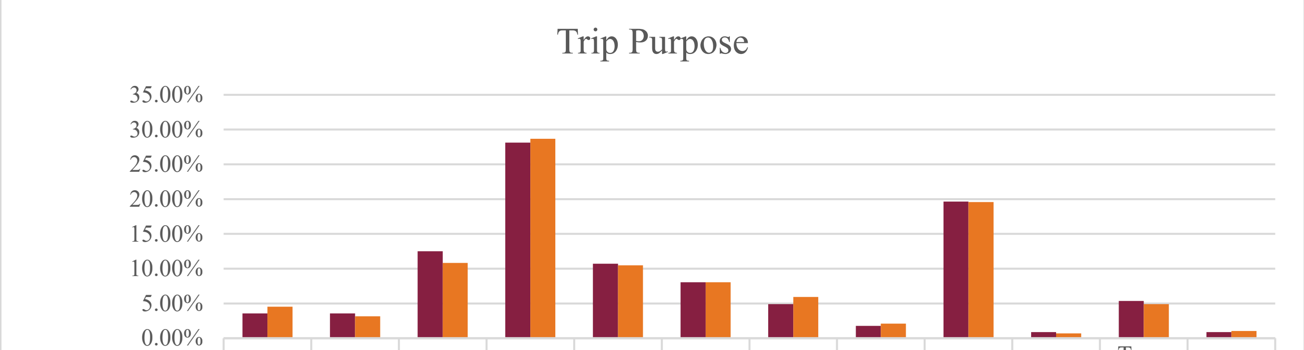


	All users must wear a helmet when riding an e-scooter	E-scooters are not allowed to ride on the sidewalk	E-scooters are not allowed to ride in the street	It is against the law to ride an e-scooter under the influence of drugs/alcohol	I don't know what the e-scooter regulations/policies are at Virginia Tech	None of the above
Pre-Deploy %	15.79%	10.93%	8.10%	23.28%	39.88%	2.02%
Post Deploy #1 %	21%	10%	9%	32%	26%	2%

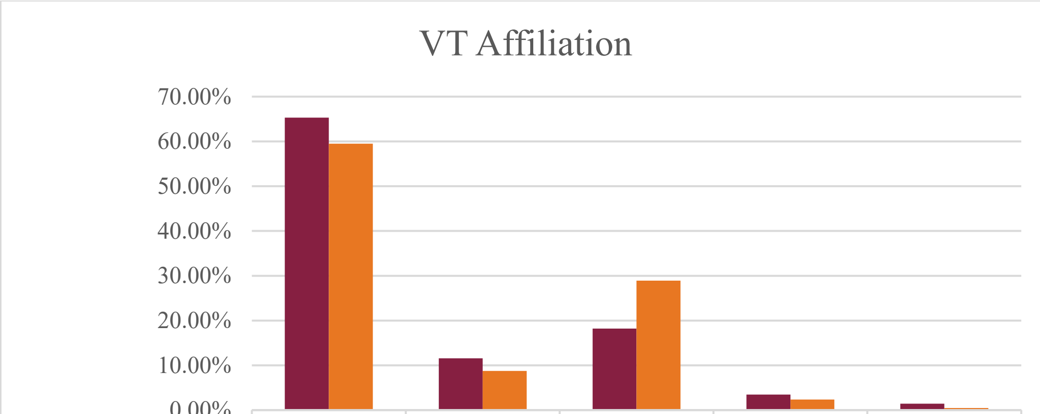
■ Pre-Deploy % ■ Post Deploy #1 %



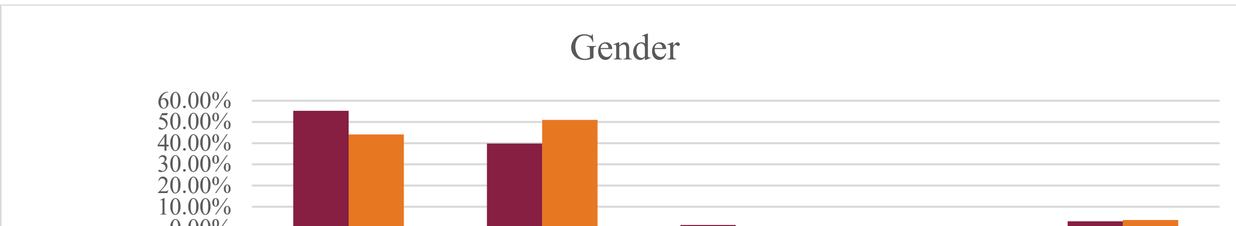
	Walk	Take a bus	Drive a personal vehicle, carshare vehicle, or other motor vehicle	Ride as a passenger in a vehicle and get dropped off by a friend, family member, or other person	Ride a bikeshare bike	Ride a personal bike	Would not take this trip
Pre-Deploy %	67.72%	11.23%	8.42%	0.70%	0.70%	9.82%	0.70%
Post Deploy #1 %	81%	8%	2%	2%	0%	2%	3%



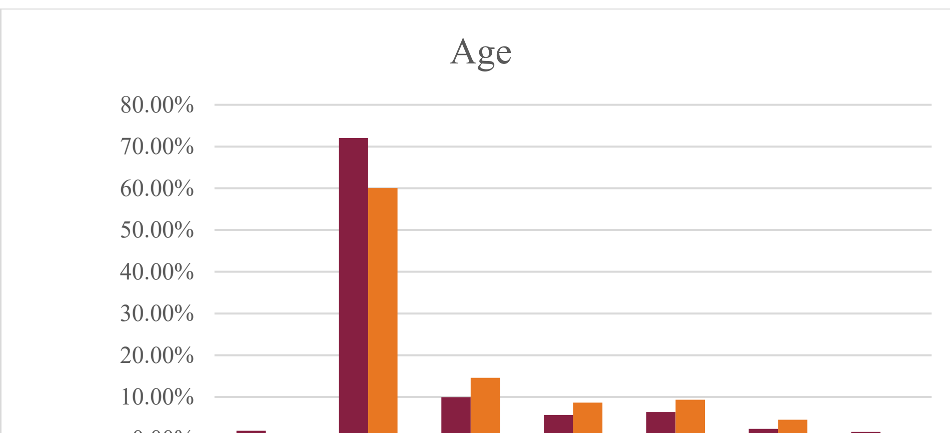
	To or from work	To or from bus	To or from parking areas	To or from class or class-related activity	To or from library, gym, or health center	Social / entertainment	Dining	Shopping / errands	For fun / recreation	To get exercise	To or from work-related meeting / appointment	Other
Pre-Deploy %	3.57%	3.57%	12.50%	28.13%	10.71%	8.04%	4.91%	1.79%	19.64%	0.89%	5.36%	0.89%
Post-Deploy %	5%	3%	11%	29%	10%	8%	6%	2%	20%	1%	5%	1%



	Virginia Tech Undergraduate Student	Virginia Tech Graduate Student	Virginia Tech Employee	Visitor to Virginia Tech	Not affiliated with Virginia Tech
Pre-Deploy %	65.32%	11.56%	18.21%	3.47%	1.45%
Post Deploy #1 %	59%	9%	29%	2%	0%



	Man	Woman	Non-Binary	Don't know	Prefer not to answer
Pre-Deploy %	55.23%	39.83%	1.45%	0.29%	3.20%
Post Deploy #1 %	44%	51%	1%	0%	4%

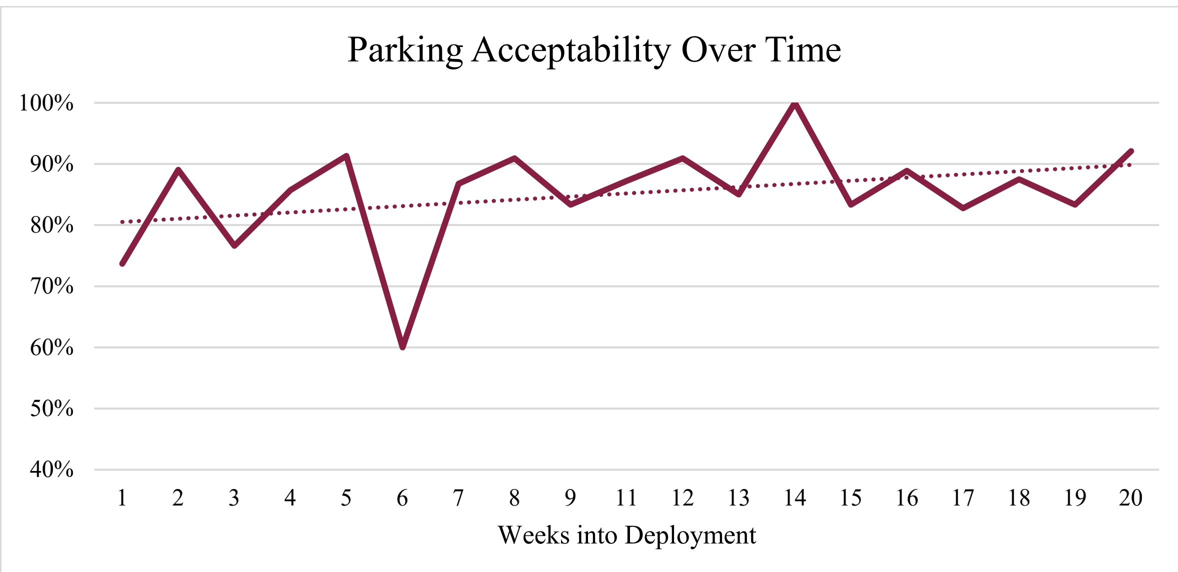


	Under 18	18-24	25-34	35-44	45-54	55-64	65 or older
Pre-Deploy %	1.90%	72.04%	9.95%	5.69%	6.40%	2.37%	1.66%
Post-Deply %	1%	60%	15%	9%	9%	5%	1%

Appendix H. Spin Application Data Collection Results

Parking Photo Results

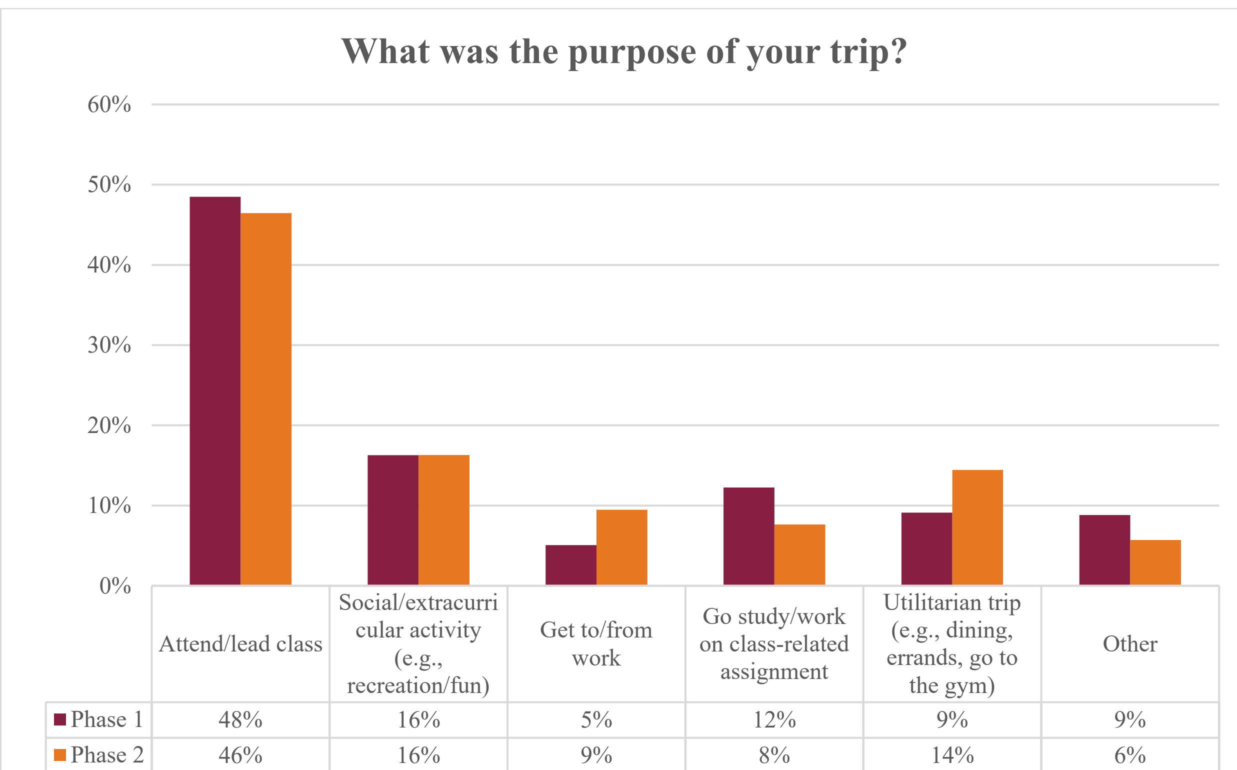
Parking Acceptability	Count	Frequency
Parked according to VT Policy	324	86%
Parked acceptably	384	
Not parked acceptably	118	14%
Total	826	100%



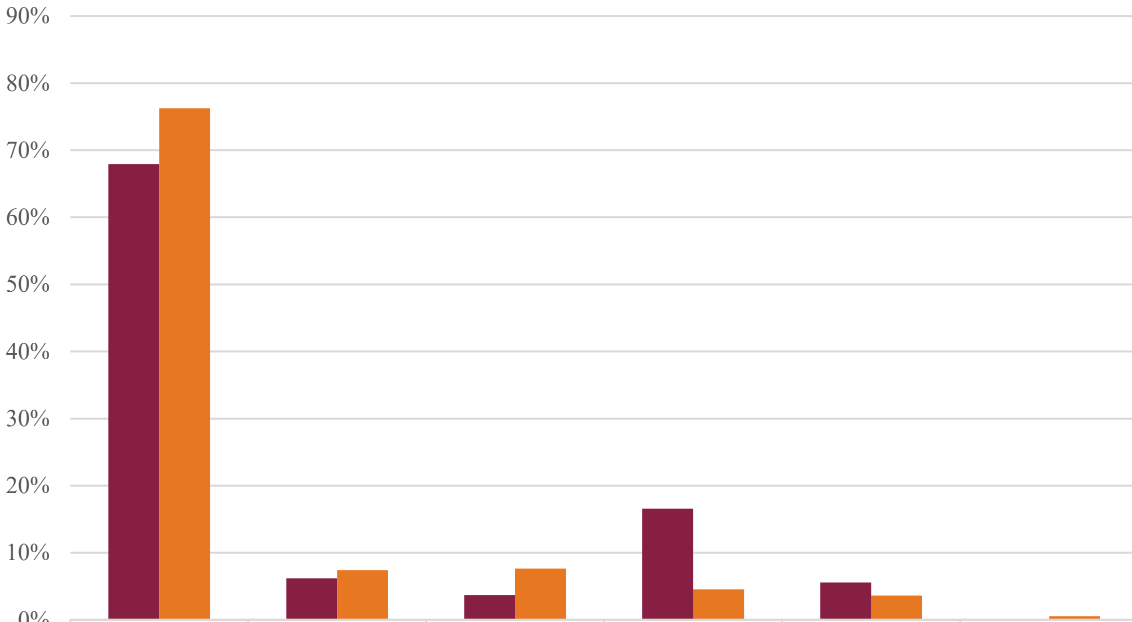
E-Scooter Parking Location	Acceptability	Count	Frequency
Parked correctly (within 5 feet of bike rack)	Acceptable	324	39.2%
Sidewalk - NOT blocking ADA access	Acceptable	348	42.1%
Other - NOT blocking ADA access	Acceptable	36	4.4%
Sidewalk - blocking ADA access	Not Acceptable	64	7.7%

E-Scooter Parking Location	Acceptability	Count	Frequency
Sidewalk - blocking ADA ramp	Not Acceptable	2	0.2%
Sidewalk - blocking stairs	Not Acceptable	13	1.6%
Sidewalk - blocking building entrance/exit	Not Acceptable	4	0.5%
Sidewalk - blocking other	Not Acceptable	12	1.5%
Parking lot - blocking vehicle and/or pedestrian right of way	Not Acceptable	17	2.1%
Other	Not Acceptable	6	0.7%
Total		826	100%

Post-Ride In-App Survey Results

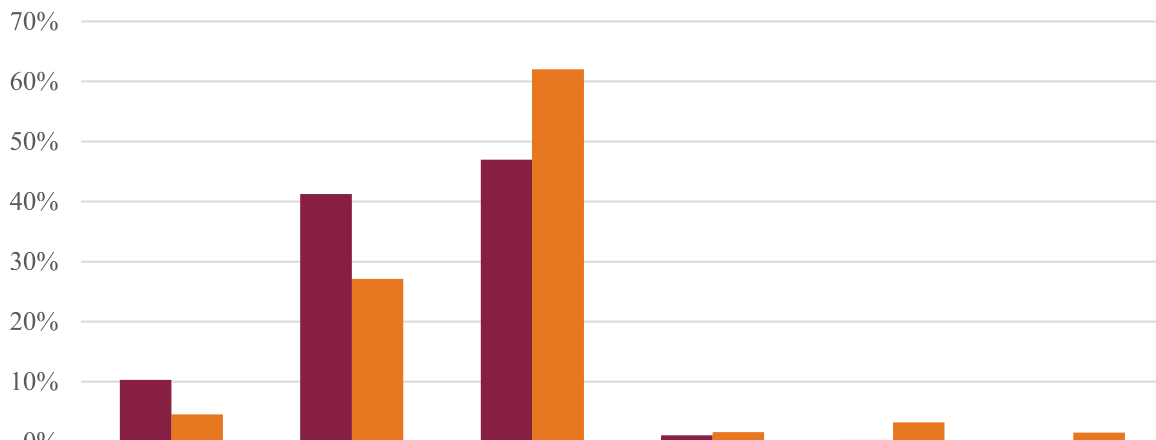


If not by e-scooter, how would you have taken this trip?



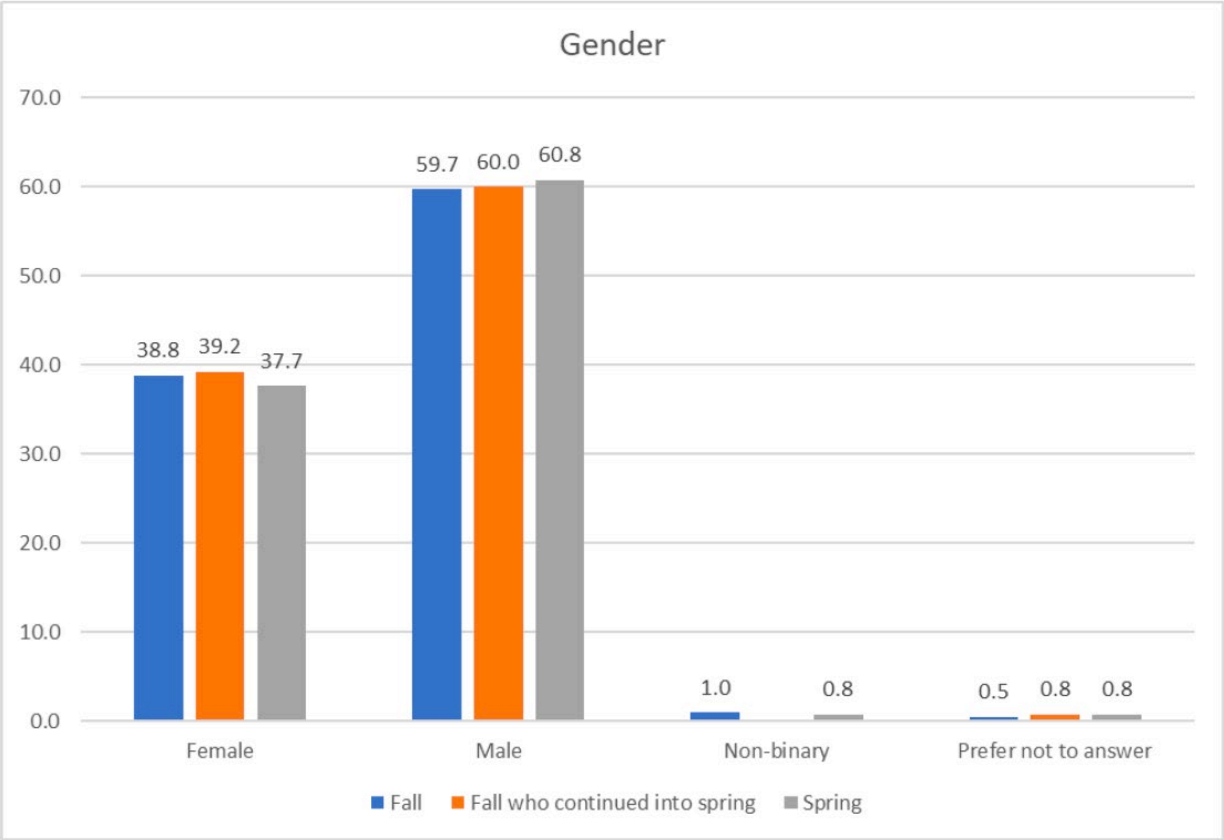
	Walk	Car	Bus	I wouldn't have made this trip	Bike	Other
Phase 1	68%	6%	4%	17%	6%	0%
Phase 2	76%	7%	8%	5%	4%	1%

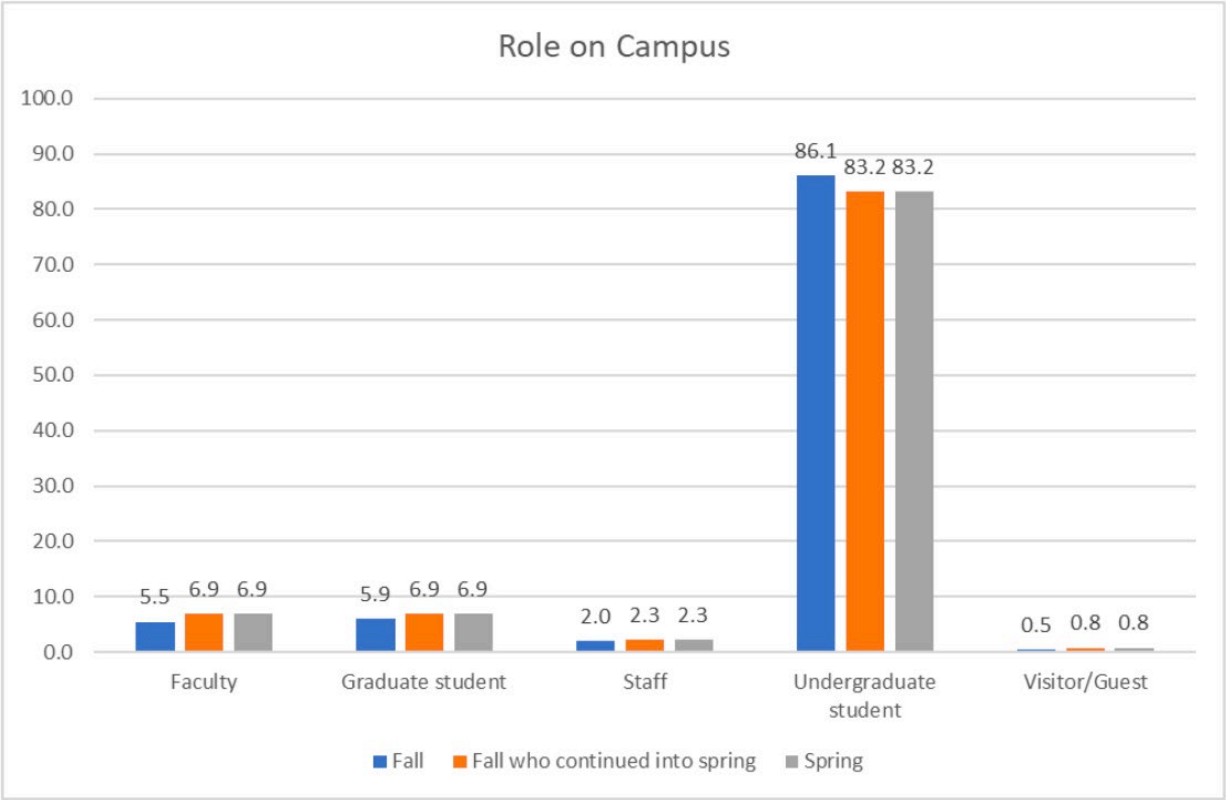
Why did you choose to ride an e-scooter for this trip?



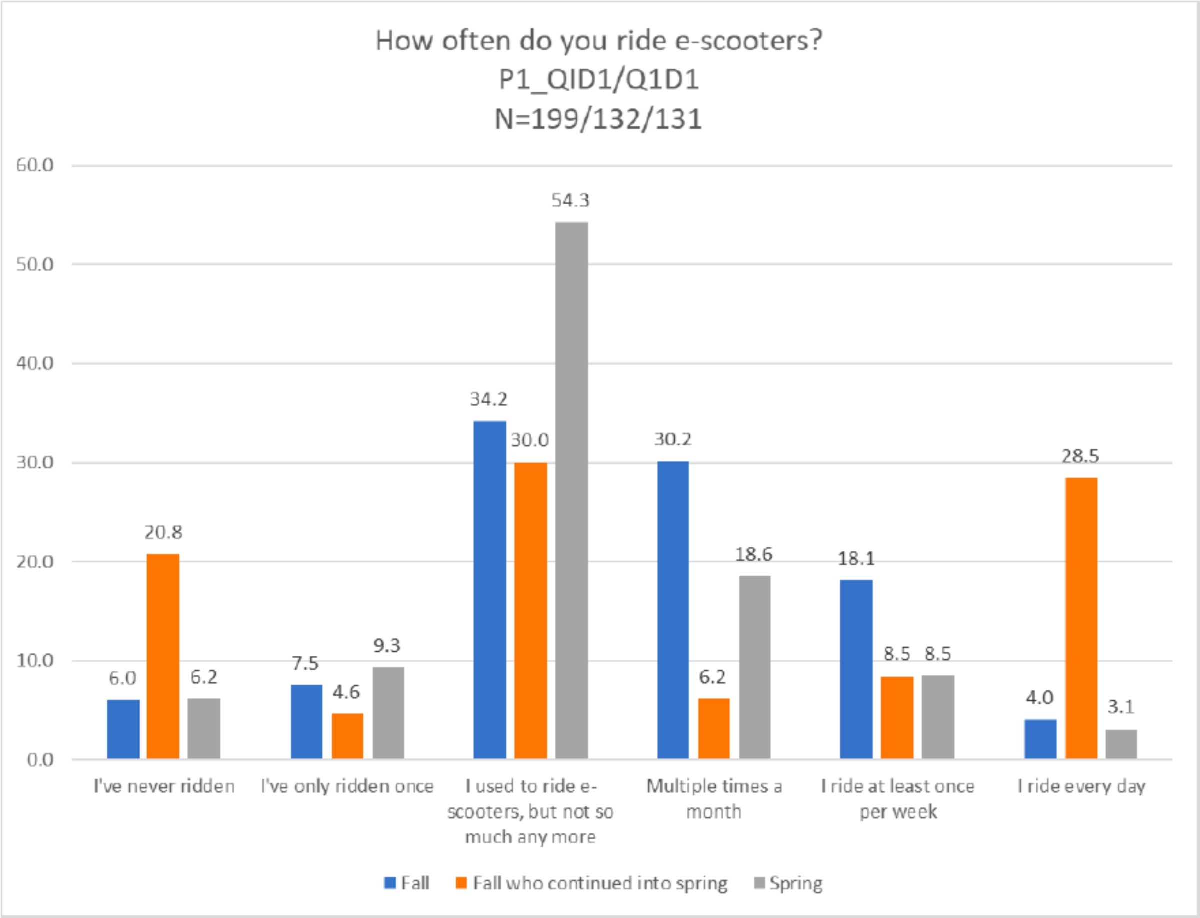
	Didn't have access to other options (bike, car, public transport)	It's fun	It was the fastest / easiest option	It was the least expensive option	Less polluting/more environmentall y friendly	Other
Phase 1	10%	41%	47%	1%	0%	0%
Phase 2	5%	27%	62%	2%	3%	2%

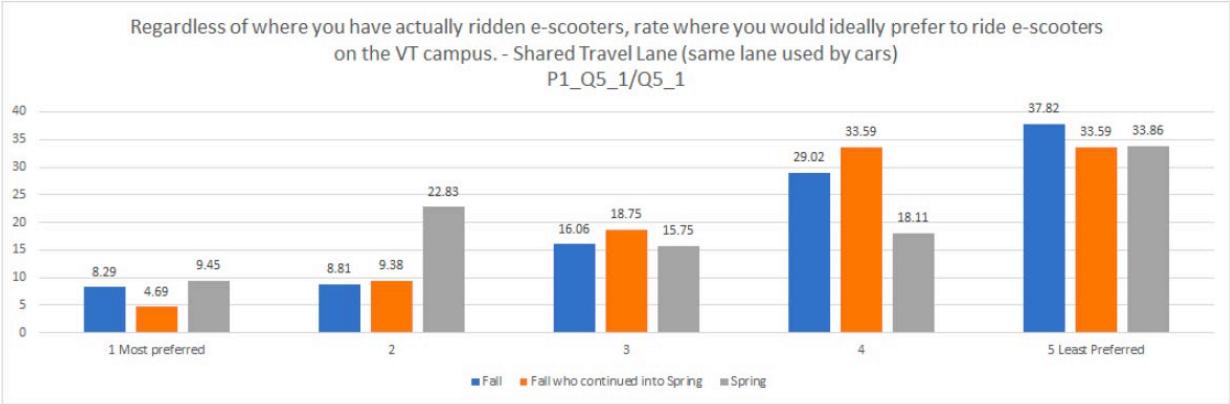
Appendix I. Re-Deployment and Panel Survey Results

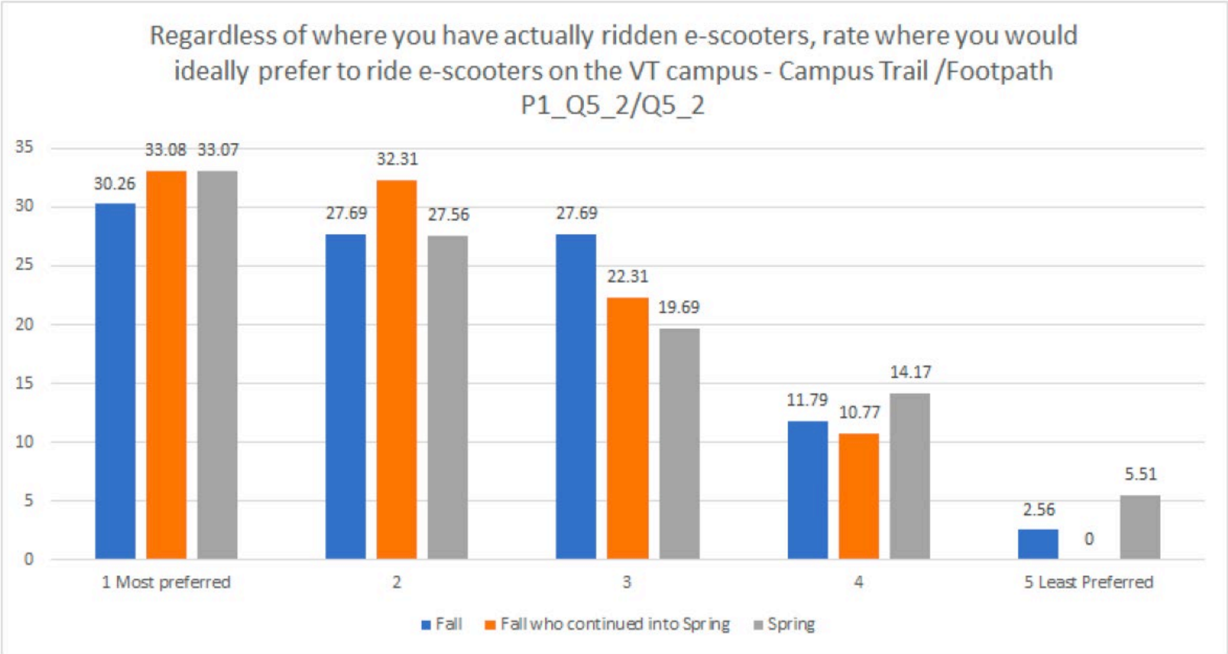


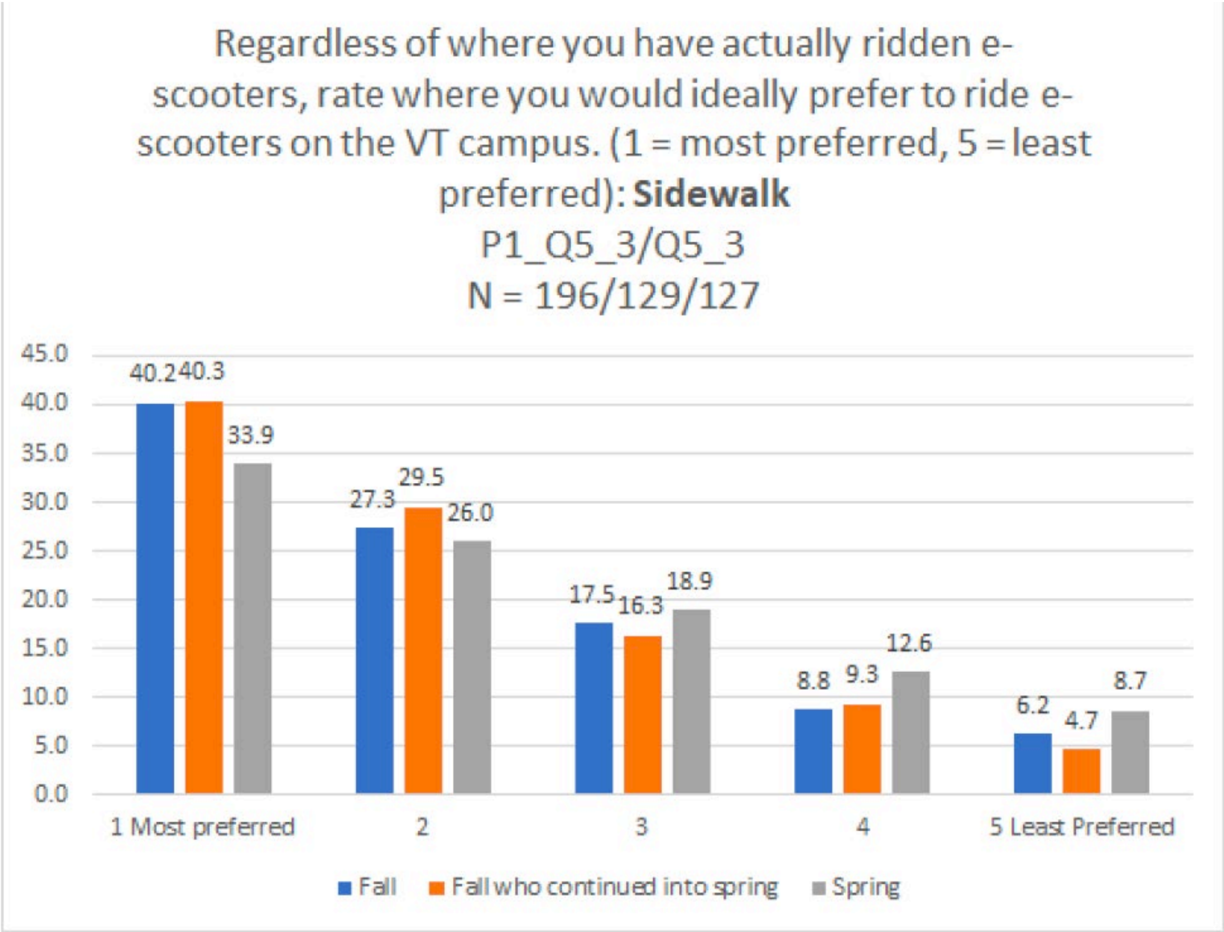


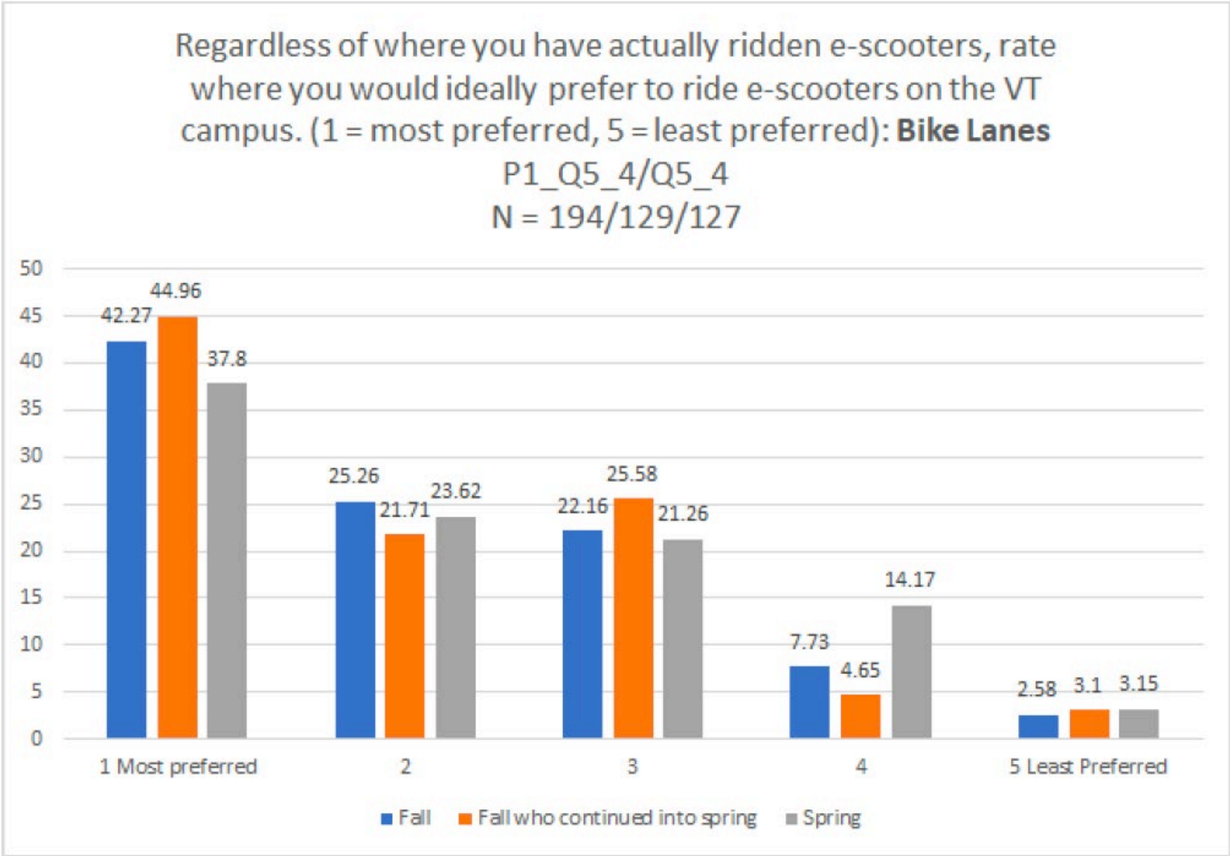
Role on Campus
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
5.5 6.9 6.9
5.9 6.9 6.9
2.0 2.3 2.3
86.1 83.2 83.2
0.5 0.8 0.8
Faculty
Graduate student
Staff
Undergraduate student
Visitor/Guest
Fall
Fall who continued into spring
Spring

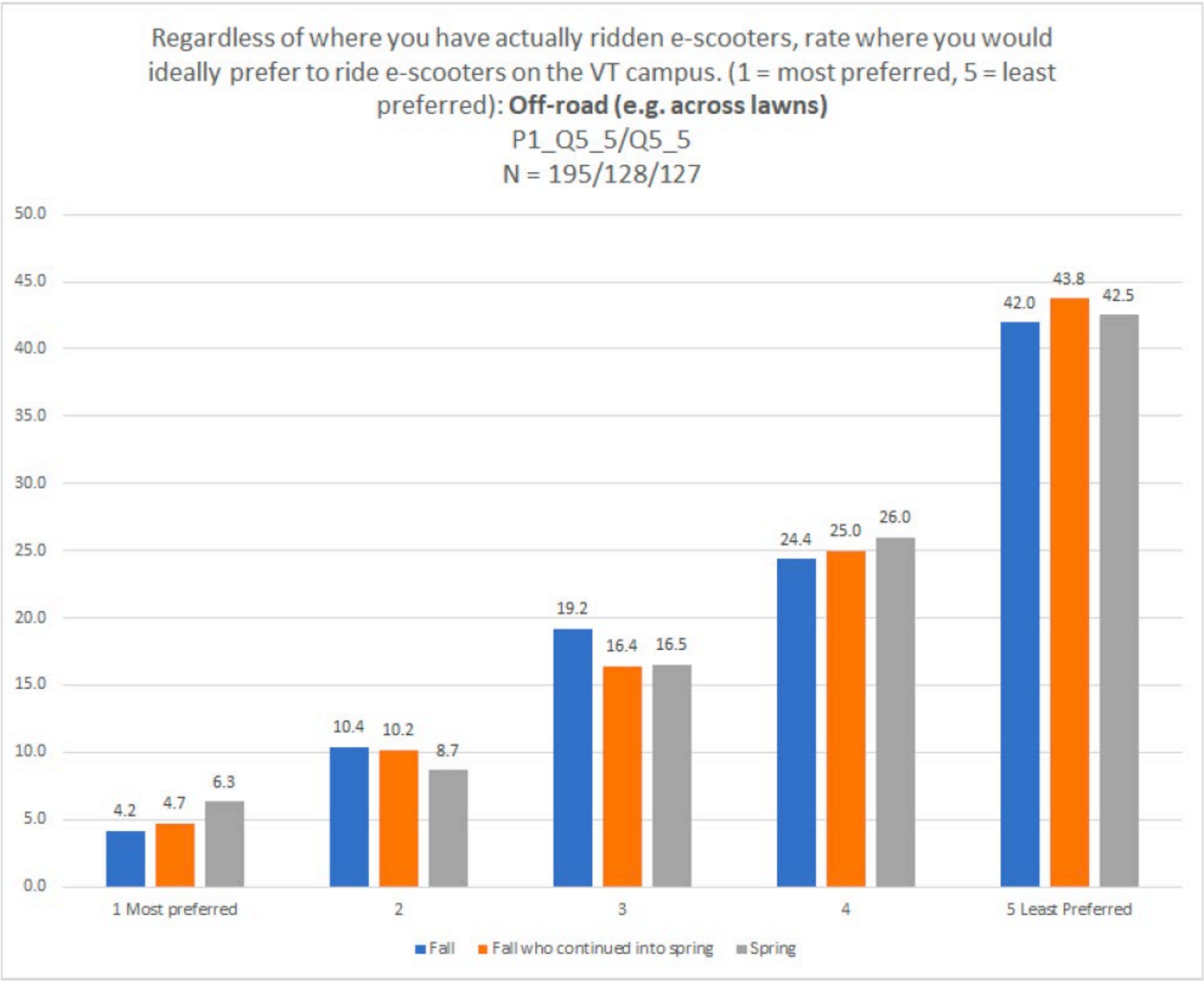

How often do you ride e-scooters?
P1_QID1/Q1D1
N=199/132/131
60.0
50.0
40.0
30.0
20.0
10.0
0.0
6.0
20.8
6.2
7.5
4.6
9.3
34.2
30.0
54.3
30.2
6.2
18.6
18.1
8.5
8.5
4.0
28.5
3.1
I've never ridden
I've only ridden once
I used to ride e-scooters, but not so much any more
Multiple times a month
I ride at least once per week
I ride every day
Fall
Fall who continued into spring
Spring

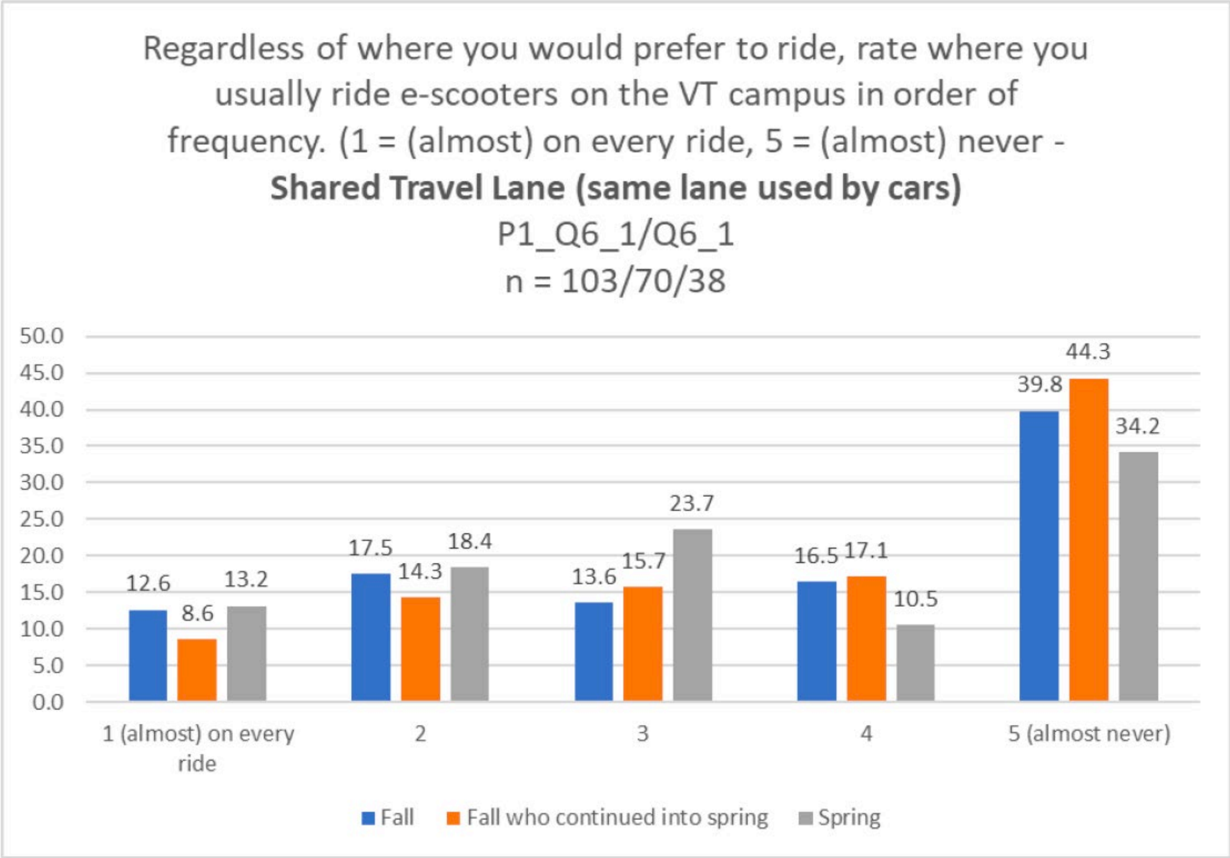

Regardless of where you have actually ridden e-scooters, rate where you would ideally prefer to ride e-scooters on the VT campus. - Shared Travel Lane (same lane used by cars)
P1_Q5_1/Q5_1
8.29
4.69
9.45
8.81
9.38
22.83
16.06
18.75
15.75
29.02
33.59
18.11
37.82
33.59
33.86
1 Most preferred
2
3
4
5 Least Preferred
Fall
Fall who continued into Spring
Spring

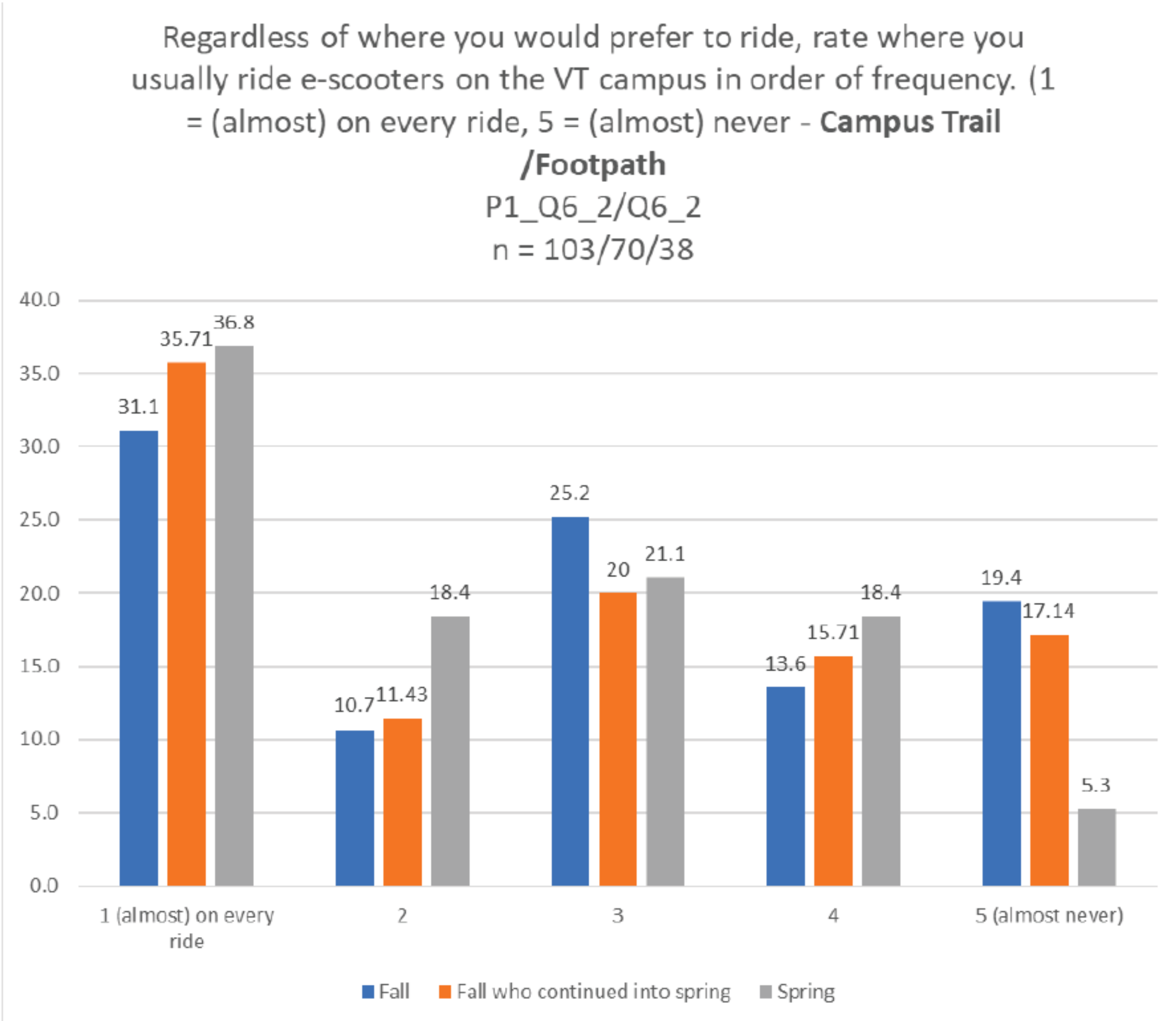

Regardless of where you have actually ridden e-scooters, rate where you would ideally prefer to ride e-scooters on the VT campus - Campus Trail /Footpath
P1_Q5_2/Q5_2
35
30
25
20
15
10
5
0
30.26
33.08
33.07
27.69
32.31
27.56
27.69
22.31
19.69
11.79
10.77
14.17
2.56
0
5.51
1 Most preferred
2
3
4
5 Least Preferred
Fall
Fall who continued into Spring
Spring

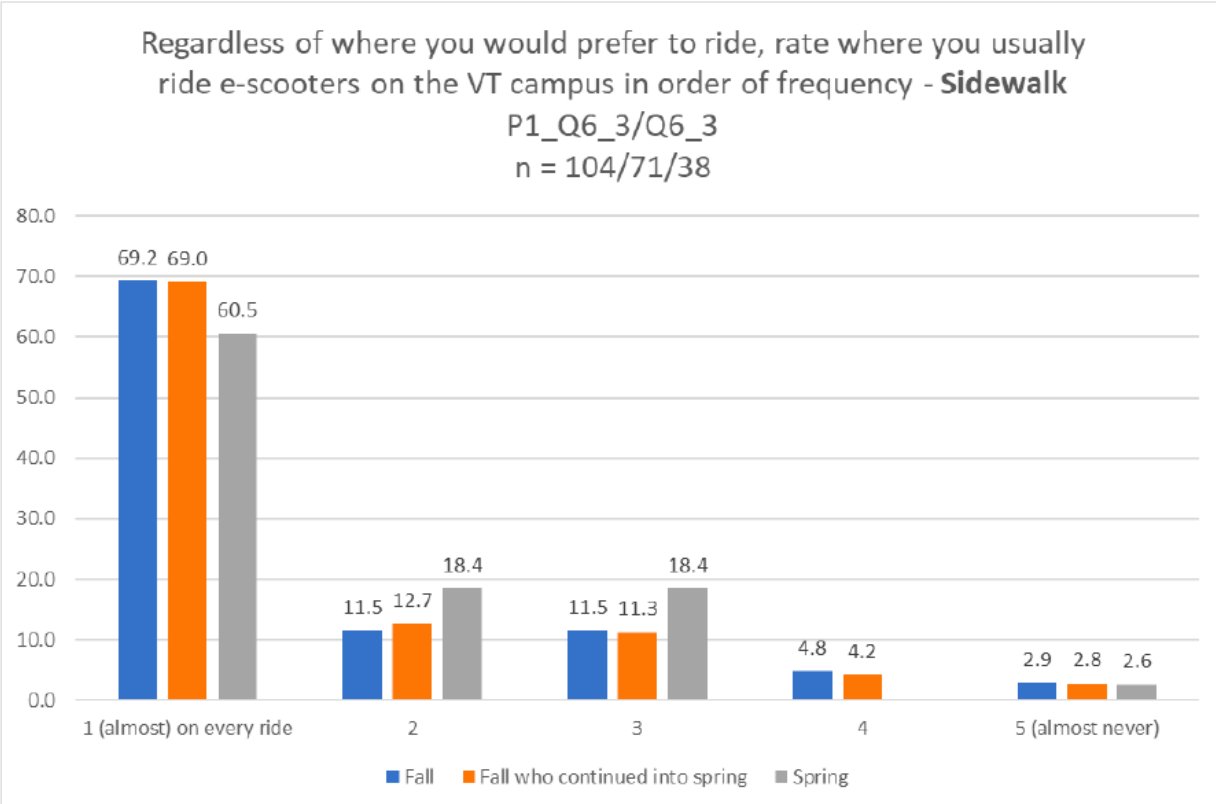

Regardless of where you have actually ridden e-scooters, rate where you would ideally prefer to ride e-scooters on the VT campus. (1 = most preferred, 5 = least preferred): Sidewalk
P1_Q5_3/Q5_3
N = 196/129/127
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
40.2
40.3
33.9
27.3
29.5
26.0
17.5
16.3
18.9
8.8
9.3
12.6
6.2
4.7
8.7
1 Most preferred
2
3
4
5 Least Preferred
Fall
Fall who continued into spring
Spring

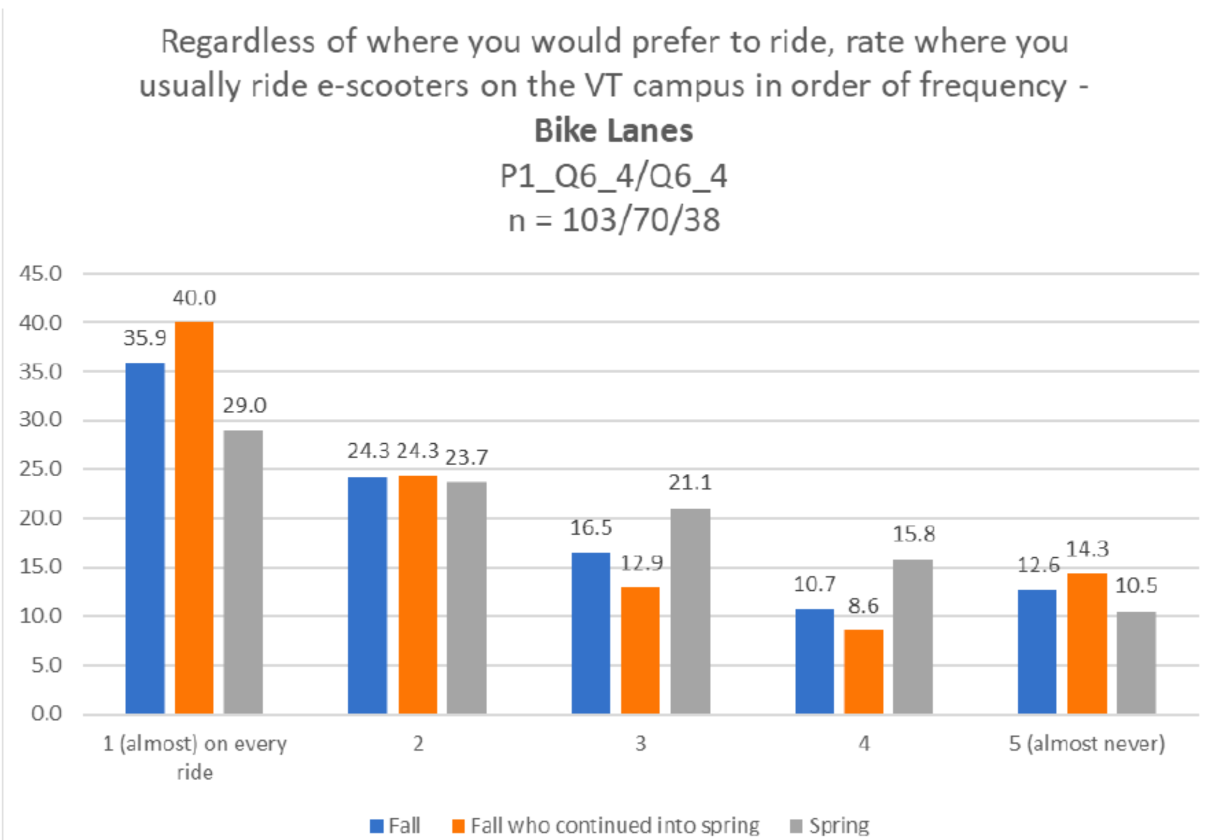

Regardless of where you have actually ridden e-scooters, rate where you would ideally prefer to ride e-scooters on the VT campus. (1 = most preferred, 5 = least preferred): Bike Lanes
P1_Q5_4/Q5_4
N = 194/129/127
50
45
40
35
30
25
20
15
10
5
0
42.27
44.96
37.8
25.26
21.71
23.62
22.16
25.58
21.26
7.73
4.65
14.17
2.58
3.1
3.15
1 Most preferred
2
3
4
5 Least Preferred
Fall
Fall who continued into spring
Spring

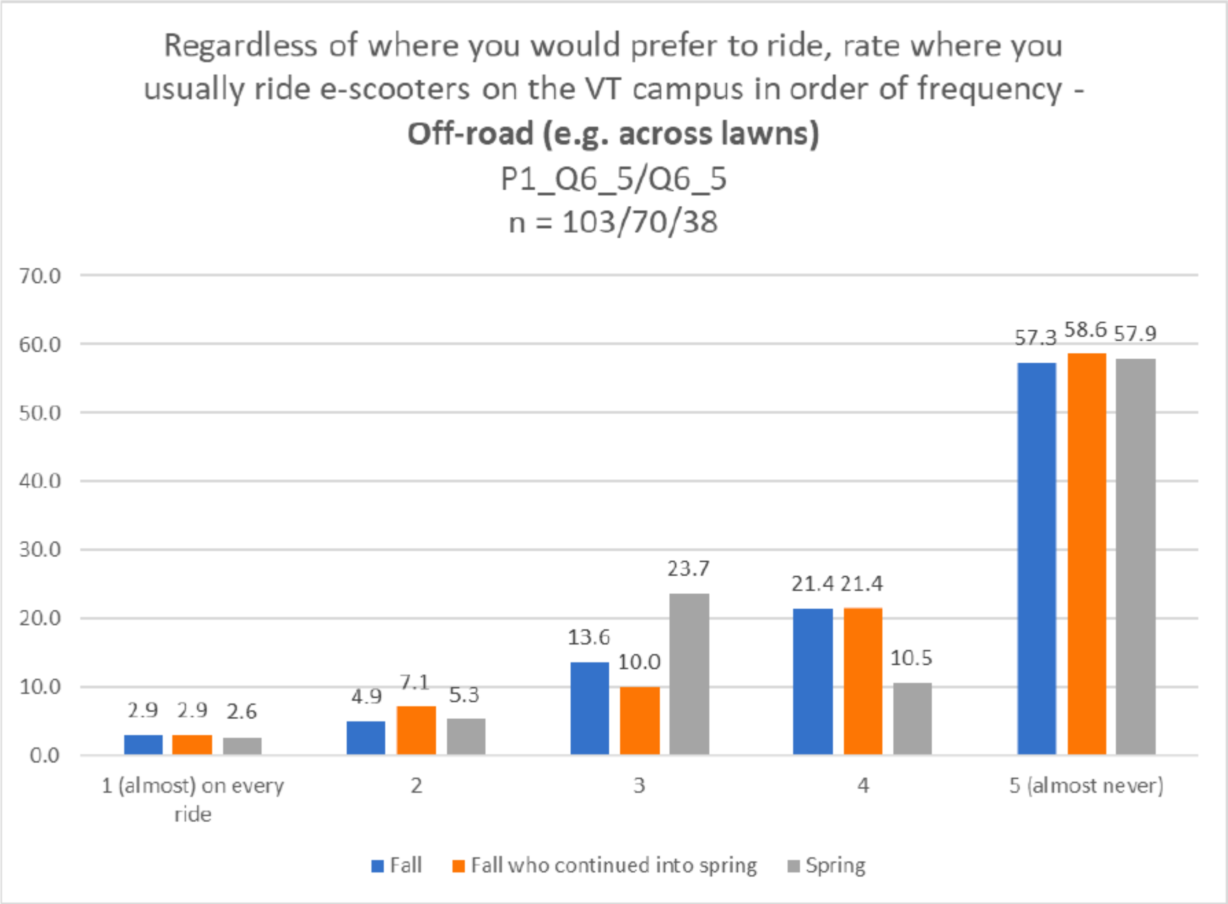

Regardless of where you have actually ridden e-scooters, rate where you would ideally prefer to ride e-scooters on the VT campus. (1 = most preferred, 5 = least preferred): **Off-road (e.g. across lawns)**
P1_Q5_5/Q5_5
N = 195/128/127
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4.2
4.7
6.3
10.4
10.2
8.7
19.2
16.4
16.5
24.4
25.0
26.0
42.0
43.8
42.5
1 Most preferred
2
3
4
5 Least Preferred
Fall
Fall who continued into spring
Spring


Regardless of where you would prefer to ride, rate where you usually ride e-scooters on the VT campus in order of frequency. (1 = (almost) on every ride, 5 = (almost) never -
Shared Travel Lane (same lane used by cars)
P1_Q6_1/Q6_1
n = 103/70/38
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
12.6
8.6
13.2
17.5
14.3
18.4
13.6
15.7
23.7
16.5
17.1
10.5
39.8
44.3
34.2
1 (almost) on every ride
2
3
4
5 (almost never)
Fall
Fall who continued into spring
Spring

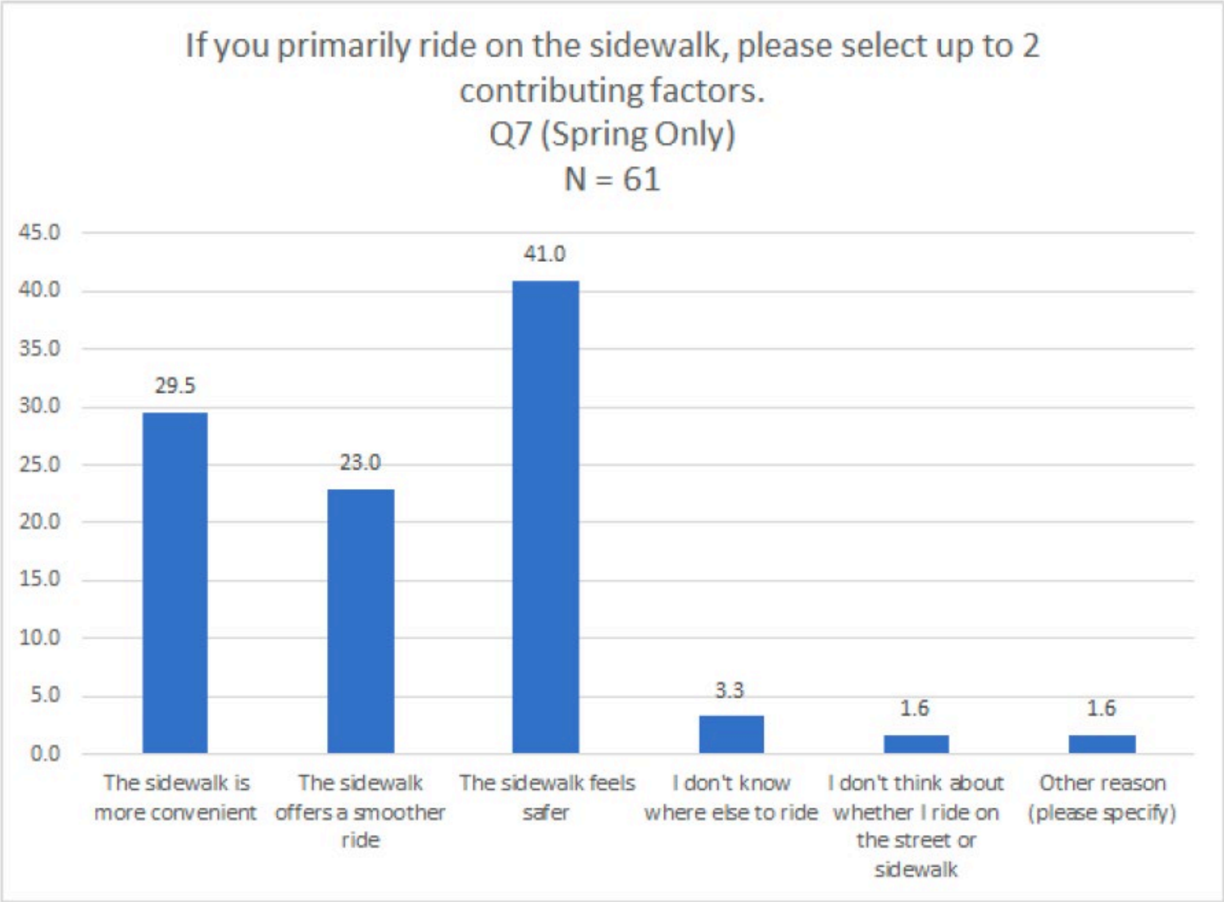

Regardless of where you would prefer to ride, rate where you usually ride e-scooters on the VT campus in order of frequency. (1 = (almost) on every ride, 5 = (almost) never - Campus Trail /Footpath
P1_Q6_2/Q6_2
n = 103/70/38
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
31.1
35.71
36.8
10.7
11.43
18.4
25.2
20
21.1
13.6
15.71
18.4
19.4
17.14
5.3
1 (almost) on every ride
2
3
4
5 (almost never)
Fall
Fall who continued into spring
Spring

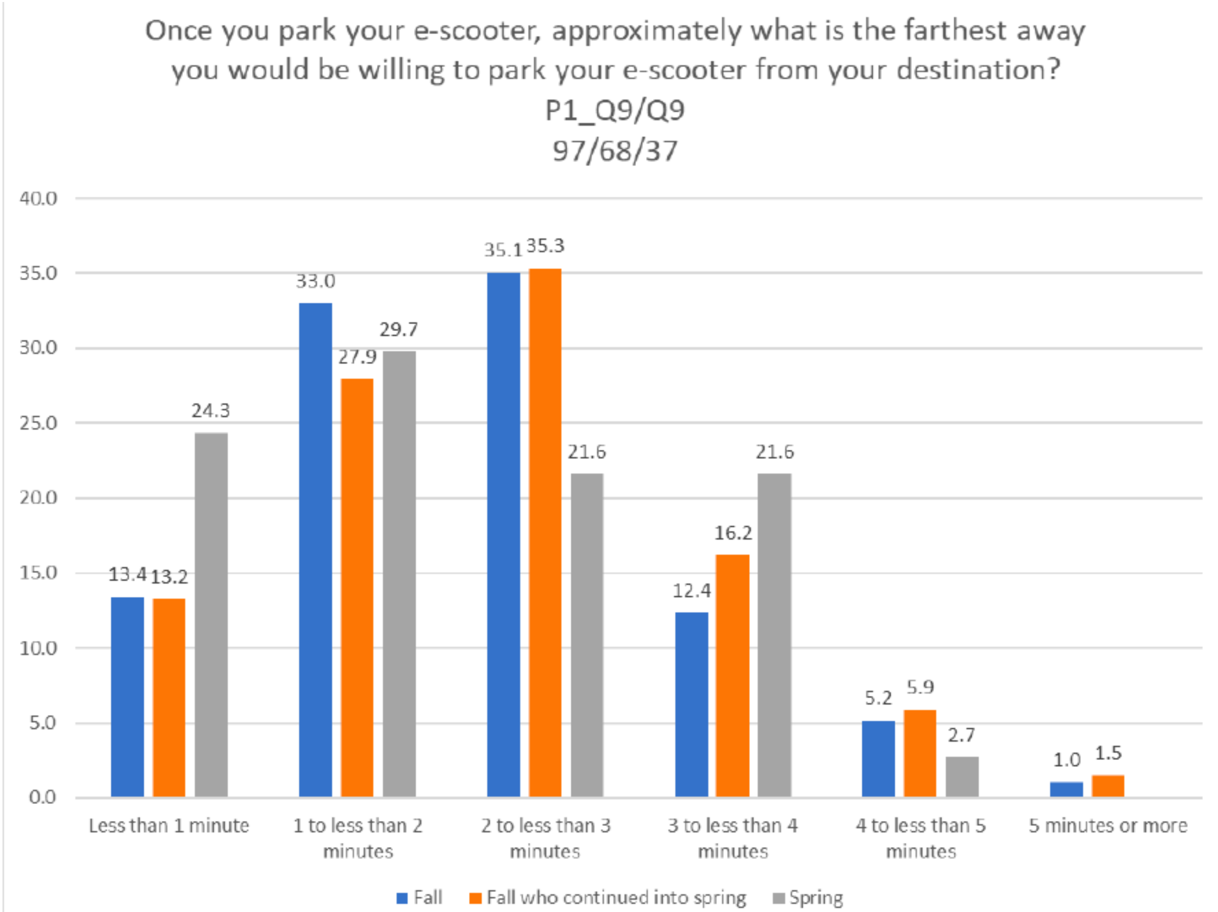

Regardless of where you would prefer to ride, rate where you usually ride e-scooters on the VT campus in order of frequency - **Sidewalk**
P1_Q6_3/Q6_3
n = 104/71/38
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
69.2 69.0
60.5
11.5 12.7
18.4
11.5 11.3
18.4
4.8 4.2
2.9 2.8 2.6
1 (almost) on every ride
2
3
4
5 (almost never)
Fall
Fall who continued into spring
Spring

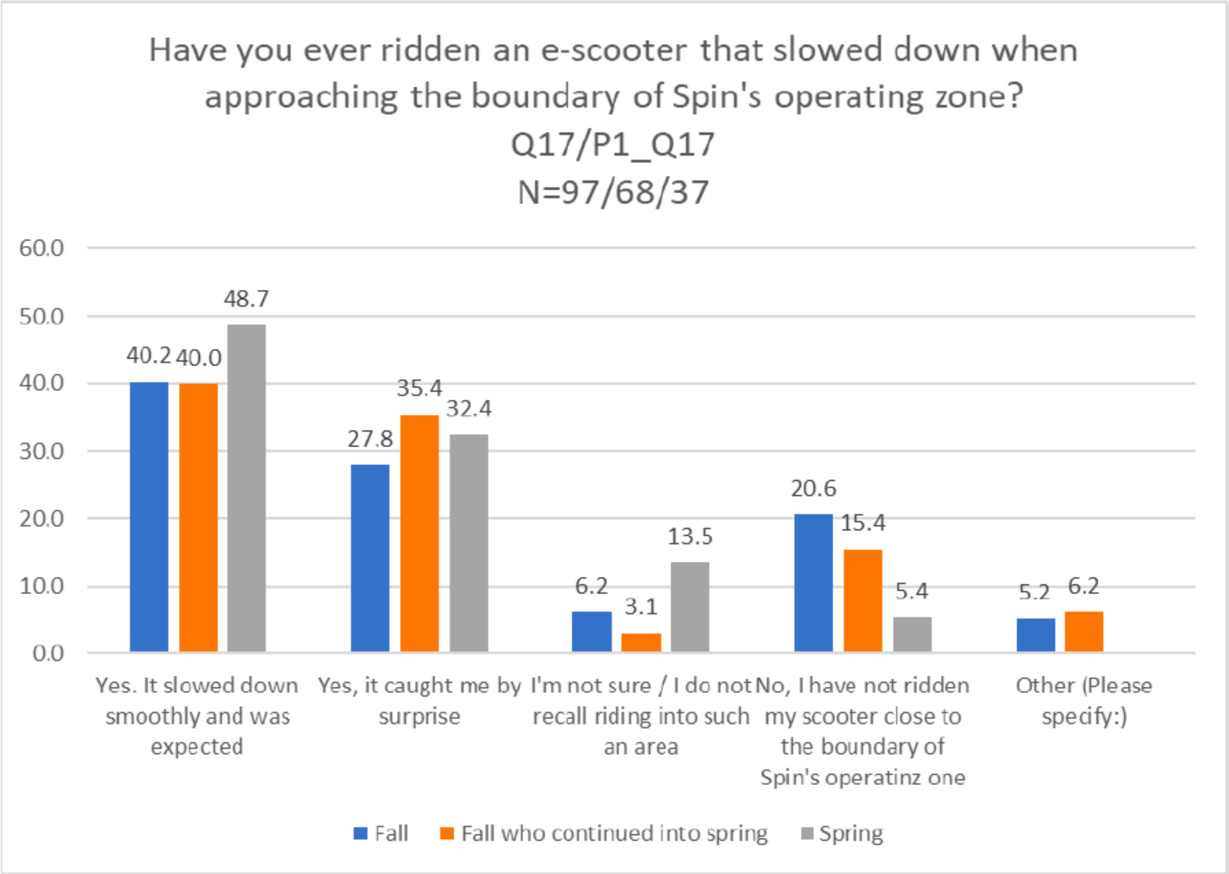

Regardless of where you would prefer to ride, rate where you usually ride e-scooters on the VT campus in order of frequency - **Bike Lanes**
P1_Q6_4/Q6_4
n = 103/70/38
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
35.9
40.0
29.0
24.3 24.3 23.7
16.5
12.9
21.1
10.7
8.6
15.8
12.6
14.3
10.5
1 (almost) on every ride
2
3
4
5 (almost never)
Fall
Fall who continued into spring
Spring

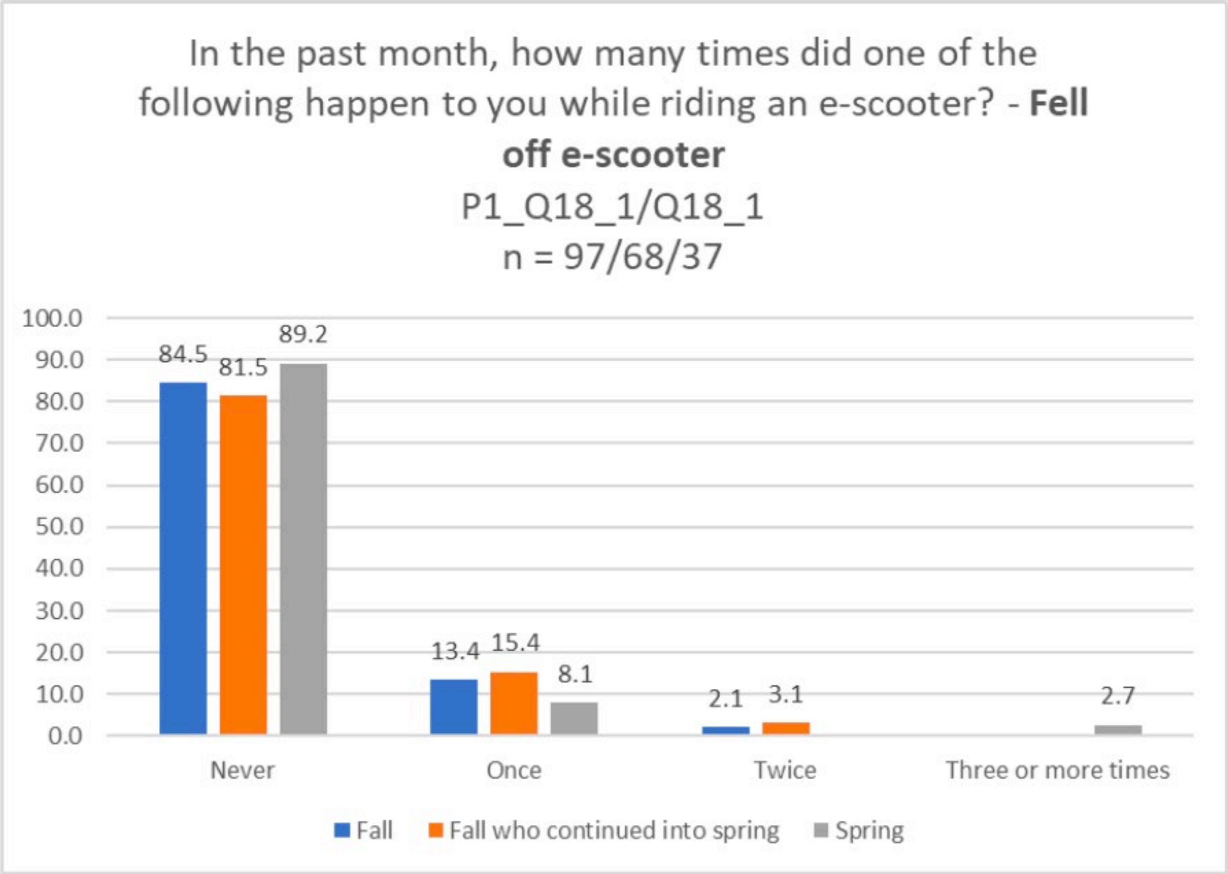


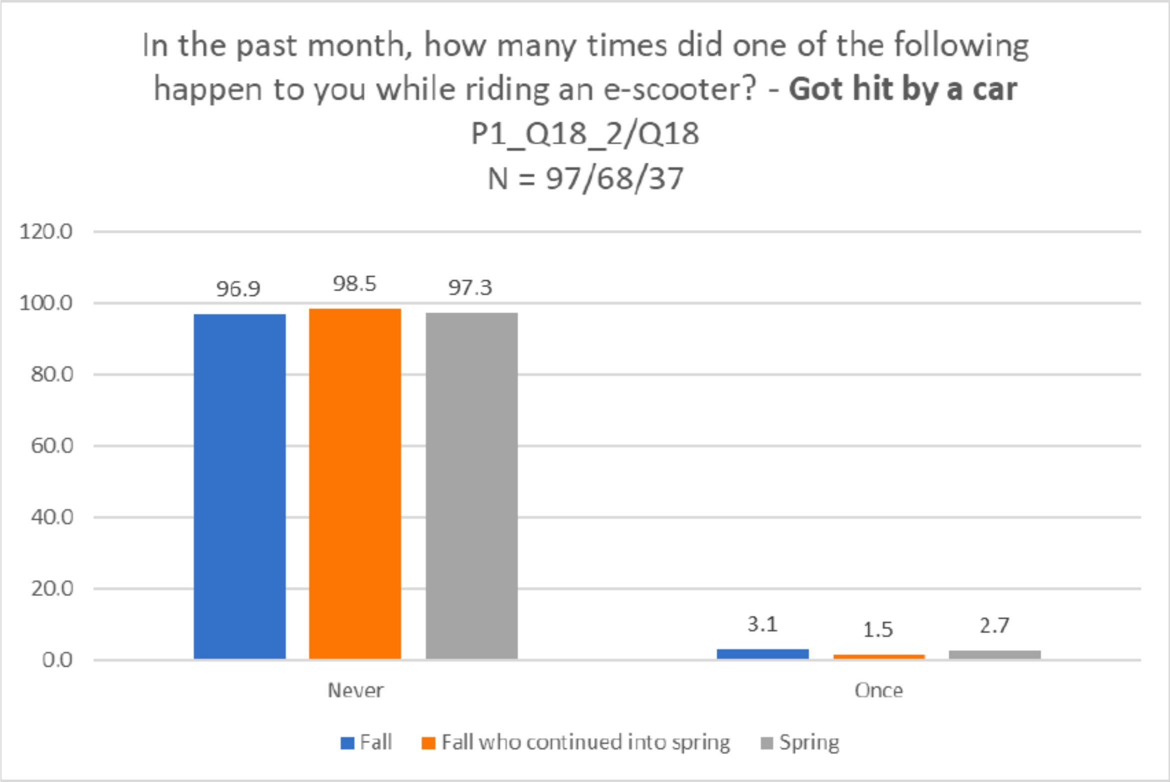
Regardless of where you would prefer to ride, rate where you usually ride e-scooters on the VT campus in order of frequency -
Off-road (e.g. across lawns)
P1_Q6_5/Q6_5
n = 103/70/38
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2.9
2.9
2.6
4.9
7.1
5.3
13.6
10.0
23.7
21.4
21.4
10.5
57.3
58.6
57.9
1 (almost) on every ride
2
3
4
5 (almost never)
Fall
Fall who continued into spring
Spring

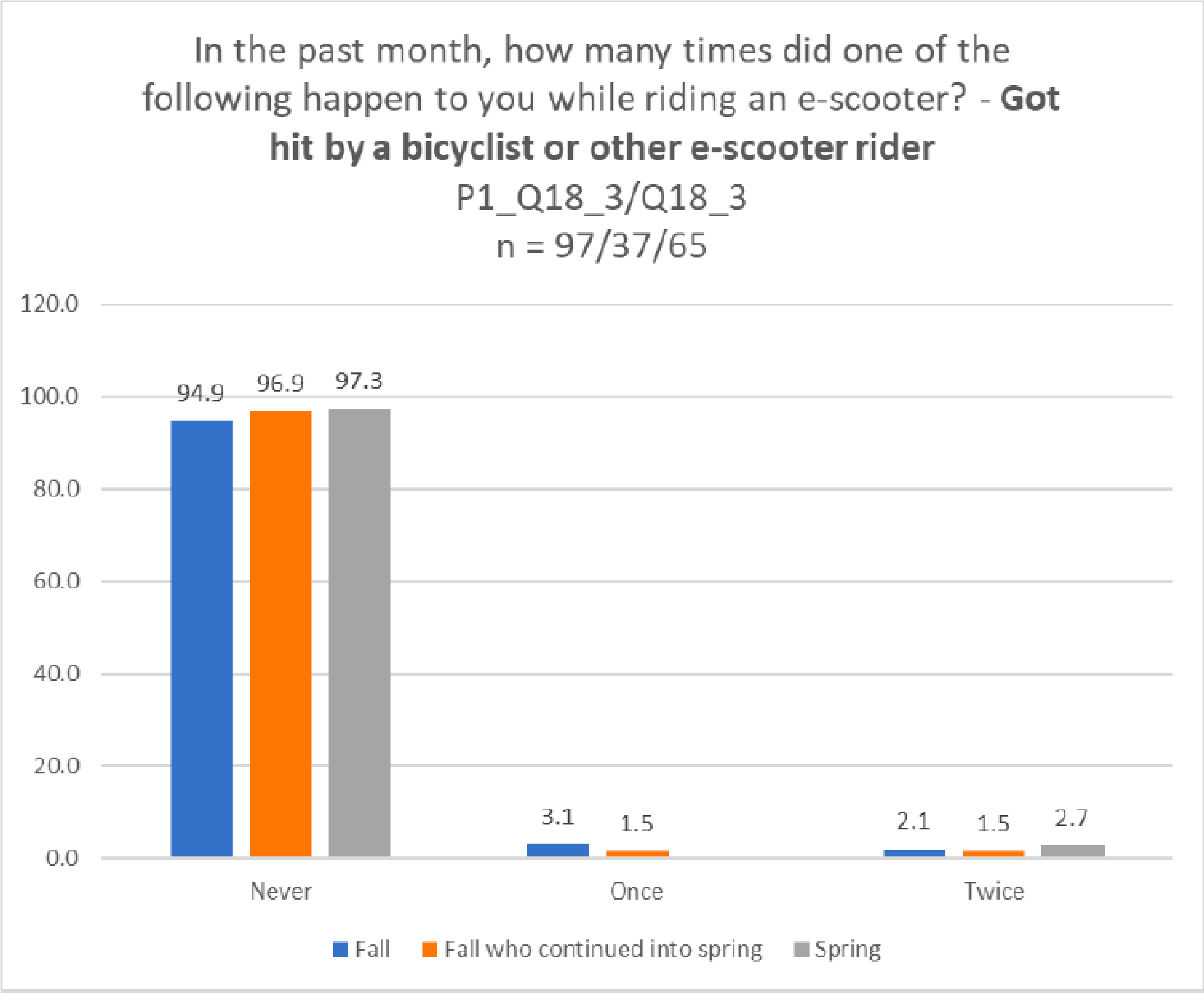

If you primarily ride on the sidewalk, please select up to 2 contributing factors.
Q7 (Spring Only)
N = 61
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
29.5
23.0
41.0
3.3
1.6
1.6
The sidewalk is more convenient
The sidewalk offers a smoother ride
The sidewalk feels safer
I don't know where else to ride
I don't think about whether I ride on the street or sidewalk
Other reason (please specify)

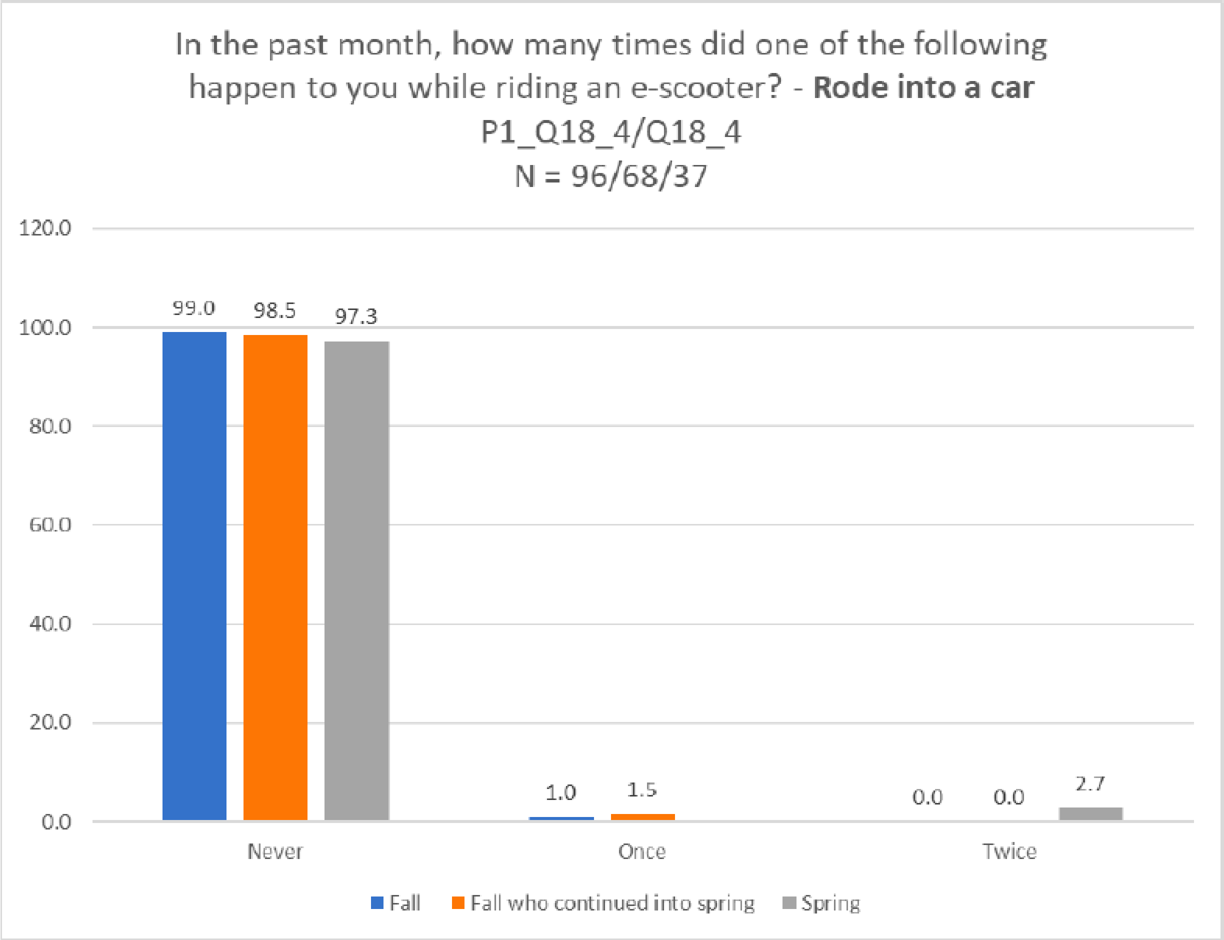

Once you park your e-scooter, approximately what is the farthest away you would be willing to park your e-scooter from your destination?
P1_Q9/Q9
97/68/37
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
13.4
13.2
24.3
33.0
27.9
29.7
35.1
35.3
21.6
12.4
16.2
21.6
5.2
5.9
2.7
1.0
1.5
Less than 1 minute
1 to less than 2 minutes
2 to less than 3 minutes
3 to less than 4 minutes
4 to less than 5 minutes
5 minutes or more
Fall
Fall who continued into spring
Spring


Have you ever ridden an e-scooter that slowed down when approaching the boundary of Spin's operating zone?
Q17/P1_Q17
N=97/68/37
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40.2
40.0
48.7
27.8
35.4
32.4
6.2
3.1
13.5
20.6
15.4
5.4
5.2
6.2
Yes. It slowed down smoothly and was expected
Yes, it caught me by surprise
I'm not sure / I do not recall riding into such an area
No, I have not ridden my scooter close to the boundary of Spin's operatinz one
Other (Please specify:)
Fall
Fall who continued into spring
Spring

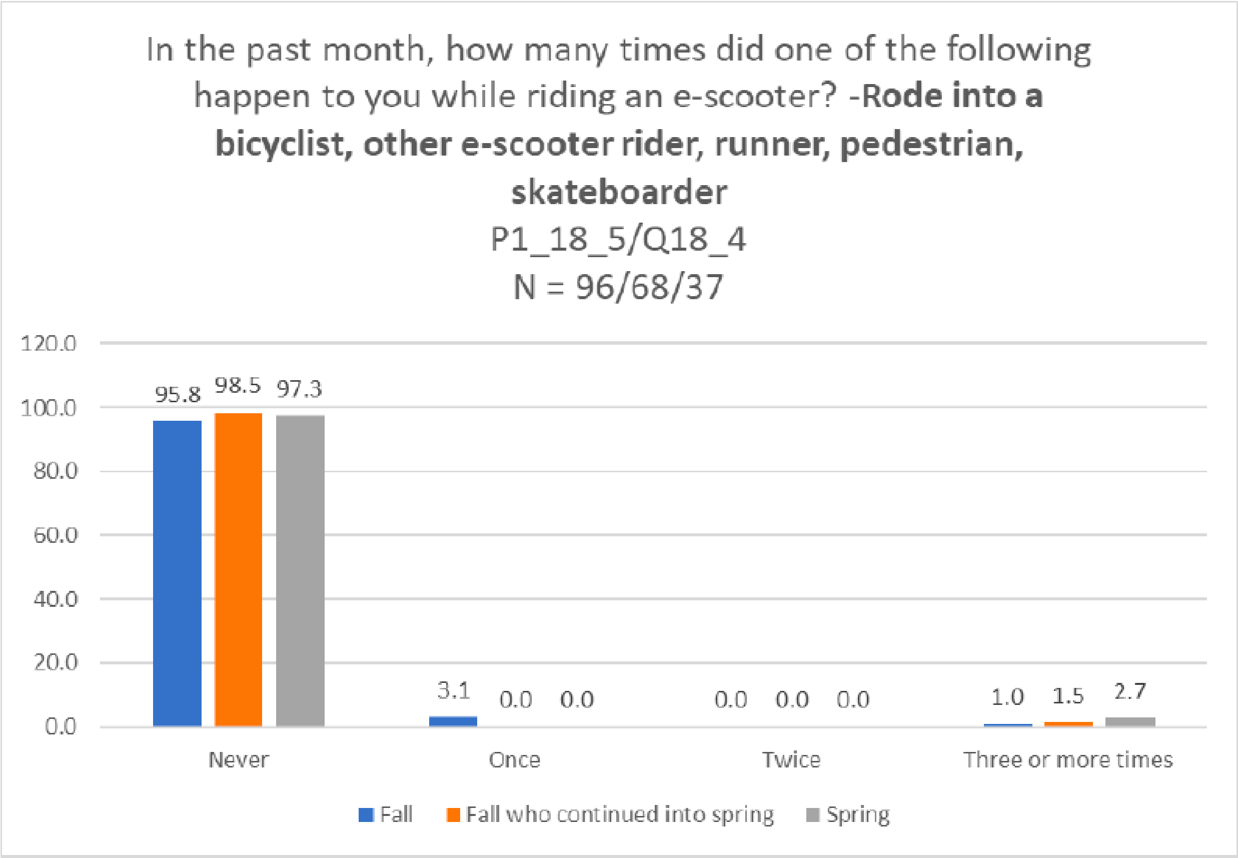

In the past month, how many times did one of the following happen to you while riding an e-scooter? - **Fell off e-scooter**
P1_Q18_1/Q18_1
n = 97/68/37
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
84.5
81.5
89.2
13.4
15.4
8.1
2.1
3.1
2.7
Never
Once
Twice
Three or more times
Fall
Fall who continued into spring
Spring

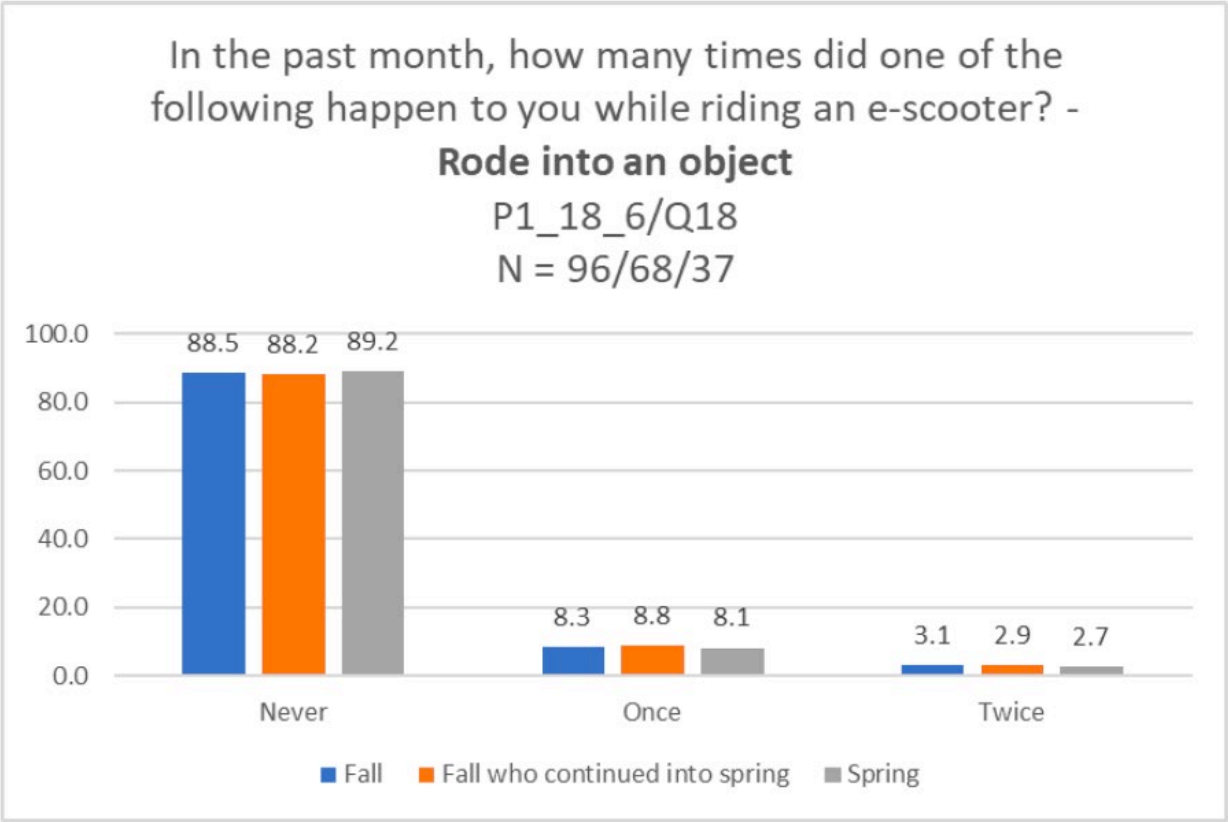

In the past month, how many times did one of the following happen to you while riding an e-scooter? - **Got hit by a car**
P1_Q18_2/Q18
N = 97/68/37
120.0
100.0
80.0
60.0
40.0
20.0
0.0
96.9
98.5
97.3
3.1
1.5
2.7
Never
Once
Fall
Fall who continued into spring
Spring

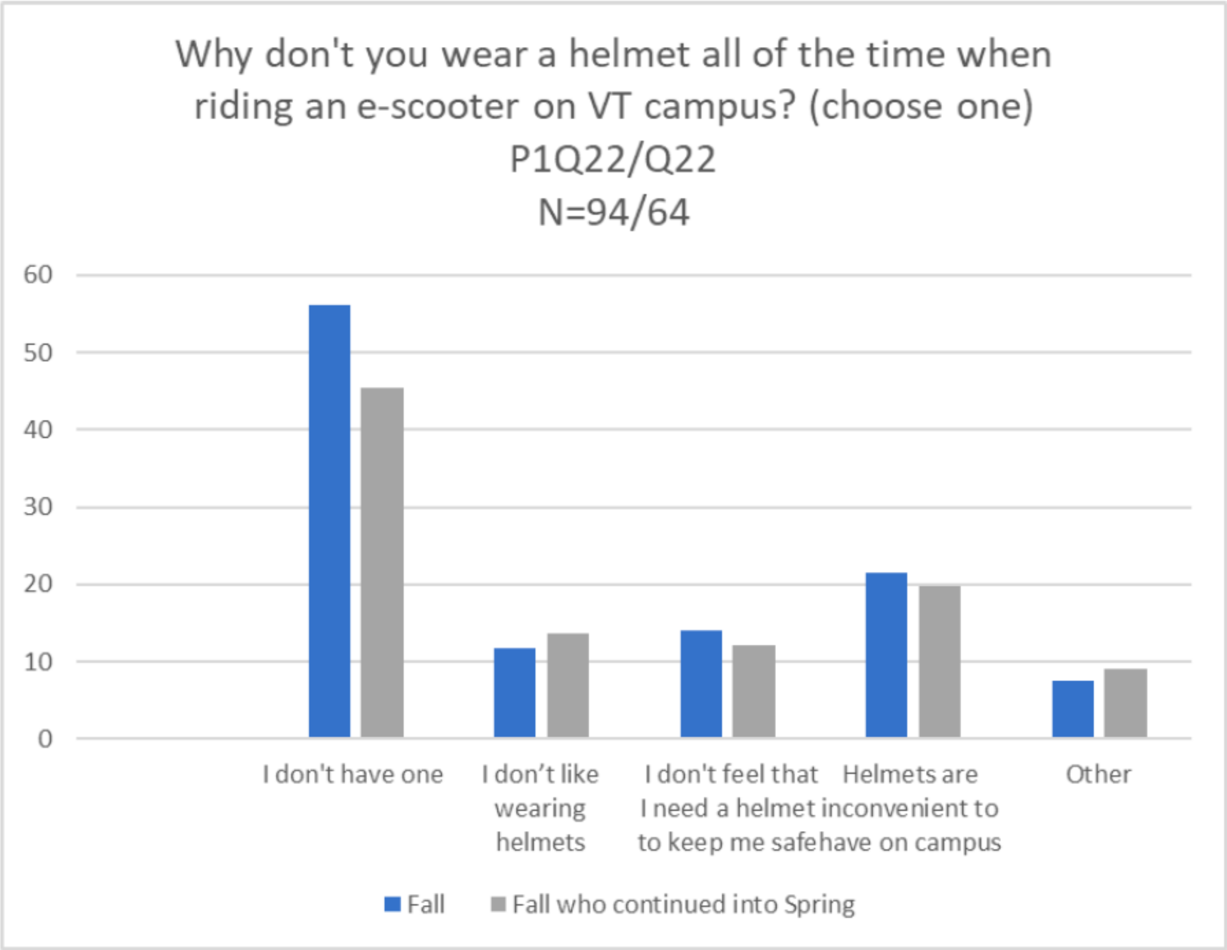

In the past month, how many times did one of the following happen to you while riding an e-scooter? - **Got hit by a bicyclist or other e-scooter rider**
P1_Q18_3/Q18_3
n = 97/37/65
120.0
100.0
80.0
60.0
40.0
20.0
0.0
94.9
96.9
97.3
3.1
1.5
2.1
1.5
2.7
Never
Once
Twice
Fall
Fall who continued into spring
Spring

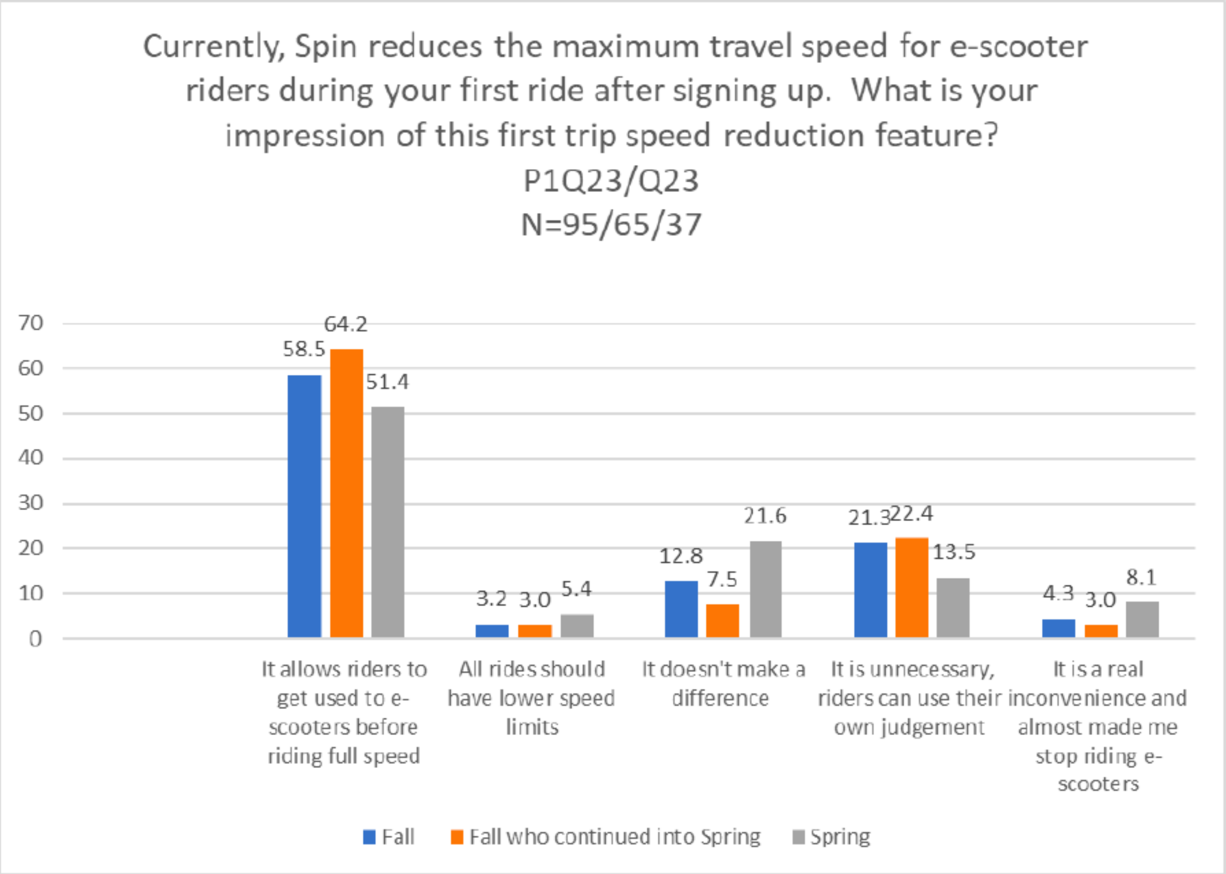

In the past month, how many times did one of the following happen to you while riding an e-scooter? - **Rode into a car**
P1_Q18_4/Q18_4
N = 96/68/37
120.0
100.0
80.0
60.0
40.0
20.0
0.0
99.0
98.5
97.3
1.0
1.5
0.0
0.0
2.7
Never
Once
Twice
Fall
Fall who continued into spring
Spring

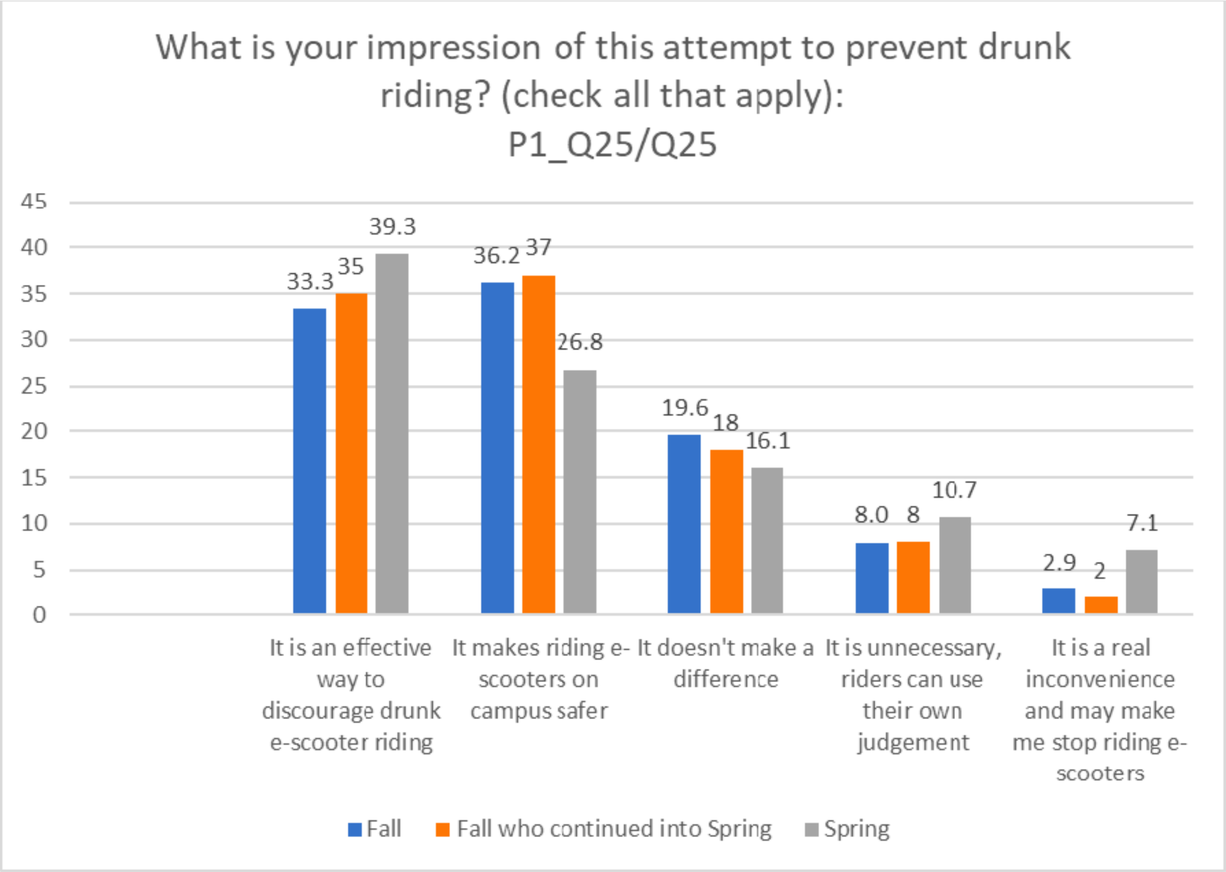
Bar char

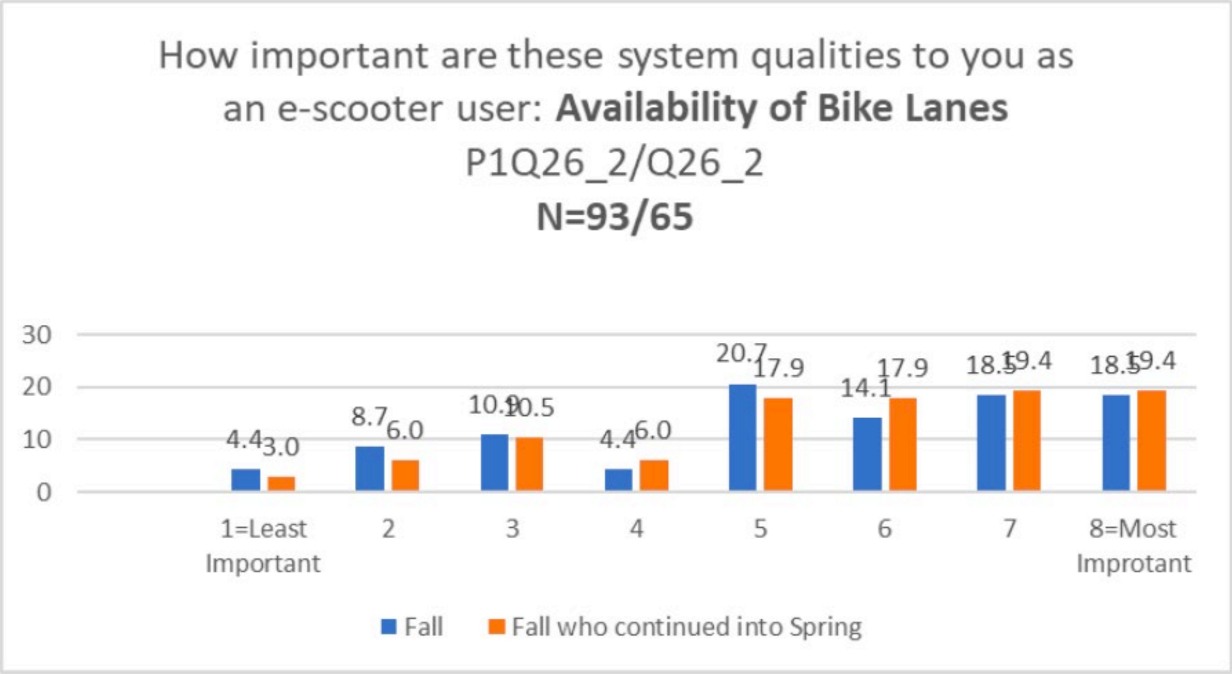

In the past month, how many times did one of the following happen to you while riding an e-scooter? -Rode into a bicyclist, other e-scooter rider, runner, pedestrian, skateboarder
P1_18_5/Q18_4
N = 96/68/37
120.0
100.0
80.0
60.0
40.0
20.0
0.0
95.8
98.5
97.3
3.1
0.0
0.0
0.0
0.0
0.0
1.0
1.5
2.7
Never
Once
Twice
Three or more times
Fall
Fall who continued into spring
Spring

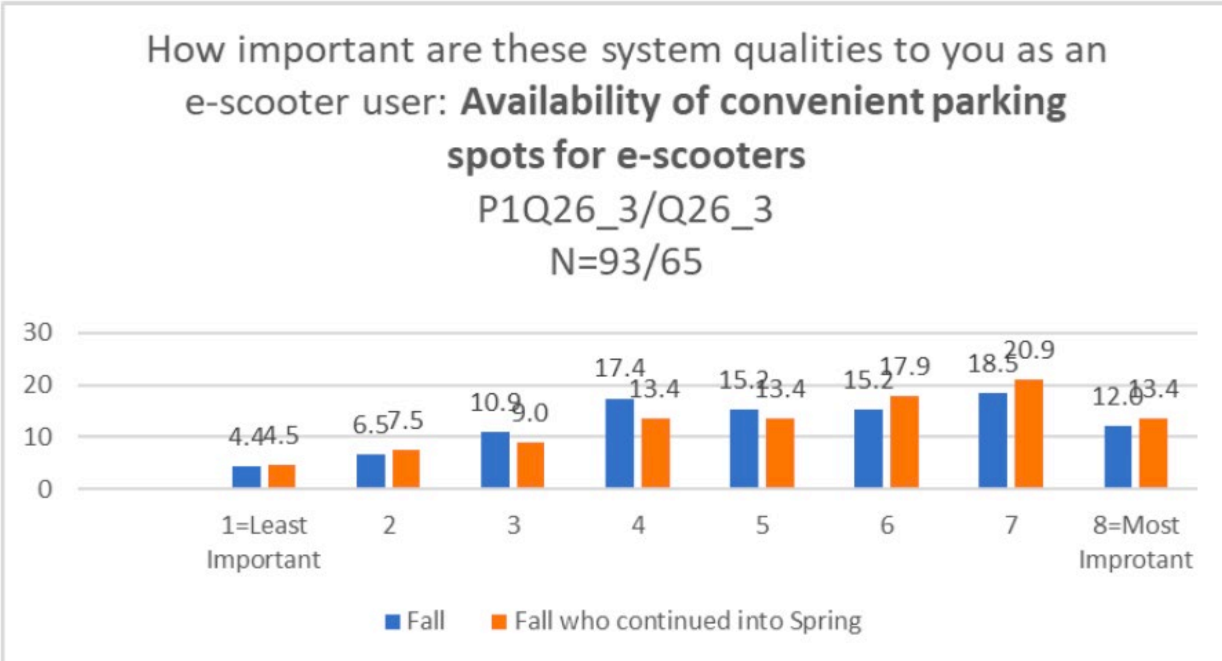

In the past month, how many times did one of the following happen to you while riding an e-scooter? -
Rode into an object
P1_18_6/Q18
N = 96/68/37
100.0
80.0
60.0
40.0
20.0
0.0
88.5
88.2
89.2
8.3
8.8
8.1
3.1
2.9
2.7
Never
Once
Twice
Fall
Fall who continued into spring
Spring

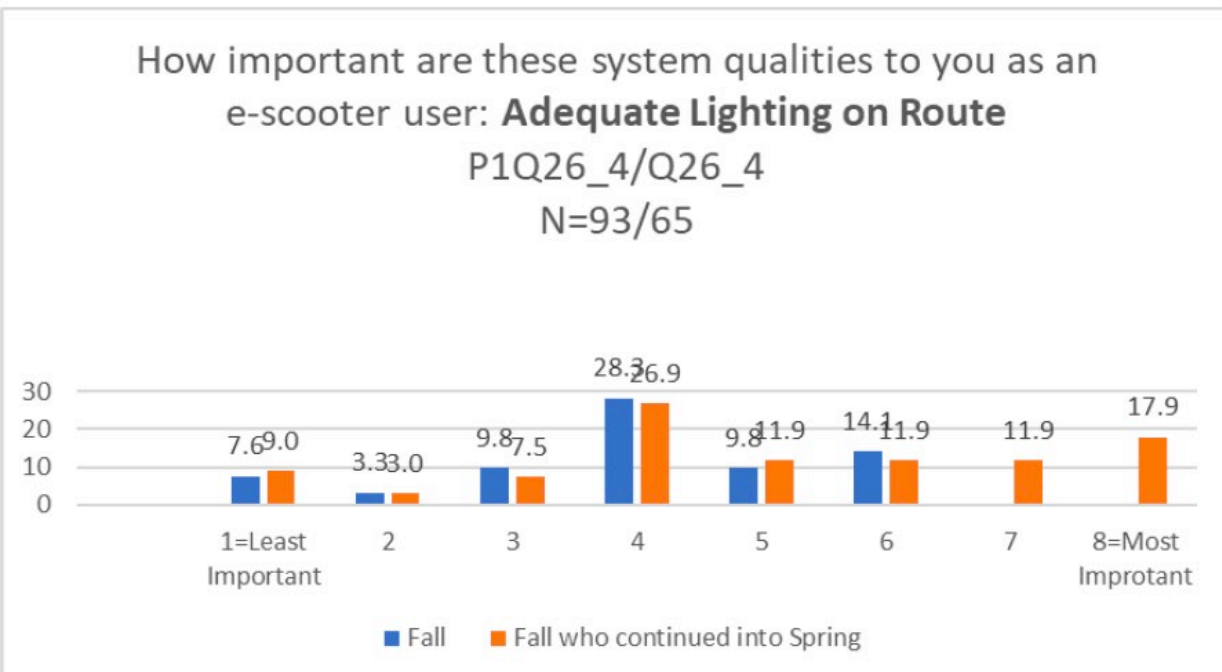

Why don't you wear a helmet all of the time when riding an e-scooter on VT campus? (choose one)
P1Q22/Q22
N=94/64
60
50
40
30
20
10
0
I don't have one
I don't like wearing helmets
I don't feel that I need a helmet to keep me safe
Helmets are inconvenient to have on campus
Other
Fall
Fall who continued into Spring

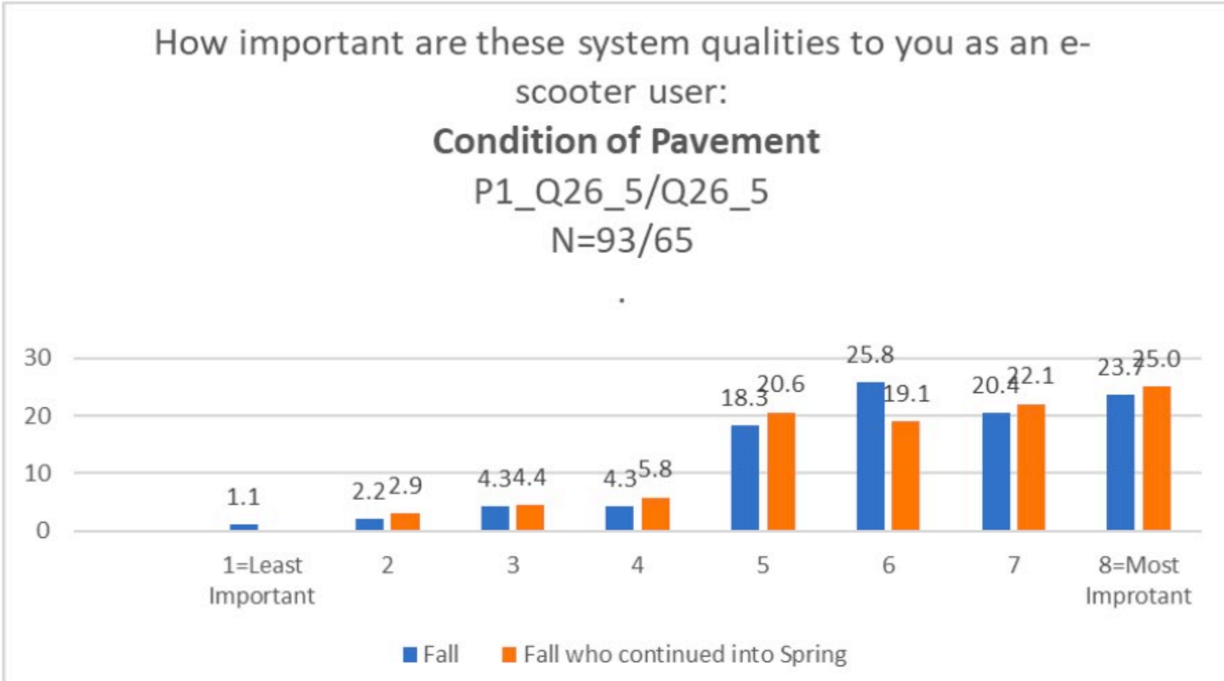

Currently, Spin reduces the maximum travel speed for e-scooter riders during your first ride after signing up. What is your impression of this first trip speed reduction feature?
P1Q23/Q23
N=95/65/37
70
60
50
40
30
20
10
0
58.5
64.2
51.4
3.2
3.0
5.4
12.8
7.5
21.6
21.3
22.4
13.5
4.3
3.0
8.1
It allows riders to get used to e-scooters before riding full speed
All rides should have lower speed limits
It doesn't make a difference
It is unnecessary, riders can use their own judgement
It is a real inconvenience and almost made me stop riding e-scooters
Fall
Fall who continued into Spring
Spring

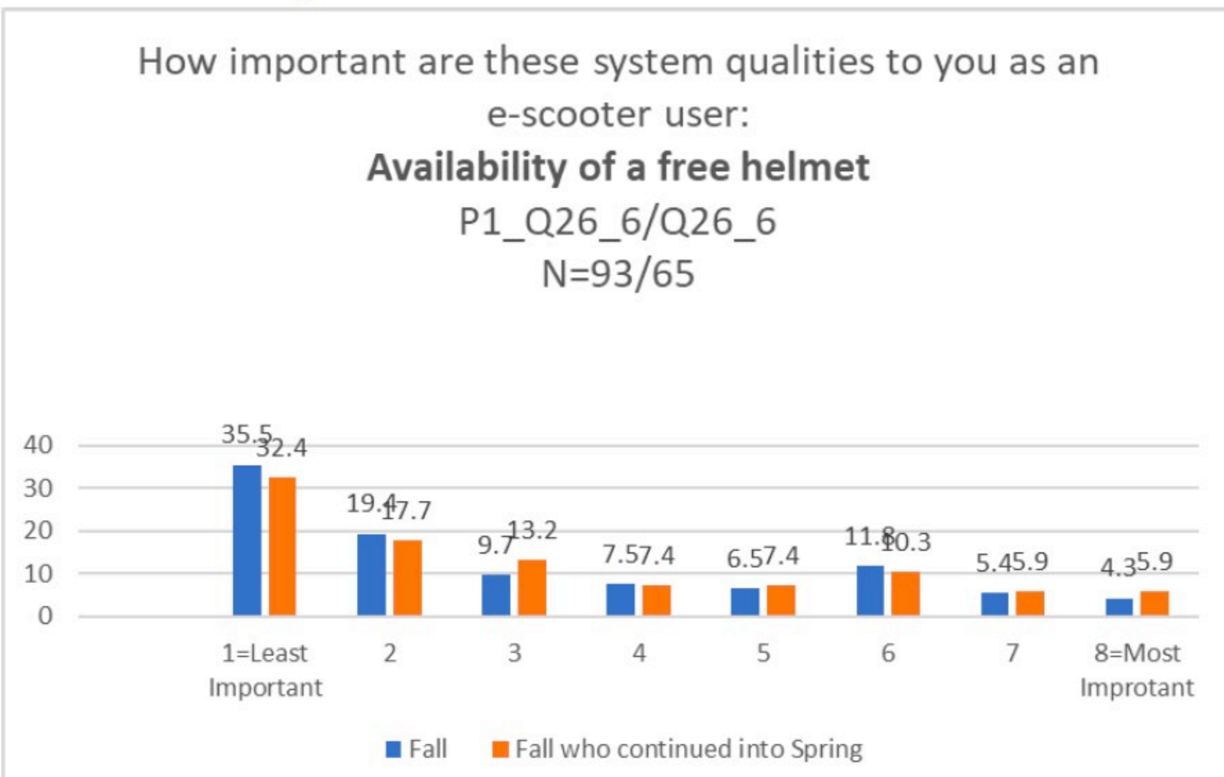

What is your impression of this attempt to prevent drunk riding? (check all that apply):
P1_Q25/Q25
45
40
35
30
25
20
15
10
5
0
33.3
35
39.3
36.2
37
26.8
19.6
18
16.1
8.0
8
10.7
2.9
2
7.1
It is an effective way to discourage drunk e-scooter riding
It makes riding e-scooters on campus safer
It doesn't make a difference
It is unnecessary, riders can use their own judgement
It is a real inconvenience and may make me stop riding e-scooters
Fall
Fall who continued into Spring
Spring

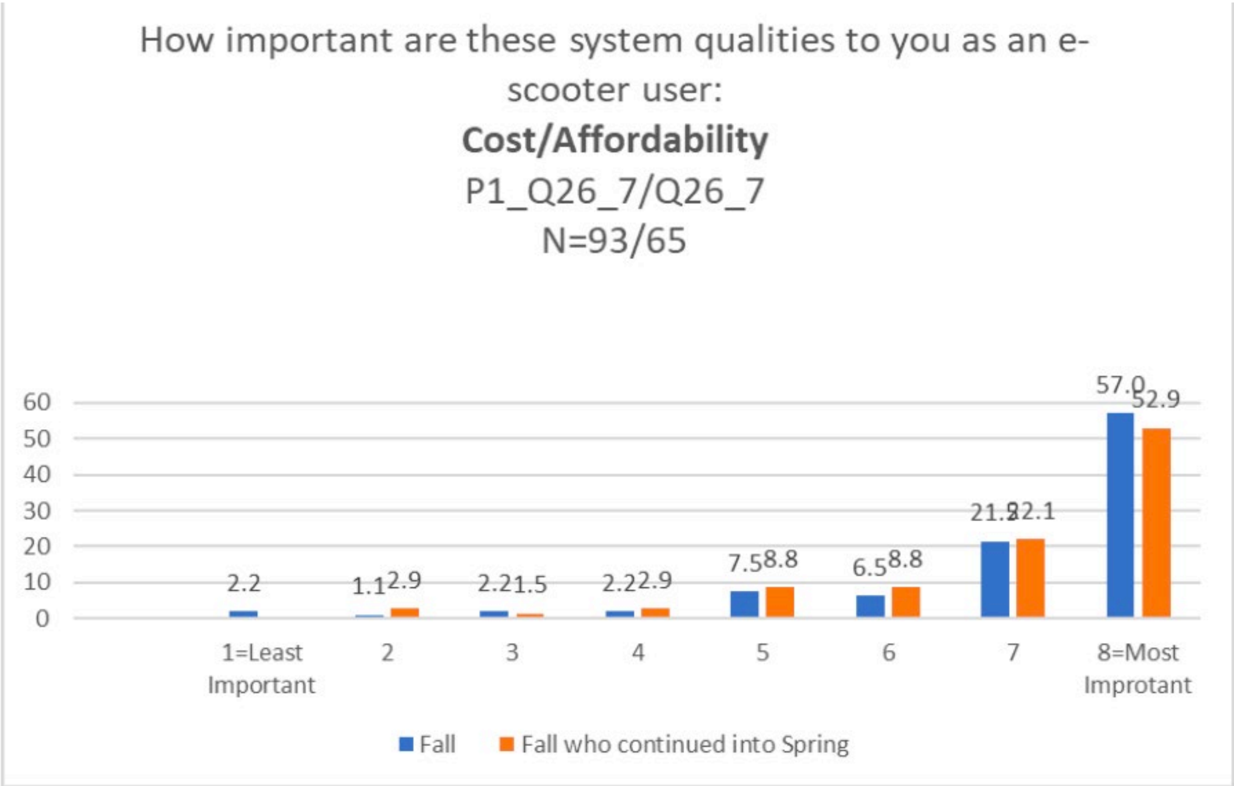

How important are these system qualities to you as an e-scooter user: Availability of Bike Lanes
P1Q26_2/Q26_2
N=93/65
30
20
10
0
4.4
3.0
8.7
6.0
10.9
10.5
4.4
6.0
20.7
17.9
14.1
17.9
18.5
19.4
18.5
19.4
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

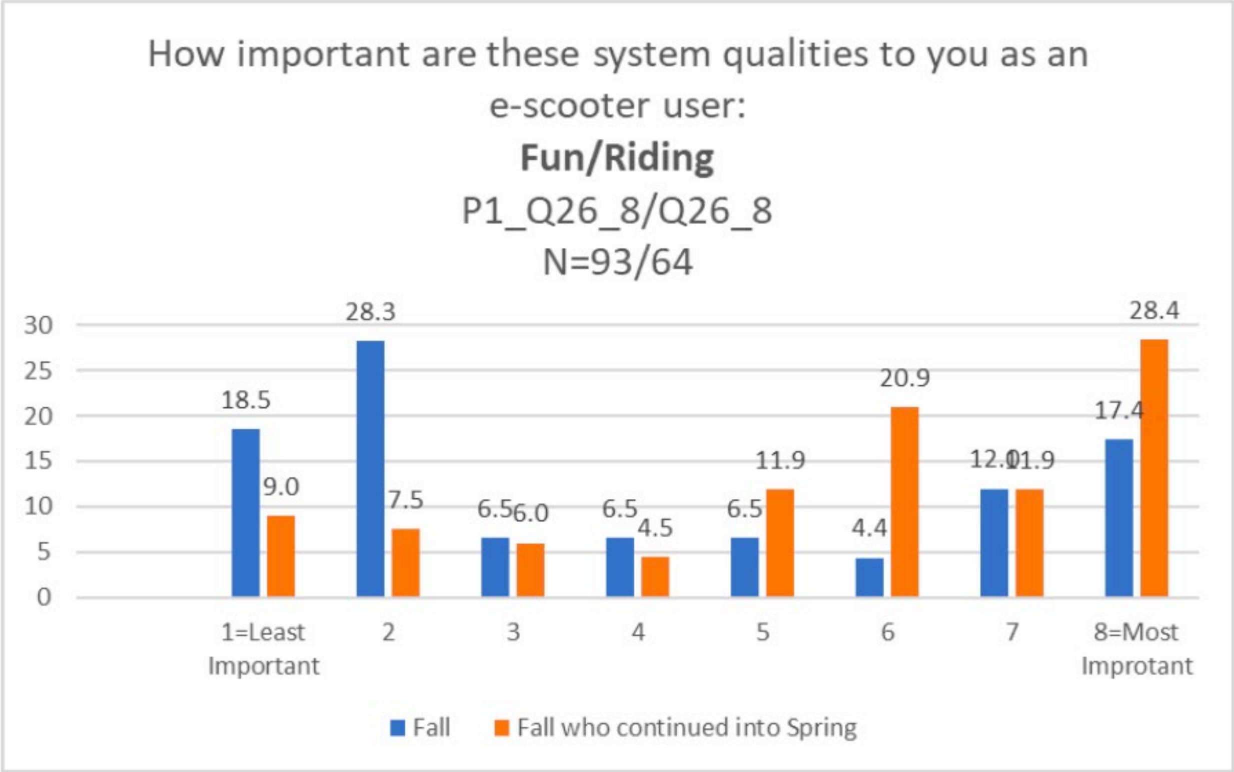

How important are these system qualities to you as an e-scooter user: **Availability of convenient parking spots for e-scooters**
P1Q26_3/Q26_3
N=93/65
30
20
10
0
4.4
4.5
6.5
7.5
10.9
9.0
17.4
13.4
15.2
13.4
15.2
17.9
18.5
20.9
12.0
13.4
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

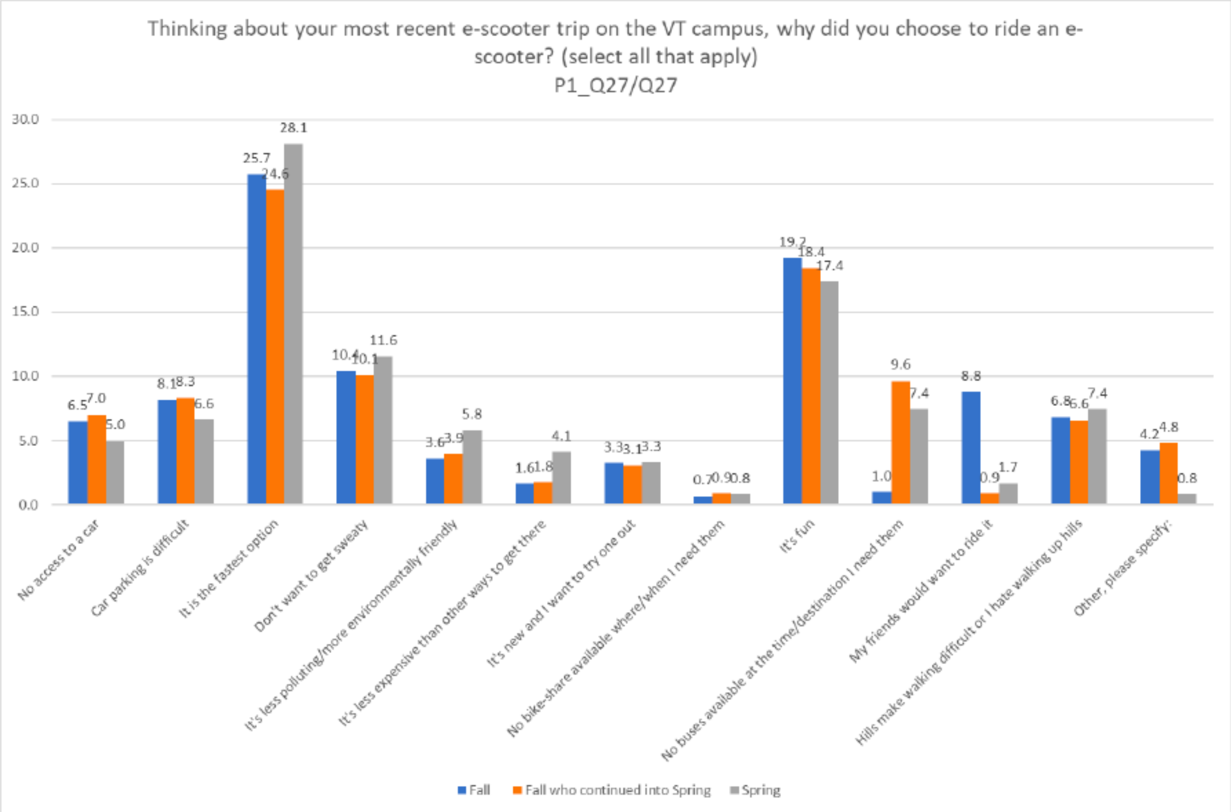

How important are these system qualities to you as an e-scooter user: **Adequate Lighting on Route**
P1Q26_4/Q26_4
N=93/65
30
20
10
0
7.6
9.0
3.3
3.0
9.8
7.5
28.3
26.9
9.8
11.9
14.1
11.9
11.9
17.9
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

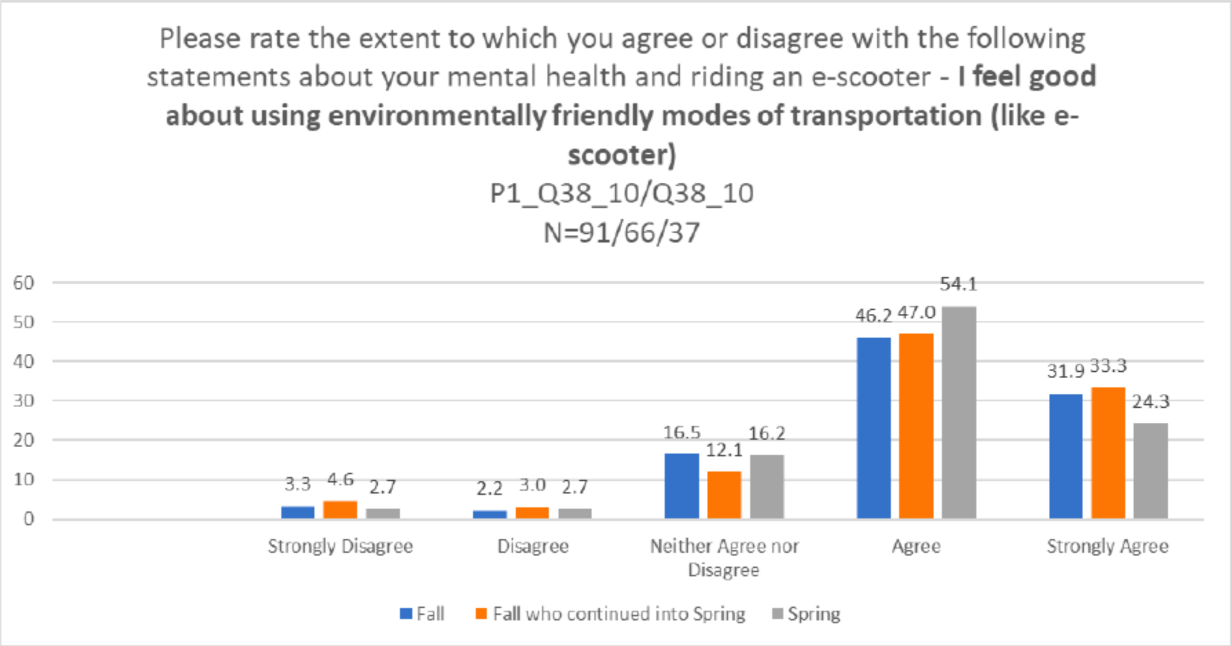

How important are these system qualities to you as an e-scooter user:
Condition of Pavement
P1_Q26_5/Q26_5
N=93/65
30
20
10
0
1.1
2.2
2.9
4.3
4.4
4.3
5.8
18.3
20.6
25.8
19.1
20.4
22.1
23.7
25.0
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

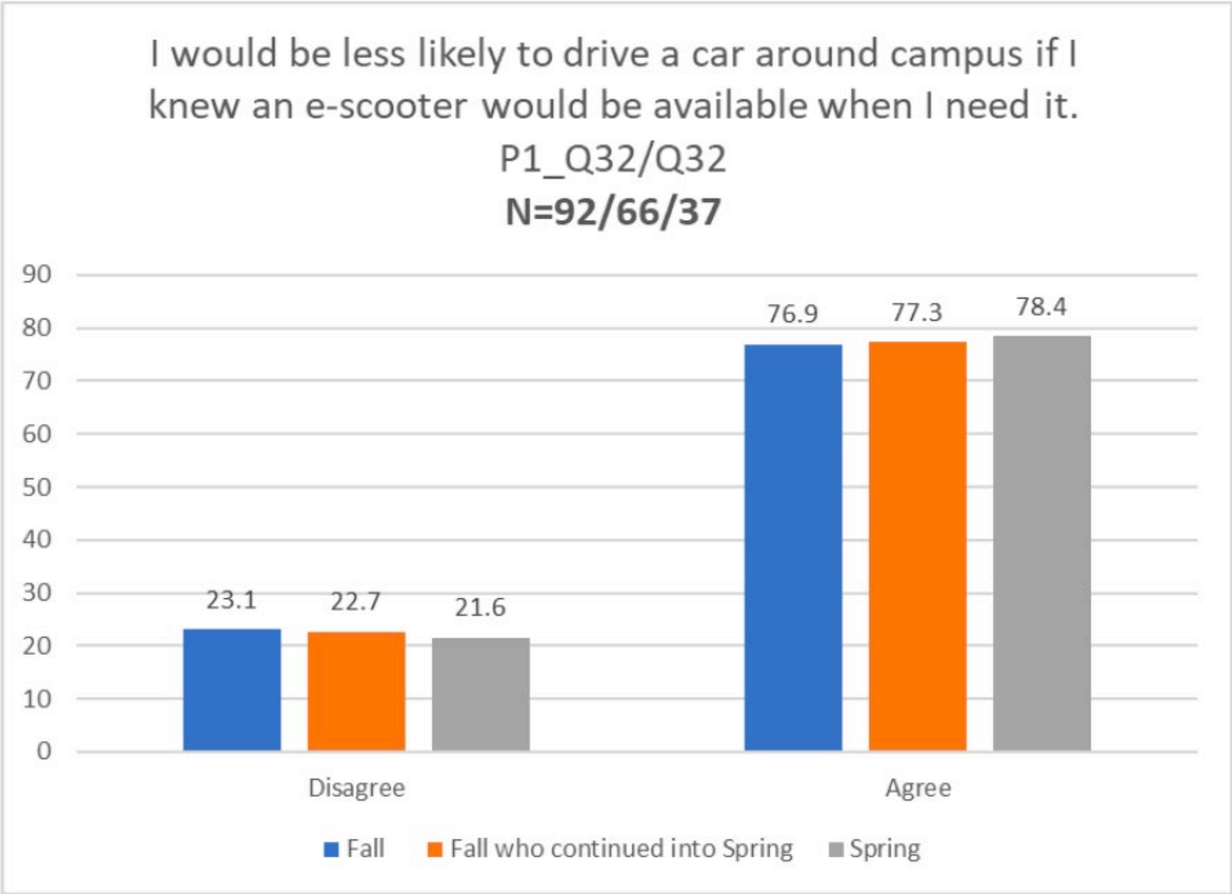

How important are these system qualities to you as an e-scooter user:
Availability of a free helmet
P1_Q26_6/Q26_6
N=93/65
40
30
20
10
0
35.5
32.4
19.4
17.7
9.7
13.2
7.5
7.4
6.5
7.4
11.8
10.3
5.4
5.9
4.3
5.9
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

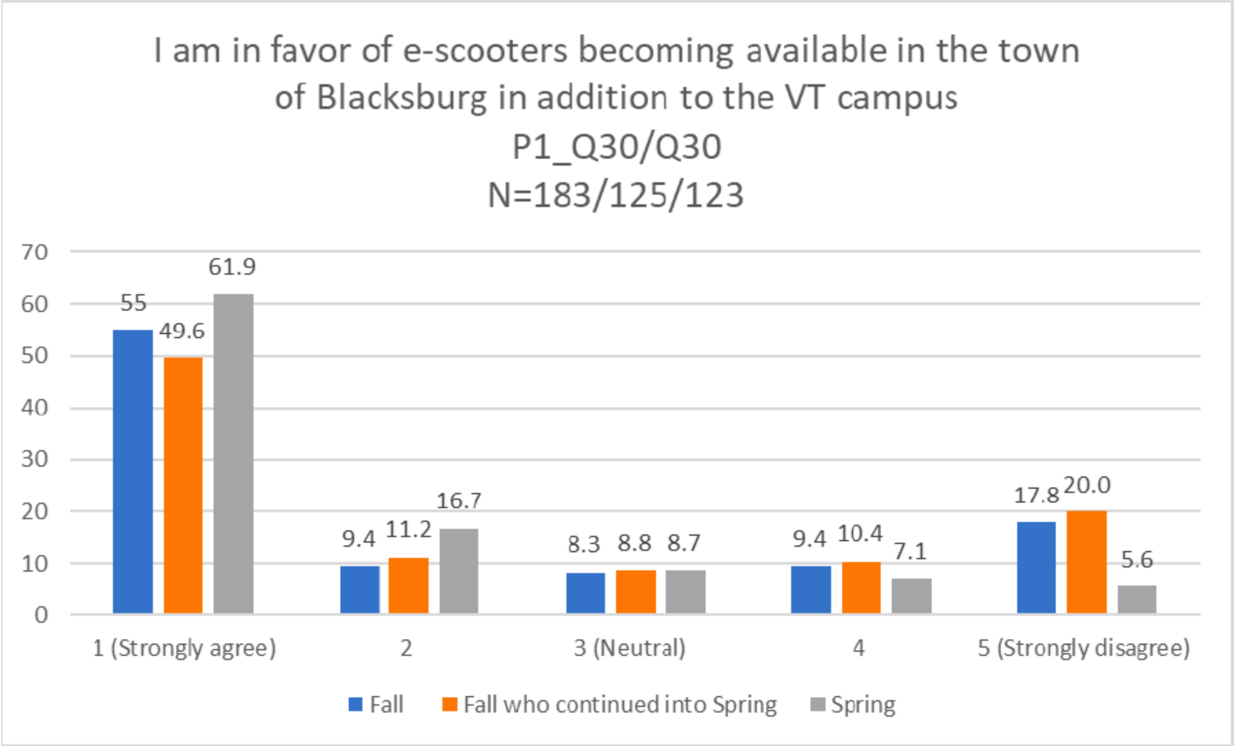

How important are these system qualities to you as an e-scooter user:
Cost/Affordability
P1_Q26_7/Q26_7
N=93/65
60
50
40
30
20
10
0
2.2
1.1
2.9
2.2
1.5
2.2
2.9
7.5
8.8
6.5
8.8
21.5
22.1
57.0
52.9
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring

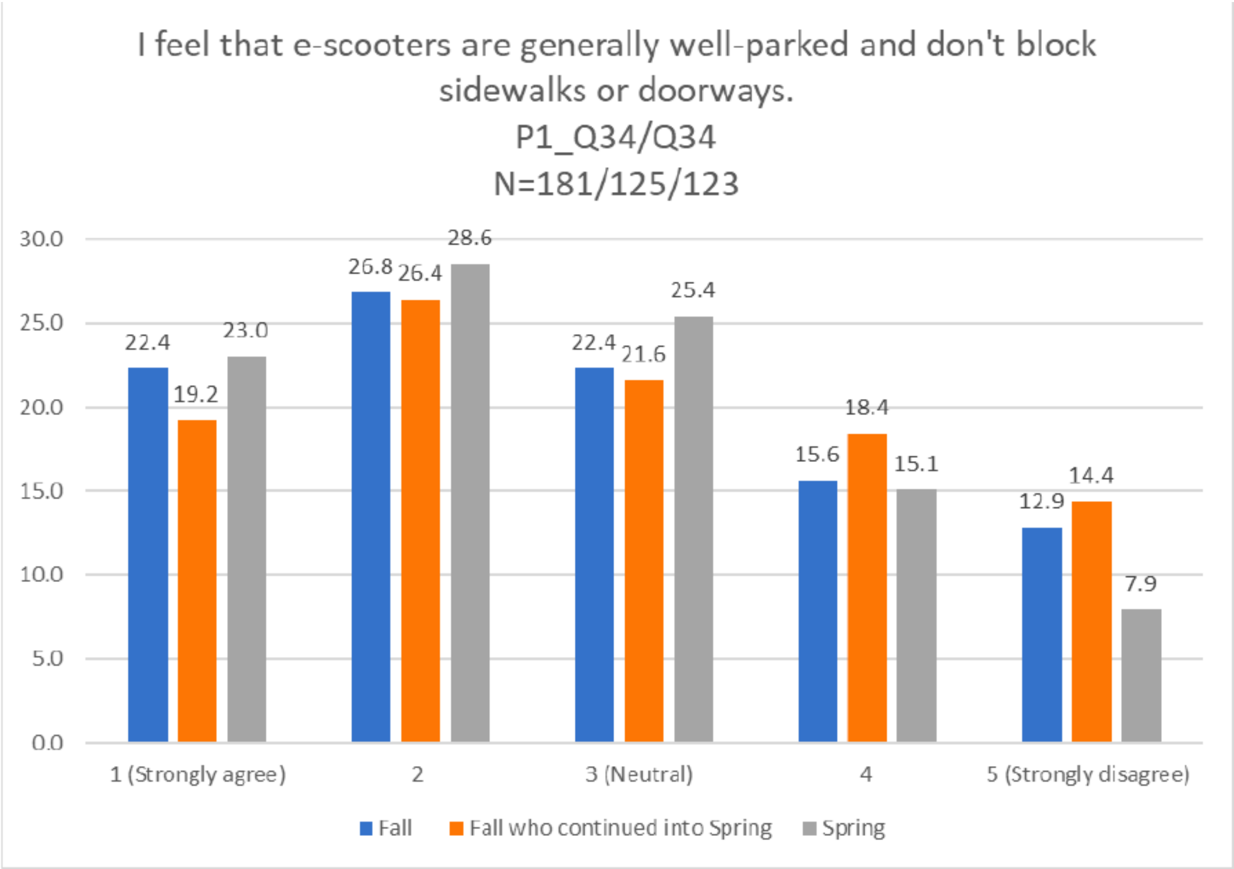

How important are these system qualities to you as an e-scooter user:
Fun/Riding
P1_Q26_8/Q26_8
N=93/64
30
25
20
15
10
5
0
18.5
9.0
28.3
7.5
6.5
6.0
6.5
4.5
6.5
11.9
4.4
20.9
12.0
11.9
17.4
28.4
1=Least Important
2
3
4
5
6
7
8=Most Improtant
Fall
Fall who continued into Spring


Thinking about your most recent e-scooter trip on the VT campus, why did you choose to ride an e-scooter? (select all that apply)
P1_Q27/Q27
30.0
25.0
20.0
15.0
10.0
5.0
0.0
6.5 7.0 5.0
8.1 8.3 6.6
25.7 24.6 28.1
10.4 10.1 11.6
3.6 3.9 5.8
1.6 1.8 4.1
3.3 3.1 3.3
0.7 0.9 0.8
19.2 18.4 17.4
1.0 9.6 7.4
8.8 0.9 1.7
6.8 6.6 7.4
4.2 4.8 0.8
No access to a car
Car parking is difficult
It is the fastest option
Don't want to get sweaty
It's less polluting/more environmentally friendly
It's less expensive than other ways to get there
It's new and I want to try one out
No bike-share available where/when I need them
It's fun
No buses available at the time/destination I need them
My friends would want to ride it
Hills make walking difficult or I hate walking up hills
Other, please specify:
Fall
Fall who continued into Spring
Spring

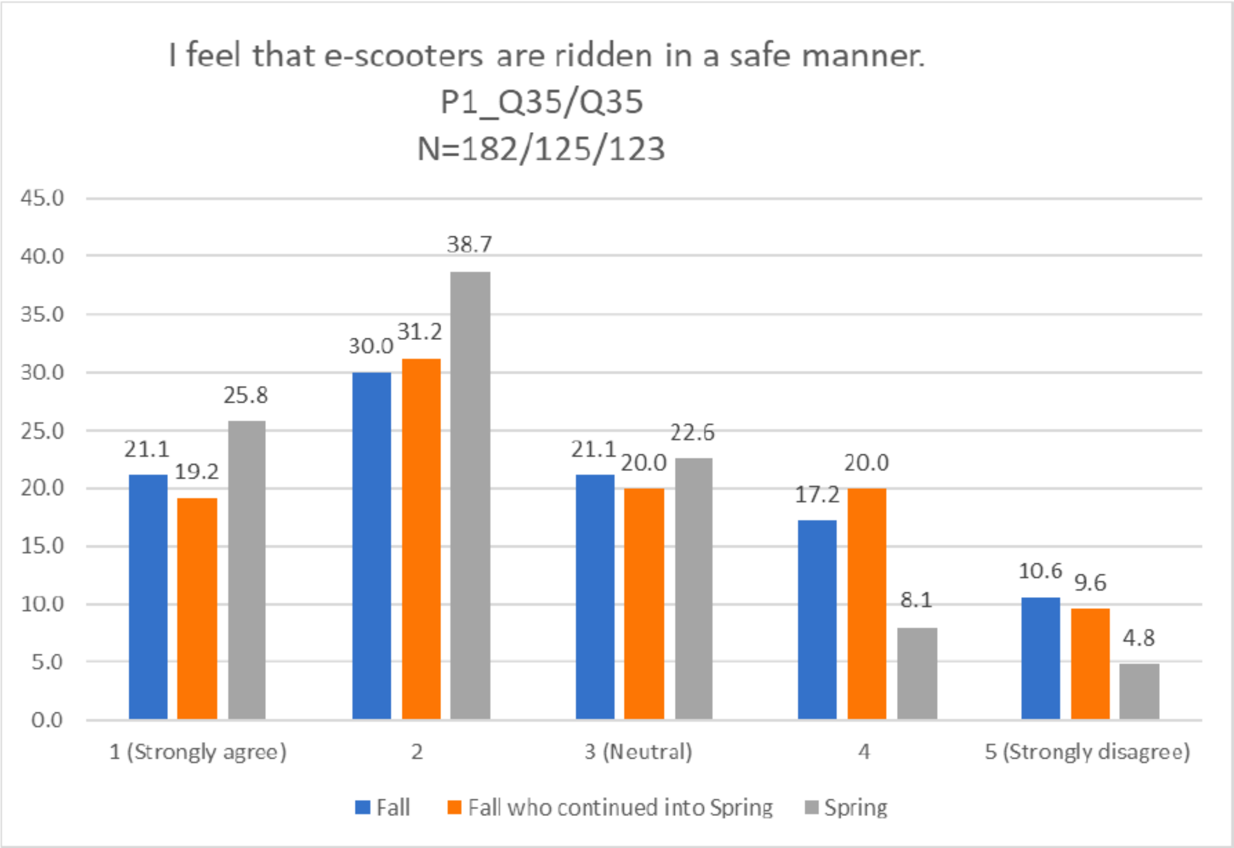

Please rate the extent to which you agree or disagree with the following statements about your mental health and riding an e-scooter - I feel good about using environmentally friendly modes of transportation (like e-scooter)
P1_Q38_10/Q38_10
N=91/66/37
60
50
40
30
20
10
0
3.3 4.6 2.7
2.2 3.0 2.7
16.5 12.1 16.2
46.2 47.0 54.1
31.9 33.3 24.3
Strongly Disagree
Disagree
Neither Agree nor Disagree
Agree
Strongly Agree
Fall
Fall who continued into Spring
Spring

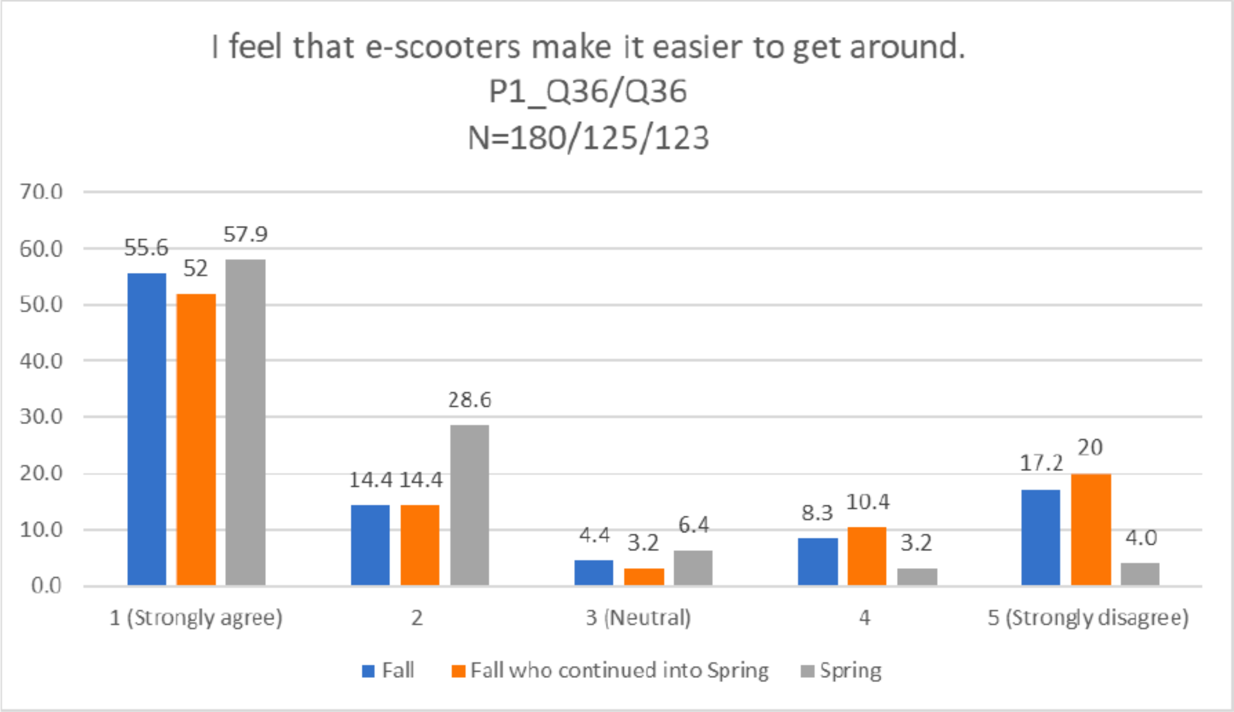

I would be less likely to drive a car around campus if I knew an e-scooter would be available when I need it.
P1_Q32/Q32
N=92/66/37
90
80
70
60
50
40
30
20
10
0
23.1
22.7
21.6
76.9
77.3
78.4
Disagree
Agree
Fall
Fall who continued into Spring
Spring

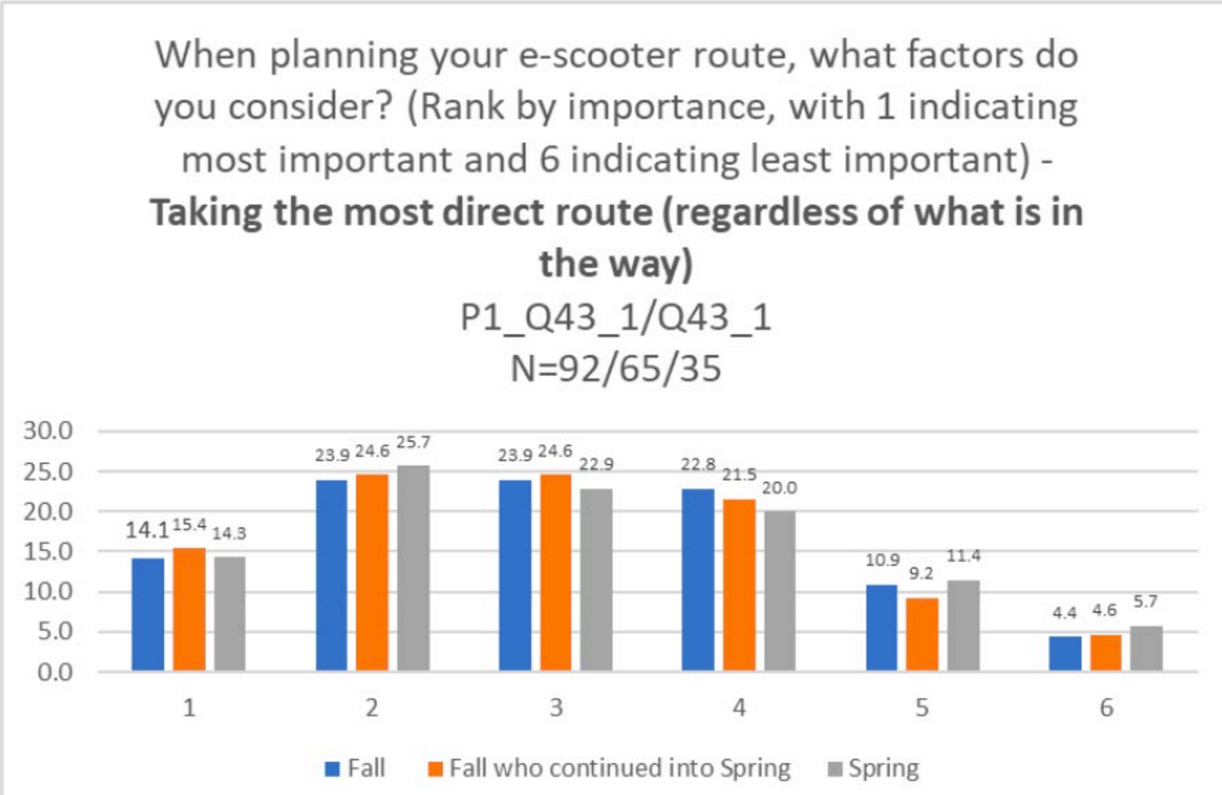

I am in favor of e-scooters becoming available in the town of Blacksburg in addition to the VT campus
P1_Q30/Q30
N=183/125/123
70
60
50
40
30
20
10
0
55
49.6
61.9
9.4
11.2
16.7
8.3
8.8
8.7
9.4
10.4
7.1
17.8
20.0
5.6
1 (Strongly agree)
2
3 (Neutral)
4
5 (Strongly disagree)
Fall
Fall who continued into Spring
Spring

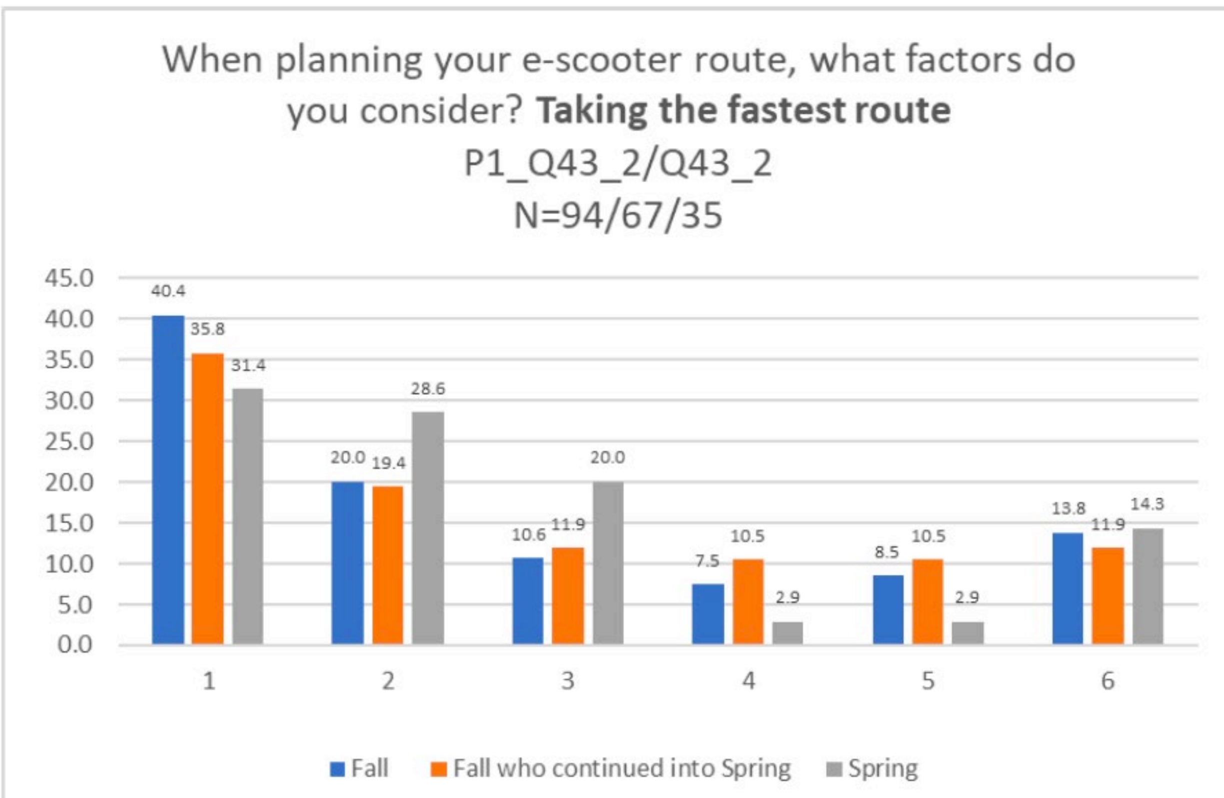


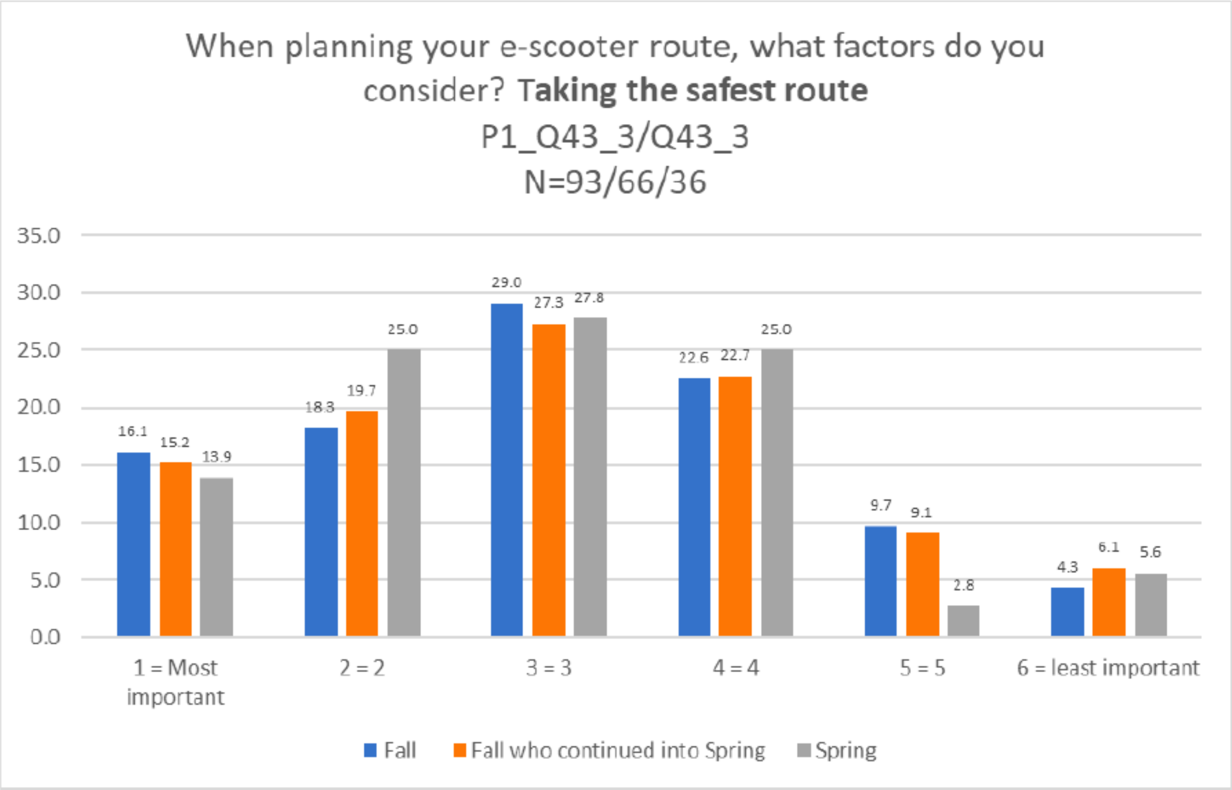
I feel that e-scooters are generally well-parked and don't block sidewalks or doorways.
P1_Q34/Q34
N=181/125/123
30.0
25.0
20.0
15.0
10.0
5.0
0.0
22.4
19.2
23.0
26.8
26.4
28.6
22.4
21.6
25.4
15.6
18.4
15.1
12.9
14.4
7.9
1 (Strongly agree)
2
3 (Neutral)
4
5 (Strongly disagree)
Fall
Fall who continued into Spring
Spring

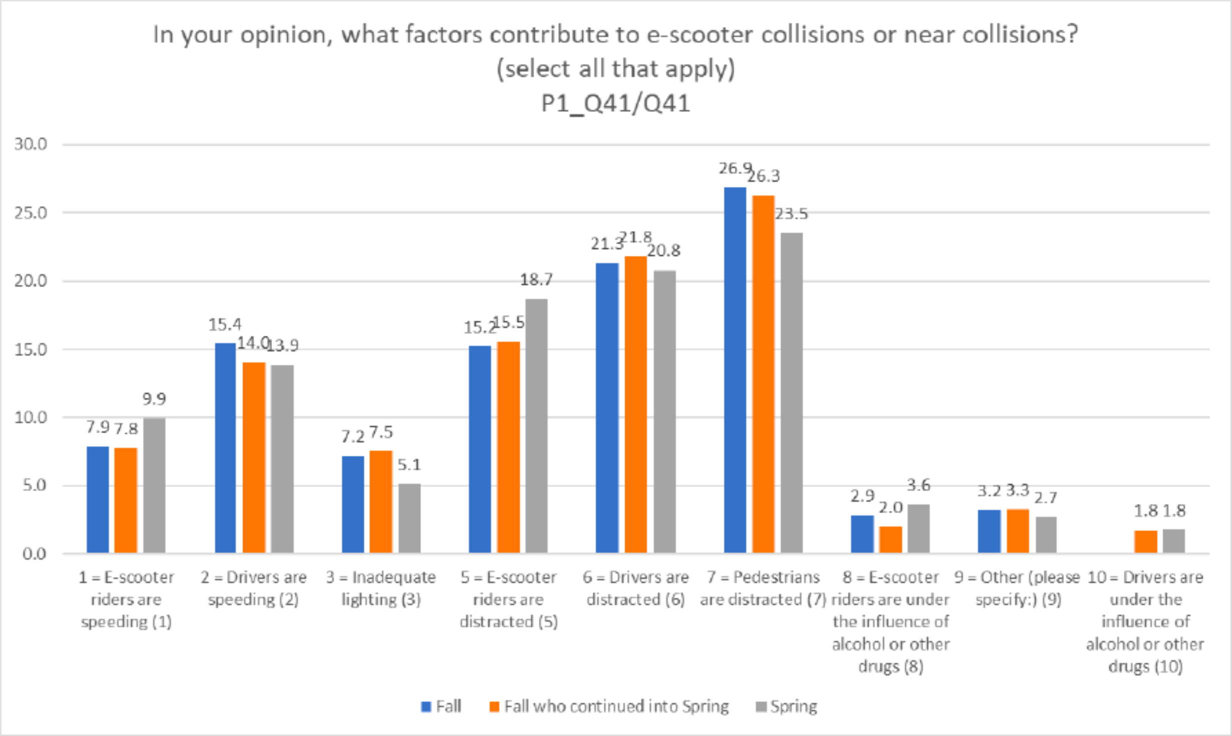

I feel that e-scooters are ridden in a safe manner.
P1_Q35/Q35
N=182/125/123
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21.1
19.2
25.8
30.0
31.2
38.7
21.1
20.0
22.6
17.2
20.0
8.1
10.6
9.6
4.8
1 (Strongly agree)
2
3 (Neutral)
4
5 (Strongly disagree)
Fall
Fall who continued into Spring
Spring

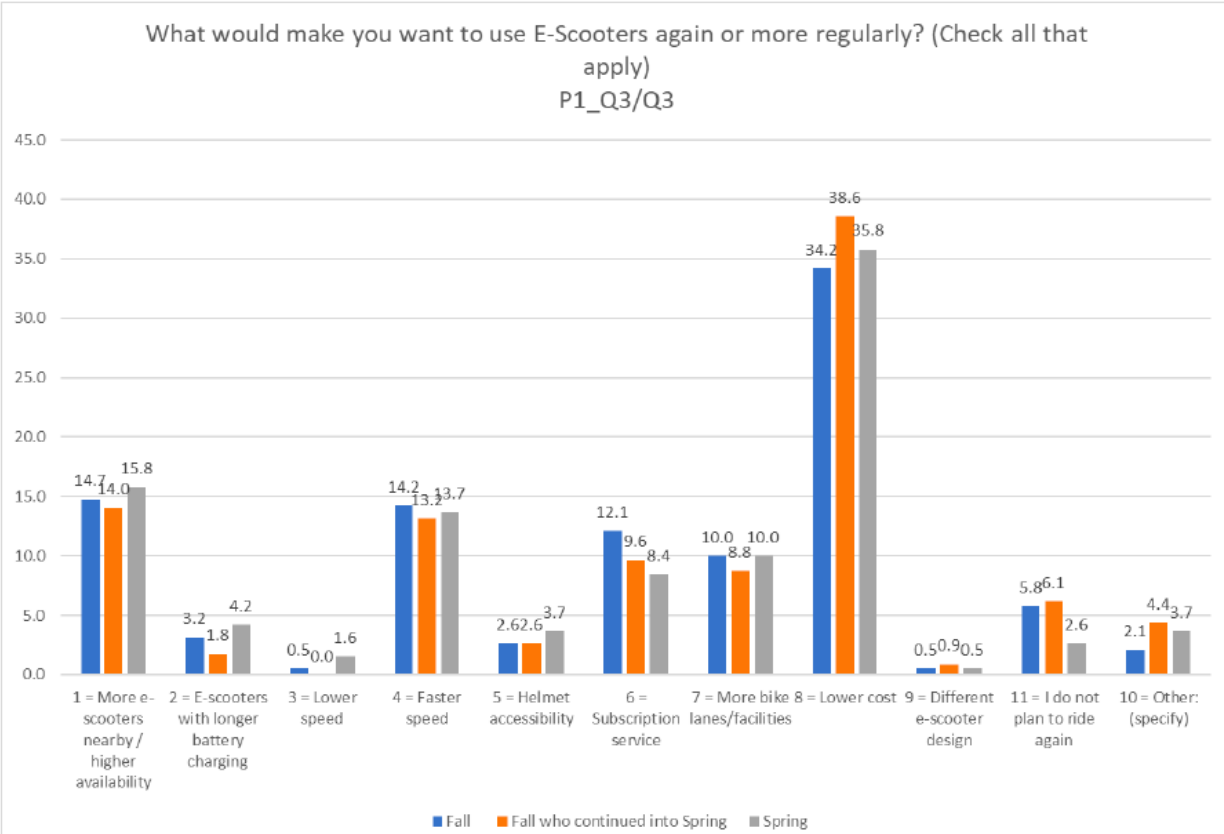

I feel that e-scooters make it easier to get around.
P1_Q36/Q36
N=180/125/123
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
55.6
52
57.9
14.4
14.4
28.6
4.4
3.2
6.4
8.3
10.4
3.2
17.2
20
4.0
1 (Strongly agree)
2
3 (Neutral)
4
5 (Strongly disagree)
Fall
Fall who continued into Spring
Spring

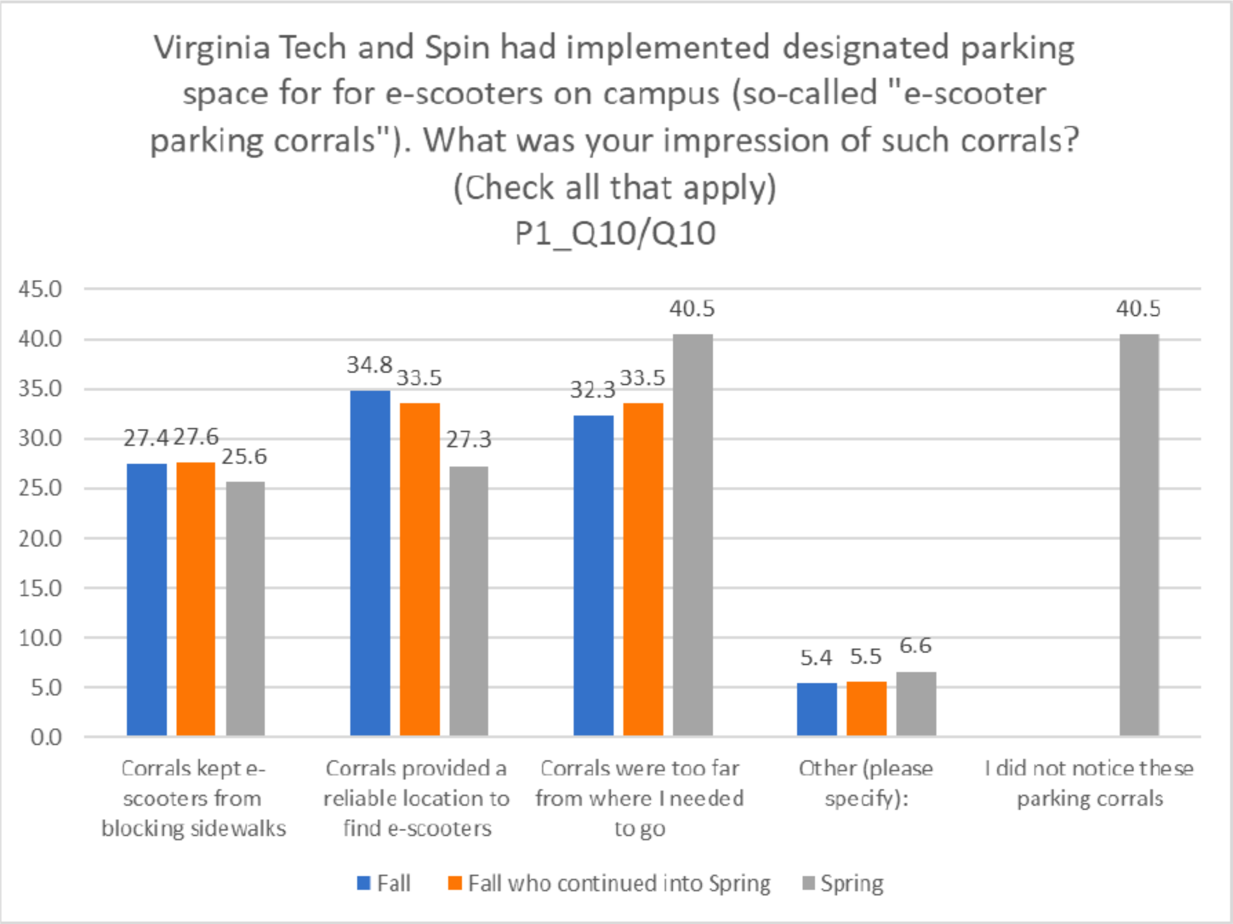

When planning your e-scooter route, what factors do you consider? (Rank by importance, with 1 indicating most important and 6 indicating least important) - **Taking the most direct route (regardless of what is in the way)**
P1_Q43_1/Q43_1
N=92/65/35
30.0
25.0
20.0
15.0
10.0
5.0
0.0
14.1 15.4 14.3
23.9 24.6 25.7
23.9 24.6 22.9
22.8 21.5 20.0
10.9 9.2 11.4
4.4 4.6 5.7
1 2 3 4 5 6
Fall
Fall who continued into Spring
Spring


When planning your e-scooter route, what factors do you consider? **Taking the fastest route**
P1_Q43_2/Q43_2
N=94/67/35
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
40.4 35.8 31.4
20.0 19.4 28.6
10.6 11.9 20.0
7.5 10.5 2.9
8.5 10.5 2.9
13.8 11.9 14.3
1 2 3 4 5 6
Fall
Fall who continued into Spring
Spring

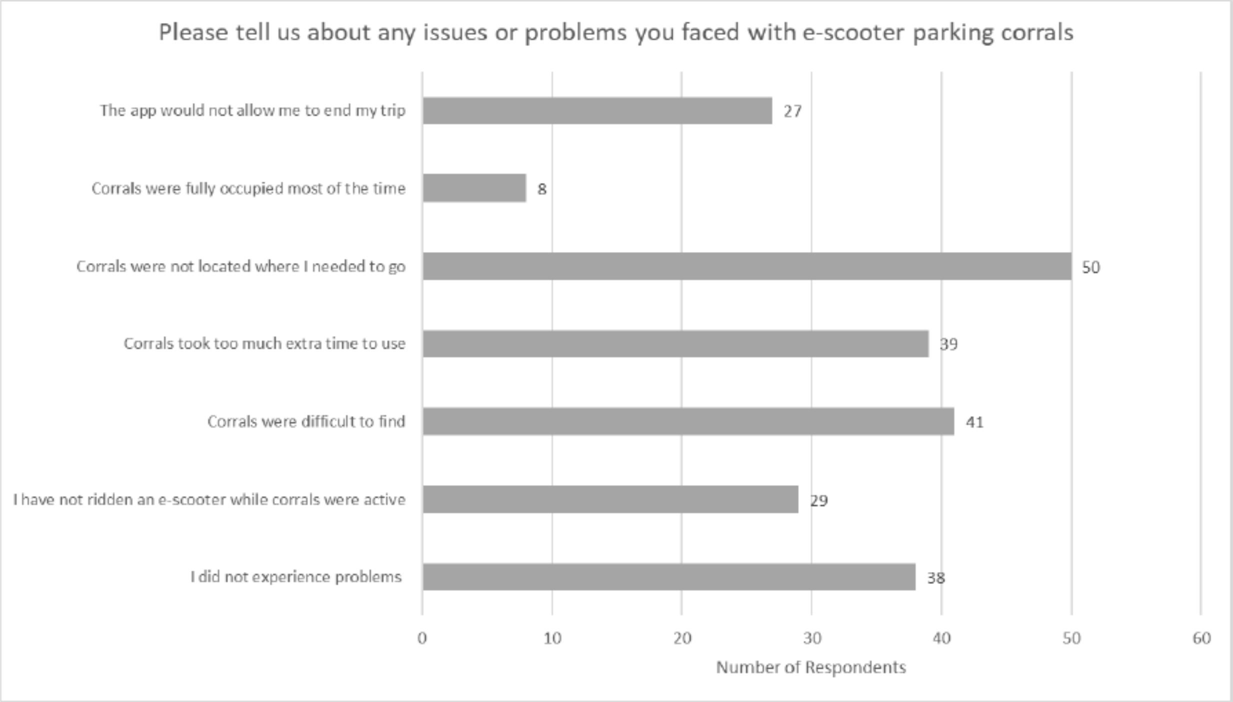

When planning your e-scooter route, what factors do you consider? Taking the safest route
P1_Q43_3/Q43_3
N=93/66/36
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
16.1
15.2
13.9
18.3
19.7
25.0
29.0
27.3
27.8
22.6
22.7
25.0
9.7
9.1
2.8
4.3
6.1
5.6
1 = Most important
2 = 2
3 = 3
4 = 4
5 = 5
6 = least important
Fall
Fall who continued into Spring
Spring


In your opinion, what factors contribute to e-scooter collisions or near collisions? (select all that apply)
P1_Q41/Q41
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7.9
7.8
9.9
15.4
14.0
13.9
7.2
7.5
5.1
15.2
15.5
18.7
21.3
21.8
20.8
26.9
26.3
23.5
2.9
2.0
3.6
3.2
3.3
2.7
1.8
1.8
1 = E-scooter riders are speeding (1)
2 = Drivers are speeding (2)
3 = Inadequate lighting (3)
5 = E-scooter riders are distracted (5)
6 = Drivers are distracted (6)
7 = Pedestrians are distracted (7)
8 = E-scooter riders are under the influence of alcohol or other drugs (8)
9 = Other (please specify:) (9)
10 = Drivers are under the influence of alcohol or other drugs (10)
Fall
Fall who continued into Spring
Spring


What would make you want to use E-Scooters again or more regularly? (Check all that apply)
P1_Q3/Q3
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
14.7
14.0
15.8
3.2
1.8
4.2
0.5
0.0
1.6
14.2
13.2
13.7
2.6
2.6
3.7
12.1
9.6
8.4
10.0
8.8
10.0
34.2
38.6
35.8
0.5
0.9
0.5
5.8
6.1
2.6
2.1
4.4
3.7
1 = More e-scooters nearby / higher availability
2 = E-scooters with longer battery charging
3 = Lower speed
4 = Faster speed
5 = Helmet accessibility
6 = Subscription service
7 = More bike lanes/facilities
8 = Lower cost
9 = Different e-scooter design
11 = I do not plan to ride again
10 = Other: (specify)
Fall
Fall who continued into Spring
Spring



Virginia Tech and Spin had implemented designated parking space for for e-scooters on campus (so-called "e-scooter parking corrals"). What was your impression of such corrals? (Check all that apply)
P1_Q10/Q10
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27.4
27.6
25.6
34.8
33.5
27.3
32.3
33.5
40.5
5.4
5.5
6.6
40.5
Corrals kept e-scooters from blocking sidewalks
Corrals provided a reliable location to find e-scooters
Corrals were too far from where I needed to go
Other (please specify):
I did not notice these parking corrals
Fall
Fall who continued into Spring
Spring



Please tell us about any issues or problems you faced with e-scooter parking corrals
The app would not allow me to end my trip
27
Corrals were fully occupied most of the time
8
Corrals were not located where I needed to go
50
Corrals took too much extra time to use
39
Corrals were difficult to find
41
I have not ridden an e-scooter while corrals were active
29
I did not experience problems
38
0
10
20
30
40
50
60
Number of Respondents