Safety Assessment of E-Scooter Riders from a Naturalistic Driving Study

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I. INTRODUCTION

Micro-mobility devices have become popular in the past several years in the USA. Among different options, electric scooters (e-scooters) have dominated the shared micro-mobility market. Over 200,000 e-scooters had been deployed by 2020 across the USA, in 100 cities, with 38 million trips taken on these e-scooters [1]. Many surveys have confirmed positive attitudes toward e-scooters as a promising mobility option, which may further increase their popularity [2]. However, e-scooter-rider-involved crashes have increased significantly, resulting in 29,000 injuries in 2018 (up from 4,800 in 2014) [3]. Some studies showed a 500% increase in the emergency room (ER) visits related to e-scooters after the launch of e-scooter rental services [4]. Two studies [5-6] have estimated that there are 20–25 e-scooter-related injuries that require ER visits for every 100,000 trips.

All these facts emphasize the importance of studying the behavior of e-scooter riders and designing related traffic management policies and vehicle safety technologies. Although different research efforts have been made to study e-scooter behaviors and vehicle-e-scooter interactions using medical records, media reports and policy reports, all these retrospective data sources have three main limitations: (1) the data were collected after the crashes and did not clearly and accurately record what happened before and during the crashes clearly and accurately; (2) the data usually only contain qualitative data like behavior descriptions or relative trajectory types, but miss much detailed and quantitative information, like velocity, moving angles, decelerations, scene videos, etc.; and (3) the crash data cannot fully reflect the normal behaviors of e-scooter riders who are not involved in crashes but who provide the baseline to understand the risks.

Therefore, this research conducted a naturalistic driving study focused on collecting and analyzing vehicle-e-scooter interaction scenarios. The data analysis tried to address three main issues:

- baseline moving patterns of e-scooters in diverse road environments and locations.
- interaction of e-scooter riders with vehicles and other road users in different scenarios.
- the common scenarios and parameters for crashes or near-miss events involving e-scooter riders.

II. METHODS

Both car-centered and e-scooter-centered naturalistic driving experiments were conducted in this research. In the first part of the data collection, 55 subjects were recruited to drive the experiment vehicle (Fig. 1), which is instrumented with LiDAR, 360-degree camera, and high-definition Real-Time Kinematic (RTK) GPS, in downtown Indianapolis, Indiana, USA. We collected 35.24 hours of driving data, including 400 encounters with e-scooter riders. To better understand the e-scooter-vehicle encountering scenarios from the e-scooter's perspective, seven additional subjects were recruited to ride an e-scooter with a wearable data collection system [7]. The wearable system covered 200-degree surroundings by fused LiDAR and cameras, and recorded the e-scooter's movements with an RTK GPS. The RTK GPS used in both the car- and e-scooter-centered data collection had a location accuracy of <1 m. A total of 16 hours of e-scooter-centered data were collected in the same area.

All the collected data went through a data preprocessing pipeline (shown in Fig. 2). After a multi-step sensor-fusion and computer-vision process, the global trajectories of the cars and e-scooter riders were generated and synchronized. Data analysis was performed for all cases using these global trajectories. For each case, an estimated time-to-collision (TTC) was calculated between cars and e-scooter riders, and the shortest TTC is recorded for each case, if it exists. Based on the TTC, the case is classified as a near-miss or baseline. Then the scenario variables, like speed, distance, movement geometry and gap time, were calculated and analyzed.

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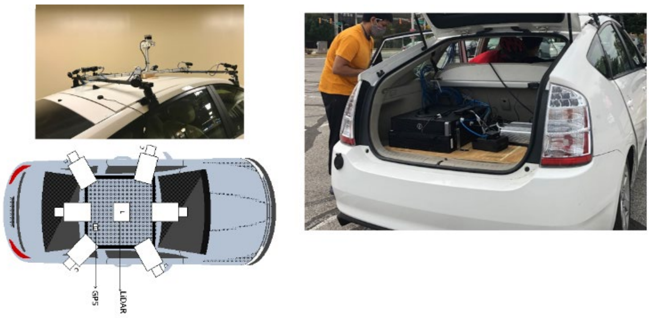

Fig. 1. Experiment Vehicle.

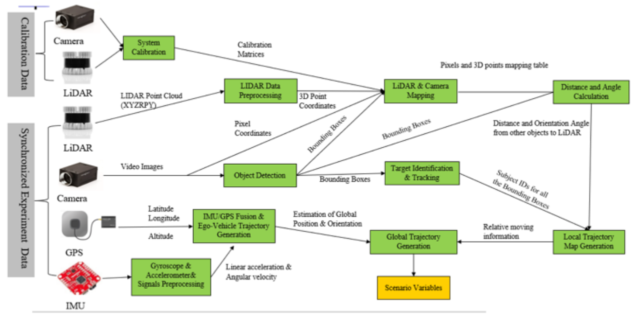

Fig. 2. Data Preprocessing Pipeline.

III. INITIAL FINDINGS

TABLE I

PRELIMINARY RESULTS OF SCENARIO VARIABLES FOR VEHICLE-E-SCOOTER ENCOUNTERS

Scenario Variables	Car-Centered Perspective			E-Scooter-Centered Perspective		
	Overall	**Potential Conflict**	**Baseline**	**Overall**	**Potential Conflict**	**Baseline**
Minimum Distance	15.29 m	16.22 m	14.94 m	8.24 m	7.81 m	8.69 m
Ego-Vehicle Median Speed	11.86 mph	18.25 mph	9.51 mph	13.53 mph	13.44 mph	13.65 mph
E-scooter Median Speed	8.48 mph	8.43 mph	8.61 mph	9.40 mph	10.74 mph	8.12 mph
Minimum Gap Time	3.09 s	0.77 s	5.54 s	2.18 s	0.84 s	6.10 s

As reported in Table I, 203 car-centered cases (53 near-misses) and 285 e-scooter-centered cases (147 near-misses) were analyzed. Additional analyses will separate the scenario variables for the different car--e-scooter encountering geometries, with geometry distributions shown in Fig. 3 and Fig. 4.

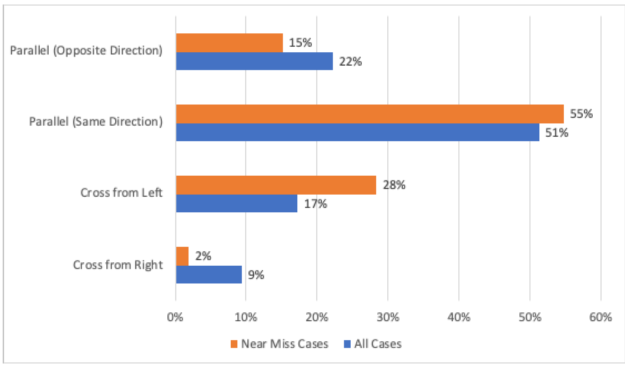

Fig. 3. Geometry Distribution for Car-Centered Data.

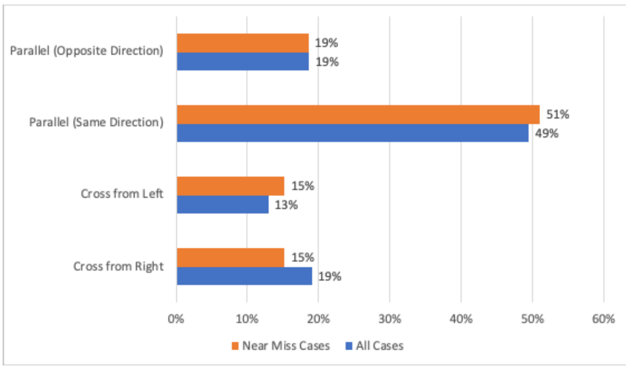

Fig. 4. Geometry Distribution for E-Scooter-Centered Data.

IV. DISCUSSION

The reported research supplements existing efforts to investigate the behaviors of e-scooter riders in the naturalistic road environment, especially during risky encounters with cars. By collecting and analyzing naturalistic driving data from the perspectives of cars and e-scooter-riders, the completed results will provide detailed quantitative measurements of movements, distances and time intervals for cars and e-scooters under different scenarios. In combination with crash data, representative car-to-e-scooter scenarios can be fully modeled, and vehicle-based safety countermeasures can be developed. We are now collecting a larger naturalistic dataset in multiple big cities in the USA to add more diversity to the data analytics.

V. REFERENCES

[1] NACTO, *Shared Micromobility in the U.S.: 2019 report*, 2020.

[2] Sanders, R. L., *et al.*, *Transportation Research Part A: Policy and Practice*, 2022.

[3] Farley, K. X., *et al.*, JAMA network open, 2020.

[4] Badeau, A., *et al.*, *Am J Emerg Med*, 2019.

[5] APH, Austin Public Health Report, 2018.

[6] Multnomah County Health Department, *Scooter-related Injuries in Multnomah County Report*, 2019.

[7] Prabu, A., *et al.*, FAST-zero conference, 2021.