An Evaluation of Road User Interactions with E-Scooters

June 2022 | Final Report

SAFE-D
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16. Abstract

Electric scooters (e-scooters) are gaining popularity due to availability, accessibility, and low cost. However, there has been little research on how e-scooters behave on the road and interact with other road users. The Virginia Tech Transportation Institute, teaming with State Farm, conducted an observational study on the Virginia Tech campus. Video data were gathered through instrumented fixed cameras located at various intersections and high-volume pedestrian areas. The analysis focused on times with a high volume of e-scooter riders, which was the period from 10:00 a.m. to 4:00 p.m. A total of 492 e-scooter trips were recorded, and 473 of those were analyzed. The analysis showed that e-scooters pose the most threat to pedestrians due to their higher speed and the greater vulnerability of pedestrians. The results also showed that the e-scooter riders adjusted their operation rules based on the traffic environment. These results suggest it might be safer to operate e-scooters in designated lanes, bike lanes, or on roadways with a speed limit of 25 mph or less. Additional countermeasures to separate e-scooter traffic from vehicles may be required on roadways with faster speed limits. Further research is needed to confirm these recommendations.

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Abstract

Electric scooters (e-scooters) are gaining popularity due to availability, accessibility, and low cost. However, there has been little research on how e-scooters behave on the road and interact with other road users. The Virginia Tech Transportation Institute, teaming with State Farm, conducted an observational study on the Virginia Tech campus. Video data were gathered through instrumented fixed cameras located at various intersections and high-volume pedestrian areas. The analysis focused on times with a high volume of e-scooter riders, which was the period from 10:00 a.m. to 4:00 p.m. A total of 492 e-scooter trips were recorded, and 473 of those were analyzed. The analysis showed that e-scooters pose the most threat to pedestrians due to their higher speed and the greater vulnerability of pedestrians. The results also showed that the e-scooter riders adjusted their operation rules based on the traffic environment. These results suggest it might be safer to operate e-scooters in designated lanes, bike lanes, or on roadways with a speed limit of 25 mph or less. Additional countermeasures to separate e-scooter traffic from vehicles may be required on roadways with faster speed limits. Further research is needed to confirm these recommendations.

Acknowledgements

This project was funded by the Safety through Disruption (Safe-D) National University Transportation Center, a grant from the U.S. Department of Transportation – Office of the Assistant Secretary for Research and Technology, University Transportation Centers Program. The research team would also like to thank Julie McCafferty, Stuart Walker, Michael Buckley for their contribution to the research project.

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Introduction

Our transportation system has been expanding to offer new options, especially for first- and last-mile services, which allow users to go directly from their homes to a mass transit option and from a mass transit stop to their final destination. Many users rely on micro-transit options for their first- and last-mile solutions. Thus, micro-transit options, such as electric scooters (e-scooters), are becoming more widely available in many urban and university communities. Besides being a viable solution for first- and last-mile service, these options can also provide transit within a geographic area that may be difficult for pedestrians to traverse (e.g., steep grades or long distances). For example, several companies have deployed sharable e-scooters on different college campuses across America.

Despite e-scooters being a booming industry, legislation and regulations regarding the safe operation of e-scooters have yet to be developed. Only a few U.S. cities have current rules on the operating environment and other safety requirements for e-scooters. For this reason, the mixed traffic conditions in which e-scooters are operated have raised concerns regarding the safety of both the riders and other road users with whom they interact.

For research related to e-scooter related injuries, Sikka et al. (2019) conducted a case study of e-scooter-related pedestrian injury. Their review of the current literature identified a general lack of research regarding the impact introducing e-scooters has on pedestrians and other road users. However, some preliminary analysis indicated that 8.4% of all e-scooter-related injuries were from pedestrians injured by e-scooter riders (Trivedi et al., 2019). Furthermore, another study identified that a large portion of e-scooter-related injuries (52%) happen on the sidewalk (Cicchino et al., 2021). Current results from naturalistic driving studies have also confirmed that e-scooters can pose a threat to pedestrians when being ridden on sidewalks, as they can come very close to pedestrians and are generally faster (Cicchino et al., 2021). From these results, it can be inferred that e-scooters can pose a threat when ridden near pedestrians.

To address the research gap in the new field of e-scooters, the Virginia Tech Transportation Institute (VTTI) has been collaborating with State Farm Mutual Automobile Insurance to conduct a safety study of e-scooters as they have been deployed on the Virginia Tech (VT) campus by Spin™ (Figure 1). As part of this safety study, continuous video data at fixed camera locations around the VT campus were collected by VTTI to assess e-scooter interactions with other road users, including pedestrians.

Each Spin scooter is approximately 31 pounds in weight, has 40 miles of range on a single charge, and is limited to a maximum speed of 15 miles per hour. The scooters are geofenced, and thus are operational only on university grounds and during daytime (7 a.m./half an hour sunset). They are also not available during raining or snowy weather or during large sporting events that would significantly increase pedestrian traffic on campus. Currently there is a total of 200 Spin scooters operating on the VT campus. Spin offers free helmets for all registered users of their e-scooter system, both on campus and through their website.

Figure 1. Photo. Spin e-scooter (from actual deployment).

Currently, the only regulation regarding the operating location of e-scooters in the State of Virginia is that they are banned on the highway. Additionally, regulations cap top speed at 20 miles per hour, and weight must be 100 pounds or less.

Purpose and Scope

The results documented in this report represent an evaluation of e-scooter behaviors on the VT campus between March 2019 and November 2019. In addition, these results provide a summary and analysis of e-scooter riding behaviors and interactions between e-scooters and other road users, including pedestrians. The purpose of this research project was to investigate the severity and distribution of safety-critical interactions between the e-scooter and other road users, along with the prevalence of safety behaviors for e-scooter riders. The primary interests were:

- investigating safety device implementation during e-scooter riding;
- understanding e-scooter behavior at different riding locations; and
- understanding the mode and safety limits of e-scooter interactions with other road users, with a special emphasis on motorized vehicles.

Method

In this study, the VTTI research team was responsible for the following tasks:

1. Instrumenting the selected locations for data collection with fixed cameras.
2. Obtaining and compiling data to identify three different event types of interest.
3. Performing video coding on these events and risk analysis based on the coded data.

Location Selection and Instrumentation

A total of 14 locations were selected to equip with fixed cameras based on the infrastructure elements present. Of these 14 locations (Figure 2), seven were chosen for analysis based on the number of trips recorded by the fixed cameras and on the roadway configuration, as the purpose of the study was to concentrate on e-scooter interactions with other road users. The seven selected sites contained sidewalks, crosswalks, bike lanes, shared lanes, stop-sign-controlled intersections, and pedestrian areas. The selected fixed camera locations were Ambler Johnston Hall East-Wing, Burruss Hall, Kelly Hall, McComas Hall, Newman Library, Old Security Building, and Squires Student Center (Figure 3 through Figure 9). A note of interest is that the camera views from the Kelly and Old Security locations capture the same intersection from two different angles. The details for each location and the exact camera views for each location are shown below.

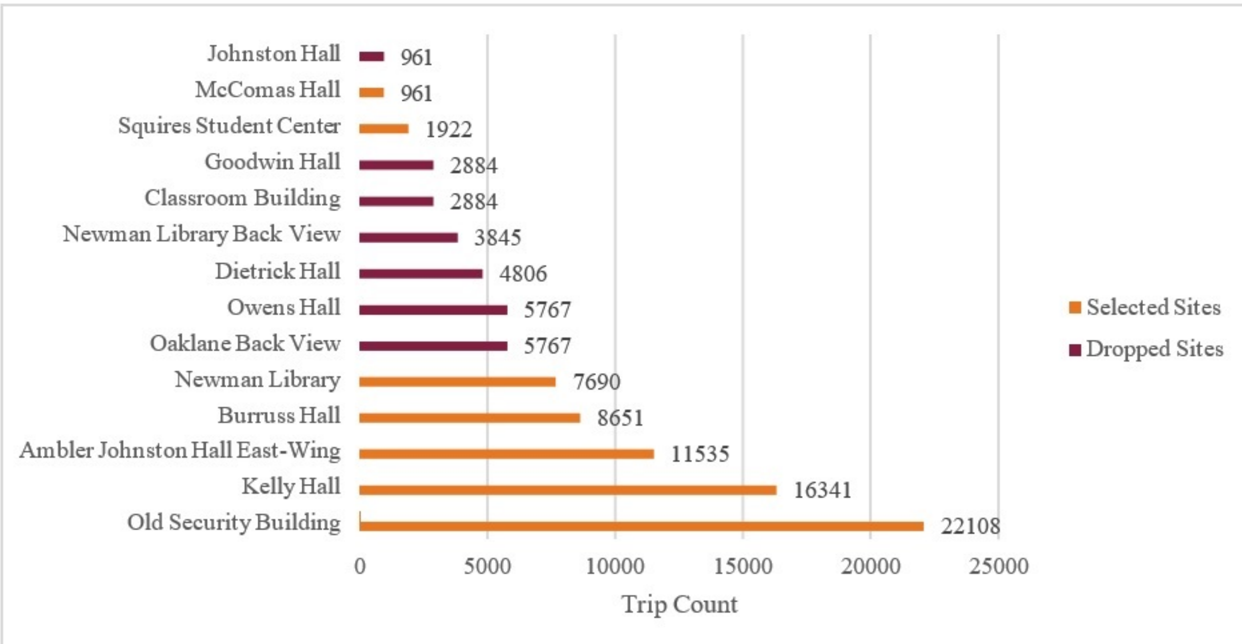

Figure 2. Bar graph. Number of trips captured at each fixed camera location (orange indicates selected sites and maroon indicates dropped sites).

Figure 3. Photo. Camera view at Ambler Johnston Hall East-Wing location.

Figure 4. Photo. Camera view at Kelly Hall location.

Figure 5. Photo. Camera view at Burruss Hall location.

Figure 6. Photo. Camera view at Old Security Building location.

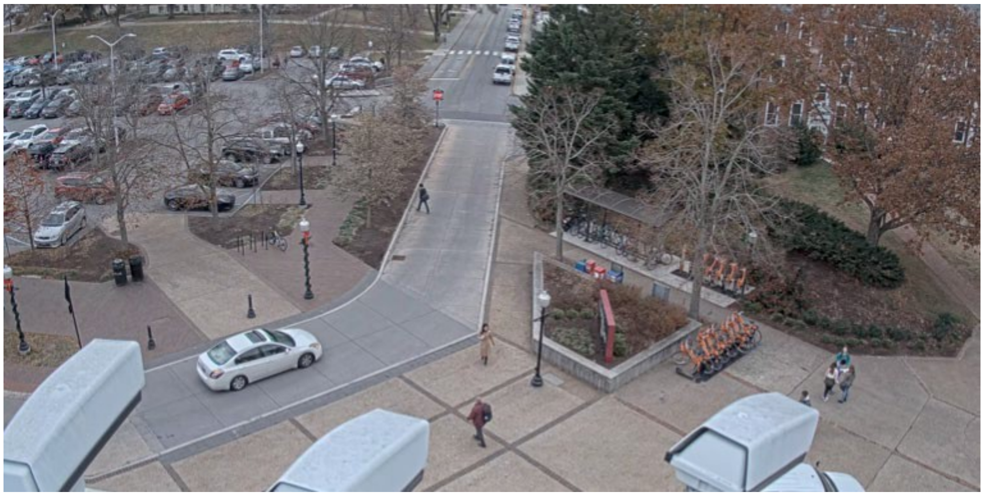

Figure 7. Photo. Camera view at Squires Student Center location.

Figure 8. Photo. Camera view at McComas Hall location.

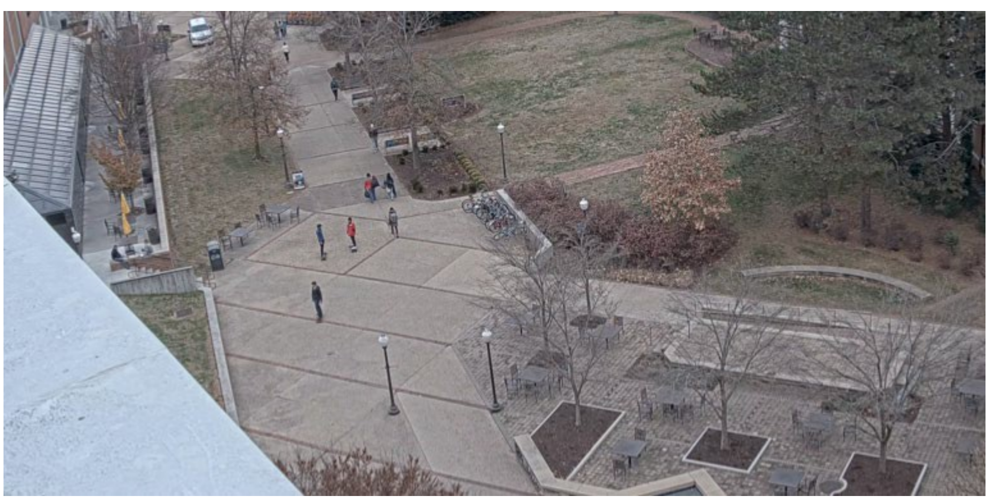

Figure 9. Photo. Camera view at Newman Library location.

For each camera location, infrastructure elements were color coded similarly to the example in Figure 10. The color coding allows the data reductionists to identify some infrastructure variables more accurately and allows the research team to better understand how e-scooters interact with different infrastructure elements.

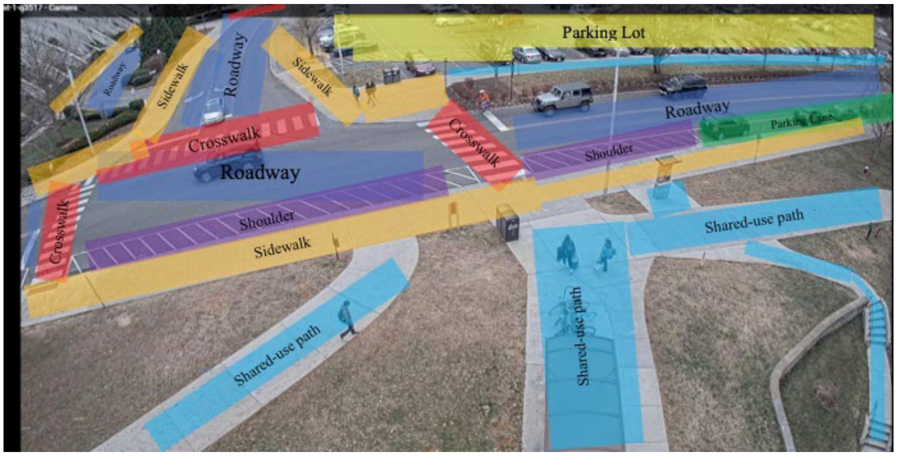

Figure 10. Photo with color labels. Color-coded infrastructure elements at camera location Ambler Johnston Hall East-Wing.

Sample Trip Selection

A fixed camera was installed for each of the selected locations to observe e-scooter movements. Due to instrumental limitations, each fixed camera location could provide only bird's-eye views of the e-scooter movements, which thus limited the amount of detail that video reduction could catch. Each of the e-scooters was equipped with a trackable GPS unit, which is how cameras could identify when an e-scooter passed across their visual field. Because camera views at Old Security Building and Kelly Hall capture the same intersection, duplicated trips captured by both cameras were only counted once for sample selection purposes.

A frequency analysis of e-scooter trips by time of day was conducted, and the results indicated that e-scooters are most active during regular class hours, between 10 a.m. and 4 p.m. (shown in Figure 11). Additionally, as this study focused on interactions between e-scooters and motor vehicles, traffic density was also determined to be higher during these hours. Thus, only trips during this time frame were considered to best represent normal e-scooter usage and capture higher road user density on a college campus. However, as Figure 11 shows, there was also a peak of e-scooter trips from 8 p.m. to 11 p.m., which is after the operation time of e-scooters. This peak is due to the moving and organizing of e-scooters for maintenance purposes after regular operating hours. The researchers would also like to point out that a different time frame when riders are not influenced by the constraint of getting to class on time may yield other behaviors than those reported here and thus may be beneficial for investigating e-scooter misuses and misbehaviors.

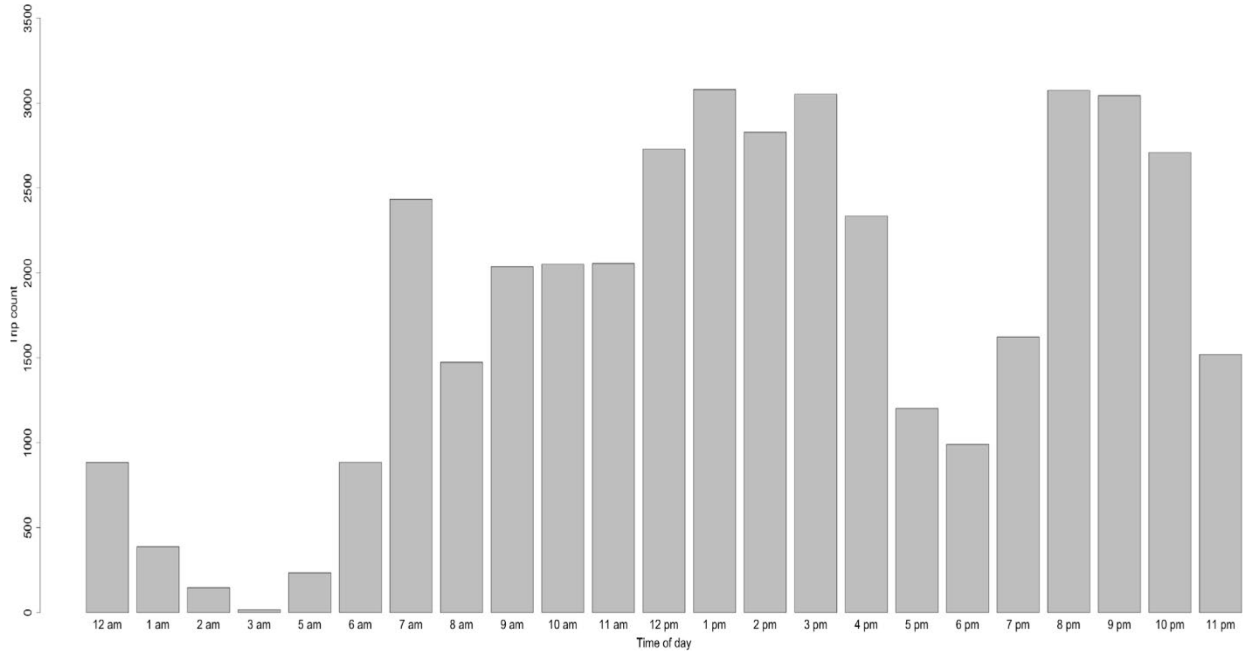

Figure 11. Bar graph. Number of e-scooter trips by the time of day.

Event Type Definition and Coding Procedure

Data were recorded continuously at these seven fixed location cameras. However, given that it was impossible to review every second of the continuous video, specific segments of video that were 10 seconds long were selected for review by trained data coders.

The coding consisted of three main scenario protocols: control baseline, interaction, and conflict scenarios. Since there was no applicable method to identify conflicts or interaction scenarios a priori from the fixed camera dataset, these were identified by trained data coders during the process of coding the control baseline scenarios. If a trained data coder recognized an interaction with another road user and/or a safety-critical conflict during the baseline coding, they would perform additional coding to capture these two additional scenarios.

Control baseline scenarios were determined to be 10 seconds long based on initial evaluations of the collected video data and randomly sampled with stratification for the time of day (providing an implied road user density) and fixed camera location, as described above. A control baseline scenario was defined as a period when an e-scooter travels through the camera's view without having any conflicts or interactions with any road user or road elements. These "normal" e-scooter riding epochs served as control baseline scenarios during the analysis. In some cases, the referenced scooter was visible for longer than 10 seconds, and in other cases, it may have left the camera field for part of the 10 seconds. The assessment included the period during which the referenced scooter was visible within the sampled window (up to a maximum of 10 seconds). A valid sample for the purpose of this coding must consist of at least 3 seconds of visible referenced e-scooter movement. Any sample where the e-scooter remained stationary for more than 7 of the 10 seconds or was not visible (e.g., out of camera field) for more than 7 of the 10 seconds was not considered and was resampled.

Interaction scenarios were coded when another road user or traffic element came within a certain radius of the referenced e-scooter rider. The research team, along with the data reduction team, reviewed several videos to operationally define an "interaction" between an e-scooter rider and another road user. The team assessed multiple interactions using the video and operationally defined a set distance between e-scooters and other road users that constituted an interaction. Then, the radius was determined accordingly to the assessment. The radius requirement for different types of road users is listed in Table 1. A count of all interactions within the sample was provided, and up to three interactions were further analyzed for each sample. Interactions were coded separately due to their proximity to potential safety-critical events.

Table 1. Interaction Radius Definition

Traffic Element	Interaction Radius
Motorized road users (vehicles, motorcycles, etc.)	4 ft
Unmotorized road users, Type A (potentially higher speed users such as bicycles, e-scooters, e-skateboards, etc.)	3 ft
Unmotorized road users, Type B (low-speed users such as pedestrians, push skateboards, etc.)	2 ft
Permanent road/infrastructure elements (road sign, bike rack, post, pothole, curb, etc.)	Physical contact
Moveable road/infrastructure elements	Physical contact

A conflict scenario is defined as a safety-critical interaction with another road user or roadway element. Conflicts include both crashes and near-crashes (non-crash conflicts). These are incidents where one of the following occurs:

- The scooter rider falls or nearly falls over.
- The scooter rider swerves or stops abruptly to avoid a crash.
- The scooter rider causes another vehicle or pedestrian to swerve or stop abruptly to avoid a crash.
- The scooter rider has physical contact with any object, vehicle, or person.

Event Coding Variables

The video collected allowed trained data coders at VTTI to review the video surrounding the event of interest and identify potential contributing factors, environmental conditions, and the role of other road users. As mentioned above, three potential scenario protocols were included in the coding procedure: control baseline protocol, road user interaction protocol, and conflict scenario protocol. The variables that were coded as part of this reduction are listed in Table 2. The complete data coding protocol that the data coders followed is available in the Appendix: Reduction Protocol.

Table 2. Reduction Variables Definitions

Variable	Definition
1. Rider Gender	Gender of the referenced scooter rider
2. Rider Age	Estimated age group of the referenced scooter rider
3. Rider Wearing Helmet	Is the referenced scooter rider wearing a helmet
4. Rider Wearing Bag	Is the referenced scooter rider wearing a backpack
5. Rider Wearing Electronics	Is the referenced scooter rider wearing/using headphones
6. Rider Phone Usage	Is the referenced scooter rider holding or using his/her phone
7. Rider Handheld Item	Is the referenced scooter rider carrying a handheld item
8. Rider Handlebar Item	Does the referenced scooter rider have an item hanging from or otherwise supported by the handlebars
9. Rider Hands	Number of hands rider has on the handlebars
10. Rider Riding Stance	Feet and body positioned on the scooter
11. Rider Riding Behavior	Trick riding/aggressive riding/multiple people on one scooter/traffic signal violation
12. Rider Riding Location	Where is the referenced scooter rider operating the scooter
13. Rider Riding Mode	What operating rules are the scooter rider following
14. Rider Group Size	Number of other e-scooters the referenced scooter is riding with
15. Surface Condition	Wet/dry/partially dry
If interaction occurred:	
16. Actor Type	Road user/element with which referenced scooter interacted
17. Rider Speed	Rider speed in relation to the other actor
18. Interaction Description	How is the referenced rider interacting with this other actor
If conflict occurred:	
19. Conflict Severity	If the interaction was a crash, near-crash, or critical incident
20. Precipitating Event	Rider action leading to the conflict
21. Conflict Type	Type of conflict (e.g., impact with vehicle)
22. Conflict Evasion	Which conflict partner(s) performed evasive maneuvers in attempt to avoid a crash
23. Conflict Role	Role of the referenced rider during conflict

Variable	Definition
24. Conflict Outcome	How did the referenced scooter(s) fall as a result of the conflict
25. Conflict Fault	Which conflict partner is at fault
26. Point of Impact	Other actor's position in relation to the referenced scooter during the conflict
27. Incident Notes	Text box where the coder could write anything additional that was not captured in the above coding protocol

For this study, a total of 492 e-scooter trips were identified, and 19 of those were removed due to the loss of data and visibility of the video. Among the 473 trips that went through video coding protocols, 72 interactions were identified, and 0 conflicts were present.

Results

Baseline Reduction Results

Rider Gender

Seventy-two percent of the riders were male, and 23% were female. The vast difference in rider gender may be due to different risk perceptions between the two genders but is hard to explain without further investigation. It is worth mentioning that the student population at VT contains 57% male and 43% female students, which has a significantly smaller gap compared to the difference in rider gender.

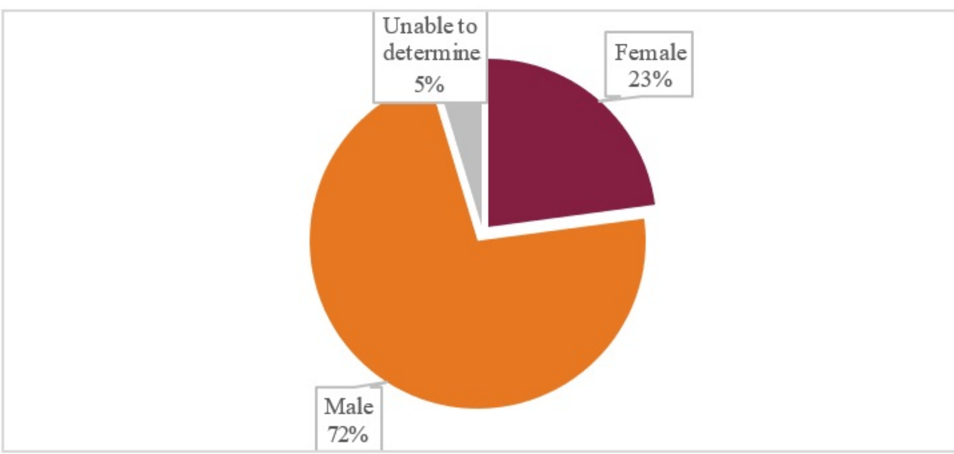

Figure 12. Pie chart. Gender distribution among e-scooter riders.

Rider Helmet Use

Most riders (96%) did not wear a helmet while riding.

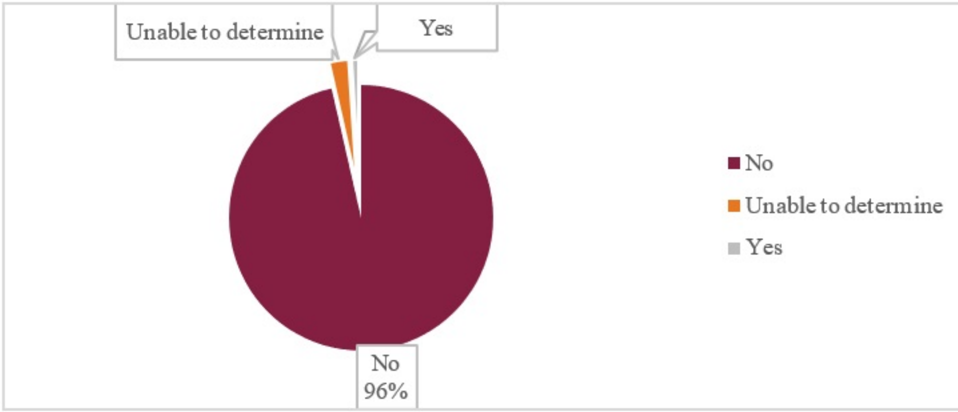

Figure 13. Pie chart. Helmet use behavior among e-scooter riders.

Rider Bag Use

Although carrying a bag while riding an e-scooter is discouraged by the manufacturer, the majority of riders (77%) carried a bag of some kind while riding. These bags were primarily carried on the rider's body and not on the e-scooter handlebars since unbalanced weight on the handlebar makes the e-scooter unstable and hard to maneuver. This behavior is expected since the data collection took place on a college campus but should lead to more detailed investigations on how having different kinds of bags may affect riding behavior. For example, will a single shoulder carrying bag restrict the rider's arm and limit their ability to react to safety-critical events?

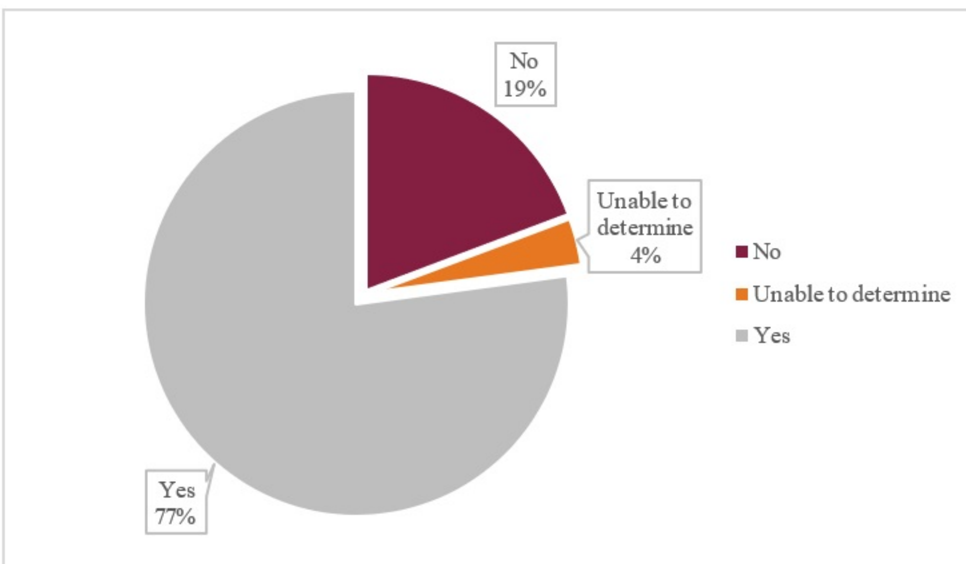

Figure 14. Pie chart. Bag use behavior among e-scooter riders.

Rider Stance and Center of Gravity

Of all the riders, 78% placed their feet on the scooter front and back (fore and aft), and 15% placed their feet side by side. In addition, 68% of riders put their center of gravity on the back of the e-scooter and 32% on the front. There has been little research on the best stance or posture to ride an e-scooter. Thus, the researchers could not explain the choice of riding potions by the riders. However, most of the riders chose to place their feet front and back and place their center of gravity at the back of the scooter. Future research should further investigate whether different stances improve or reduce safety.

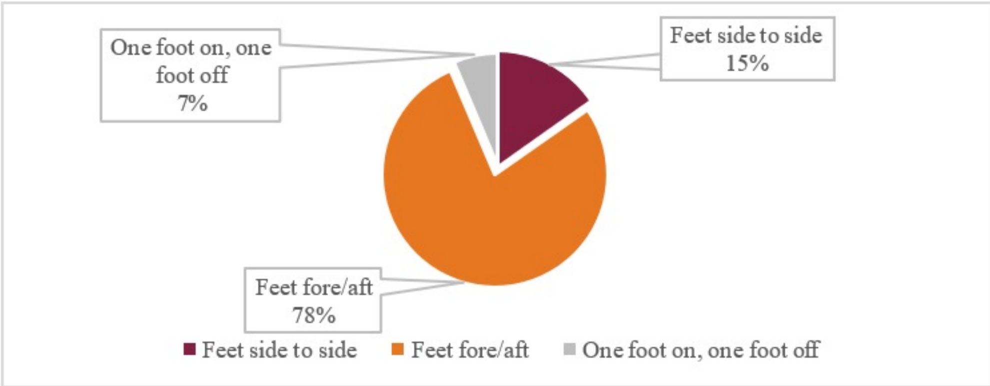

Figure 15. Pie chart. E-scooter rider feet position choice.

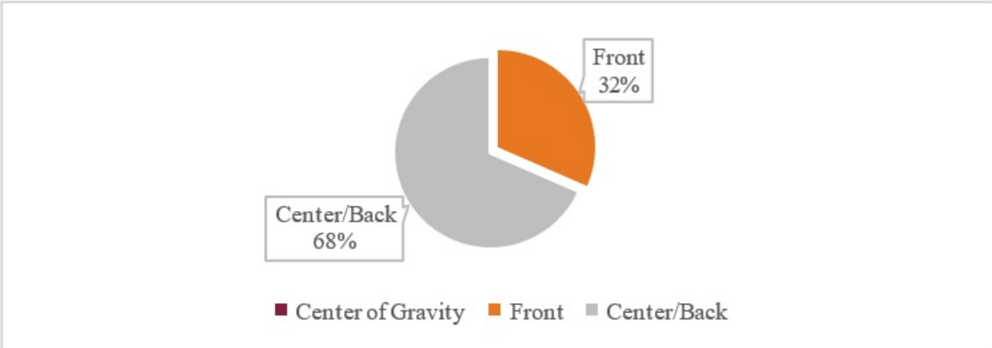

Figure 16. Pie chart. E-scooter rider center of gravity position choice.

Rider Behavior

The most common unsafe behavior recorded was aggressive riding. Sign/signal violation and trick riding are listed as second and third among unsafe riding behaviors. Trick riding includes donuts, wheelies, slalom, or weaving just for fun (not aggressively with other users). Aggressive riding covers behaviors such as aggressive/dangerous weaving, excessive speed compared to surrounding road users, and causing close/unsafe proximity to other users, etc. The number of unsafe riding behaviors (n = 45) is not significantly alarming when compared to the total number of baseline events (n = 473). However, some of these unsafe behaviors pose a threat to other vulnerable road users and thus should be further investigated.

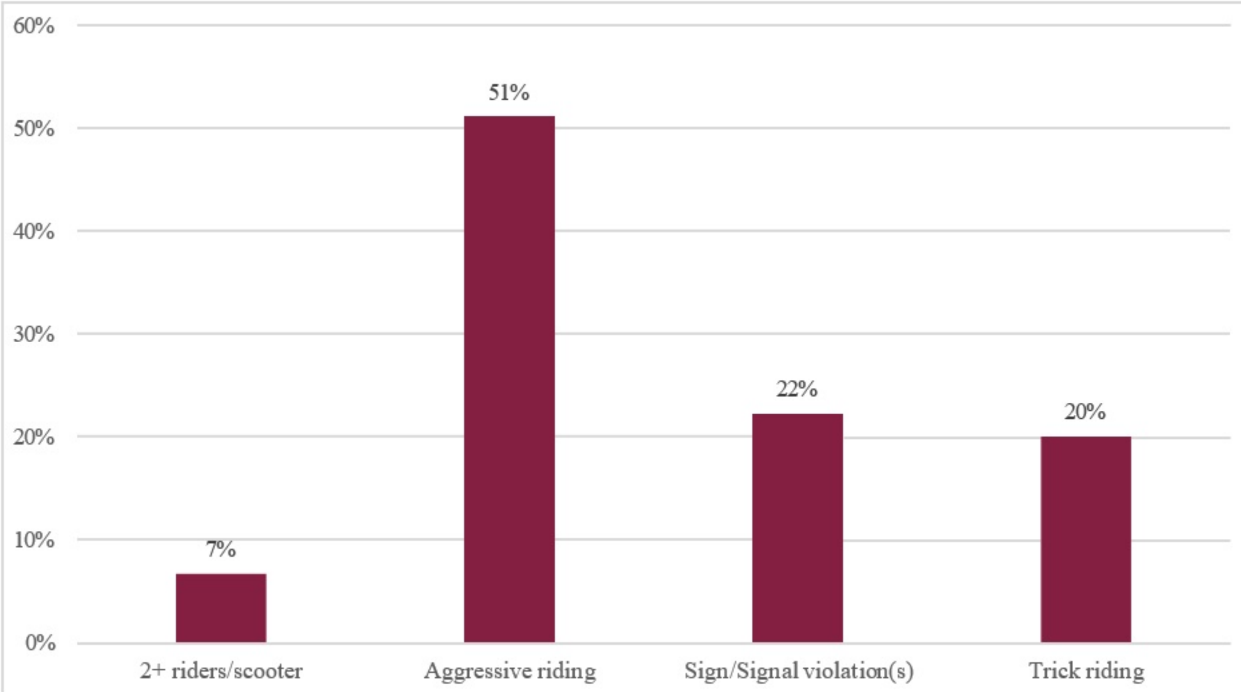

Figure 17. Bar graph. E-scooter rider unsafe riding behavior distribution (total of 45 unsafe riding events).

Riding Group Size

When e-scooter riders ride together, a group of two is the most common configuration. This result is interesting to the research team, as group riding can be riskier when compared to riding alone, especially with large riding groups.

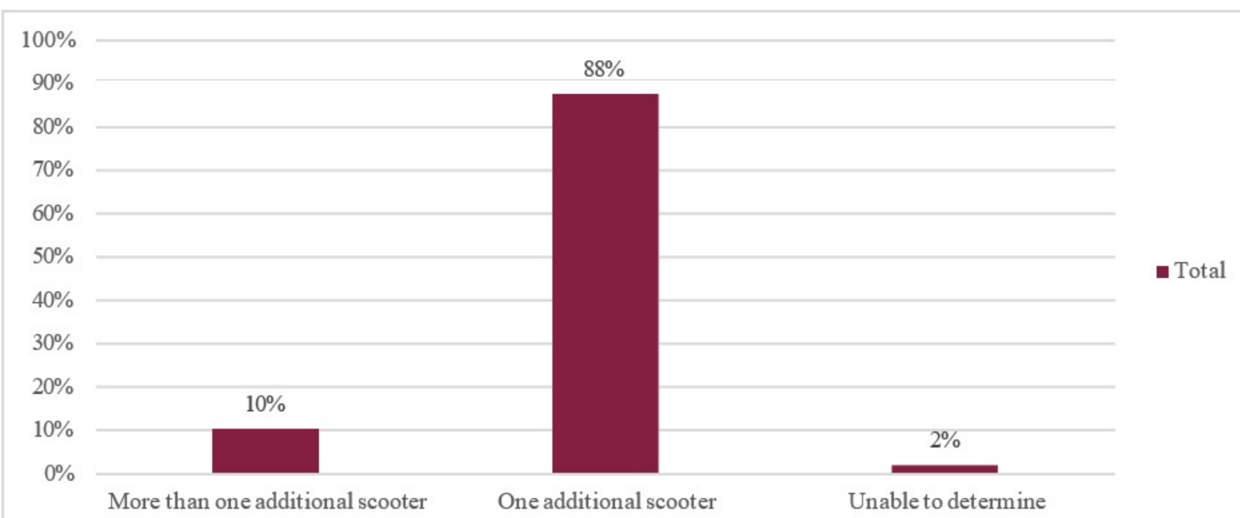

Figure 18. Bar graph. E-scooter rider riding group size distribution (total of 48 events with more than 1 rider).

Riding Location

The results show that e-scooter riders were riding on crosswalks and sidewalks the most, which is consistent with the high frequency of interactions with pedestrians. However, there are also some cases where e-scooters were ridden on roadways and bike lanes, indicating that e-scooters potentially do interact with motor vehicles and cyclists.

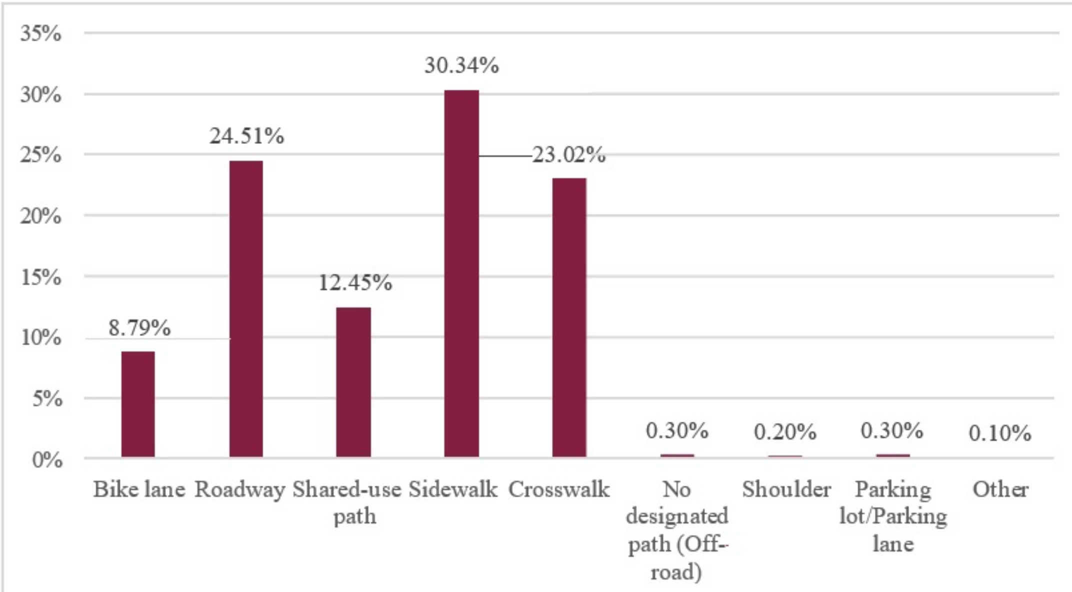

Figure 19. Bar graph. E-scooter rider riding location distribution (total of 473 baseline events).

Riding Mode and Riding Location Trend Comparison

When comparing the trends for e-scooter riding location and riding mode stratified by camera locations, the research team found that e-scooter riders generally behave like pedestrians when riding on sidewalks and like cyclists when riding in bike lanes. When an e-scooter rider 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, the research team decided that the e-scooter rider is behaving like a cyclist.

When an e-scooter rider is using the sidewalk, crosswalks, access ramps, or shared use path, and behaving as one would expect for that location, the research team classified it as behaving like a pedestrian. There are discrepancies in the trend for Newman Library and Squires Student Center, which have shared use paths (e.g., used by both bike and pedestrians). This is supported by the similar trends between these two behaviors and riding locations stratified by camera locations, especially when compared to the trends of other behaviors and riding locations. While the research team did observe e-scooter riders behaving like a motor vehicle, the frequency of observing this behavior did not correspond to the frequency of riding location (i.e., on the roadway). Thus, this may be a high-risk behavior that should be considered in future analyses. The total sum of percentages exceeds 1 since for each baseline trip, there may be multiple behaviors or riding locations recorded.

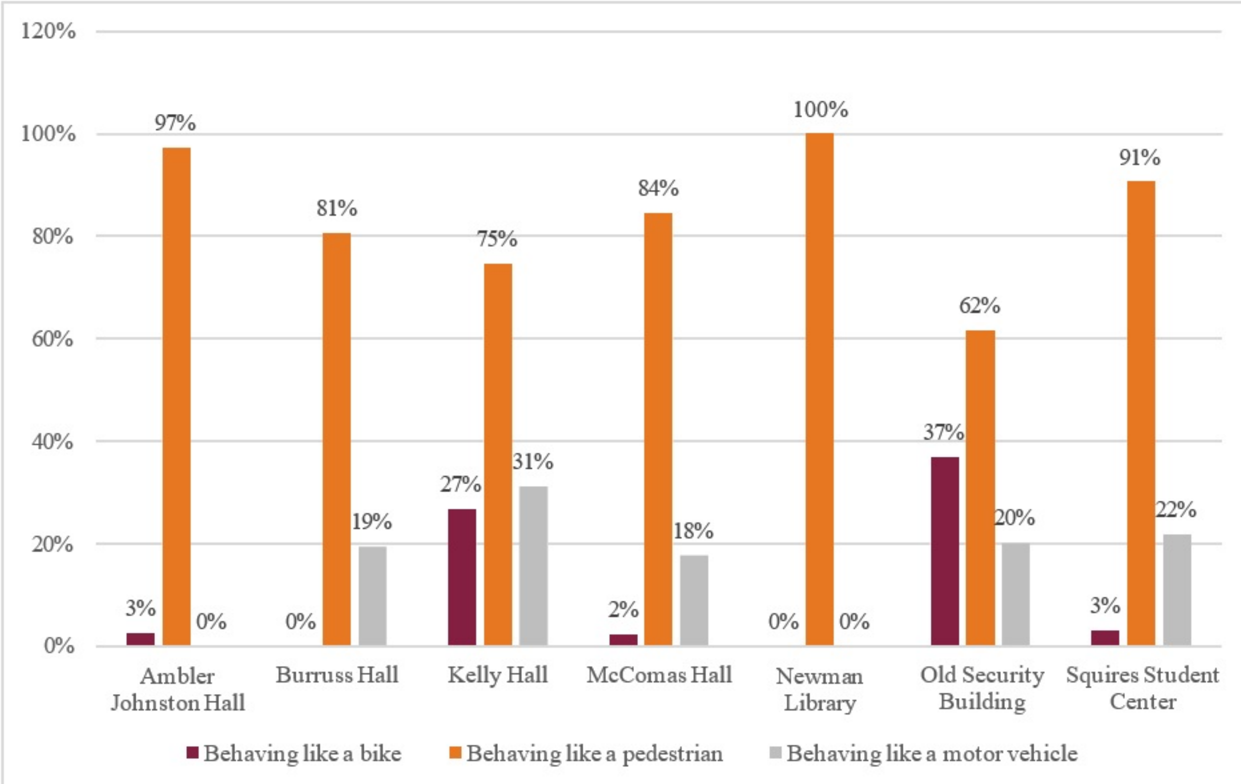

Figure 20. Bar graph. E-scooter riding behavior distribution by camera location (the sum of percentage exceeds 1 since for each 10-second baseline trip, there may be multiple behaviors).

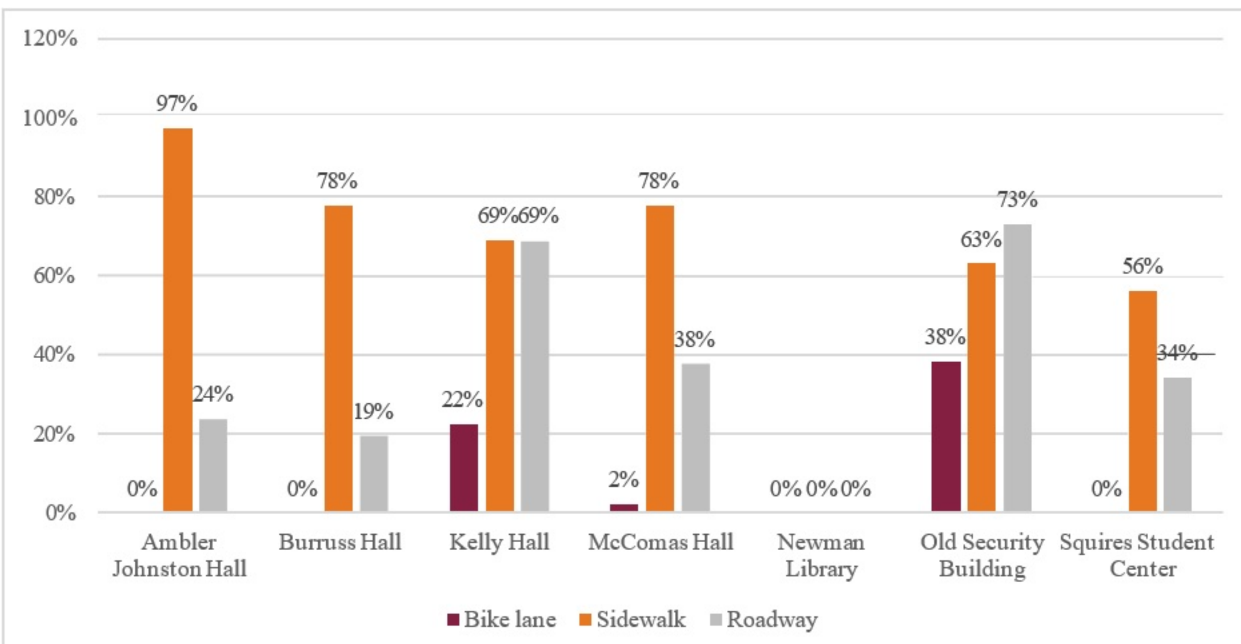

Figure 21. Bar graph. E-scooter riding location distribution by camera location (the sum of percentage exceeds 1 since for each 10-second baseline trip, there may be multiple riding locations).

Interaction Reduction Results

Type of Road User During Interaction

A total of 72 interactions between e-scooters and other road users were identified. Among these interactions, pedestrians (n = 51) were the most common road users present. Motorized vehicles were the second most common road user interaction; however, interactions with pedestrians were 3 times more frequent than interactions with motorized vehicles. Since data collection took place on a college campus with many sidewalks and a large amount of pedestrian traffic, this result was expected.

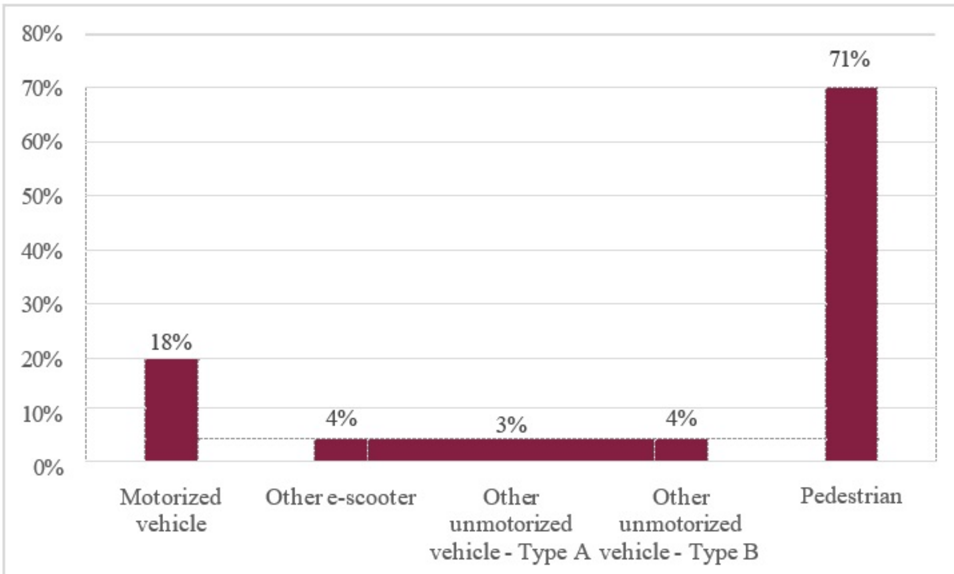

Figure 22. Bar graph. E-scooter rider interaction actor distribution (total of 72 interaction events were recorded).

Type of Interactions

Passing/overtaking unmotorized road users was the most common interaction type for e-scooter riders, which is consistent with the result that most of the interactions were between an e-scooter and a pedestrian (n = 51). This is when the e-scooter overtakes a pedestrian, passes an oncoming pedestrian, or passes stopped pedestrians.

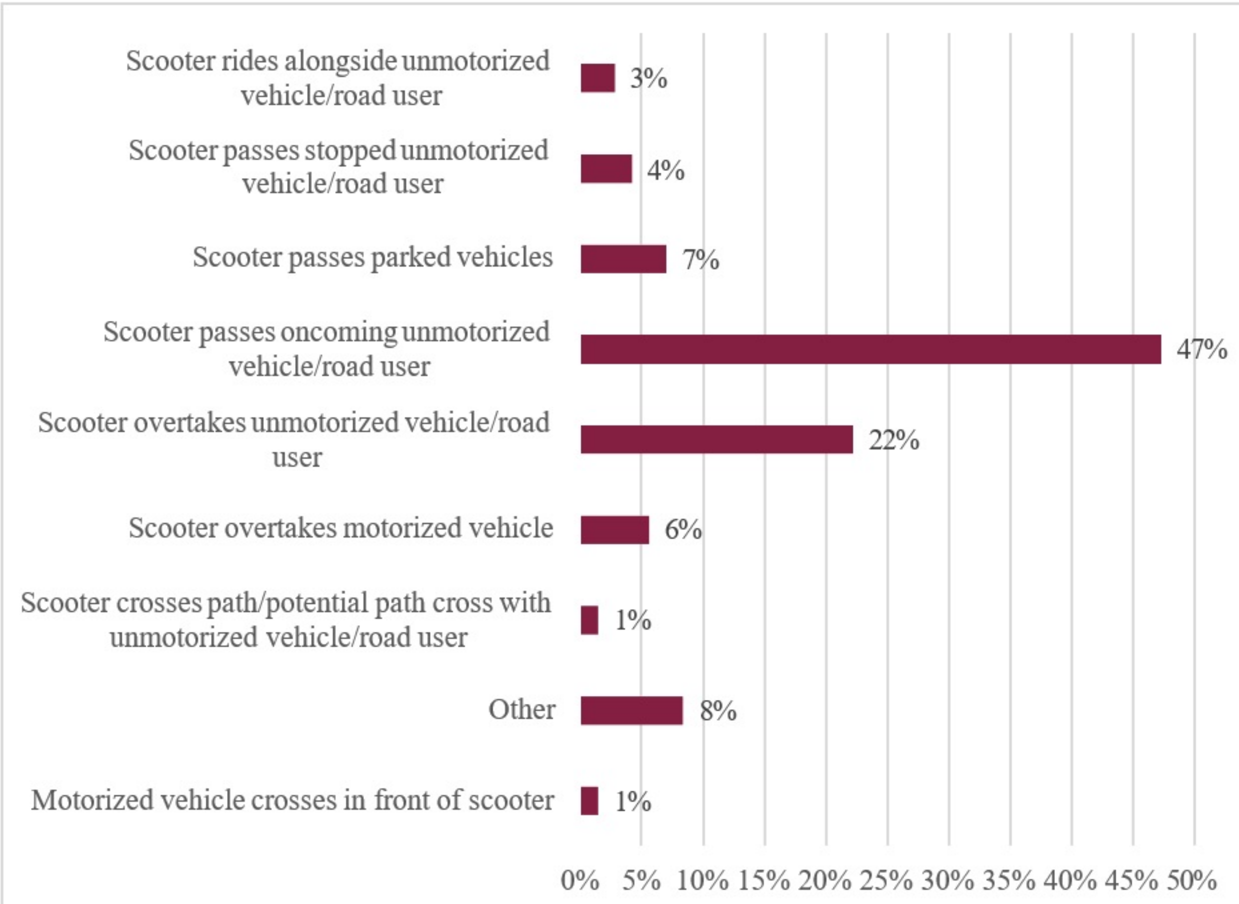

Figure 23. Bar graph. E-scooter interaction type distribution (total of 72 interaction events were recorded).

E-scooter Speed by Interaction Partners

When e-scooters interact with pedestrians, they are faster than pedestrians (n = 29). This is true for interactions between e-scooters and motorized vehicles as well, showing that e-scooters interact with motorized vehicles mostly when they are parked or stopped in traffic (n = 7).

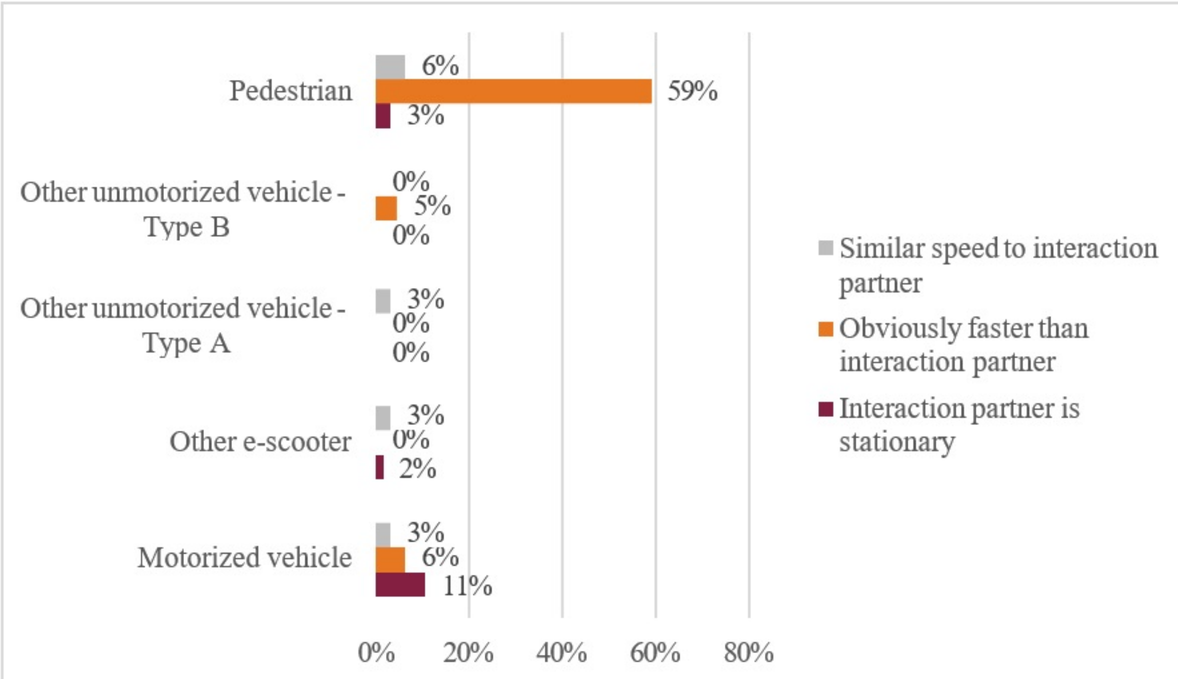

Figure 24. Bar graph. E-scooter speed distribution during interaction by interaction actor type (total of 72 interaction events were recorded).

Discussion

From the video data reduction results, the researchers explored the riding behaviors of e-scooters on a college campus and how they interacted with other road users. Results showed that the e-scooter riders, although not totally oblivious about safety implementations and operations of the e-scooter, do participate in unsafe riding behaviors. About 96% of the riders were not wearing a helmet while riding, despite having free access to helmets provided by Spin, both on campus and online. Perhaps the lack of publicity on the availability of helmets and the resistance of carrying a helmet around were contributing factors to the lack of helmet use. Additional research should be conducted on increasing publicity regarding helmet use and availability to determine if there is an increase in helmet use and safety awareness. About 77% of riders carried a bag of some sort while riding; this is expected as the study took place on a college campus. However, some bags may affect the mobility and balance of the riders and, as a result, limit their ability to react to emergencies on a scooter. The effect of different bags should be further examined to provide a safety guideline on bag usage for e-scooter riders. Currently, there is little research on how foot stance and center of gravity could affect the operation of an e-scooter. The results of this study suggested that 78% of riders had their feet in the front and back position, and 68% had their center of gravity in the center/back position of the scooter. This was the position riders adopted most and thus should be further examined to see if there is an optimal stance and center of gravity for e-scooter riding.

Even though it was not common in this sample, riders did engage in aggressive riding behavior (51%), signal/sign violation (22%), and trick riding behaviors (20%). Aggressive/trick riding by e-scooters can pose a threat for other road users, especially pedestrians, because e-scooters share the same sidewalks and paths with them but are significantly faster. The potential threats to pedestrians were also confirmed by interaction type and interaction actor type, with 71% of interactions with pedestrians and 47% of cases when the e-scooter passed or overtook a pedestrian. Also, when e-scooters interact with pedestrians, they are generally faster than pedestrians. Even though this is also true for interactions with motor vehicles, pedestrians are exposed to more significant risks in the same scenario due to their vulnerability. Also, since all interactions between e-scooters and motor vehicles happened when the e-scooter was the faster actor, the interactions between these two may not be as severe as one would expect.

The above results suggested that e-scooters pose the most threats to pedestrians on a college campus and should be separated from large pedestrian groups to maintain safety on the sidewalk. When comparing the trends for e-scooter riding location and riding mode by different camera locations, researchers discovered that e-scooter riders behave like cyclists and pedestrians while they are riding in bike lanes and sidewalks/crosswalks. However, this study was conducted on a college campus where the speed limit of a typical roadway does not exceed 25 mph, which is not much higher than the 15-mph speed limit of the e-scooters. Thus, this observation may not be generalizable to roadways with a higher speed limit due to greater speed differences between e-scooters and the surrounding traffic. However, the idea of limiting the speed difference between e-scooters and their surrounding road users should be considered while regulating e-scooter operations.

Among all the trips identified for this study, no conflicts (safety-critical events) were observed. The lack of conflicts may be due to the time frame selected (10:00 a.m. to 4:00 p.m.). During this normal class time, especially on a college campus, riders primarily use e-scooters for transportation purposes. Therefore, if different hours of the day were selected, the research team may have observed more unsafe events, including conflicts (safety-critical events).

One of the limitations of this study is the data gathering process. Because all fixed camera locations were selected based on the infrastructure elements present, the dataset gathered does not have a truly random baseline. The lack of a true baseline limits the power of the data and the ability for researchers to run risk analysis and regression analysis. Also, the strategy of following one e-scooter rider during the total sample time may have limited the number of collected samples. The research team under sampled ($N = 492$) due to lack of scooter trips, but if interactions instead of trips were sampled, the research team could potentially have a larger sample size with higher statistical power. The sampling plan was to follow one e-scooter per recorded trip and ignore all other e-scooters in the camera view because the research team was more interested in interaction between e-scooters and road users. This strategy along with the time restraint limited the number of sample trips available. Also, due to the clarity of the camera, sometimes it was hard for the coders to determine details like the gender of the rider, or whether the rider was wearing electronics, a bag, or a helmet. Thus, there are circumstances where the coder would have to enter "unable to determine" for that variable. Another limitation is the traffic environment in which the study was conducted. On the college campus where this study took place, there is a higher density of pedestrian traffic and a lower speed limit (25 mph) for motor vehicles, making it hard to generalize the study results to roadways with higher speed limits. Some neighborhoods that will benefit from the first- and last-mile services the e-scooter can provide may have a higher speed limit on their roadways, and how e-scooters could be implemented in those areas may need further investigation.

Conclusions and Recommendations

E-scooters are a great solution to the question of first- and last-mile services and can provide easy and quick transportation within a certain area. However, some limitations should be kept in mind when implementing these new technologies. E-scooters, when not appropriately ridden, can become a threat to other road users, especially pedestrians. They are generally faster than pedestrians, and when ridden on the sidewalk, they can come dangerously close to pedestrians as well. Also, e-scooter riders can adjust the operation rules they follow when traveling on different roadways. These results suggest that it might be safer to operate e-scooters in designated lanes, bike lanes, or on roadways with a speed limit of 25 mph or less. On roadways with faster speed limits, additional countermeasures to separate e-scooter traffic from vehicles may be required. Additional research is needed to confirm these recommendations.

Additional Products

The Education and Workforce Development (EWD) and Technology Transfer (T2) products created as part of this project can be downloaded from the project page on the Safe-D website. The final project dataset is located on the Safe-D Dataverse.

Education and Workforce Development Products

This project featured Yubin Hong as a graduated research assistant throughout the project.

The result of this study will be developed into a learning module for the Human Factors in Transportation course and presented during Spring 2022.

Technology Transfer Products

The result of this study was featured in a poster that was presented at the Transportation Research Board annual conference.

Data Products

The data uploaded are the reduction result of video data, and the research subjects are unidentifiable. The reduction data include but are not limit to e-scooter riders' riding behavior, interactions with other objects or road users, helmet usage, speed, and dangerous maneuvers. The reduction was done in a similar fashion to another project using the same video dataset.

References

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Appendix: Reduction Protocol

Safe-D Project (00-030) An Evaluation of Road User Interactions with E-Scooters

E-scooter Data Reduction Protocol for Fixed Camera Views (last updated 4/7/2021)

For this task, the reduction will consist of two main scenario types: conflict scenarios and control baseline scenarios (the latter of which may or may not also include interaction scenarios). Since there is no applicable method to identify the conflict or interaction scenarios from the fixed camera dataset, these will be recognized during the process of control baseline scenario coding. Interaction scenarios will be counted and assessed during the fixed camera baseline and interaction reduction. Any conflict scenarios identified will trigger a different coding protocol that is described as a fixed camera conflict reduction.

Control baseline scenarios are 10 seconds long and partially randomly selected based on time of the day (providing an implied road user density) and fixed camera location (total trips recorded). A control baseline scenario is defined as a period of time where an e-scooter travels through the view of the camera without having any conflicts or interactions (defined below) with any road user or road elements. These "normal" e-scooter riding epochs will serve as control baseline scenarios during the analysis.

The sampled epochs are 10 seconds long. A valid epoch for the purpose of this reduction must consist of at least 3 seconds of reference e-scooter movement. Any sample where the e-scooter remains stationary for more than 7 of the 10 seconds will not be considered and will be resampled.

Interaction scenarios are coded as when a different traffic element comes within a certain radius of the referenced e-scooter rider. The radii are listed below. Note that there may be multiple interaction scenarios within a given epoch. A count of all interactions within the epoch will be provided, and up to three interactions will be further analyzed for each sampled epoch.

Traffic Element	Interaction Radius
Motorized road users **(vehicles, motorcycles, etc.)**	4 ft radius (just beyond arm's reach)
Unmotorized road users type A **(bicycles, e-scooters, etc.)**	3 ft radius (straight arm's reach)
Unmotorized road users type B **(pedestrians, skateboards, etc.)**	2 ft radius (relaxed arm's reach)
Permanent road/infrastructure elements **(road signs, bike rack, lamp pole, pothole, etc.)**	physical contact
Movable road/infrastructure elements **(trash can, items on the road, etc.)**	physical contact

A conflict scenario is defined as a critical interaction with another road user or roadway element. Conflicts include both crashes and near misses (non-crash conflicts). These are incidents where one of the following occurs:

- The scooter rider falls or nearly falls over.
- The scooter rider swerves or stops abruptly to avoid a crash.
- The scooter rider causes another vehicle or pedestrian to swerve or stop abruptly to avoid a crash.
- The scooter rider has physical contact with any object, vehicle, or person.

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 at the end of the event window.

There will be two separate reduction tasks for two types of samples, 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. Fixed camera baseline and interaction 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). Duplicate samples (same trip captured by different cameras) will be removed.

b. Baselines will be selected as 10 s long with anchor point defined as above. That is, the reduction team will focus on one e-scooter for every epoch selected and follow the event progression of that e-scooter until it leaves the camera. The rider's demographic information, riding characteristics, surrounding environment, and other detailed descriptors of riding behaviors and interactions will be coded.

c. Potential sampling plan: 500 individual e-scooter epochs

II. Fixed camera conflict reduction (from stationary cameras affixed at key locations on VT campus)

a. This will require conflicts (crashes, near-crashes, crash-relevant conflicts) to be identified first during the baseline reduction (above). Then, identified conflicts will undergo a separate conflict reduction task.

i. This will include crashes and non-crash conflicts (near crashes, crash-relevant 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. The conflict reduction will be performed under the same event ID as baseline, but there may be several conflicts under one event ID. The reductionist should code the five most severe conflicts if there are more than five conflicts in the duration of the baseline trip.

I. Fixed Camera Baseline and Interaction Reduction

A. Baseline/Rider Scenario Info:

Code the demographic information and basic appearance information of the rider of interest using this system.

1. RiderGender. **What is the gender of the referenced scooter rider?**

- Male

- Female
- Unable to determine

2. RiderAge. **What is the estimated age group 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

3. RiderWearingHelmet. **Is the referenced scooter rider wearing a helmet?**

    - Yes
    - No
    - Unable to determine

4. RiderWearingBag. **Is the referenced scooter rider wearing a backpack or other type of bag?** Includes purse, side bag, 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

5. RiderWearingElectronics. **Is the referenced scooter rider wearing/using headphone or other electronics interfering with sensory perception of the rider?** Includes headphones, Google glasses, bone conduction headphones, GoPro, and other video cameras.

    - Yes
    - No
    - Unable to determine

6. RiderHandheldItem. **Is the referenced scooter rider carrying a handheld 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. RiderHandlebarItem. **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. RiderHands. **How many hands does the referenced scooter rider have on the handlebars at the anchor point?**

- None
- One
- Two
- Unable to determine

9. RiderRidingStance. **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)

- Ground – one foot is placed on the ground next to the scooter
- 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
- One foot on, one foot off – one foot on the scooter, the other being used to manually ride or balance
- Unable to determine

10. RiderRidingBehavior. **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, traffic signal or traffic law during the assessment window (leave note on type of violation)

11. RiderRidingLocation. **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 roadway.
- 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. SurfaceCondition: **What is the condition of the surface the referenced scooter is traveling on? (check all that apply)**

- Wet

- Partially wet
- Dry
- Icy (considered icy when there are any icy spots on the surface)
- Unpaved path (gravel, sand or similar)
- Unpaved path (grass, soil or similar)
- Other – leave a note

13. ConflictCount. **How many conflicts (crash, near-crash, or crash-relevant) was the referenced scooter involved in during the sampled epoch?** Conflicts are defined as in 4.2 Standard. Enter 0 (zero) if no conflicts occur. NOTE 1: Interactions that do not meet the defining criteria for a safety critical incident should not be counted here. NOTE 2: Two safety critical interactions that are closely related (e.g., the evasive maneuver for one led to the second) should be counted as one conflict here. If two conflicts occur independently of each other, count them separately.

- Text box

16. ConflictEvent. **If one or more conflicts are coded as present above, enter the Event_IDs of the conflict here, separated by commas.**

  - Text box. Event_IDs of conflict, leave blank if referenced rider is not involved in a conflict

19. BaselineNotes. **Leave notes for any "unable to determine" or "other" categories or for anything notable not covered under other baseline variables.** If a conflict occurs within a baseline, describe it here as well. Also, please describe anything that was notable but was not included in the detailed reduction above.

- Text box

B. Interaction Scenarios:

20. InteractionCount: **How many interaction scenarios was the referenced scooter involved in?** Interaction scenarios are coded as when a different traffic element comes within a certain radius of the referenced e-scooter rider. The radii are listed below. Note that there may be multiple interaction scenarios within a given epoch. A count of all interactions within the epoch will be provided, and up to 3 interactions will be further analyzed for each sampled epoch.

Traffic Element	Interaction Radius
Motorized road users **(vehicles, motorcycles, etc.)**	4 ft radius (just beyond arm's reach)
Unmotorized road users type A **(bicycles, e-scooters, etc.)**	3 ft radius (straight arm's reach)
Unmotorized road users type B **(pedestrians, skateboards, etc.)**	2 ft radius (relaxed arm's reach)
Permanent road/infrastructure elements **(road signs, bike rack, lamp pole, pothole, etc.)**	physical contact
Movable road/infrastructure elements **(trash can, items on the road, etc.)**	physical contact

- Text box

21. Interaction(1-3)Type. **Road user/element with which referenced scooter interacted.** What type of road user/element did the referenced e-scooter interact with? (When more than one interaction is present, only the first 3 will be coded)

- Pedestrian
- Motorized vehicle
- Unmotorized vehicle
- Other e-scooter
- Other micro-personal transportation
- Infrastructure elements
- Moving object
- Wild animal
- Animal (pet)

- Other
- Unable to determine

22. Interaction(1-3)RiderSpeed. **How fast was the referenced rider riding at the start of the interaction?**

    - Following speed of nearby road users
    - Obviously faster than nearby road users
    - Obviously slower than nearby road users
    - Unable to determine
    - Speed varies (In this case, the relative speed of the e-scooter while the interaction took place will be coded)

23. InteractionRiderMotorizedVehicleInteraction (If more than one interaction is present, check all that apply). **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 vehicles – 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 crossroad, 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
- Vehicle passes scooter, oncoming lane – a motorized vehicle drives past the referenced rider in the oncoming traffic lane or scooter passes motorized vehicle in oncoming lane
- 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.
- NA – No interaction – rider is riding on a roadway, bike lane, shoulder, parking lane, or parking lot but there is either no interaction due to lack of other actors or no passing/crossing interaction with existing actors.

24. Rider Unmotorized Road Users Interaction (If more than one interaction is present, check all that apply). **How is the referenced rider interacting with unmotorized vehicles/road users in the roadway during the assessment window? (check all that apply)** (this question applies only if roadway, bike lane, shoulder, parking lane, sidewalk, shared-use path or parking lot are coded above.)

- Scooter passes stopped unmotorized vehicle/road user – referenced rider is at risk of hitting or being hit by stopped unmotorized vehicle/road user.
- Scooter overtakes unmotorized vehicle/road user – referenced rider goes around a slow or stopped unmotorized vehicle/road user (e.g., skateboarder trying to accelerate, bikers trying to switch gears, wheelchairs)
- Scooter crosses path/potential path cross with unmotorized vehicle/road user – referenced rider crosses in front of a non-parked unmotorized vehicle/road user, at a crosswalk, at a driveway, on the sidewalk, while making a turn, or otherwise
- Unmotorized vehicle/road user passes moving scooter – an unmotorized vehicle/road user drives past the referenced rider while the scooter is in motion in the sidewalk, bike lane, roadway, parking lane, or otherwise
- Unmotorized vehicle/road user passes standing scooter – an unmotorized vehicle/road user drives past the referenced rider while scooter is standing still (e.g., waiting to cross the road, looking at phone, chatting with friends, etc.)

- Other – leave a note
- Unable to determine
- NA – Location type not applicable to unmotorized vehicles/road user – rider is not riding on a roadway, bike lane, shoulder, parking lane, parking lot, sidewalk or bike lane
- NA – No interaction – rider is riding on a roadway, bike lane, shoulder, parking lane, or parking lot but there is either no interaction due to lack of other actors or no passing/crossing interaction with existing actors.

25. Rider Riding Mode. **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 motor vehicle – 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 like a skateboarder – scooter is using both sidewalk and bike lanes, behaving as one would expect for that of a skateboarder. (Swerving between pedestrians, trick riding)
    - 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, sidewalks, or parking lot.

26. InteractionNotes. **Leave notes for any "unable to determine" or "other"**

categories or for anything notable not covered under other interaction variables.

- Text box

II. Fixed Camera Conflict Reduction

For conflicts seen in the fixed camera baseline reduction, the variables in this section will also be coded during a separate conflict reduction task. The first couple of questions 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 physical contact** with any object, vehicle, or person

27. FixedBaselineEvent. **Enter the Event_ID of the baseline event where this conflict was coded to the referenced rider.**
    - Event_ID of corresponding fixed cam baseline (text box)
28. 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)
29. 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)

30. ConflictSeverity. **Conflict Presence/Severity (for referenced rider).**

- No Conflict
- Crash – includes falling over or making contact with any object, vehicle, or person.
- Near-crash – includes where e-scooter rider is 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.
- Crash-relevant conflict – includes the rider taking their eyes off the road for any reason, the scooter going over 12 miles per hour or presenting behaviors from the rider behavior category and riding on sidewalks, crosswalks at the same time. (Could be expanded in the future)
- Proximity Conflict – defined as when the referenced rider is oblivious of the situation and another road user was required to make a rapid, evasive response to avoid critical incident with e-scooter rider.
- Unable to determine

31. ActorsCount.Present. **Number of actors (scooters, other road users, objects, etc.) involved in the conflict.**

- Enter a number (text box)

32. 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, skateboarder
- Conflict with other scooters, electric wheelchair
- 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
- Conflict resulting from using electronics – if known
- Other – leave a note
- Unable to determine – leave a note

33. 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, skateboarder
    - Impact with other scooters
    - 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

34. 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

- Non-referenced scooter – select if the other conflict partner is a scooter not referenced in the baseline reduction (or Rider Reference 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 road user Type A – select if conflict partner is a non-motorized road user such as a bicycle, e-scooter, etc., and performs an evasive maneuver

- Non-motorized road user Type B – select if conflict partner is a non-motorized road user such as a pedestrian, e-scooter, etc. and performs an evasive maneuver

- NA – Conflict is a crash

35. 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 (losing control of the scooter)

- Unknown – leave a note

36. EnvironmentalFactors. **Environmental elements indirectly or directly contributed to the conflict (road surface condition, weather, bike rack present, steps present, etc.)**

Please take a note on all environmental factors that indirectly contributed to the conflict. (text box)

37. 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

38. ConflictFault. **Which conflict partner is at fault?** Indicates which conflict partner (scooter, bicycle, pedestrian, skateboarder, 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. If more than one other party is at fault, please indicate the number and party in the text box below.
    - Shared fault – More than one conflict partner committed errors that contributed to the Event.
    - No fault – No user errors were committed 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 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.

39. PointOfImpact. **Point of impact (with reference to the e-scooter)**

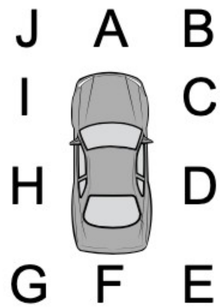

Figure 5. Regarding Motorist/Non-Motorist/Animal/Object Location. Subject vehicle is pictured. Location of conflicting vehicle, person, animal, or object is coded A-J in relation to subject vehicle.

40. Final Narrative. **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.**