Case Studies on Transport Policy

Gender split and safety behavior of cyclists and e-scooter users in Asbury Park, NJ

--Manuscript Draft--

Manuscript Number:	CSTP-D-23-00235R1
Article Type:	Research Paper
Keywords:	shared e-scooters; cyclists; observational study
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Abstract:	Micromobility usage has increased significantly in the last several years as exemplified by shared e-scooters and privately owned bicycles. In this study, we use traffic camera footage to observe the behavior of over 700 shared e-scooters and privately owned bicycles in Asbury Park, New Jersey. We address the following questions: (1) What are the behavioral differences between bicycle and e-scooter usage in terms of helmet use, bike lane / sidewalk use, gender split, group riding, and by time of day? (2) Are more protective conditions associated with helmet use and bike lane / sidewalk use? And (3) what is the gender split between e-scooter users and cyclists? We find notable differences in safety precautions: around one third of cyclists but no shared e-scooter users were observed wearing a helmet. Among cyclists, helmet use was more prominent among men than women. However, men were more likely to ride on the road than women. We also found that the gender split was narrower among e-scooter users, with a nearly even gender split – as opposed to cyclists, where only 21% of cyclists were observed to be women. Our findings suggest that e-scooter users take fewer safety precautions, in that they are less likely to use a bike lane and to wear a helmet. We conclude with policy implications with regards to safety and gender differences between these two modes.

Conflict of Interest

We know of no conflicts of interest associated with this publication and there is no financial support for this work that could have influenced its outcome.

Cover Letter

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13-Jul-23

Dear Editors:

We would like to resubmit the following revised manuscript entitled "Gender split and safety behavior of cyclists and e-scooter users in Asbury Park, NJ" by H. Younes, R. Noland, C. Andrews. A response note to reviewers is included in our submission.

We declare that this manuscript is original, has not been published before and is not currently considered for publication elsewhere.

We know of no conflicts of interest associated with this publication and there is no financial support for this work that could have influenced its outcome. The manuscript has been read and approved by all authors.

Sincerely,

Robert Noland

Robert Noland

Highlights

Research highlights:

- Cyclists are more likely to wear helmets and to use the bike lane than e-scooter users
- Shared e-scooters are more of a group activity than private cycling
- Women were less likely to wear a helmet and ride on the road
- The gender gap among e-scooter users is narrower than among cyclists
- E-scooter users take fewer safety precautions but are more gender equitable

Gender split and safety behavior of cyclists and e-scooter users in Asbury Park, NJ

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Gender split and safety behavior of cyclists and e-scooter users in Asbury Park, NJ

Abstract

Micromobility usage has increased significantly in the last several years as exemplified by shared e-scooters and privately owned bicycles. In this study, we use traffic camera footage to observe the behavior of over 700 shared e-scooters and privately owned bicycles in Asbury Park, New Jersey. We address the following questions: (1) What are the behavioral differences between bicycle and e-scooter usage in terms of helmet use, bike lane / sidewalk use, gender split, group riding, and by time of day? (2) Are more protective conditions associated with helmet use and bike lane / sidewalk use? And (3) what is the gender split between e-scooter users and cyclists? We find notable differences in safety precautions: around one third of cyclists but no shared e-scooter users were observed wearing a helmet. Among cyclists, helmet use was more prominent among men than women. However, men were more likely to ride on the road than women. We also found that the gender split was narrower among e-scooter users, with a nearly even gender split – as opposed to cyclists, where only 21% of cyclists were observed to be women. Our findings suggest that e-scooter users take fewer safety precautions, in that they are less likely to use a bike lane and to wear a helmet. We conclude with policy implications with regards to safety and gender differences between these two modes.

1. Introduction

Micromobility devices can be broadly defined as small, low-speed, human or electric-powered vehicles which include scooters, bicycles, and other lightweight, wheeled apparatuses (FHWA, 2022b). Micromobility can help fill in the gaps of a city's transportation network. These vehicles can help people make first-mile and last-mile trips, short-distance commutes, and inter- or intra-neighborhood trips (Yanocha & Allan, 2021). Having access to electric micromobility devices can give people greater access to jobs, health care, education, and other services in communities with low car ownership and underserved by transit (Blickstein et al., 2019; Price et al., 2021). Furthermore, since electric-powered bikes, scooters, and other devices need less physical power to operate, there are opportunities to enhance the mobility of youth, seniors, and individuals with disabilities (Blickstein et al., 2019). However, cycling has long been male dominated compared to other modes of transportation, and there is some evidence that e-scooters are also male dominated, although few studies have investigated the gender split in e-scooter riding and the differences in behavior between genders (Campisi et al., 2021; Dill, 2019; Toll, 2022).

Micromobility devices can be shared or individually owned. In a shared micromobility system, the vehicles are rented to the public, typically by a private company, and meant for short point-to-point trips. Shared micromobility services normally must obtain approval to operate from the local government, which usually comes in the form of a license, contract, or permit. These services can be operated as a docked system where the vehicles must be returned to designated stations, or as a dockless system where riders can leave them anywhere within a geofenced area (such as the city limits) when they finish using them. The docked system is championed for not cluttering sidewalks and being more orderly, but the location of its stations can limit access and restrain the customer base and the service's geographic coverage (Chen et al., 2020).

Micromobility vehicles share many characteristics and thus, planning resources tend to address them without differentiating between the modes. We investigate the variation in how riders use the road, who they are, and what safety precautions they take depending on the micro-vehicle type and on whether the vehicle is privately owned or shared. In this study, we analyze the behavioral differences between two micromobility modes: privately owned bicycles and shared e-scooters with a focus on gender differences. We analyze several behaviors: helmet use, bike lane usage, and group riding. We also analyze differences in usage by time of day and weekend.

1. What are the behavioral differences between bicycle and e-scooter usage in terms of helmet use, bike lane use, gender split, group riding, and temporal variations?
2. Are more protective conditions associated with helmet use and bike lane use?
3. Is there a gender split between e-scooter riding and cycling, as well as in their behavior?

To answer these questions, we analyze traffic camera footage at an intersection in the New Jersey shore community of Asbury Park. Two of the four legs of the intersection we analyze have permanent, painted, unprotected bike lanes. Our research team added a temporary pop-up bike lane on the remaining two legs, along with plastic delineators to clearly delineate the lane for cyclists in the intersection. We analyze bike lane usage along with helmet use, riding as a group, and gender split in order to understand behavioral differences between shared e-scooter riders and private cyclists.

2. Literature Review

2.1. Safety precautions: bike lane and helmet use

Helmet and bike lane use are two safety precautions that decrease the likelihood and severity of crashes for cyclists. The National Highway Traffic Safety Administration (NHTSA) reports that helmets reduce the likelihood of serious head injury by 60%. Moreover, cyclists who sustain a head injury while riding without wearing a helmet are three times more likely to die than those injured while wearing a helmet (Cheung, 2019).

Changes in perceptions of risk can affect the choice of mode and behavior of users (Noland, 1995). Esmaeilikia et al. (2019) reviewed the literature on risk compensation and helmet use while cycling. Generally, there is not much evidence to support risk compensation while wearing a helmet. However, just two of the studies analyzed helmet use and bike lane use and both are in the context of crashes and use crash data (Esmaeilikia et al., 2019). Both studies found that among bicycle-involved crashes, helmet use was not associated with risky behavior (Salon & McIntyre, 2018; Webman et al., 2013).

There are a number of studies that have used observational techniques to examine helmet use. Kim & Park (2021) observed helmet use by cyclists and non-cyclists (which included both e-scooter and skateboard users) and found that, for a university campus in California, around 48% of cyclists wore a helmet, compared to just 6% of non-cyclists (Kim & Park, 2021). Another observational study in New York City found that around 42% of privately owned e-scooter users, 46% of privately owned e-bicyclists, and just 27% of bikeshare users wore a helmet. The authors point out that when omitting commercial and delivery riders, who are required to wear a helmet in New York City, helmet use falls from 44% to 35% overall. Their study did not analyze helmet use of those using conventional privately owned bicycles, and shared e-scooters are not available in the area (Tuckel & Pok-Carabalona, 2022). Basch et al. (2014) analyzed helmet use among privately owned cyclists and shared cyclists. They found that around 50% of all observed cyclists wore a helmet in New York City. Among shared bicyclists (Citi Bike), just 15% did so (Basch et al., 2014). In one observational study in Brisbane, Australia, where helmet use is a legal requirement, shared e-scooter users were much less likely to wear a helmet than private bicycle users: around 63% of shared e-scooter users wore one compared to 99% of cyclists. They also observed helmet use for private e-scooter users and shared bicyclists and found that private micromobility users are more likely to wear a helmet and that cyclists are typically more inclined to wear one compared to e-scooter users. They did not, however, find any significant differences in helmet use between men and women (Haworth et al., 2021). Bike lane use was not analyzed in the aforementioned studies.

The Federal Highway Administration (FHWA) suggests that bike lane additions can reduce crashes by between 30-49% depending on the road configuration (FHWA, 2022a). Survey data shows that micromobility riders feel safer when using a bike lane (Emond et al., 2009). The New Jersey Department of Transportation (NJDOT) found that the majority of cyclists in New Jersey do not use bicycles regularly because of the lack of bike lanes and of their perceptions of motorists as incautious around cyclists (Azzi, 2022). There is evidence that women place more importance on bike lane infrastructure than men (Dill, 2019; Emond et al., 2009).

2.2. Gender differences and split

Gender differences and equity assessments in micromobility have traditionally been done through the use of surveys. Previous research suggests that men are more likely to cycle than women, and for longer periods (Heesch et al., 2012). Recent work shows that men cycle faster on average than women, and that women tend to avoid complex route elements more than men (e.g., intersections without traffic lights, left turns, and changes in road type) (Rupi et al., 2023). Women are more likely than men to report that cycling to work makes someone too sweaty for work and that the clothes needed to work are not compatible with cycling (Fang, 2020). The research on use of e-scooters by gender is less clear. In Portland, Oregon, the gender split between e-scooters and cycling is about the same: one third are women according to survey data. Moreover, Portland women ride less frequently than men. Safe cycling infrastructure was more important to women than to men in increasing e-scooter use. The desire to ride separate from cars was stronger among women respondents than men (Dill, 2019). A Populus survey found that slightly more women reported a positive perception of e-scooters (72%) than men (67%). Some speculate that e-scooters are easier to ride in restrictive clothing (such as heels and dresses) than a bicycle and that e-scooters require less physical exertion (Marshall, 2018). Dill & McNeil (2020) reviewed the literature on shared vehicles and equity. Based on results from four shared e-scooter surveys from 2019 in four U.S. cities (San Francisco CA, Arlington VA, Santa Monica CA, and Portland OR), women made up between 20% and 34% of shared e-scooter users. The study did not look at private micromobility, although surveys for bikeshare use showed a much wider variation in gender split: between 22% in some cities (New York, Dublin, and Melbourne) to 50% in several cities (Washington D.C., Montreal, Porto Alegre, Brazil). The caveat of looking at gender split in this manner is that we do not know the frequency with which men and women take trips (Dill & McNeil, 2020).

We know of two observational (non-survey) peer-reviewed studies that have investigated gender differences in micromobility riders. Kim & Park (2021) found no difference in the gender split between cyclists and non-cyclists (including e-scooter and skateboard users) at Cal Poly, Pomona, in California. Around 17% were female and 83% were male for both modes. Haworth et al. (2021) observed a narrower gap for shared e-scooter users than for private bicycle users in Brisbane, Australia (24% of shared e-scooter users were women, compared to 16% of private bicycle users) (Haworth et al., 2021).

In relation to helmet use and gender, results have been mixed. Basch et al. (2014) found that men were more likely to wear a helmet than women in New York City for both private and shared bikes. Valero-Mora et al. (2018) also found evidence that male cyclists (61%) were more likely to wear a helmet than female cyclists (51%) from a survey conducted in 17 European countries. They suggest one possible reason for lack of helmet use is that they use bicycles in a more cautious way than men so they feel that they do not need a helmet as much (Valero-Mora et al., 2018). In contrast, a study looking at shared bikes found that women were more likely to wear a helmet than men in Washington, DC and Boston, MA (Fischer et al., 2012). As for lane usage, an observational study of cycling in Japan found that women prefer riding on the sidewalk compared to men (Duc-Nghiem et al., 2018). However, the authors did not analyze bike lane use preference, as it was lumped together with traffic lane usage.

2.3. Our contribution

Safety is a result of both individual and collective choices, as well as contextual factors. Individuals vary widely in choosing whether and when to undertake risky activities such as cycling and scooter riding. People also choose whether to wear helmets, reflective vests, or lights when riding. Within physiological and cognitive constraints, they develop competencies to become better riders. In terms of collective action, municipalities choose whether to establish protected bike lanes, enforce traffic laws, or even prohibit certain types of road users. Individuals then respond to these changes through their own behavior. As novel mobility devices enter widespread use, both individuals and our communities need to adapt to new circumstances and adopt new safety strategies. The motivating question for this study is to understand better how individuals' safety-related behaviors vary given a specific municipal adaptation to these new mobility technologies.

The extant literature shows that helmet use is typically lower among e-scooter users than cyclists, and that fewer women than men use both bicycles and e-scooters. We examine these issues using observational data and include observations of how a bicycle lane is used, after it is introduced. We examine associations between helmet use, lane usage, group riding, and gender, something not previously examined. While we cannot explain why differences exist in usage patterns, this work provides a useful snapshot to understand differences between these modes and the safety behavior of different users within the context of our specific case study of Asbury Park, New Jersey.

3. Methods

3.1. Study Site

Asbury Park sits on the New Jersey shore with a permanent population of approximately 16,000 according to the U.S. Census Bureau (*American Community Survey 5-year estimates (2016-2020)*, 2020), and an estimated 72,000 people in the summer (including overnight visitors and day trippers), according to the Monmouth County Sewerage Authority (*Summer Coastal Population Study*, 2008). The city has a median household income of $47,000, much lower than the New Jersey average of $82,500. Around a quarter of the households have no vehicle available. The city has a slightly younger population than the rest of the state. Just under 23% of Asbury Park workers rely on other means than driving alone to get to work (*American Community Survey 5-year estimates (2016-2020)*, 2020). Shared e-scooters were introduced in the city in July 2019, were phased out in 2020 due to the COVID-19 pandemic and reintroduced by a new company in May 2021. The city is well served by painted, unprotected bike lanes. The town caters to day visitors and is well known for its music scene due to Bruce Springsteen's association with The Stone Pony (https://www.stoneponyonline.com/).

We worked with the city of Asbury Park to select a site that had high motor-vehicle, pedestrian, and cycling traffic, while also being a potentially hazardous intersection for non-motorists (Manzella et al., 2018). The city made the video footage available to us for selected days, which we discuss in more detail in 3.2. The intersection we analyzed is situated one block away from the beach and boardwalk and three blocks from downtown Asbury Park (**Figure 1**). The two streets each have one lane going in each direction (two lanes for each street). The intersection is particularly hazardous due to its wide turning angle for drivers coming from downtown traveling towards the beach. Motor vehicles often do not slow down sufficiently when turning right.

Figure 1: Study Site. To the left (west) is downtown, and to the right (east) is the beach.

The pop-up bike lane was implemented from April 1st to April 25th, 2022. We used temporary white, yellow, and green spray paint and orange cones to create the bicycle lane and white delineators to protect riders turning right from Cookman Avenue onto Asbury Avenue and from Asbury Avenue to Kingsley Avenue (**Figure 2**). No cones were placed in front of a bus stop on Cookman Avenue to allow buses to pull up to the curve and no cones were placed on Asbury Avenue because there was not enough clearance. We also used a bicycle stencil to denote the temporary bike lane. These connect to a larger network of existing bike lanes, one westbound on Asbury Avenue and northbound on Kingsley Avenue. Ocean Avenue does not currently have bicycle lanes but has a wide lane that bicyclists and e-scooter users share with motor-vehicles.

Figure 2: Temporary Pop-Up Bike Lane. The first image (left) shows the traffic camera view, which faces south – the beach is to the left of the image. The second image (right) is the bike lane on Cookman Avenue (going towards downtown).

3.2. Observational study

Traffic video footage was collected with an AXIS P1427-LE network camera, ideal for 24/7 traffic conditions monitoring. We used the videos to manually observe micromobility road use for four to six hours per day for seven days between 7AM-10AM and 3PM-6PM. We observed 35 hours total, 17.5 hours in the morning and 17.5 hours in the afternoon, and 15 hours total for three days pre-installation and 20 hours total for four days post-installation (**Table 1**). We considered weather conditions by downloading historical weather data to compare times when the ground was not wet and when it was not raining (NOAA, 2020). The temperature was consistent between the period before and after the implementation of the bike lane, ranging between the high 50s to the low 70s degrees Fahrenheit (11-23° Celsius).

Table 1: Summary of Traffic Camera Footage

Date	Day of the week	Temperature	Bicycle Lane Conditions
3/16/2022	Wednesday	H: 63°F; L: 43°F (H: 17°C L: 6°C)	Not implemented
3/19/2022	Saturday	H: 73°F; L: 50°F (H: 23°C; L: 10°C)	Not implemented
3/26/2022	Saturday	H: 52°F; L: 43°F (H: 11°C; L: 6°C)	Not implemented

4/12/2022	Tuesday	H: 72°F; L: 46° F (H: 22°C; L: 8°C)	Cones on Cookman: Present Delineators: Present
4/13/2022	Wednesday	H: 74°F; L: 50°F (H: 23°C; L: 10°C)	Cones on Cookman: Present Delineators: Present
4/16/2022	Saturday	H: 73°F; L: 48°F (H: 23°C; L: 9°C)	Cones on Cookman: Present Delineators: Present
4/23/2022	Saturday	H: 59°F; L: 51°F (H: 15°C; L: 11°C)	Cones on Cookman: Present Delineators: Present

We sought to collect data on the following characteristics and behaviors: helmet use, bike lane use, sidewalk use, gender, and riding in a group or alone. For groups, we also analyzed whether the lead was a man or a woman. Around 20 micromobility vehicles were observed per hour – or one every three minutes. Therefore, it was relatively straightforward to observe a group, as it was a group of people riding the same micromobility vehicles, going in the same direction, and displaying behavior that showed that they were together (looking at each other, waiting for one another at the intersection, riding very close to each other). In the results that follow, we first provide an overview of descriptive results. This is followed by estimating two regression models to determine associations with helmet use and bike lane use. For helmet use, only cyclists are considered since no e-scooter user was observed wearing a helmet. For bike lane use, we consider observations for the time period when the temporary bike lane was introduced in the month of April 2022. We use a multinomial logistic regression to address lane usage and a binomial logit regression to address helmet use.

4. Results

4.1. Descriptive results

4.1.1. Helmet use

We observed 707 e-scooters and bicycles with around 2/3rd (507) bicycles and 1/3rd (200) e-scooters (**Table 3**). E-scooter users were much more likely to ride in groups (81%) compared to cyclists (36%). Helmet use was low: only 35% of cyclists wore a helmet while no e-scooter rider was observed wearing one. Helmets are not required by law for adults in the state of New Jersey. Cyclist helmet use was more likely to occur in the morning (53%) than in the afternoon (25%). Women cyclists were less likely to wear a helmet (26%) than male cyclists (37%). Cyclists who wore helmets were less likely to use the bicycle lane than cyclists who did not wear a helmet. **Table 2** displays the proportion of cyclists wearing a helmet depending on the lane that they rode, both before and after the implementation of the bike lane. After the implementation of the bike lane, around 63% of cyclists wore a helmet, compared to 27% of those who used the bike lane and 11% of those who used the sidewalk.

Table 2: Helmet use among cyclists by lane use

Lane use	# of cyclists observed	# of cyclists wearing a helmet	% of cyclists wearing a helmet
Before the implementation of the bike lane			
Sidewalk	29	4	14%
Traffic lane	150	62	42%
Total	179	66	37%
After the implementation of the bike lane			
Bike lane	226	62	27%
Sidewalk	34	4	11%
Traffic lane	74	47	63%
Total	334	113	34%

4.1.2. Group riding

Forty-nine percent of micromobility users were seen riding as a group – although two groups were seen riding on the same scooter (multiple people on one e-scooter is illegal in Asbury Park ("Chapter 3 Police Regulations: Electric Scooter Rules and Regulations," 2019)). One hundred and fifty-two groups were observed, ranging from two to seven people. The breakdown of groups by gender is as follows: 23% of the groups were all male, 16% were all female, 39% of the groups were mixed with a male leading the group, and 18% were mixed with a female leading the group. We observed that mixed-gender groups were more than twice as likely to have a male lead the group as opposed to a female. Cyclists were slightly more likely to wear a helmet when in a group (41%) than if riding alone (32%).

4.1.3. Bike lane usage

We observed 396 bicyclists and e-scooter users after the bike lane was installed. Around 65% of them made use of the bike lane when it was available. Prior to the availability of the bike lane, of the 263 micromobility vehicles we observed, 85% used the road and 15% used the sidewalk. Differences in bike lane use existed between gender and micromobility mode (**Figure 3**). Some users used both roads, sidewalks, and bike lanes while observed but for the purpose of this figure, we identify "road users" as those who did not use the bike lane or sidewalk while observed by the research team. Sidewalk users were users who were not observed using the bike lane at all but may have used the road in addition to the sidewalk. Bike lane users may include users who were observed on the road or sidewalk for a brief period. We found that women and e-scooter users, respectively, more often used the sidewalk than men and cyclists.

Bike lane use was evenly split among women and men cyclists, and slightly higher for women e-scooter users compared to men e-scooter users.

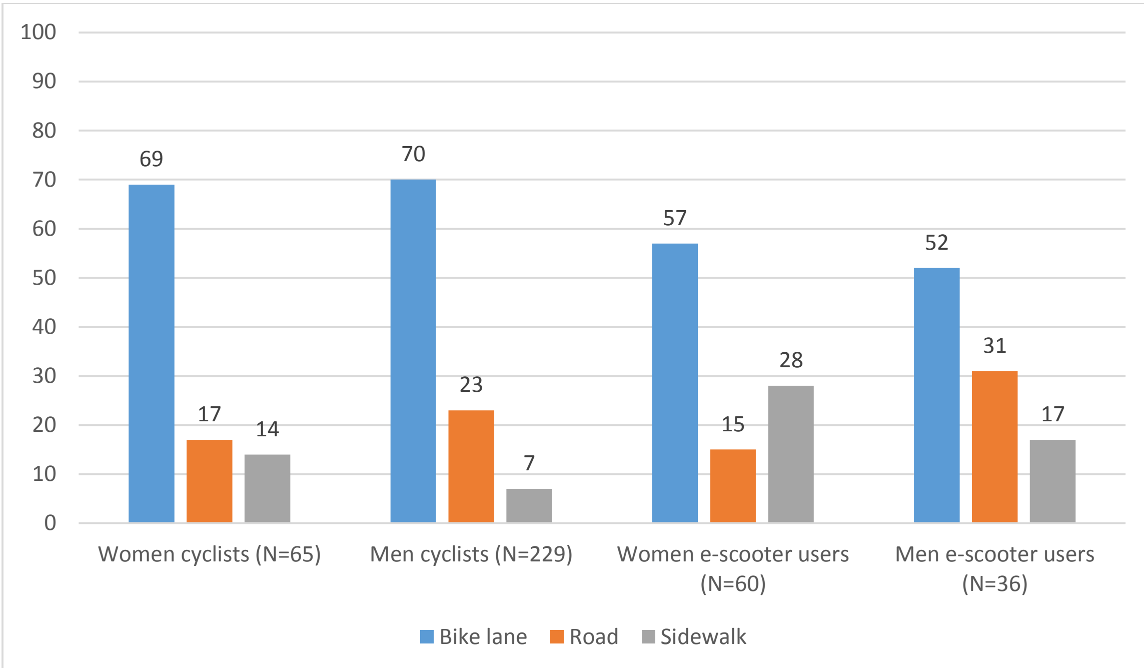

Figure 3: Bike lane, road, and sidewalk use (%) by gender and micromobility mode after the implementation of the bike lane, where available.

4.1.4. Temporal variations

There were differences between bicycle and e-scooter usage depending on the time of day and day of the week. Usage was higher in the afternoon than in the morning for both e-scooter users and cyclists (**Table 3**). However, 93% of e-scooter users were observed in the afternoon, compared to 63% of cyclists. Weather variations may explain some of these variations, as temperatures were cold in the morning and more moderate in the afternoon. Cyclists were observed evenly during the weekend and weekdays: 41% of the time observed was on weekdays, which is precisely the proportion of cyclists we observed during that time. In contrast, a smaller proportion (32%) of e-scooter riders were observed on weekdays.

4.1.5. Gender

The gender split was close to even for e-scooter users (51% female vs 49% male). In contrast, over 75% of bicyclists were male. Women overall were far more likely to be seen riding in groups: 79% rode in a group compared to 36% of men. Among cyclists, women were still seen riding in a group 63% of the time compared to men, who were observed as part of a group 29% of the time. The gender differences in usage may suggest that shared e-scooters are more gender equitable than private cycling. However, observations cannot tell us about frequency of use. Previous research has shown that women are less likely to be frequent micromobility users than men. Hence, even though we observed a nearly even split in e-scooter usage among men and women, we cannot conclude whether individual women use them as frequently as men. The fact that it is more of a group activity among women than men could suggest casual recreational use, although that is speculative and surveys would be needed to test this hypothesis. Nonetheless, initial results suggest that shared e-scooter use is used equally by both genders compared to privately owned bicycles in Asbury Park.

Table 3: Summary of Observational Traffic Camera Footage

	Bicycles	**E-scooters**	**All**
Total vehicles	507 (71.7%)	200 (28.3%)	707 (100%)
Helmet use	179 (35.3%)	0 (0%)	179 (25.3%)
Gender			
Males	392 (77.3%)	97 (48.5%)	489 (69.2%)
Females	108 (21.3%)	103 (51.5%)	211 (29.8%)
Riding in group or alone			
Riding in group	183 (36.1%)	161 (80.5%)	344 (48.7%)
Riding alone	323 (63.7%)	35 (17.5%)	358 (50.6%)
Lane use (Before)			
Road	150 out of 179 (83.8%)	70 out of 84 (83.3%)	220 out of 263 (83.7%)
Sidewalk	29 out of 179 (16.2%)	14 out of 84 (16.7%)	43 out of 263 (16.3%)
Lane use (After)			
Use of bike lane during demonstration project (where available)	208 out of 299 (69.6%)	53 out of 97 (54.6%)	261 out of 396 (65.9%)
Road	65 out of 299 (21.7%)	21 out of 97 (21.6%)	86 out of 396 (21.7%)
Sidewalk	26 out of 299 (8.7%)	23 out of 97 (23.7%)	49 out of 396 (12.4%)
Day time use			
Morning (17.5 hours)	187 (36.9%)	14 (7%)	201 (28.4%)
Afternoon (17.5 hours)	320 (63.1%)	186 (93%)	506 (71.6%)
Week day use			
Weekday (14.5 hours)	211 (41.6%)	64 (32%)	275 (38.9%)
Weekend (20.5 hours)	296 (58.4%)	136 (68%)	432 (61.1%)

4.2. Logistic regressions

We sought to estimate two regression models to control for various behaviors related to (1) bike lane / sidewalk use and (2) helmet use. Bike lane users were limited to the four days observed after the implementation of the bike lane; 17.5 hours of observations. Helmet users are limited to cyclists, since no e-scooter users were observed using a helmet during the time period observed. For lane use, we consider three choices in a multinomial logit regression: bike lane, traffic/drive lane, and sidewalk. For helmet use, the dependent variable is binary: either they used or did not use a helmet. We were particularly interested in protective behavior and gender differences in behavior. That is, do helmet users also use a bike lane more often? And are men more likely to wear a helmet than women when controlling for other factors? We used the Variance Inflation Factor (VIF) to test for multicollinearity and ensuring that the VIF did not exceed 2 (O'brien, 2007). We report both the coefficients and the corresponding odds ratio for each significant variable.

4.2.1. Bike lane usage

The multinomial logistic regression compares bike lane usage (reference) with road and sidewalk usage (see **Table 4**). Results suggest that users of the temporary bike lane tended to be (1) cyclists, (2) unhelmeted, and (3) traveling alone, compared to users of the traffic lane. Gender in lane usage for bike lane versus traffic lanes were insignificant. However, women were more likely to ride on the sidewalk than men were, compared to their use of other lanes. Helmet use was negatively associated with both riding on the sidewalk and using the bike lane, compared to riding in the traffic lane. People were more likely to ride in the traffic lane in the morning than in the afternoon relative to bike lane and sidewalk users. We include time of day to account for traffic flow. Morning traffic was lighter than the afternoon, and thus micromobility users may feel safer riding in the road. In a separate analysis (Younes et al., 2023), we used computer vision techniques to count motor-vehicles. Nearly 4 times more motor-vehicles passed through the intersection between 4pm-6pm than between 7am-9am. The difference was even larger on weekends. Around 120 vehicles per hour passed through the intersection between 7am and 9am and 450 vehicles per hour passed through between 4pm and 6pm.

The direction in which the user was riding was a particularly important control in this regression. People making a right turn were ten times as likely to use the bike lane and 4 times as likely to use the sidewalk than to use the traffic lane, compared to those making a left turn. We configured the road so that right turns were clearly delineated (**Figure 2**), and thus people going straight or making a left may have had a more difficult time using the bike lane.

Table 4: Bike lane usage regression

	Dependent variable: *Type of lane used* *Reference: Bike lane used (N = 281)*	
	Sidewalk used only N = 50	Road used only N = 106
Gender: woman (Reference: man)	**0.630***	-0.073
	(0.370)	(0.321)
Vehicle Type: e-scooter (Reference: bicycle)	0.399	**0.953****
	(0.405)	**(0.382)**
Wore a helmet	-0.628	**1.074*****
	(0.585)	**(0.334)**
Riding in a group (Reference: alone)	0.360	**0.570***
	(0.418)	**(0.325)**
Direction: right (Reference: left)	**-0.917***	**-2.339*****
	(0.510)	**(0.519)**
Direction: straight (Reference: left)	0.142	0.441
	(0.467)	(0.364)
Riding in the afternoon (Reference: morning)	0.680	**-1.103*****
	(0.585)	**(0.341)**
Weekend (Reference: weekday)	0.105	0.277
	(0.347)	(0.297)
Constant	-2.616***	-1.012**
	(0.706)	(0.478)
Akaike Inf. Crit.	662.285	
McFadden's R2	0.18	
Observations	437	
Note:	$^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$	

4.2.2. **Helmet use by cyclists**

Helmet use was observed for 35% of cyclists. We use a binomial logit regression in order to control for various factors (see **Table *5***). Among the nearly 500 cyclists observed (fourteen observations were removed where gender or group riding was not obvious), those who are male, riding in a group, riding on the road, riding in the morning, and riding on weekends, were associated with a higher propensity of wearing a helmet. In this case study, protective actions do not necessarily beget protective behavior – helmet users were less likely to use the bike lane than non-helmet users. Perhaps the added protection of wearing a helmet makes cyclists feel safer riding on the road, or it could be that other factors that we do not directly control for (such as user experience and traffic flow) also affect how often the bike lane is used. Morning cyclists were nearly three times (OR: 2.7) as likely to wear a helmet than cyclists riding in the afternoon. While traffic flow was not included in the model, as noted previously, morning traffic flow tended to be visibly lower than afternoon traffic flow, which could have influenced cyclists' decisions to ride on the road. While we did not find significant gender differences in bike lane usage, we find significant ones for helmet use. Men were around twice as likely to wear a helmet once controlling for other factors. Cyclists riding on the road were two and five times as likely to wear a helmet than cyclists riding on the bike lane and sidewalk, respectively.

Table 5: Helmet use regression

	Dependent variable:	
	Helmet use among cyclists	
	Coef s.e.	Odds Ratio
Gender: woman (Reference: man)	**-0.624****	**0.536**
	(0.278)	
Riding in a group (Reference: alone)	**0.454****	**1.575**
	(0.229)	
Riding in the bike lane (Reference: on the road only)	**-0.678*****	**0.508**
	(0.213)	
Riding on the sidewalk (Reference: on the road only)	**-1.743*****	**0.175**
	(0.460)	
Riding in the afternoon (Reference: morning)	**-0.995*****	**0.370**
	(0.213)	
Weekend (Reference: weekday)	**0.531****	**1.701**
	(0.224)	
Constant	-0.596*	
	(0.352)	
Observations	493	
TJUR R2	0.16	
Log Likelihood at 0	-317.584	
Log Likelihood	-276.119	
Akaike Inf. Crit.	566.237	
Note:	$^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$	

5. Discussion

In this study, we observed 35 hours of traffic camera footage in order to analyze the behaviors of micromobility users after installation of a temporary bike lane. We sought to examine safety behaviors, including bike lane use and helmet use, and gender differences. We were able to obtain information on the usage of a helmet, gender breakdown, lane and sidewalk usage, group riding, and temporal usage. We addressed three questions: What are the behavioral differences between bicycle and e-scooter usage in terms of helmet use, bike lane use, gender split, group riding, and temporal variations? Are more protective conditions associated with helmet use and bike lane use? Is the gender gap narrower for e-scooter use than cycling? We discuss the results of these three questions in this section.

5.1. Differences in behavior between modes

We found notable differences between privately owned bicycle users and shared e-scooter users. Where one third of cyclists wore a helmet, no e-scooter user was observed wearing one. The shared e-scooter vendor in Asbury Park strongly encourages helmet use (Superpedestrian, 2021) and partners with a helmet company to offer a discount (which leads to a price of $45+ per helmet), but that is insufficient to ensure that bike helmets are worn. Helmets for adults are not mandated in Asbury Park, and the observed helmet use rate among cyclists is lower than what has been observed in other cities both with and without helmet mandates. E-scooter users were more likely visitors to Asbury Park and would not have brought a helmet with them.

Bike lane use varied slightly between the two modes. E-scooter users were more inclined to use both the sidewalk and traffic lane than cyclists. Another major difference between the modes was that e-scooter riding appeared to be more of a group activity than bicycling. Just 18% of e-scooter users were observed riding alone, compared to 63% of cyclists. Moreover, we observed some temporal differences in the two micromobility modes. Shared e-scooter users were rarely observed riding in the morning, which previous literature has observed as well (Younes et al., 2020). Around two thirds of cyclists biked in the afternoon, compared to 93% of e-scooter users. The location where our observations were recorded was on a road connecting the downtown area (with many restaurants) to the beach and boardwalk (with entertainment venues and additional restaurants). Evening e-scooter activity could reflect recreational travel between both these venues, while morning bicycle use could be more for commute purposes.

These differences have implications for planning. Riding on the sidewalk is illegal in Asbury Park. Yet, around one quarter of e-scooter users were observed riding on the sidewalk even after the implementation of the bike lane. A few reasons may explain why this is the case. First, shared e-scooter users are more likely to be novice users. They may not be comfortable riding in the road or in the bike lane with motor-vehicles nearby. Moreover, they were not wearing helmets and perhaps had a greater sense of vulnerability. Second, they may not be aware of the laws regarding micromobility use on sidewalks. Finally, our observations were in the Spring, a rather calm period with relatively few pedestrians on the sidewalks for this coastal town that sees a surge in summer visitors. The temporary bike lane was not a protected lane (i.e. with a physical barrier between the lane and the traffic) and this may be needed to shift e-scooter users into the lane and off the sidewalk. Some micromobility vendors have in the past given discounts to users who wear helmets while riding by using AI technology to detect helmet use (Hawkins, 2019), although it is not clear how successful these programs have been. Moreover, shared e-scooter users are likely to be recreational users and thus it is unlikely that they will bring their helmet with them, especially if traveling to the beach for the day. The focus on micromobility safety could shift to protected bike lane infrastructure rather than traffic safety campaigns, which alone are unlikely to be effective.

5.2. Helmet use and bike lane use

Cyclists who wore a helmet were nearly three times as likely (OR: 2.9) to ride on the road than to ride in the bike lane, after controlling for other factors. Cyclists riding on the sidewalk at the time of observation, while rare, exhibited the lowest rate of helmet use (12% on average). This indicates that helmet users may behave differently on the road than non-helmet users. Perhaps they feel a greater sense of safety riding in the road because they have a helmet on; and consequently, non-helmet users may stay in the bike lane as a safety precaution. Helmet use may also be more strongly associated with the type of bicycle ridden, but was not easy to collect from the video observations. This may be of interest for future studies. With respect to motor-vehicle clearance (i.e., how close motor vehicles pass vulnerable road users), one study found a negative association between helmet use and motor-vehicle clearance (Walker, 2007), although a subsequent study by the same author no longer found associations (Walker et al., 2014). Helmet use was also more prevalent when riding as a group. This could suggest that there may be greater peer pressure to wear a helmet when others do. However, group riding may have different characteristics, such as trip purpose and length that can also affect helmet use.

5.3. Gender

The gender gap is much narrower for shared e-scooter users than for private cyclists: the split is nearly even for e-scooter users, whereas just 21% of cyclists were observed to be women. The caveat with observational studies is that we do not know about the frequency of usage – it is possible that men use e-scooters more frequently than women, as previous literature has suggested (Dill, 2019). We also don't know if our case study is broadly generalizable and whether this is idiosyncratic to Asbury Park and our observations. Women were more likely to ride in a group than alone. Overall, 79% of women were observed riding as a group compared to 36% of men. Even among cyclists – which is less of a group activity than shared e-scooters in Asbury Park, women were still far more likely to ride as a group. Other gender differences were observed in terms of bike lane use and helmet use. Male cyclists were more likely to wear a helmet (37%) than female cyclists (26%). This finding is similar to what other studies have found (Basch et al., 2014; Valero-Mora et al., 2018), although one study did find an opposite relationship (Fischer et al., 2012). Women were generally more likely to ride on the sidewalk and less likely to ride on the road than men, which is similar to (Duc-Nghiem et al., 2018). When looking at bike lane usage, gender was not a significant factor after controlling for other factors. We are not aware of other studies looking at gender and bike lane usage. However, previous research suggests that bike lanes can induce more women to bicycle (AitBihiOuali & Klingen, 2022). Increased cycling by women is seen as an indicator of a safer bicycling environment (Garrard et al., 2012). On the other hand, the relatively equal use of e-scooters is suggestive of this being recreational usage, as is the larger use of e-scooters as a group activity.

6. Limitations

We acknowledge several limitations in this study. First, this demonstration project occurred in a small New Jersey shore community in an off-peak period, and results from this study may not easily transfer to other settings. This is true of any case study, but still adds to a shared evidence base. Second, only two micromobility modes were observed in Asbury Park, whereas shared bicycles and privately owned e-scooters are two other common modes of micromobility transportation, as are e-bikes. We also cannot attribute our findings to shared versus private and bicycle versus e-scooter, but it is likely that both lead to differences in usage and gender split. Third, observational studies may be prone to error. When the researchers processing the footage were in doubt, the vehicles/users were excluded. Lastly, there are limitations to the variables that we could collect solely from looking at traffic camera footage: race/ethnicity, age, experience, helmet ownership, trip purpose and destination, which would require survey data.

7. Conclusions

Not all micromobility modes are created equal and our findings suggest the behavior associated with their usage is also not equal. Yet, decision makers, planners and engineers have generally treated them with the same approaches, either relegating them to traffic lanes, by prohibiting sidewalk use, not providing sufficient infrastructure, or ignoring them. Our study uncovered differences in how users behave and which safety precautions they may take, as well as in the gender differences between users. Differences in lane usage and in helmet use were prominent both for e-scooter and bicycle users and for men and women. This has important implications for planning micromobility. E-scooter users in Asbury Park may benefit from protected bike lanes as they appear to take fewer safety precautions, given that we find they are less likely to use a bike lane and to wear a helmet. While this study focused on a single town, frequented by visitors, previous literature has also suggested that e-scooter users and shared micromobility users are less likely to wear a helmet (Haworth et al., 2021). While we cannot know about their prior experience from this study, previous literature suggests that shared micromobility users are often less experienced road users than private cyclists. These combined factors suggest that a more protective approach, such as protected bike lanes, is needed to ensure the safety of e-scooter users and , of course, can also be beneficial for cyclists.

We also found behavioral differences between men and women in terms of micromobility vehicle usage, helmet use, group riding, and lane use. We found that women made up a much larger proportion of e-scooter riders than of cyclists. This may indicate that women find the mode more attractive, and thus implementing e-scooter share programs can help increase micromobility use and low-carbon transportation options for women (who may not be inclined to use a bicycle). Alternatively, this may be an indicator of recreational use in Asbury Park. Women cyclists, nonetheless, were less likely to wear a helmet than men. If it is not possible to ensure helmet use, ensuring safe roads for micromobility users by implementing protected bike lanes can help achieve safety targets and make micromobility use an attractive option for all.

Acknowledgment:

This work was supported by the National Science Foundation (NSF) under Grant #1951890.

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We would like to thank both reviewers for their careful attention to detail and thoughtful comments for improving our manuscript.

Reviewer #1: The paper, based on traffic camera footage, seeks to analyze the behaviors of e-scooter and bicycle users after the installation of a temporary bike lane: in particular, bike lane and helmet use, and gender differences were investigated. I enjoyed reading this paper. It is clear and concise and tackles a relevant and timely issue. The topic is no doubt relevant according to Case Studies on Transport Policy Journal themes and to its audience.
The article is interesting and overall well written, but there are some aspects that leave me perplexed. See below my related comments.

- *Page 18 - Lines 375-376: "....he split is nearly even for e-scooter users, whereas just 20% of cyclists were observed to be women." Instead in the abstract the authors state: "....where only one quarter of cyclists were observed to be women." There is an inconsistency.*

Thank you for pointing this out. Upon reviewing, the percentage of female cyclists is 21.3%. We've revised the abstract and text to reflect that percentage.

- *The literature review is quite up-to-date and extensive, but for example, about the gender split in micromobility users and the differences in behavior between genders, the authors could refer to Rupi et al. Analysis of gender-specific bicycle route choices using revealed preference surveys based on GPS traces, Transport Policy, 2023.*

We have added this relevant article to our section 2.2. "Recent work shows that men cycle faster on average than women, and that women tend to avoid complex route elements more than men (e.g., intersections without traffic lights, left turns, and changes in road type) (Rupi et al., 2023)." Thank you for your suggestion.

- *Page 3 - Lines 40-42: "We investigate the variation in how riders use the road, who they are, and what safety precautions they take depending on the micro-vehicle type and on whether the vehicle is privately owned or shared. In this study, we analyze the behavioral differences between two micromobility modes: privately owned bicycles and shared e-scooters with a focus on gender differences." It would have been better to analyze the behavioral differences between privately owned bicycles and shared bicycles and the behavioral differences between privately owned e-scooters and shared scooters.*

We agree fully. We were hoping to observe more privately owned e-scooters. We knew going into this study that shared bicycles were not available. However, we only observed one privately owned e-scooter user in the 35 hours spent observing the data. Therefore, we could only observe those two modes. We note this limitation in our limitation section.

"Second, only two micromobility modes were observed in Asbury Park, whereas shared bicycles and privately owned e-scooters are two other common modes of micromobility transportation, as are e-bikes. We also cannot attribute our findings to shared versus private and bicycle versus e-scooter, but it is likely that both lead to differences in usage and gender split."

- *Authors should explain why they chose a specific intersection*

We worked with the city of Asbury Park and they made this video footage available. This is a complex and frequently used intersection for people going from downtown to the beach.

We have revised the text (new text underlined) in 3.1:

"<u>We worked with the city of Asbury Park to select a site that had high motor-vehicle, pedestrian, and cycling traffic, while also being a potentially hazardous intersection for non-motorists (Manzella et al. 2018). The city made the video footage available to us for selected days, which we discuss in more detail in 3.2.</u> The intersection we analyzed is situated one block away from the beach and boardwalk and three blocks from downtown Asbury Park (**Figure 1**). The two streets each have one lane going in each direction (two lanes for each street). The intersection is particularly hazardous due to its wide turning angle for drivers coming from downtown traveling towards the beach. Motor vehicles often do not slow down sufficiently when turning right."

- *Regarding the period of making the traffic video footage, mixing observations carried out during the weekdays with observations carried out on Saturday could provoke some problems, because trip purposes are very different (commuter use versus recreational use).*

You are correct. We do not make any conclusions with respect to trip purpose in this study. However, helmet use may depend on trip purpose (i.e., people who cycle for exercise may be more inclined to wear a helmet). In our regression analysis looking at helmet use, we control for weekends and indeed find that helmet use on weekends is more than 1.7 times more likely than on weekdays. In the last sentence in 5.2, we note that trip purpose likely impacts helmet use. In our limitations section, we further emphasize that trip purpose and destination were unobservable and may limit our findings.

- *How many days before 4/12/2022 was the new cycle lane implemented? This is an important aspect to highlight.*

We have added a sentence to clarify the time period that the pop-up bike lane was implemented in 3.1. The underlined portion is new:

"<u>The pop-up bike lane was implemented from April 1st to April 25th, 2022</u>. We used temporary white, yellow, and green spray paint and orange cones to create the bicycle lane and white delineators to protect riders turning right from Cookman Avenue onto Asbury Avenue and from Asbury Avenue to Kingsley Avenue (**Figure 2**). No cones were placed in front of a bus stop on Cookman Avenue to allow buses to pull up to the curve and no cones were placed on Asbury Avenue because there was not enough clearance. We also used a bicycle stencil to denote the temporary bike lane. These connect to a larger network of existing bike lanes, one westbound on Asbury Avenue and northbound on Kingsley Avenue. Ocean Avenue does not currently have bicycle lanes but has a wide lane that bicyclists and e-scooter users share with motor-vehicles."

- *Pag. 9 Line 212 "Helmets are not required by law for adults in the state of New Jersey." How many children were there in the sample?*

You bring up a good point. We observed just 3 people who were visibly children, all riding a bicycle with their parents and all wearing helmets. There may have been other young adults who were adolescents but appeared to be adults or where it was not clear. Shared e-scooter users cannot be rented by children 17 and younger, although again, there may have been some adolescents in the mix if they used their parents account or put a fake birth year when registering.

Because the vast majority of micromobility users appeared to be adults, most of the language here focuses on that. The purpose of the sentence was to inform international readers that the low helmet usage may be partly explained by the fact that the local law does not require its usage. While it would be interesting to look at compliance rates among children, our low sample cannot give us much to say for this study.

- *It is not clear why after the implementation of the bike lane, the number of cyclists observed becomes so large 334 vs 179 (+87%). An extra day of surveying is not a sufficient reason to explain this increase.*

This is an interesting observation. We went ahead and checked the before/after numbers for e-scooter users. There were 84 e-scooters observed before the implementation of the bike lane (or 28 per day), and 116 observed after the implementation (or 29 per day on average). Therefore, the number of e-scooters observed doesn't vary much before and after in the same way that private cyclists does.

At this point, we can only speculate why there are so many more cyclists after the implementation, especially in comparison to e-scooter users. One speculation is that weather warmed up a bit (average before: 63F or 17C; average after: 70F or 21C) and more cyclists were inclined to cycle. Meanwhile, we may not see the same jump in e-scooter activity because e-scooters tend to be less likely to ride on weekdays than on weekends. One of the days before the implementation of the bike lane was a weekday (33%) compared to two out of the four days after the implementation were weekdays (50%).

- *Pag. 13 Line 291 The relationship with traffic flow is very important. Maybe it is better to put it in the text instead of in the footnote*

We have moved the text to the main paper and have deleted the footnote.

- *Regarding the comparison between bike lane usage (reference) with road and sidewalk usage, it would have been interesting to understand how the speed of micromobility users varied in the three sections (see for example Bernardi et al. Quantifying the role of disturbances and speeds on separated bicycle facilities, Journal of Transport and Land Use 2016).*

This would indeed be interesting, although it would require analysis that is beyond the scope of this paper. We plan to tackle this issue for future work.

Minor Comments
Pag. 12 Line 264 "bothgenders". Typo.
Pag. 15 Line 311 "road..". Typo.
Pag. 17 Line 367 "………observations. this may……….". Typo.
Pag. 19 Line 422 "……. lane use.. We ….." Typo.

Thank you, all have been fixed.

Reviewer #2: Technically, the paper is fine. However, I have two major issues with it:
- The study is very localised. I am not sure whether any generalisations can be drawn from a study of a single intersection in a single, small city in the US.

Thank you for your concern. We know that generalizations are limited for this study, which is why Case Studies was chosen as our journal for submitting this paper. However, the intersection that we use is a high traffic corridor in Asbury Park. Based on Strava data (an app used to record running and cycling trips) and on bike share GPS data, this intersection has high frequency of usage by cyclists and runners (Maps 6 and 7 on page 34 in the Asbury Park Bike/Ped Master Plan linked below). It is also one of the few routes where a bus goes through (Map 2 on p. 26 in Asbury Park Bike/Ped Master Plan). Cookman Avenue connects downtown to the beach and thus, many of the visitors and residents pass through this intersection when going to the boardwalk of Asbury Park.

(Source: https://www.cityofasburypark.com/DocumentCenter/View/857/Asbury-Park-Plan-for-Walking--Biking)

We have further clarified our reasoning for choosing this intersection in 3.1. (underlined text is new):

“We worked with the city of Asbury Park to select a site that had high motor-vehicle, pedestrian, and cycling traffic, while also being a potentially hazardous intersection for non-motorists (Manzella et al. 2018). The city made the video footage available to us for selected days, which we discuss in more detail in 3.2. The intersection we analyzed is situated one block away from the beach and boardwalk and three blocks from downtown Asbury Park (**Figure 1**). The two streets each have one lane going in each direction (two lanes for each street). The intersection is particularly hazardous due to its wide turning angle for drivers coming from downtown traveling towards the beach. Motor vehicles often do not slow down sufficiently when turning right.”

- Gender has been determined by looking at videos rather than asking people directly. This could work (although many now prefer to self-identify) except people here are wearing helmets and presumably some are wearing unisex cycling clothes. This makes the data quite weak.

You are correct. Gender is nuanced and only apparent gender was determined by the researchers (which may differ from the one that people identify as). For the vast majority of cases, gender was evident (i.e., very few cases involved unisex clothing or helmets that obstructed the appearance of the user). In the case where there was doubt (N=13, or 1.8% of observations), we opted not to include those people in analysis where gender was concerned. We attempted to collect age and race/ethnicity as well, but those were much more challenging to observe and we opted not to discuss those in this study.

Credit Statement:

Conceptualization: Younes, Noland, Andrews; Data curation: Younes; Formal analysis: Younes; Methodology: Younes; Supervision: Noland, Andrews; Funding acquisition: Noland, Andrews; Writing-original draft: Younes, Noland, Andrews; Writing – review & editing: Younes, Noland, Andrews.