Literature Review

SAFER STREETS WITH SHARED MICROMOBILITY: IDENTIFYING AND ADDRESSING SAFETY RISKS FOR VULNERABLE ROAD USERS

Emmaline Shields, MPH

Texas A&M Transportation Institute

Table of Contents

Introduction

The field of shared micromobility, including docked and dockless bike share systems (pedal and electric-powered bikes or e-bikes) and electric scooters (e-scooters), has expanded and evolved over the past ten years. Since their introduction in the United States in 2015, the use of micromobility devices has expanded to the streets and sidewalks of over 350 cities, and all indicators point to continued growth.[1] In 2022, trip-making reestablished itself to pre-pandemic levels with approximately 128 million trips taken on shared micromobility transport modes.[1] Moreover, there were over 250 thousand micromobility devices deployed across North America on an average day in 2022, which represents nearly a 25 percent increase from the previous year.[1] While many communities with micromobility programs have observed social, health, economic, and environmental benefits of enhanced multimodal travel and having more alternatives to vehicle use, these effects are often accompanied by safety challenges.[2]

Understanding the fact that shared micromobility devices are sharing the road (or sidewalks) with motor vehicles, traditional bicycles and pedestrians, there are inherent safety issues. In the publication *Countermeasures That Work: A Highway Safety Countermeasures Guide for State Highway Safety Offices*, the National Highway Traffic Safety Administration (NHTSA) recognizes that while many behavioral safety issues between traditional bicycles and shared micromobility is common, there are differences that may require additional laws and targeted countermeasures. NHTSA notes that using e-bikes may subtly change bicyclist perceptions of the risks, as these bikes provide better hard braking capabilities than traditional bicycles. Furthermore, cyclists also choose higher travel speeds on e-bikes than traditional bicycles. Quantifying safety issues is also challenging with these forms of transportation, since underreporting may be common. Specifically, incident and crash reporting is seldom specific enough to indicate these bike types, with e-bike crashes often recorded as bicycle crashes, and e-scooter crashes often recorded as pedestrian crashes. [3]

Although injuries and fatalities are likely underreported for micromobility-involved crashes, a recent report found that emergency room treated injuries and deaths with these transport modes are increasing as shared micromobility devices are increasing in popularity.[4] From 2017 to 2022, there were an estimated 360,800 emergency room visits associated with micromobility. Injuries happened most frequently to the head and the neck, as well as lower and upper limbs. Even more concerning is that the number of fatalities has been steadily increasing as well. The Consumer Product Safety Commission (CPSC) is aware of 233 fatalities from micromobility products from 2017 to 2022. The top hazards in e-scooter and e-bike fatalities were incidents with motor vehicles and dangerous user behaviors, such as high speed, impairment, and inexperience.[4] Additionally, micromobility users are often non-compliant with micromobility traffic laws and safe operating rules, which play a factor in crashes and injuries.[5] Research found that micromobility road users are often unaware of the rules, including where they can

---

[1] North American Bikeshare and Scootershare Association [NABSA]. *2022 Shared Micromobility: State of the Industry Report* (Portland, Maine: NABSA, 2023)

[2] National Academies of Sciences, Engineering, and Medicine. *E-Scooter Safety: Issues and Solutions* (Washington, DC: The National Academies Press, 2023)

[3] Venkatraman, et al. *Countermeasures That Work: A Highway Safety Countermeasures Guide for State Highway Safety Offices, 10th edition* (Washington, DC: National Highway Traffic Safety Administration, 2021)

[4] Consumer Product Safety Commission [CPSC]. *Micromobility Products-Related Deaths, Injuries, and Hazard Patterns: 2017-2022* (Washington DC: CPSC, 2023)

[5] Governor's Highway Safety Association [GHSA]. *Understanding and Tackling Micromobility: Transportations New Disruptor* (Washington DC; GHSA, 2020)

operate a device, underage riding, speed limits, helmet use, cellphone use, and other safety issues. Furthermore, law enforcement officers, who are ultimately charged with enforcing micromobility traffic laws and regulations, are often times unaware of the specific statute or ordinance and have received little to no training on micromobility laws and safety.[6]

Micromobility programs are already in many urban Texas cities (e.g. Austin, Dallas, San Antonio) and college campuses (e.g. UT- Austin, Texas Tech), and will likely be in rural areas and smaller towns in the near future as these localities work to improve accessible public transportation options. As shared micromobility programs continue to expand into more Texas cities, there is a critical need to evaluate the safety impacts of these transportation modes. In an effort to gain a better understanding of shared micromobility, the Texas A&M Transportation Institute (TTI) conducted a thorough literature review of information related to micromobility usage and safety trends. The findings are detailed in this technical memorandum.

Study Methods and Data Sources

The TTI project team drew from published literature to gather information about existing micromobility usage, safety trends, and best practices. The search was conducted through Transportation Research International Documentation database. Keywords included “electric scooter/”e-scooter”/”dockless scooter, “electric bike”/“e-bike”/”dockless bike”, “micromobility/micro-mobility”, “docked bike” and “injury, “crash”, “fatality”/”death”, or “safety”. The search resulted in 1252 articles for review. The TTI project team manually reviewed the search results and excluded items that focused only on motorcycles, mopeds, personal mobility scooters, traditional bicycles, and pedestrians, as these modes do not fit within this research’s definition of shared micromobility.

The TTI project team also searched for literature in the form of reports published by professional organizations, nongovernmental organizations, and governments with experience with micromobility. This literature was identified by individually searching the websites of relevant organizations and municipalities for publications. Organizations targeted include: NHTSA, National Transportation Safety Board (NTSB), North American Bikeshare and Scootershare Association (NABSA), Governor’s Highway Safety Association (GHSA), Association of Metropolitan Planning Organizations (AMPO), AAA Foundation for Traffic Safety, TTI, Virginia Tech Transportation Institute, and University of North Carolina Highway Safety Research Center. Additionally, reports from municipalities with known pilot shared micromobility programs, such as Arlington (VA), Austin (TX), Atlanta (GA), Boise (ID), Santa Monica (CA), Portland (OR), and San Diego (CA) were also included.

In total, 392 studies and reports met the inclusion criteria. Most of these were scholarly articles published in peer reviewed journals, but some were agency or municipality reports. The project team reviewed the studies in detail and created a spreadsheet of micromobility literature that includes the study title, date, authors, publication, and findings of each study. The team categorized them into the relevant task areas: injury/crash/fatality data, safety, behavioral and usage trends, and best practices. Some pertained to multiple task areas and were therefore cross-tagged.

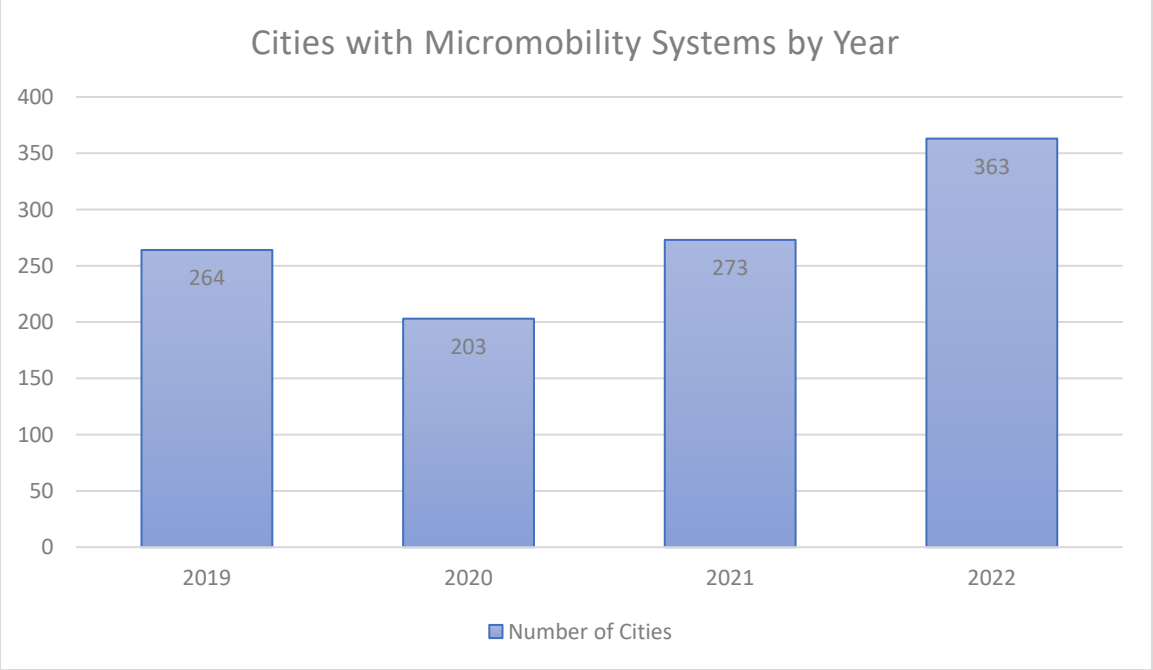
[6] GHSA, Understanding and Tackling Micromobility

Micromobility Markets

Since the introduction of shared micromobility, the usage and popularity of these devices, especially e-devices, has continued to grow. Shared micromobility services have emerged from either brand-new companies dedicated solely to micromobility devices (e.g., Bird) or from other rideshare companies shifting their operational domains (e.g., Lyft, Uber). By examining yearly trends in the number of cities with shared micromobility systems, the number of trips taken on these devices, and the number of devices deployed, it is clear shared micromobility has emerged as one of the most resilient transportation options coming out of the COVID-19 pandemic. In 2022, trip-making re-established itself to pre-pandemic levels, and there was a rapid increase in the number of cities with shared micromobility. [7,8]

In 2022, approximately 363 cities in the United States had a least one shared micromobility system, which represents a 33 percent increase from 2021 (see Figure 1). About 34 percent of cities had bikeshare only systems, 36 percent had scootershare only systems, and 30 percent had both bikeshare and scootershare systems. Moreover, 79 percent of all shared micromobility systems include e-devices (e-bike or e-scooter). The number of systems with e-devices continues to increase year after year, which reflects a trend toward electrification.[6]

Figure 1. Number of Cities with Shared Micromobility Systems by Year



The number of trips taken on shared micromobility devices returned to pre-pandemic levels in 2022 (see Figure 2). In 2022, there were approximately 128 million trips taken in the United States. E-scooters accounted for about half of these trips and bikeshare (e-bikes and pedal bikes) accounted for the other half. Interestingly, in 2022, shared pedal bikeshare trips increased 14 percent from 2021 while e-bike trips increased nearly 65 percent from 2021. This further highlights the growing trend towards the

[7] NABSA, 2022 Shared Micromobility Report
[8] GHSA, Understanding and Tackling Micromobility

electrification of shared micromobility. The average shared micromobility trip length has remained relatively constant since 2019 at approximately 1.5 miles long. Similarly, the average trip duration has remained relatively unchanged from year to year at about 15 minutes.[9]

Figure 2. Number of Shared Micromobility Trips by Year

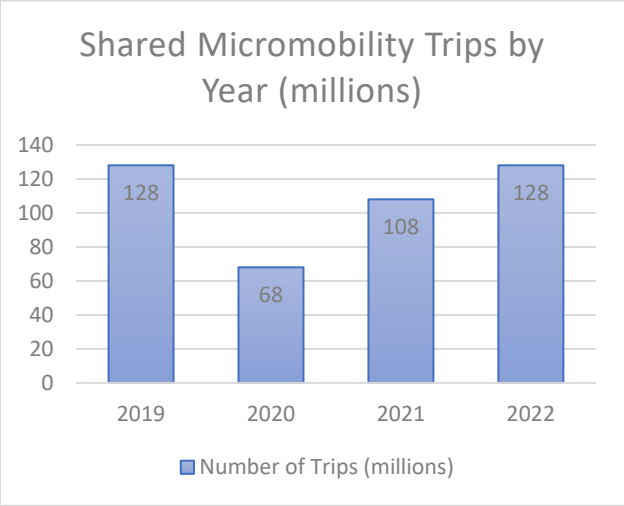
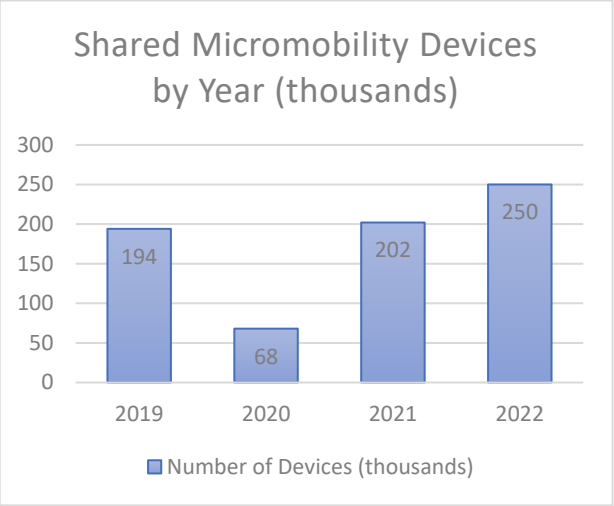


Figure 3. Number of Shared Micromobility Devices by Year



Another indicator of shared micromobility growing in popularity, is the increase of shared micromobility devices deployed across the United States. In 2022, the United States had access to an estimated 250 thousand shared micromobility devices. This is approximately 24 percent greater than in 2021. The number of e-scooters now represents about 66 percent of all shared micromobility devices deployed and the number of e-bikes is now over 40 percent of the bikeshare fleet.[9]

Electrification Trends

With the rapid growth of e-scooter share systems in 2018 and 2019, the shared micromobility industry made a significant move toward electrification. During that same time, e-bikes also became more prevalent. In 2022, the number of e-bikes increased by 71 percent from 2021, and the number of e-scooters grew 28 percent. Furthermore, e-bikes have now surpassed pedal bikes in popularity in systems that have both bikeshare options; e-bikes were ridden approximately 56 percent more than pedal bikes in 2022. Moreover, e-bikes are ridden further than pedal bikes on average. E-scooters were also ridden more than ever before in 2022, with nearly 10 million more trips compared to 2021. [9]

E-bikes and e-scooters are undeniably popular and they will only become more prevalent as states and regions build incentive programs for e-bikes and e-scooter use. For some bike share users, electrification can make bike share more accessible by lowering physical barriers to bicycling. Incorporating e-bikes and e-scooters into a shared micromobility fleet adds choice and is an important component of expanding access. [9] E-bikes and e-scooters will be the focus for the remainder of this report, as they are the most popular shared micromobility transportation options and also have unique safety concerns compared to pedal bicycles. One metanalysis that assessed the frequencies and severities of non-

[9] NABSA, 2022 Shared Micromobility Report

electric micromobility devices (pedal bikes) with electric micromobility devices (e-bikes, e-scooters) found that injuries were more frequent and severe for electric micromobility devices.[10]

Shared Micromobility User Characteristics

NABSA complied user surveys in cities with shared micromobility. About one-third of shared micromobility users reported that they ride for social activities, entertainment, and dining out. An additional 27 percent of users reported they ride for exercise and recreation, followed by work or school (25 percent) and shopping, errand, and appointments (15 percent). Additionally, NABSA reported that 64 percent of riders use shared micromobility to connect to transit, with 18 percent of users reporting that they do so weekly. [11]

Demographic information on shared micromobility users was also collected by NABSA. High income earners (>$100,000) are overrepresented, followed by the lowest income earners (<$15,000). Those earning an annual household income of $15,000 to $49,999 were the most underrepresented, followed by middle income earners ($50,000 to $100,000). Males are overrepresented and females are underrepresented. Older adult participation (over 44 years of age) continue to be underrepresented. Shared micromobility users 25 to 44 years of age are overrepresented, followed by 18 to 24 year-olds. People of color were slightly better represented in 2022; however, White populations were still substantially over-represented. [11]

Large vs. Medium vs. Small Cities with Shared Micromobility

Growth in e-scooter and e-bike ridership is driven by the popularity of these devices in urban areas. In fact, the growing use of e-scooters and e-bikes is concentrated in cities like Chicago, Illinois; Boston, Massachusetts; San Francisco, California; and New York City, New York; and Austin, Texas.[11] These findings are consistent with other studies that highlight the urban nature of e-scooter and e-bike use in the United States. Further, e-scooter and e-bike ridership was often found to be prevalent on and around college campuses, due to their accessibility and affordability. For example, in a study conducted in Knoxville, Tennessee, e-scooter ridership was found to occur predominantly on campus. However, data now shows that the use of shared micromobility has expanded to smaller cities as well. [12]

Shared micromobility programs span the country and do not discriminate by population size. There are systems in larger cities, such as New York, NY, to smaller cities like Savannah, GA. Shared micromobility systems have different operating characteristics in cities of different sizes, including the number of systems, average vehicles per system, average vehicle densities, average trips, and number of operators. A large city is defined as more than 500 thousand people, a medium city is defined as 200 to 500 thousand people, and a small city is defined as less and 200 thousand people. Bikeshare and scootershare densities were lower in large cities but utilization was greater. Large cities also have more micromobility operators (such as Uber, Bird, and Lime) than small and medium cities.[11]

In 2022, small cities experienced a large increase in the number of systems, vehicles per system, and vehicles per capita compared to 2021. This could point towards the continued expansion of shared

---

[10] Niemann, et al. “Dangers Of E-Mobility: A Systematic Review And Meta-Analysis Of Sustained Injury Patterns And Injury Severity”, *Safety Science,* 167 (2023)

[11] NABSA, 2022 Shared Micromobility Report

[12] National Transportation Safety Board [NTSB]. *Micromobility: Data Challenges Associated with Assessing the Prevalence and Risk of Electric Scooter and Electric Bicycle Fatalities and Injuries* (Washington, DC: NTSB, 2023)

micromobility in rural communities. Systems in rural settings are often regional and connect more than one city, town, or county to the same network. This benefits communities by spurring economic development, connecting people in rural locations to urban centers, increasing access to local and state park nature trails, providing access to bikes and particularly e-bikes, and adding vibrancy, quality of life, and a fun way to engage with the community.[13] [14]

Texas Shared Micromobility Market

In Texas, there are seventeen cities with shared micromobility systems (as of January 2024). The Texas cities with shared micromobility systems range from large, urban cities (i.e., Dallas) to smaller cities like Edinburg. Table 1 shows the Texas cities with shared micromobility systems according to the Bureau of Transportation Statistics and the New Mobility Atlas. The primary service operators in Texas include Bird, Lime, LINK, and B-Cycle.[15,16]

Austin, TX was one of the first cities in the United States to embrace shared micromobility services and has collected valuable data on these vehicles, such as the number of vehicles, number of trips, distance traveled, and trip speed. On average (from 1/1/2019-12/31/2023), there have been 8,600 trips taken by e-scooter riders each day and 300 trips taken by e-bike riders each day in Austin, Texas. This amounts to over 10,200 miles traveled per day on e-scooters and 500 miles traveled per day on e-bikes in Austin, Texas. This data highlights the popularity of these devices, and the trend other Texas cities could begin to experience with the expansion of shared micromobility systems.[17]

Table 1. Texas Cities with Shared Micromobility Systems

City	E-Scooter	Dockless Bike (e-bike)	Docked Bike (pedal bike)
Austin	☑	☑	☑
Bryan	☑		
College Station	☑	☑	
Corpus Christi	☑	☑	☑
Dallas	☑	☑	
Edinburg	☑	☑	☑
El Paso	☑	☑	☑
Fort Worth			☑
Houston			☑
Laredo	☑		
Lubbock	☑		
McAllen			☑
Plano	☑	☑	☑
San Antonio	☑		☑

[13] NABSA, 2022 Shared Micromobility Report
[14] National Academies of Sciences, Engineering, and Medicine. E-Scooter Safety: Issues and Solutions
[15] "Bikeshare and E-scooter Systems in the US", The Bureau of Transportation Statistics [BTS], 2023, https://data.bts.gov/stories/s/Bikeshare-and-e-scooters-in-the-U-S-/fwcs-jprj/
[16] "NUMO New Mobility Atlas", New Urban Mobility Alliance, January 2024, https://www.numo.global/new-mobility-atlas#2/22.9/19.5
[17] "Micromobility Dashboard: Austin, Texas", Ride Report, 2024, https://www.numo.global/new-mobility-atlas#2/22.9/19.5https://public.ridereport.com/austin

San Marcos	☑	☑	
Texarkana	☑		
Waco	☑		

Safety Concerns

While shared micromobility does have many benefits, such as reduced carbon emissions and increased access to affordable transportation options, there are serious concerns with injuries and fatalities associated with micromobility use. Research studies examining medical records and emergency room data show that e-scooters and e-bikes are involved in crashes and people are injured and killed while using these devices.[18,19] From 2017 to 2022, there were an estimated 360,800 emergency room visits associated with micromobility. Injuries happened most frequently to the head and the neck, as well as lower and upper limbs. Even more concerning is that the number of fatalities has been steadily increasing as well. The CPSC is aware of 233 fatalities from micromobility products from 2017 to 2022. [20] Stakeholders recognize that with increased use of micromobility transportation comes new consequences and concerns related to traffic safety. This section details injury and fatality data identified in the literature review, as well as specific safety concerns for shared micromobility users.

Injuries and Fatalities

In this section, e-scooters and e-bikes are discussed separately as the literature reviewed predominately separates injury and fatality data for these transport modes.

E-scooter

In the United States, an estimated total of 169,300 emergency room visits from 2017 to 2022 were caused by an e-scooter incident. The CPSC found an increasing linear trend for emergency room visits associated with e-scooters, which is statistically significant increase in injuries. CPSC also identified 111 e-scooter fatalities from 2017 to 2022. Motor vehicle accidents and control issues were top hazards associated with e-scooter fatalities. In a special study on e-scooters, CPSC staff followed up on 309 e-scooter NEISS injury cases in 2022. Of the 309 cases, 37 percent of the e-scooter related emergency room visits were accounted for by rental e-scooters, including Bird, Lime, Lyft, etc. The study found that:

- Sixty-three percent of the injuries occurred on paved roads.
- Twenty-three percent of the victims reported that the cause of the accident was dark or difficult to see.
- Eleven percent of the victims reported that the cause of the accident was a source of distraction, such as music/cell phone/loud music while riding the scooter.
- Thirty-two percent of the injured were carrying or holding something while riding the e- scooter.
- Thirteen percent of the riders were wearing a helmet; and forty-two percent were wearing blinking lights/head lamp while riding the e-scooter. [12]

A 2022 study examined 1,191 patients who sustained e-scooter injuries from 2013-2018. Similar to CPSC, the investigators found that hospital admissions for e-scooter injuries increased by an average of 13 percent each year of the study period. The most common injury locations included the head (34%),

[18] Niemann, Dangers of e-mobility

[19] Osti, et al. "E-Scooter and E-Bike Injury Pattern Profile in an Inner-City Trauma Center in Upper Manhattan." *Injury* 54, no. 5 (2023): 1392-95.

[20] CPSC, Micromobility Products

lower limbs (17%), and lower trunk (12%). Falls and motor vehicle collisions were the most common mechanisms resulting in hospitalization.[21] Several other studies support the increase in e-scooter related injuries and hospitalizations in recent years, with the majority of injuries occurring to the head and limbs. [22,23,24] This calls for improved rider safety measures and regulation surrounding vehicular collision scenarios, such as increased separation between e-scooter riders and motor vehicles.

Studies also examined causation factors. Most e-scooter injuries were the result of falls, collisions with objects such as light poles, manhole covers or curbs or crashes involving motor vehicles. Other factors identified in the studies included inexperience, alcohol and speed.[21,22,23,24] In Southern California, where researchers examined medical records from two urban emergency departments, five percent of injured riders tested positive for alcohol.[21] Another study involving 103 male scooter riders treated at trauma centers in San Diego and Austin, found 79 percent tested for alcohol and 48 percent of those individuals were over the legal limit (0.08). Additionally, 60 percent were screened for drugs, with slightly more than half (52 percent) testing positive.[25]

In addition to e-scooter riders posing a risk to themselves, several studies also found e-scooters pose a risk to pedestrians. In the South California study cited above, 52 percent of the pedestrians seeking treatment had been hit by a scooter and 24 percent tripped over a device that was parked on the sidewalk.[21] This has prompted some cities to ban sidewalk riding to prevent injuries and reduce liability claims. However, micromobility providers and advocates worry that prohibiting sidewalk riding poses risks to scooter riders who would be forced to operate on high-speed and/or high-volume roadways that are unlikely to have separate or protected infrastructure.[26]

When it comes to gender and age, male e-scooters riders were more likely to be injured than females and the average age ranged from 29 to 39.[27] However, people of all ages were represented in the studies. That said, the Southern California study found that nearly 11 percent of e-scooter injuries involved patients under 18 years of age, despite state law requiring riders to be at least 16 (and 18 years of age per provider rental agreements).[21] In addition, 60 percent of the riders injured in Austin were residents, while a third either lived out of town, in other states or other countries.[28]

Austin, Texas Case Study

To advance knowledge on the public health impact of e-scooter use, the Austin Public Health Department (APH), with assistance from the Centers for Disease Control and Prevention (CDC), launched

---

[21] Trivedi, et al. "Injuries Associated with Standing Electric Scooter Use." *JAMA Network Open* 2, no. 1 (2019): e187381-e81.

[22] Ioannides, et al. "E-Scooter Related Injuries: Using Natural Language Processing to Rapidly Search 36 Million Medical Notes." *PLoS One* 17, no. 4 (2022)

[23] Traynor, et al. "Association of Scooter-Related Injury and Hospitalization with Electronic Scooter Sharing Systems in the United States." *Am J Surg* 223, no. 4 (Apr 2022): 780-86

[24] Navarro, et al. "Risk of Hospital Admission Related to Scooter Trauma Injuries: A National Emergency Room Database Study." *BMC Emergency Medicine* 22, no. 1 (2022): 150.

[25] Kobayashi, et al. "The E-Merging E-Pidemic of E-Scooters." *Trauma Surgery & Acute Care Open* 4, no. 1 (2019)

[26] National Academies of Sciences, Engineering, and Medicine. *E-Scooter Safety Toolbox,* (Washington, DC: The National Academies Press, 2023)

[27] CPSC, Micromobility Products

[28] Austin Public Health [APH]. *Dockless electric scooter-related injuries study, Austin, Texas, September–November 2018* (Austin, Texas: Epidemiology and Public Health Preparedness Division, 2019)

an epidemiological investigation to collect data on injuries involving rentable e-scooters in Austin, Texas. In addition, to identify risk factors associated with injuries, telephone interviews were conducted with injured e-scooter riders. This is believed to be the first study to conduct interviews with injured e-scooter riders. The study identified 190 people who suffered injuries from potential e-scooter related crashes from September 2018 to November 2018. They learned that 55 percent of the injured riders were male, and the majority of riders were between the ages of 18 and 29 years old. The injured riders were predominately White (65%), followed by individuals who identified as Hispanic/Latino (22%).[29]

Nearly half (48%) of reported injuries were to the head. Other reported injuries were to the upper limbs (70%), lower limbs (55%), and chest/abdomen (18%). Over a third of the injured riders sustained a bone fracture(s). Of concern, half of the riders suffered a severe injury, which was defined as bone fractures, nerve, tendon, or ligament injuries, spending more than 48 hours in the hospital, severe bleed, and sustained organ damage. Fifteen percent of riders had evidence suggestive of a traumatic brain injury. Less than one percent of individuals was wearing a helmet at the time of injury.[29] Studies have shown that bicycle riders reduce the risk of head and brain injuries by wearing a helmet. Helmet use might also reduce the risk of head and brain injuries in the event of an e-scooter crash.[30]

More than half of the interviewed riders were injured in the street and one-third were injured on the sidewalk. Most scooter injuries were the result of falls, collisions with objects such as light poles, manhole covers or curbs or crashes involving motor vehicles. Sixteen percent of the incidents with injured riders involved a motorized vehicle. These incidents include colliding and swerving, stopping, and jumping off the scooter to avoid a collision.[29]

According to the APH study, impairment, inexperience, and high speed were the leading factors contributing to e-scooter-crashes and injuries. Approximately 33 percent of the interviewed riders were injured during their first scooter ride. Furthermore, according to the APH study, 29 percent had consumed alcohol in the 12 hours preceding their injuries. More than one-third (37%) reported that excessive scooter speed contributed to their injury. Nineteen percent believed the scooter malfunctioned (e.g., brakes, wheels, etc.).[29]

Of note, seventy percent of injured e-scooter riders received training on scooter use. Most (60%) received that training via the scooter companies' phone application.[29] It is evident, that the training available on safe e-scooter riding practices was not effective in preventing injuries.

E-Bikes

According to the CPSC, from 2017 to 2022, there were an estimated 53,000 emergency room visits due to e-bike incidents. This accounts for 15 percent of the overall micromobility injury estimate in the same timeframe. CPSC also identified 104 e-bike fatalities from 2017 to 2022. Motor vehicle accidents and control issues were top hazards associated with e-bike fatalities.[31]

There have been several other studies published that point towards a high injury risk associated with e-bikes. One study, published in 2017, was the first to specifically investigate the e-bike related orthopedic injuries, based on a national trauma registry. A total of 549 cases were reviewed and 65 percent of patients sustained orthopedic injuries, out of them 64 percent (n=230) sustained limb/pelvis/spine

[29] APH, E-Scooter Case Study
[30] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety Toolbox
[31] CPSC, Micromobility Products

fractures. The study found that lower extremity fractures were more prevalent than upper extremity fractures. Approximately 42 percent of patients sustained associated injuries, with head/neck/face injuries being the most prevalent (30.3%). A collision between e-bike and a motorized vehicle was the mechanism of injury in 35 percent of cases. In this mechanism of injury, patients had 1.7 times the risk for associated injuries and the risk for major trauma was more than the double. [32] There have been additional studies that have found that e-bike related collisions could lead to severe consequences in spine injuries. [33]

A study published in 2019 that analyzed NEISS data from 2000 to 2017 to identify injury patterns and trends associated with e-bikes found there were 3,075 injuries accounting for 0.13 injuries per 10,000 total U.S. emergency department injuries. The average age of a person injured on an e-bike was about 32, with riders 18-44 and 45-65 accounting for 41 percent and 28 percent of all injuries, respectively. Moreover, males were more likely than females to be injured (83 percent). [34]

Studies also found that, unlike e-scooter injuries, e-bike-related injuries were nearly three times more likely to be the result of a collision with a motor vehicle and to be severe enough to necessitate hospitalization due to internal injuries. E-bike injuries were also three times more likely than e-scooter injuries to involve a collision with a pedestrian. This may be due to the disparity in weight and speed between a traditional bicycle and an e-bike and the fact that e-bikes, unlike motor vehicles, are quiet.[32,33,35]

Data Limitations

The researchers involved in many of the described above studies pointed out that the prevalence of e-bike and e-scooter related injuries were likely underestimated. Limitations with the data make it difficult to report the injury and fatality numbers. E-bikes are typically identified as bicycles in crash reports and medical records, while e-scooters may not be identified at all. The current lack of a standardized reporting mechanism for micromobility-related crashes coupled with underreporting on the part of law enforcement and providers makes it difficult for transportation safety officials and their partners to understand micromobility's impact on traffic safety. [36,37,38]

At present, hospital data is considered the best source of micromobility-related crash, injury and fatality data. But this data can be problematic, since it is dependent on hospital personnel properly coding the patient's injuries. To address this problem, in 2020, the National Center for Health Statistics approved the use of new ICD- 10-CM (International Classification of Diseases, 10th Revision, Clinical Modification) external cause codes. This will provide health care practitioners the means to differentiate micromobility-related injuries by device and cause. However, NTSB found that emergency room admission data was still found to be inadequate due to inadequate coding of e-scooters and e-bikes.[36] There is clearly still a need to educate health care practitioners on the new ICD-10-CM. [37,38]

---

[32] Tenenbaum, et al. "Orthopaedic Injuries among Electric Bicycle Users." *Injury* 48, no. 10 (Oct 2017): 2140-44

[33] Wu, et al. "A Retrospective Study of Spine Injuries in Electric Bicycles Related Collisions." *Injury* 53, no. 3 (2022): 1081-86

[34] DiMaggio, et al. "Injuries Associated with Electric-Powered Bikes and Scooters: Analysis of Us Consumer Product Data." *Inj Prev* 26, no. 6 (Dec 2020): 524-28.

[35] Niemann, Dangers of e-mobility

[36] NTSB, Micromobility: Data Challenges

[37] GHSA, Understanding and Tackling Micromobility

[38] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety Toolbox

To collect reliable micromobility crash data, state crash reporting systems should include a unique field element with attributes for all micromobility devices currently permitted to operate on state and local roadways. A micromobility element for non-motorists has been in the most recent update to the Model Minimum and Uniform Crash Criteria (MMUCC).[39] If these micromobility data elements were to be included in the Texas CR-3 form, officers would need to be trained on micromobility typology and classification. It is important that states adopt the micromobility elements proposed in the MMUCC sixth edition (published in 2024).

The Infrastructure Investment and Jobs Act requires agencies to collect more robust data on micromobility devices, specifically e-scooters and e-bikes, and provides some guidance about how to do so. Improving data quality leads to better decision-making about how to improve safety for e-scooter and e-bike riders. Accurate data can provide useful information to help us identify safety trends and patterns, gain insights into safety and usage, make comparisons with other transportation modes, evaluate policy, and educate the traveling public.[39]

Conclusion

According to several publications, stakeholders mentioned the growing use of shared-use micromobility devices as an emerging safety issue. Specifically, stakeholders are concerned about battery-powered electric scooters and bicycles (e-scooters and e-bikes) and nonmotorized bicycles organized specifically for shared-use operations. A common problem stakeholders noted most often was the lack of commonly understood definitions for the various shared-use micromobility devices. They also stressed how little is known about these devices and the potential safety issues they present.[40,41,42] The rapidly expanding shared-use mobility industry underscores the need to understand these issues and to develop new evidence-based countermeasures for preventing crashes and mitigating injuries involving these devices.

In the previous section, safety concerns for shared micromobility were described. While some of the injuries and fatalities are related to infrastructure, such as lack of separation between transportation modes, many of the safety concerns are attributed to unsafe behaviors by road users. These unsafe behaviors include underage riding, impairment, helmet use, and other safety issues; these behaviors can be addressed through education and enforcement. The following sections detail best practice recommendations identified in the literature to improve micromobility safety on Texas roadways.

Infrastructure

In Austin, where over 7,000 shared micromobility vehicles are active on an average day, community members were surveyed and found that e-scooter and bike riders were most comfortable on protected bike lanes, followed by paved urban trails, painted bike lanes and residential streets with no marked traffic lanes, bike lanes or sidewalks. Sidewalks on busy, multi-lane roads were less comfortable than natural surface trails, but more comfortable than multi-lane streets with marked traffic lanes but no bicycle lanes or sidewalks. When researchers set out to learn why male e-bike and e-scooter riders

[39] NTSB, Micromobility: Data Challenges
[40] NTSB. *Bicyclist Safety on US Roadways: Crash Risks and Countermeasures*, *Safety Research Report NTSB/SS-19/01* (Washington, DC: NTSB, 2019).
[41] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety: Issues and Solutions
[42] GHSA, Understanding and Tackling Micromobility

outnumbered females riders two to one, it was not fear of the devices but lack of fully separated and protected lanes that alienated women.[43]

The evidence is clear that providing infrastructure that separates riders— bicyclists, e-bikes, and e-scooters—from motorists is the most effective countermeasure for preventing crashes.[44] When physical separation is not possible, reducing the distance or time bicycles (pedal-powered and/or motorized) are exposed to risk is essential. [45] This can be done through marked bike lanes, bicycle boulevards or greenways, bike boxes (pavement marking that features a stop line closer to the intersection to give bicyclist and micromobility riders a head-start when the light turns green) and specially marked traffic lights that provide an advance green signal for riders. [46] But separate paths and bike lanes also make communities safer for drivers, not just riders.

Many of the complaints about micromobility center around sidewalk parking and riding. Because dockless vehicles can be left anywhere, concerns about vehicles blocking the right of way (a significant problem for people with physical, visual and cognitive impairments) and not being parked upright garnered significant attention the past couple of years by city transportation officials and disability rights advocates – especially for e-scooters. Since then, many cities have taken steps to address the parking problem from posting signage to developing apps to report improperly parked bikes and establishing designated parking areas specifically for micromobility.[47] In 2018, Santa Monica created 107 on-street and sidewalk parking zones and required providers to offer parking incentives to encourage use.[48]

When it comes to addressing sidewalk riding, infrastructure improvements may be the best solution. E-bikes and e-scooters make some pedestrians feel unsafe because they move at a higher rate of speed.[49] But for those micromobility riders that do not feel safe on the adjacent street due to road conditions (i.e., uneven pavement, potholes, gravel, grates, sewer covers), traffic volumes and/or motor vehicle speeds, the sidewalk is often the best option. [43] That is why traffic safety organizations are calling for more bike lanes and paths, bikeways and other clearly marked, comfortable and safe places to ride.[47,50] It is important for stakeholders to educate law enforcement, elected officials, and the public about infrastructure needs and how particular countermeasures improve safety for all road users. [47]

Public Education

Education is essential for ensuring micromobility users operate devices safely and respectfully and other road and sidewalk users are accepting of this mode.[47] Some cities, such as Austin, Texas; Portland, Oregon; Chicago, Illinois; and Arlington, Virginia have created educational materials with safe operating tips, how to ride and park videos and links to rules and/or local ordinances. Educational materials should

[43] City of Austin. *Dockless Mobility Community Survey Report*. (Austin, TX: Transportation Department, 2019)
[44] NTSB, Bicyclist Safety on US Roadways
[45] NHTSA. Bicyclist and Pedestrian Safety, (Washington, DC: NHTSA, 2019)
[46] Brookshire, et al. *Advancing pedestrian and bicyclist safety: A primer for highway safety professionals, Report No. DOT HS 812 258*, (Washington, DC: NHTSA, 2016)
[47] GHSA, Understanding Micromobility
[48] City of Santa Monica. *Shared Mobility Pilot Program Summary Report* (Santa Monica, CA: City of Santa Monica, 2019).
[49] Trivedi, Injuries Associated with E-Scooters
[50] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety: Issues and Solutions

address a handful of tips such as conducting a pre-ride check, following the rules, yielding to pedestrians, wearing a helmet and parking properly.[51]

Additionally, educating micromobility riders about the importance of being predictable, so other modes have a better idea of what they are going to do next and can react accordingly, is essential. Other road users (motorists, pedestrians and bicyclists) should also be educated about how micromobility devices work and why riders may switch from the sidewalk to the street to a protected bike lane (i.e., poor pavement conditions, local restrictions, preference) all in the same trip. Motorists, especially, need to understand what these devices are and how they operate; the disparity in size and weight between micromobility devices, motor vehicles and others on and near the road; and the danger of speeding and impairment caused by alcohol, and other drugs, drowsiness and distraction.[51] Crash data indicate that speed, alcohol and distraction are common causation factors in crashes involving motor vehicles and vulnerable road users.[52] Most micromobility injuries are single vehicle (i.e., the rider fell, collided with a fixed object) but 90 percent of fatalities are the result of a collision between a motor vehicle and a micromobility device.[53]

Shared micromobility programs are frequently used by out-of-towners and/or tourists. Cities can also convey safety tips and information about where not to ride to visitors and locals through on-device and on-street messaging. Street signage, sidewalk decals, digital message boards and billboards are also likely to be seen by out-of-towners, while blog posts, community emails and social media notifications can be used to reach residents.[51] An example from Boise Idaho is displayed below. Boise displayed the safety tips and information on panels affixed to the micromobility devices (see Figure 4).

Figure 4. Boise Micromobility Safety Education Campaign

Helmet Use

A common theme in the literature reviewed was lack of helmet use by micromobility riders, which is known to be protective but is consistently low across studies. For micromobility riders, reinforcing the importance of wearing a helmet is critical as the majority of shared bike and scooter riders do not wear helmets and are significantly less likely to do so compared to cyclists who own their bicycles.[54] Micromobility providers urge riders via their apps and websites to wear helmets but they do not typically provide them at the time of rental. An evaluation of the barriers and facilitators to helmet use among bikeshare riders in Australia, where helmet use is mandatory, found that 61 percent cited helmet inaccessibility or the desire not to wear one as the main barriers to using the mode.[55] Providers, however, do not advocate for helmet laws as the requirement could impact a rider's spur-of-the-

[51] GHSA, Understanding and Tackling Micromobility
[52] NHTSA, Bicyclist and Pedestrian Safety
[53] Collaborative Sciences Center for Road Safety [CSCRS]. *List of e-scooter fatalities* (Chapel Hill, NC: CSCRS, 2021)
[54] DiMaggio, Injuries associated with electric-powered-bikes and scooters
[55] Graves, et al. "Public Bicycle Share Programs and Head Injuries." *Am J Public Health* 104, no. 8 (Aug 2014)

moment ability to use a shared device. It was e-scooter operator, Bird, that sponsored the bill in California that rescinded the state's helmet requirement for all riders 18 and older. [56]

Enforcement

Most cities require providers to inform riders about the rules through their apps, but enforcement of these rules ultimately falls to police and municipal code enforcement officers. That effort, however, may be hampered by the lack of officer training on state micromobility statutes and/or local ordinances. Law enforcement training is essential for ensuring officers understand the rules and enforce them fairly and equitably.[57]

It is recommended that law enforcement receive a primer in micromobility typology and how these devices operate; how to identify them in crash reports, especially if there is no unique identifier for micromobility devices; safe riding practices; and how can they help educate riders, drivers and pedestrians about safely sharing the road. Some cities, such as Baltimore, required all officers to review a series of slides and pass an online quiz when the e-scooter pilot program first launched. Other cities have developed reference guides to help officers cite the appropriate statute or ordinance associated with a micromobility violation.[57,58]

Law enforcement officials in some cities also play an active role in educating micromobility users about local ordinances as well as safe riding practices. For example, when the shared micromobility program first launched in Santa Monica, California, the Santa Monica Police Department (SMPD) conducted enforcement based on key community complaints. They issued citations but also gave warnings to violators, conveyed information via digital messaging boards and posted on social media. Ticketing peaked in July 2018 at 250 citations and had dropped to an average of 50 per month in 2019, as riders gained skill and greater awareness of the local laws.[59] Other police department, such as the Atlanta Police Department filmed a Public Service Announcement to help the public understand the city's new scooter ordinance. The Atlanta PSA covered no sidewalk riding or cellphone use, riding with traffic and following traffic laws, giving pedestrians the right-of-way and parking do's and don'ts.[57]

Finally, some communities expand the enforcement net by asking the public to report micromobility violations or unsafe riding practices. In addition to providing information about how to use e-bikes and e-scooters in Boise, ID, the city's website includes a form the public can complete and submit to report violations.[60] These are routed to a Compliance Officer for investigation. Ultimately, as with traditional vulnerable road user safety, the combination of engineering, education, and enforcement will contribute to safer conditions for micromobility users.

---

[56] "Bird goes after helmet laws for electric scooters; The e-scooter rental company quietly sponsors a bill to get rid of some California safety rules", Kerr, 2018, https://www.cnet. com/news/bird-goes- after-helmet-laws-for-electric-scooters/

[57] GHSA, Understanding Micromobility

[58] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety Toolbox

[59] City of Santa Monica, Shared Motility Pilot Program

[60] "File a Complaint About E-bike or E-scooter", City of Boise, 2023, https://www.cityofboise.org/departments/finance-and-administration/how-to-use-e-scooters-and-e-bikes/file-a-complaint-about-an-e-bike-or-e-scooter/

Future Considerations

Micromobility's popularity is undeniable. The mode's tremendous growth – fueled by people seeking a more efficient, less costly and fun transportation alternative – cannot be ignored. While many communities with shared micromobility programs have observed social, health, economic, and environmental benefits of enhanced multimodal travel and having more alternatives to vehicle use, these effects are often accompanied by real and perceived safety challenges. The literature review identified several challenges posed by the rapid growth of micromobility devices, e-bikes and e-scooters in particular.

- **Oversight**. Statutes and regulations vary from state to state and/or locality to locality, making it difficult for riders and other road users to know what is permitted and for law enforcement officials to address unsafe behaviors.[61,62]
- **Data**. Micromobility-involved crashes and injuries are likely underreported due to the lack of a universal reporting standard.[60,61,63,64]
- **Infrastructure**. Separating transportation modes is the most effective way to reduce crashes. If separate infrastructure does not exist, micromobility riders will go where they feel safe and innovate based on what is available.[60,65,66]
- **Enforcement**. Most cities require providers to inform riders about safe operating rules, but enforcement of those rules is the responsibility of local law enforcement officials who may be hampered by the lack of laws and regulations and little or no officer training.[60,61]
- **Education**. Education is essential for ensuring micromobility users operate these devices safely and respectfully and other road and sidewalk users respect the right of micromobility users to operate on the public way.[60, 61]

Future research and evaluation should focus on these identified challenges and potential solutions. Arguably, improved data collection and analysis should be at the top of traffic safety stakeholder's priority lists. Without robust data, it is impossible to make informed decisions about how this mode should be regulated, where to make infrastructure improvements and deploy enforcement or how best to engage with all road users to ensure they safely share the road.

[61] GHSA, Understanding and Tackling Micromobility
[62] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety
[63] NTSB, Micromobility Data Challenges
[64] National Academies of Sciences, Engineering, and Medicine, E-Scooter Safety Toolbox
[65] City of Austin, Community Survey Report
[66] NTSB, Bicyclist Safety on US Roadways

References

1. Austin Public Health [APH]. *Dockless electric scooter-related injuries study, Austin, Texas, September–November 2018* (Austin, Texas: Epidemiology and Public Health Preparedness Division, 2019), https://www.austintexas.gov/sites/default/files/files/Health/Epidemiology/APH_Dockless_Electric_Scooter_Study_5-2-19.pdf
2. "Bikeshare and E-scooter Systems in the US", The Bureau of Transportation Statistics [BTS], 2023, https://data.bts.gov/stories/s/Bikeshare-and-e-scooters-in-the-U-S-/fwcs-jprj/
3. "Bird goes after helmet laws for electric scooters; The e-scooter rental company quietly sponsors a bill to get rid of some California safety rules", Kerr, 2018, https://www.cnet.com/news/bird-goes- after-helmet-laws-for-electric-scooters/
4. Brookshire, K., Sandt, L., Sundstrom, C., Thomas, L., & Blomberg, R. *Advancing pedestrian and bicyclist safety: A primer for highway safety professionals,* Report No. DOT HS 812 258, (Washington, DC: NHTSA, 2016), https://www.nhtsa.gov/sites/nhtsa.gov/files/812258-peds_bike_primer.pdf
5. City of Austin. *Dockless Mobility Community Survey Report*. (Austin, TX: Transportation Department, 2019), https://www.austintexas.gov/sites/default/files/files/Transportation/Dockless_Mobility_Community_Survey_Report_2-28-19.pdf
6. City of Santa Monica. *Shared Mobility Pilot Program Summary Report* (Santa Monica, CA: City of Santa Monica, 2019), https://learn.sharedusemobilitycenter.org/overview/santa-monica-shared-mobilitypilot-program-summary-report-santa-monica-ca-2019/
7. Collaborative Sciences Center for Road Safety [CSCRS]. *List of e-scooter fatalities* (Chapel Hill, NC: CSCRS, 2021), https://www.roadsafety.unc.edu/wp-content/uploads/2021/03/escooter_fatalities_Mar_2021.pdf
8. Consumer Product Safety Commission [CPSC]. *Micromobility Products-Related Deaths, Injuries, and Hazard Patterns: 2017-2022* (Washington DC: CPSC, 2023), https://www.cpsc.gov/s3fs-public/Micromobility-Products-Related-Deaths-Injuries-and-Hazard-Patterns-2017-2022.pdf?VersionId=BekCvIY03IvMU9nHr2ErziUNXNkPAghJ
9. DiMaggio, C. J., M. Bukur, S. P. Wall, S. G. Frangos, and A. Y. Wen. "Injuries Associated with Electric-Powered Bikes and Scooters: Analysis of Us Consumer Product Data." *Inj Prev* 26, no. 6 (Dec 2020): 524-28.
10. "File a Complaint About E-bike or E-scooter", City of Boise, 2023, https://www.cityofboise.org/departments/finance-and-administration/how-to-use-e-scooters-and-e-bikes/file-a-complaint-about-an-e-bike-or-e-scooter/
11. Governor's Highway Safety Association [GHSA]. *Understanding and Tackling Micromobility: Transportations New Disruptor* (Washington DC; GHSA, 2020), https://www.ghsa.org/sites/default/files/2020-08/GHSA_MicromobilityReport_Aug31Update.pdf
12. Graves, J. M., B. Pless, L. Moore, A. B. Nathens, G. Hunte, and F. P. Rivara. "Public Bicycle Share Programs and Head Injuries." [In eng]. *Am J Public Health* 104, no. 8 (Aug 2014): e106-11.
13. Ioannides, K. L. H., P. C. Wang, K. Kowsari, V. Vu, N. Kojima, D. Clayton, C. Liu*, et al.* "E-Scooter Related Injuries: Using Natural Language Processing to Rapidly Search 36 Million Medical Notes." [In eng]. *PLoS One* 17, no. 4 (2022): e0266097.
14. Kobayashi, Leslie M, Elliot Williams, Carlos V Brown, Brent J Emigh, Vishal Bansal, Jayraan Badiee, Kyle D Checchi, Edward M Castillo, and Jay Doucet. "The E-Merging E-Pidemic of E-Scooters." *Trauma Surgery & Acute Care Open* 4, no. 1 (2019)

15. “Micromobility Dashboard: Austin, Texas”, Ride Report, 2024, https://www.numo.global/new-mobility-atlas#2/22.9/19.5https://public.ridereport.com/austin
16. National Academies of Sciences, Engineering, and Medicine. *E-Scooter Safety: Issues and Solutions* (Washington, DC: The National Academies Press, 2023), https://nap.nationalacademies.org/catalog/27252/e-scooter-safety-issues-and-solutions
17. National Academies of Sciences, Engineering, and Medicine. *E-Scooter Safety Toolbox*, (Washington, DC: The National Academies Press, 2023), https://nap.nationalacademies.org/catalog/27253/e-scooter-safety-toolbox
18. National Transportation Safety Board [NTSB]. *Bicyclist Safety on US Roadways: Crash Risks and Countermeasures*, *Safety Research Report NTSB/SS-19/01* (Washington, DC: NTSB, 2019), https://www.ntsb.gov/safety/safety-studies/Documents/SS1901.pdf
19. National Transportation Safety Board [NTSB]. *Micromobility: Data Challenges Associated with Assessing the Prevalence and Risk of Electric Scooter and Electric Bicycle Fatalities and Injuries* (Washington, DC: NTSB, 2023), https://www.ntsb.gov/safety/safety-studies/Documents/SRR2201.pdf
20. Navarro, Sergio M., Victor R. Vakayil, Rafat H. Solaiman, Evan J. Keil, Matthew W. Cohen, Ellen J. Spartz, Christopher J. Tignanelli, and James V. Harmon. "Risk of Hospital Admission Related to Scooter Trauma Injuries: A National Emergency Room Database Study." *BMC Emergency Medicine* 22, no. 1 (2022/09/01 2022): 150.
21. Niemann, Marcel, Karl F. Braun, Ellen Otto, Michael Tiefenbrunner, Jonas Wüster, Ulrich Stöckle, Sufian S. Ahmad, Sven Märdian, and Frank Graef. "Dangers of E-Mobility: A Systematic Review and Meta-Analysis of Sustained Injury Patterns and Injury Severity." *Safety Science* 167 (2023)
22. North American Bikeshare and Scootershare Association [NABSA]. *2022 Shared Micromobility: State of the Industry Report* (Portland, Maine: NABSA, 2023), https://nabsa.net/2023/08/10/2022industryreport/
23. “NUMO New Mobility Atlas”, New Urban Mobility Alliance, January 2024, https://www.numo.global/new-mobility-atlas#2/22.9/19.5
24. Osti, Narayan, Ameer Aboud, Shamon Gumbs, Ryan Engdahl, Stephen Carryl, Brian Donaldson, and Robert Davis. "E-Scooter and E-Bike Injury Pattern Profile in an Inner-City Trauma Center in Upper Manhattan." *Injury* 54, no. 5 (2023): 1392-95.
25. Tenenbaum, S., D. Weltsch, J. T. Bariteau, A. Givon, K. Peleg, and R. Thein. "Orthopaedic Injuries among Electric Bicycle Users." [In eng]. *Injury* 48, no. 10 (Oct 2017): 2140-44
26. Traynor, M. D., Jr., S. Lipsitz, T. J. Schroeder, M. D. Zielinski, M. Rivera, M. C. Hernandez, and D. J. Stephens. "Association of Scooter-Related Injury and Hospitalization with Electronic Scooter Sharing Systems in the United States." [In eng]. *Am J Surg* 223, no. 4 (Apr 2022): 780-86
27. Trivedi, Tarak K., Charles Liu, Anna Liza M. Antonio, Natasha Wheaton, Vanessa Kreger, Anna Yap, David Schriger, and Joann G. Elmore. "Injuries Associated with Standing Electric Scooter Use." *JAMA Network Open* 2, no. 1 (2019): e187381-e81.
28. Venkatraman, V., Richard, C. M., Magee, K., & Johnson, K. *Countermeasures That Work: A Highway Safety Countermeasures Guide for State Highway Safety Offices, 10th edition* (Washington, DC: National Highway Traffic Safety Administration, 2021), https://www.nhtsa.gov/sites/nhtsa.gov/files/2021-09/15100_Countermeasures10th_080621_v5_tag.pdf
29. Wu, Shengda, Xiaoxiang Li, Feilong Wei, Xiaodong Yan, and Jixian Qian. "A Retrospective Study of Spine Injuries in Electric Bicycles Related Collisions." *Injury* 53, no. 3 (2022/03/01/ 2022): 1081-86.