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Bystanders of Shared Micromobility

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According to the U.S. Department of Transportation, micromobility is "a category of modes of transportation that includes very light, low-occupancy vehicles such as electric scooters (e-scooters), electric skateboards, shared bicycles, and electric pedal assisted bicycles (e-bikes)" (Bureau of Transportation Statistics, 2020). According to Horace Dediu (see Joselow, 2020) is widely credited with originally coining the term micromobility and defined them as "everything that is not a car" that weighs less than 1,000 pounds. Over the last few years, shared micromobility has evolved considerably.

Until recently, shared micromobility consisted of shared e-bikes in a few select cities. E-bikes fit well into the existing transportation system since there was already legislation pertaining to bicycles and e-bikes. People generally knew what to expect from bicycles: where they would ride, how fast they would go, and how they would behave. In 2018, the shared e-scooter market exploded (Bureau of Transportation Statistics, 2020). In many cities, officials were not informed of planned scooter deployments before they occurred, leading to confusion. Unfortunately, the existing bicycle and e-bike legislation was often not universally applicable to e-scooters. However, since that time, significant progress has been made and many areas now have robust legislation governing shared e-scooters. Through the publication of their findings, cities have shared their knowledge with others.

This work analyzes and summarizes the findings from many cities, gained through published reports, websites, and discussions with planners, as well as research publications. The goal is to help planners and legislators who are integrating micromobility (mainly e-scooters) into their transportation infrastructures, with a special focus on the needs and responsibilities of bystanders (non-riders). The focus of this work is e-scooters since these popular devices require new rules and legislation in many areas. These devices affect the entire transportation infrastructure. The rise of micromobility has changed the conversation around transportation from car-centric to a multimodal perspective that considers the needs of all users. The impact was well-stated by Johnston (see Scholz, 2020), associate director of the Center for the Comparative Study for Metropolitan Growth, who said "Not since the arrival of bikes and automobiles have we experienced such rapid change". As research on shared e-scooters is still limited (Yanocha, & Allan, 2019; Shaheen & Cohen, 2019), this paper provides general information and resources about e-scooters.

History of e-Scooters

According to the Online Bicycle Museum (n.d.), the Autoped Company was the "true ancestor of the modern scooter" in the early 1900s. These devices were quite popular and even adopted by the U.S. Post Office and New York City Police. The Autoped Company was bought by Eveready in 1918, who replaced the gasoline powered engine with battery operated propulsion. Their popularity spread, leading them to be licensed in England, Germany, and Czechoslovakia. In the more recent past, dockless e-scooters began appearing in U.S. markets in 2017 (although only in only one city). By the end of 2018, they had reach nearly 100 U.S. cities. Distribution reached a high of 115 cities in 2019 (Bureau of Transportation Statistics, 2020). This rapid expansion proved to be unsustainable, and the number of locations with scooter systems decreased in 2020 to 69 cities.

Initially, there was some regulatory confusion. Santa Monica, CA was the one of the first U.S. cities where scooters were deployed without warning from providers (Heinselman, Milder, & Weiner, 2019). The city responded by filing a misdemeanor criminal complaint against Bird, which claimed that Bird began operating without city approval and ignored citations requiring them to obtain proper licenses and remove the scooters from sidewalks. This was resolved with Bird pleading no contest to the charges, securing the proper business licenses, and paying more than $300,000 in fines. This pattern of deploying without notice, or asking forgiveness rather than permission, was repeated in other cities (Rayaprolu, McCarthy, & Gifford, 2020) such as San Francisco, who issued cease and desist letters to Spin, Lime, and Bird in 2018 after receiving a flood of complaints about sidewalk riding, sidewalk parking, and devices being thrown into the San Francisco Bay (Keeling, 2018).

Even prior to the COVID-19 pandemic, e-scooter companies had begun to leave markets, possibly due to excessive competition and other market pressures (NACTO, 2020). The City of Portland, OR reported that in late 2019, e-scooter companies were already being challenged with difficulties in reaching profitability and responded by reducing their service areas in the city significantly (City of Portland Bureau of Transportation, 2020). Then with COVID-19 there came a 90% drop in overall worldwide mobility demand during the first lockdown, with decreases of 40-70% that continued during the recovery period (May-June 2020) based on Apple Maps data (Van Audenhove et al., 2020). In the U.S., household trips fell 68-72% nationwide, and transit ridership fell 80% from the previous year (NACTO, 2020). The City of Portland, OR reported that in March when the stay-at-home orders were issued, ridership dropped 90% from its pre-pandemic level, with some providers suspending service altogether (City of Portland Bureau of Transportation, 2020). In many cities where e-scooter providers were not contractually obligated to operate, they paused operations during this time (NACTO, 2020). Micromobility providers suffered large decreases in global revenues, market valuations of many have fallen, and some have had layoffs (NACTO, 2020).

While these statistics seem somewhat grim, COVID-19 has certainly not meant an end for shared micromobility. According to the Governor's Highway Safety Association (GHSA), people turned to micromobility during the pandemic (Shadel Fischer, 2020). For example, Spivak (2020) reported that the New York bikeshare ridership was up 67% in mid-March 2020 compared to the previous year (note that there were no scooters in New York City at that time). Similarly, Sam Schwartz (2020) reported that Chicago's Divvy reported twice the usage in March 2020 over March 2019. Similarly, the City of Portland, OR determined that micromobility was an essential service, and partnered with providers to reduce fares in April and May, during which time ridership began to increase. At the time of the report, ridership in Portland, OR had nearly returned to pre-pandemic levels (City of Portland Bureau of Transportation, 2020). Operators in a number of cities have offered unlimited free rides to essential workers, including Kansas City, MO; Detroit, MI; Memphis, TN; and Big island, HI (Shadel Fischer, 2020). Reduced costs may not be the only reason for shared e-scooters to continue to be a viable transportation option. In cities where transit options have decreased, micromobility has increased (Rivett, Lee, & Rainwater, 2020). For instance, in Detroit, MI a scooter provider worked with the city when they decreased bus routes to ensure e-scooters would be placed along the closed or reduced bus route sections (Spin, 2020). And as unemployment claims skyrocket, ensuring the continued availability of low-cost transportation options such as micromobility has become more important (NACTO, 2020).

While many markets have seen reduced e-scooter usage, some areas, including Chicago, IL; Minneapolis, MN (White, 2020); and New York, NY (Closson, 2020) have overturned previous bans. Another transportation change occurring with COVID-19 is the slow streets movement, where traffic volumes are reduced to a minimum, allowing for people to walk and use micromobility more safely. This may be one reason that e-scooter trip length appears to be increasing (Lazo, 2020).

Method

This paper and the accompanying website (https://micromobility.mitre.org) were developed through an environmental scan of current technologies and e-scooter research, interviews with researchers, transportation planners, and industry professionals, and a deep dive into current micromobility programs and regulations. One challenge was acquiring data regarding usage and injuries, which are only published piecemeal through individual cities, making it difficult to compare nationally.

Findings

The following sections include findings from the deep five into current micromobility programs and regulations, a description the needs and responsibilities of bystanders, including other micromobility users, pedestrians, motor vehicle drivers, and community members who do not necessarily use micromobility. Challenges and solutions for micromobility deployments are also discussed.

Analysis of Micromobility Programs

Research was conducted on 31 cities in the United States using various sources including micromobility and transportation websites, pilot program reports, ordinances, and news stories. Of these cities, 23 had active programs (others, listed below, were not yet approved, had been prohibited, or had been approved but had no e-scooter providers). Of the cities evaluated, eight were operating pilot programs and 16 had established rules and ordinances. Scooters were approved but not available (no providers were currently offering scooters) in two of the cities surveyed (Fairfax County, VA, and Raleigh, NC), while scooters were prohibited in six cities (Houston, TX; Phoenix, AZ; Philadelphia, PA; Dallas, TX; Fort Worth, TX; and Jacksonville, FL). Cities were initially selected in order of size, with the 15 largest cities in the U.S. being included here. Other cities were added later based on location or interesting factors. It should be noted that this is meant to be anecdotal reference, rather than a representative analysis of current trends in the U.S. As of 2020. scooters were available in 69 cities in the U.S., so this dataset represents fewer than half of the regulated areas.

Most of the cities surveyed listed a maximum number of scooters allowed, but this could be variable based on usage or behaviors by the device providers such as their participation in equity programs. Some also specify a minimum number of devices. Annual costs varied widely among the cities listed here, as did fee implementation. These costs are generally broken down into permit fees, application fees, and per-device fees. Requiring a fee for each trip (per-trip fee) is also somewhat common. Some cities also require taxes and/or right of way fees as part of the costs. Speed limits on the devices are typically around 15 mph, with some cities as low as 10 mph or as high as 20 mph. Some cities have recently begun implementing separate speed limits for sidewalks and other types of special areas as geofencing technologies have improved.

Helmets are often required for certain age groups (for instance, those under 18), but rarely required for adults. While the age required to operate scooters varies, this should not be truly relevant since most scooter companies require renters to be 18 years of age. The issue of where to ride varies by city, and is generally based on infrastructure. For instance, in cities that have robust bike lane systems, it is more reasonable to prohibit sidewalk riding than in cities without bike lanes – especially near streets with higher speed limits for cars. This is one of the reasons some cities prohibit sidewalk riding in some parts of their jurisdiction, and allow it in other areas. While riding in bike lanes is generally allowed and often encouraged, riding on trails is sometimes prohibited.

Most cities specify parking upright in an area that does not block the public right of way. Some specify landscape/furniture zones and bike racks as acceptable places to park. Some require using only corrals, while others have corrals but allow riders to park on the sidewalk as well. Lock-to devices are required by some cities, and these devices can also prevent vandalism.

In most cities surveyed, e-scooter providers are generally required to have some level of public engagement. This may include such activities as hosting or attending community meetings, interfacing with local community leaders, and working with the city to collect survey data. Rider education is also a common requirement, and it may include information provided before the rental through the mobile app, hang-tags on the devices, and/or education through the provider website. Some cities also require e-scooter providers to host events where community members can learn to ride the scooters. Equity requirements can take many forms, and at least some equity measures are generally required. A few cities also require a mechanism for compliance audits, to ensure e-scooter requirements are being met. Customer service requirements are also common. However, some cities require that customer service requests are resolved in a certain amount of time. Some also require that the specific resolutions be tracked.

Some cities describe a list of challenges (such as parking, equity, and community engagement) and have the e-scooter providers give solutions to each challenge as part of the application process rather than specify exactly how those challenges should be resolved. This method can be beneficial because it leverages the knowledge e-scooter providers already have, which can lead to unique solutions.

Appendix A: Regulations by City contains a spreadsheet that provides information on city/county regulations. However, many local regulations are governed by or based on state regulations. A comprehensive set of state laws can be found here: https://unagiscooters.com/articles/the-2021-comprehensive-guide-to-electric-scooter-laws/

Bystanders

In this paper, we use the term bystanders refers to the people who interact with micromobility. These include other road and sidewalk users, such as pedestrians, drivers, other micromobility users and automated/autonomous vehicles. Even citizens who do not directly interact with micromobility are impacted. For instance, cyclists may benefit from the introduction of e-scooters in their cities if it results in more bike lanes being created. Each type of bystander will have unique experiences interacting with micromobility and each type of bystanders has unique needs and responsibilities. These categories are not static. For instance, a person can begin their commute as a pedestrian (bystander), then become a rider for another leg of their commute. Safety is obviously a primary concern for bystanders. A recent report on e-scooter related injuries from Trivedi (2019) indicates that while bystanders do suffer injuries, they are generally less severe and less frequent than those of riders. This report showed that out of a total of 249 injuries they identified, only 8% were nonriders, and the injuries were slightly less severe than those observed in riders. Similarly, the Chicago, IL pilot report indicated that only 5% of the injuries observed during their pilot period involved pedestrians, and one incident involved a cyclist (City of Chicago, 2020); and Santa Monica, CA reported 7% of injuries during their pilot period involved pedestrians (City of Santa Monica, 2019). Fatalities are also less common for bystanders than riders. Of the 36 e-scooter-related fatalities recorded since 2016, only two of the victims were non-riders (Dwyer, Curran-Groome, & Harmon, 2020), including one pedestrian and one cyclist. So, while the safety risk exists for micromobility bystanders, only about 5-10% of those injured in e-scooter accidents are bystanders.

Communication issues can arise from unpredictable behavior by micromobility users or bystanders. However, gaps exist in defining the behavioral expectations for both riders and bystanders, and without well-accepted expectations about what behavior is appropriate, it is difficult for anyone to behave in a predictable manner. More research is needed on how to normalize behavior for riders and bystanders, and how to widely communicate mandates and norms. In this way, needs and expectations for riders and bystanders can become widely known. In the following sections, the bystanders are classified (other micromobility users, pedestrians, motor vehicle drivers, and community members), and the needs and responsibilities of each are discussed.

Other Micromobility Users

Laws around where and how e-scooters can be used are often modeled after existing cycling laws, meaning there is competition for the often limited (and sometimes non-existent) protected space to ride. For this reason, in many areas, other micromobility users (such as cyclists), must interact with e-scooters in roadways, protected bike lanes, and sidewalks. This conflict is worsened when micromobility devices are parked in a way that obstructs bike lanes, which can be dangerous for riders. Most cities now provide contact information to have improperly parked e-scooters removed (often integrated with 311 services), but this is not helpful in the immediate moment to a cyclist who must maneuver around the obstacle and is even more problematic for wheelchair users. While micromobility users may benefit from the infrastructure additions made possible by e-scooter integration, sharing that infrastructure with e-scooters poses its own challenges.

Needs

All types of transportation users need infrastructure, including micromobility riders. The safest place for micromobility users is in dedicated, preferably protected lanes (e.g. bike lanes). Micromobility users also need to know what to expect from other infrastructure users, and how they themselves are expected to behave based on local laws and norms.

Responsibilities

Above all, micromobility users are responsible for behaving in a predictable manner, so that other users of the transportation infrastructure know what to expect from them. This means not only following the current rules in the area, but clearly indicating intentions to those around them. It also means micromobility riders should avoid any sudden changes. In some cities and states, there are laws requiring hand signal use while cycling. However, hand signals are not universal, nor is the requirement typically enforced. Partially as a result, many people do not know when or how to use hand signals, or how to interpret the hand signals they see. Further, hand signals may be difficult for novice e-scooter riders (Löcken, Brunner, & Kates, 2020). While the shared micromobility provider Veo has incorporated turn signals onto their scooters, this is not the norm. This is unfortunate because lack of clear, universally understood signaling mechanisms makes it more difficult to behave predictably.

Another important responsibility of micromobility users is parking. To ensure safe use for everyone sharing the infrastructure, parking regulations must be followed. These regulations vary by jurisdiction, with some cities requiring that they be parked upright on the sidewalk and not blocking access for other sidewalk users, others using corrals, and still others requiring lock-to mechanisms so devices be can be locked to certain types of infrastructure (such as bike racks).

Pedestrians

For pedestrians, interacting with micromobility can be difficult, with problems ranging from minor annoyances such as e-scooters blocking the sidewalks, to deadly collisions as was the case for a woman in Barcelona who lost her life due to a collision with an e-scooter (Catalan News, 2019).

Needs

As the most vulnerable transportation infrastructure users, pedestrians should be the most protected. Pedestrians need to know what to expect from e-scooters, both when they are in use, and when they are parked. Pedestrians should be able to discern where e-scooters are able to ride, how fast they are likely to move, and where they are likely to be parked. One major concern for pedestrians has historically been the sidewalk clutter associated with e-scooter use. While great strides have been made in the effort to de-clutter the sidewalks, including parking corrals and lock-to systems, problems persist.

Responsibilities

When interactions occur, it is the pedestrian's responsibility to clearly communicate with e-scooter riders in the same way they would with cyclists. These communications are often non-verbal. Pedestrians should behave predictably and responsibly, which means clearly indicating their intentions through body language and avoiding sudden stops or changes in direction.

Motor Vehicle Drivers

Motor vehicle drivers are a unique group of bystanders because they are typically not at risk of injury from e-scooter riders. However, they are at risk of causing harm or death to e-scooter riders. Of the 36 identified e-scooter fatalities reported in, 75% involved a motor vehicle (Dwyer, Curran-Groome, & Harmon, 2020). Motor vehicles are also at risk of property damage. This can occur whether drivers are in their vehicles or not (e.g. e-scooter riders can hit parked cars).

Needs

Like the other types of bystanders discussed here, drivers need predictability from e-scooter riders. In many areas, the laws for e-scooters are modeled after cyclists, which makes predictability easier. In theory, drivers should already be familiar with the likely behaviors cyclists exhibit and be able to transfer and apply that knowledge to e-scooter riders.
Drivers also need to know where they can expect to encounter e-scooters. Where e-scooters are allowed to ride differs by area, and since drivers are able to travel great distances across multiple jurisdictions, a driver might pass through places with widely differing rules on a single trip. Information regarding what to expect from micromobility could be provided to drivers as part of licensing and registration.

Responsibilities

In order to have appropriate expectations, it is important that drivers know the rules and laws regarding e-scooters in the location where they travel. Training on interacting with e-scooters is typically not included on drivers tests (Shadel Fischer, 2020), so drivers may not know how to respond appropriately. It is important that drivers understand that e-scooter riders are vulnerable road users and know to treat them with the same caution afforded to cyclists.
While hand signals exist for cyclists, these are often not used by e-scooter riders, meaning that even if a driver knows these signals they may not be of much use in predicting what behavior an e-scooter rider might choose. Body language (e.g. contact, a nod, or a wave) can be a good

indicator, but often times the drivers cannot see the face of an e-scooter rider and the e-scooter rider may not even know that the vehicle is present and so they may not communicate. Given the lack of established communication methods, it is important to go slow, give e-scooter riders plenty of space, be predictable, and expect the unexpected. For drivers, being predictable means clearly indicating intentions using signals, following speed limits and other rules, and avoiding sudden behaviors such as stopping or changing direction.

Community Members

Even people who never come into contact with e-scooters may be impacted by the presence of them in their communities. The integration of shared e-scooters may have positive and/or negative impacts on the environment, the job market, and how the transportation budgets are allocated. Not only are the actual impacts important, perceptions of the impacts (which may not always be based in fact) are also important.

Needs

Community members need to have access to clear information regarding what changes might occur in their areas. Integration of e-scooters into the transportation infrastructure can seem overwhelming when many devices are deployed, so providing information and getting community feedback ahead of deployment is crucial to successful micromobility integration.

Responsibilities

Community members are responsible for keeping up-to-date with changes in their communities, and voicing concerns when necessary.

Benefits

There are potential benefits associated with integrating micromobility into transportation systems, including last mile transportation, environmental sustainability, local employment, transportation equity, and increased safety in transportation.

Last Mile Transportation

It is not possible for every potential transit user to live within a feasible walking distance from bus stops or transit stations; micromobility has the potential to extend the range of transit users. This could be a major breakthrough for public transportation, since the last mile can be the most difficult and expensive to solve as it is often farthest from the center of transit. However, initial evidence suggests that the real-world use of micromobility in this context is currently limited. For instance, the City of Portland Bureau of Transportation (2020) reported that based on their survey data, only 8% of respondents reported using e-scooters to access transit, and that a very small percentage of usage (0.5-1.9%) occurred along transit lines.

Environmental Sustainability

When people use e-scooters, they are often replacing another form of transportation (this is known as modal shift). When the replaced mode is an automobile, this can result in considerably less environmental impact. Automobiles are inherently inefficient for short trips with single occupants, and many of these types of trips can be replaced using micromobility. Tilleman and Feasley (2018) determined that the most inefficient part of driving is the automobile itself, since they typically weigh approximately 4,100 pounds, which is about 23 times the weight of the person it carries. This results in much higher fuel needs – the cost of fueling an e-scooter is approximately 1% of the cost of fueling an energy efficient automobile. This weight is also more damaging to the roads, degrading the infrastructure. Tilleman and Feasley (2018) also report that about 60% of US trips are under 5 miles with a single occupant. Similarly, NACTO reported that 35% of all US car trips are under 2 miles, suggesting many car trips could be replaced by micromobility. Further evidence comes from the National Household Travel Survey (NACTO, 2020) which found that 45% of micromobility users in Santa Monica, CA; Alexandria, VA; Bloomington, IN; Brookline, MA; Hoboken, NJ; Oakland, CA; and San Francisco, CA would have completed their trips using a vehicle.

There is some evidence of mode shift from survey data. The City of Portland reported that 37% of e-scooter trips replaced car trips, but that for Portland, OR residents 58% replaced low carbon modes such as walking, transit, biking or not taking the trip at all; however for visitors, the replacement was a more even split with 47% replacing car trips and 52% replacing low carbon modes. They also reported similar ratios in Calgary, ONT; Denver, CO; Arlington, VA; Oakland, CA; San Francisco, CA; and Santa Monica, CA (Portland Department of Transportation, 2020). Similarly, Chicago, IL respondents reported that if an e-scooter had not been available, 32% would have used a ride-hail service and another 11% would have used a private car (City of Chicago, 2020). Los Angeles, CA reported that e-scooters and bikes have changed the transportation landscape with most riders (44%) driving less and using ride-hailing services less (49%; Los Angeles Department of Transportation, 2020). Baltimore reported the most reduction in ride-hailing and taxi, reported by 51% of respondents. Additionally, 10% of respondents reported reducing their households' number of cars owned as a direct result of dockless vehicles being available (Baltimore City Department of Transportation, 2020).

Local Employment

Staff are necessary to complete a number of jobs related to shared micromobility distribution and customer service in order to be deployed. These jobs can offer career paths for under-served residents when companies commit to equitable hiring practices and providing fair wages and good working conditions (City of Portland Department of Transportation, 2020). To incentivize this goal, Portland, OR offered an additional allotment of e-scooters to companies that created partnerships with workforce development organizations to hire traditionally underserved people (City of Portland Department of Transportation, 2020). Another potential impact shared micromobility may have on employment is improving access to jobs. According to a report developed to evaluate potential mobility benefits of shared e-scooters in Chicago, IL, e-scooters could increase access to jobs by making about 16% more jobs reachable within 30 minutes than the current public transportation system (Smith & Schwieterman, 2018).

One concern is that many micromobility-related jobs are temporary independent contractor (i.e. gig work), which lack stability. Los Angeles, CA reported the desire to shift the industry away from temporary independent contractor positions that do not guarantee a living wage or benefits (Los Angeles Department of Transportation, 2020). Providing stable employment options to the community could improve perceptions of micromobility providers and their relationships with the communities they serve.

Increased Safety

While micromobility safety is certainly a concern, there is some evidence that replacing automobile trips with micromobility could increase overall transportation safety in some areas. According to the City of Portland Bureau of Transportation (2020), the "strongest predictor of transportation-related injuries is total vehicle miles travelled" (p. 38). Similarly, the International Transportation Forum, in their Safe Micromobility Report, indicates that a modal shift in cities from motor vehicles to micromobility devices like e-scooters would make the transportation system safer – however, a shift from walking to the same micromobility technologies would make the system less safe (Santacreu, Yannis, de Saint Leon, & Crist, 2020). By replacing car trips with e-scooter trips, e-scooter use could potentially contribute to an overall reduction in injuries and fatalities compared to the status quo.

As more people use micromobility like e-bikes and e-scooters, road safety for these devices may improve (Yanocha & Allan, 2019) through the "safety in numbers" effect. This is a well-documented effect where increased numbers of cyclists or pedestrians do not lead to proportional increases in cyclist or pedestrian related accidents, so that the overall risk per user goes down. The mechanism behind this is effect is under debate, but most believe that it is due to adaptations in transportation culture and infrastructure. As people become more familiar with various micromobility devices, they have more appropriate expectations for their presence and behaviors.

Challenges

Data Privacy

There is a growing concern about how personal data can be used, and what it means to have data privacy. For shared micromobility, the data can provide specific information about where a trip starts and ends, how long the trip took, and what time of day a trip occurred. As Duarte and Jerome (2018) point out in a letter to the City of Los Angeles, CA regarding their security concerns over the cities' Model Data Specification (MDS), "Location information is among the most sensitive data, especially when collected over extended periods of time." These travel data can provide information that reveal personal information about the users' travel patterns. For this reason, the U.S. Supreme Court recognizes the privacy interest associated with location data, therefore protected by the Fourth Amendment warrant requirement. While these data are de-identified, the authors point out that they can be easily re-identified. Specific concerns include the possibility of data leaks and hacks, but also access by law enforcement to personal data. On the other hand, cities need these data for planning, to understand the usage of shared mobility (Kaye, 2019).

Potential solution: Protect Personal Data

Equity

According to Williams, Kramer, Keita, and Boyd (2020), "equity is a representation of fairness in the distribution of benefits and burdens" (p.1). A number of inherent barriers exist to transportation equity, including geographic/spatial, temporal, economic/financial, psychological, and social (Shared-Use Mobility Center, 2019). While micromobility can ameliorate some of the inequities in transportation, inequities in terms of how, and to whom, shared micromobility is provided. For instance, while many cities have equity goals and require providers to offer equity programs, the goals are often not met. For instance, in Chicago, IL, providers consistently failed to meet rebalancing requirements involving priority areas which were based on disadvantaged communities (City of Chicago, 2020). Similarly, Los Angeles, CA found that fleet cap incentives and reduced fees were not sufficient to induce providers to deploy in disadvantaged communities (Los Angeles Department of Transportation, 2020).

Spatial Equity

Spatial equity refers to physical distance. Long distances often exist between transit stops, sometimes in hostile environments, making walking challenging. This can decrease the opportunities people have access to. Micromobility devices can only address this problem if they are available in these areas. According to the Los Angeles Department of Transportation, "Ridership patterns mirror deployment patterns. The more vehicles that are deployed, the more people use them" (p. 35). When providers do not deploy in certain areas or communities, the opportunity for spatial equity that could be provided by micromobility is low. Further, scooters do not often travel far from where they are initially deployed.

Temporal Barriers

Temporal barriers refer to the ability to make spontaneous trips or time sensitive travel. Many types of public and shared transportation (including e-scooters) are not available 24 hours a day, significantly limiting transit opportunities. However, this is an opportunity for micromobility. If this is considered in planning, micromobility can fill the transportation availability gaps when other public transportation is not available.

Financial Equity

Economic/financial position is a barrier to transportation for many people. Even subsidized transit costs can still be insurmountable for some. And while many cities require e-scooter providers to offer financial equity programs, many users are not aware of them. For instance, the Los Angeles Department of Transportation (2020) user survey reported 85% of respondents were not aware of equity programs. Similarly, the City of Portland Bureau of Transportation (2020) reported that low-income plans were used by less than 1% of riders. When queried, 59% of low-income respondents in Portland, OR did not know of low income plans, 38% did not know there were cash payment options, and 25% did not know non-smartphone rentals were possible. For economic subsidies to be beneficial, eligible people must be informed about them.

Physiological and Social Equity

Physiological and social inequities, including cognitive conditions, can make some transportation options challenging. These are not only specific disabilities but also may be related to age, physical fitness or capability or willingness to risk injury. Some social or cultural contexts make comfort with shared micromobility less likely, including histories of discrimination and lack of trust in institutions that provide and support shared micromobility, or a minority language or culture. Since shared e-scooters require riders to follow specific rules, use can have unintended consequences for certain users, often people of color, making them vulnerable to potentially dangerous interactions with police or fines. One example comes from Chicago, IL, where black neighborhoods receive more tickets for sidewalk biking than other communities (Shared-Use Mobility Center, 2019). Another example of social backlash comes from early e-bike use in New York City. Immigrant delivery workers who used e-bikes faced significant backlash, from not only the public, but also police, because some e-bike users had been violating traffic laws, and threatening public safety. These workers were vulnerable to being targeted because of their lower power status in the society (Yanocha & Allen, 2019). These types of concerns can lead to reluctance to participate in new mobility programs.

Potential solutions: Economic Equity Plans, Form Meaningful Partnerships with Micromobility Providers, Provide a Variety of Device Configurations, Socially Inclusive Outreach

Inconsistent Regulations

Abutting jurisdictions with different regulations can be problematic for riders and bystanders, because they make it difficult for riders and bystanders to know what to expect. For instance, if one jurisdiction allows sidewalk riding, but the neighboring one does not, riders may inadvertently break the law. Pedestrians too could be at increased risk of collision if they are not aware that e-scooter riders may be on sidewalks. This is also a concern for drivers, since regulations often differ in terms of street riding. Additionally, the inconsistent rules from city to city can create a confusing regulatory landscape. Consistent information for bystanders is key to public safety and perceptions (Rayaprolu, McCarthy, & Gifford, 2020), and knowledge of statutes and regulations can be a challenge since they vary from state to state and locality to locality (Shadel Fischer, 2020).

Potential solutions: Regulation Harmonization

Safety

Safety is one of the most serious issues in micromobility, for both riders and bystanders. The sections below describe safety challenges, including an overview of injuries and fatalities from reports and academic sources, helmet usage, novice riders, rider impairment, and issues with data and reporting.

Since the shared e-scooter market is still in its infancy, there are limited data available on injuries. However, a few studies have been conducted and some pilot programs have reported injury statistics. From a national perspective, Tark (2020) reported 132,800 e-scooter related emergency department visits from 2017 through 2019, with the number rising each year. In 2017, 2018, and 2019, there were 34,000, 44,000, and 54,800 e-scooter-related injuries, respectively. It should be noted that these statistics do not differentiate between privately-owned and shared e-scooters, and dockless shared scooters did not see widespread distribution until 2018.

Shared e-scooter fatality information is available from the Collaborative Sciences Center for Road Safety at University of North Carolina Highway Safety Research Center (Dwyer, Curran-Groome, & Harmon, 2020). Of the 36 e-scooter related fatalities that have been recorded since 2016, 34 were e-scooter riders, one pedestrian, and one cyclist. The majority (n = 25) occurred on the roadway. Most of the fatal accidents (*n* = 27) involved motor vehicles. Some (*n* = 3) were privately owned scooters, but most (*n* = 27) were rental scooters, with the remaining 6 being unknown/unreported. While rental scooter companies do not typically rent to minors, four of the fatalities were minors, and these were all rented (rather than privately owned) e-scooters. Most of the fatalities occurred between 6pm and 6am (*n* = 22) with another two reported less specifically as occurring in the evening.

Helmet Usage

Helmet usage is a contentious issue in the cycling community, and this carries over into the domain of other micromobility devices. Many people believe that the best way to increase safety for micromobility is through higher adoption (the "safety in numbers effect"), and that forcing helmet usage can actually result in decreases in ridership. Another reason for dockless e-scooters popularity is their on-demand availability – a rider doesn't necessarily need to plan ahead to use them. "Convenience is a main driver of SMDs (small mobility devices)" (p. 47, Arlington Mobility Lab, 2019). This makes helmet usage less likely, especially since they are not provided with the devices. As one user in Portland, OR reported: "I wish I could be safer by using a helmet, but oftentimes I do not have one on hand" (p. 38, City of Portland Bureau of Transportation, 2020). Some evidence suggests helmet use is somewhat rare. For instance, during the Chicago, IL pilot study, staff observed riders at various sites and recorded only about 2.7% of the riders wearing helmets (City of Chicago, 2020).

Novice Riders

While many of the studies evaluated here do not provide specific data about the experience levels of riders who experienced crashes, the Austin Public Health (2019) interviewed riders and queried them about their experience levels. These researchers identified lack of experience as a significant problem and reported one-third of the accident victims they interviewed were first-time riders, with 63% having ridden 9 or fewer times.

Rider Impairment

Rider impairment may be a significant factor in e-scooter accidents, but it is difficult to assess the frequency because it is often self-reported. In the Austin Public Health (2019) study, 29% of participant reported that they had alcohol in the preceding 12 hours. Similarly, in Salt Lake City, UT, 16% of the incidents involved alcohol intoxication, again based on self-reported data. Both Trivedi and colleagues (2019) and Kobayashi and colleagues (2019) reported results based on screenings. In the case of Trivedi, only five of the 36 cases used in the study provided this information, with one case (3%) indicating impairment. However, the Kobayashi (2019) study screened 79% of participants for alcohol, and 60% for other illicit substances. They found 48% for alcohol (over legal limit >80 mg/dL), 52% for other illicit substances, and concluded that the intoxication rate was higher than previous studies of cyclists or skateboarder accidents. Lack of reporting is also a problem in understanding fatality data. Rider impairment status was only recorded in 14% of the fatalities, with one of those indicating rider impairment at the time of the accident (Dwyer, Curran-Groome, & Harmon, 2020).

Data and Reporting Issues

E-scooter injuries are difficult to quantify, and even more difficult to compare to other modes of transportation. One challenge for quantification is reporting standards – as the Shadel Fischer (2020) reported, obtaining micromobility injury data from healthcare providers is difficult because of an inability to distinguish between crashes involving e-scooters, mopeds, and e-skateboards, as well as differences between shared and personally owned devices. Further, e-scooters are not necessarily easy to differentiate from non-electric scooters in historical records. Arlington Mobility Labs (2019) suggests that crashes are likely underreported because micromobility mode specific data on crashes is not available from local hospitals, and state forms do not track shared e-scooter crashes. Further complicating matters, some areas use accidents reported by riders, others use injuries reported by riders, and still others rely only on information from medical providers – which can consist of primary care doctors, urgent care clinics, hospitals, or some combination thereof. As e-scooters are new to the transportation system, data standards on how and what to report are still emerging. For these reasons, and due to a lack of a universal reporting standard, micromobility accidents are likely under-reported.

Often, the purpose of quantifying e-scooter safety data is to compare it to other transportation modes. While it is becoming standard to report safety data for e-scooters in terms of number of trips or distance of each trip made via e-scooter, these metrics may not be as meaningful as they are for other transportation modes. Confounding factors such as rider inexperience may also play a role. Similarly, injury data are collected differently across the various transportation modes, making it difficult to make comparisons. For instance, only fatalities and serious injuries are tracked for automobile accidents, whereas minor injuries are not typically tracked. Further, the types of trips are also incomparable. For instance, shared e-scooter trips typically only occur in urban areas, where transportation is an inherently different environment because more people are sharing the transportation space (City of Portland Bureau of Transportation, 2020).

Some progress in reporting has come in the form of International Classification of Diseases (World Health Organization, 2018; a common framework and language to report, compile, use and compare health information, Center for Disease Control) codes, which now differentiate between e-scooters and other devices, as well as whether the rider falls on or strikes a pedestrian or a stationary object on the ground; and whether the rider was struck by a non-motorized vehicle, a motorized vehicle, or a railway train. Further improvements come from the Fatality Analysis Reporting System (FARS) which was modified in 2020 to indicate whether indicate whether the personal conveyance was motorized, non–motorized, or unknown. FARS does not include motorized bicycles. FARS data can only be accurately coded if specific information such as scooter motorized or scooter non-motorized is included in state crash reports. Without providing this level of detail on state crash forms, the change to FARS do not improve the data (Shadel Fischer, 2020).

While there are safety issues, it is important to note that there are safety issues with any type of transportation. As with other modes of transportation, micromobility safety statistics should be considered in context and only compared in a standardized way.

Potential solutions: Collect Data, Educate Riders and Bystanders, Limit Device Speeds, Provide Infrastructure, Safety Data Reporting And Standardization, and Support Helmet Use

Parking

Since shared e-scooters are generally deployed in high population density environments, their parking locations can be problematic. In some cities, there are so many pedestrians during rush hour that even pedestrians are slowed by the crowd.

Urban space in particular tends to be at a premium. Adding space for micromobility parking, including e-scooters and bicycles, can be challenging. This can be a major issue for bystanders. For instance, in Alexandria, VA, 66% of complaints received about the e-scooter programwere for improperly parked devices that blocked sidewalks (City of Alexandria, 2019). In a compliance audit, the Los Angeles Department of Transportation (2020) found that 26% of e-scooters were parked in the pedestrian zone, with 20% causing obstruction to the pedestrian zone by failing to provide at least 6 feet of clearance. Similarly, City of Portland Bureau of Transportation (2020) found that only about 28% of scooters were in compliance with all city parking regulations. Improper scooter parking can be a safety issue for bystanders. In the analysis by Trivedi (2019), researchers found 19% of the injuries suffered by non-riders were caused by people attempting to lift or carry a scooter that was not in use, which was likely due to needing to move them out of the way because they were improperly parked.

This is especially problematic for users with disabilities, who may not be able to move the devices. A Los Angeles Department of Transportation (2020) compliance audit found that 7% of vehicles were blocking disability access ramps. The proliferation of scooters can potentially conflict with cities' obligations under the Americans with Disabilities Act (ADA) which prohibits discrimination and ensures equal opportunity regardless of disabilities (Americans With Disabilities Act, 1990). Under this act, cities are responsible for ensuring the rights-of-way are readily accessible and useable by people with disabilities. Multiple cities have in fact been sued by parties asserting ADA violations regarding denial of access to the sidewalk (Heinselman, Milder, & Weiner, 2019).

While parking is one of the major issues with shared e-scooters, Fang and colleagues recently observed that most scooters were parked correctly. These researchers conducted a parking study in July of 2018 in San Jose wherein they photographed 530 parked shared e-scooters and found that 90% were parked out of the way of pedestrians, either on the edge of sidewalks or in furniture zones, and less than 2% blocked access for the disabled.

The responsibility for appropriate parking, much like appropriate riding, must be on the riders. And while many cities have modeled regulations for users around what they already have in place for cyclists, this does not necessarily work for parking. According to the City of Portland Bureau of Transportation (2020) "…limitations on parking near public art, grating/access lids, signs, and drinking fountains make sense when installing permanent bike racks but do not apply well to dockless e-scooters" (Appendix B). They also reported that parking challenges are improving as people learn the rules, so patience is key. However, if a convenient solution is not available, compliance is not likely.

Potential solutions: Lock-To Systems, Parking Corrals, Penalties For Improper Use

Rule Awareness and Compliance

It is important for e-scooter riders and bystanders to be aware of the norms, rules, and regulations guiding use, so they can adjust their behaviors and expectations accordingly. However, in the case of e-scooter bystanders, people do not often seek out information about rules and regulations that do not apply to them directly. Even riders, to whom the rules do apply, may not fully read or understand the information provided by e-scooter providers or local governments. In a rider survey, the Los Angeles Department of Transportation (2020) found that only 67% of riders surveyed knew that a valid driver's license is required to ride e-scooters and e-bikes. Similarly, Arlington Mobility Lab (2019) reported from their pilot study that 20-22% of e-scooter riders and 43% of non–riders did not know the laws governing e-scooter use.

Awareness of relevant laws and regulation varies by location. For instance, Santa Monica, CA reported that "85% of riders and 90% of the general public reported a general awareness of the pilot's basic parking and riding rules" (City of Santa Monica, 2019, p6), which they credited to the city's active role in educating the public.

Sometimes even people who know the rules choose not to follow them. Lack of compliance is an important reason that law enforcement officials also need to know these rules. Unfortunately, according to Shadel Fischer (2020) they often lack training for these situations. For instance, they describe the instance in Austin, TX, the police department was caught off guard when more than 5,000 e-scooters appeared on the streets: "Riders were in the middle of the street, going the wrong way, parking anywhere and blocking sidewalks. We didn't have a state law or city ordinance; we were literally flying blind" (p. 28).

Potential solutions: Educate Riders and Bystanders, Facilitate Community Engagement, Form Meaningful Partnerships with Micromobility Providers, Penalties For Improper Use, Provide Infrastructure, Regulation Harmonization

Sidewalk Riding

One issue cities and counties contend with when developing their rules and ordinances is where people are allowed to ride e-scooters. These interactions can be confusing since the rules governing sidewalk riding vary by jurisdiction or even within the same jurisdiction. For instance, some cities allow sidewalk riding, but only in the absence of bike lanes.

Evidence suggests that sidewalk riding may be a hazard. For instance, the Baltimore, MD rider survey found that riders who reported always riding on the sidewalk also reported experiencing more close calls and accidents (City of Baltimore, 2020). In a study conducted by the Insurance Institute for Highway Safety in Washington, D.C., researchers interviewed more than 100 e-scooter riders who had injuries resulting in emergency room visits. They found that nearly three out of five of these injuries occurred on the sidewalk, and that about one-third of the injuries occurred in areas where sidewalk riding is prohibited (Insurance Institute for Highway Safety, 2020). However, it is also possible that people more prone to accidents choose to ride on the sidewalk, but this is difficult to parse out without controlled experimentation.

Even in areas where sidewalk riding is banned, lack of compliance is common. Badeau (2019) indicated concern over the proportion of accidents in their study which occurred on sidewalks

(44%), especially since sidewalk riding is illegal in Salt Lake City, where the study was conducted. For instance, while Oregon state law prohibits sidewalk riding, the City of Portland Bureau of Transportation (2020) found that riders typically use sidewalks because they feel safer than they do on the streets. They also reported that anecdotal observations indicated that riders were up to twice as likely to ride on the sidewalk when no bike infrastructure was present. In Los Angeles, CA, a survey found that the majority (82%) of riders know sidewalk riding is prohibited, but 33% still reported that they prefer to ride on sidewalks (Los Angeles Department of Transportation, 2020).

Potential solutions: Collect Data, Educate Riders and Bystanders, Penalties For Improper Use, Provide Infrastructure

Vandalism

There have been a plethora of vandalism incidents against e-scooters – so many that an Instagram social media account called "Bird Graveyard" with over 70,000 followers that is "devoted to destroying rideshare scooters" has recently been nominated for a 2021 Shorty Award, which honor the best of social media (Shorty Awards, n.d.). Since its inception in June of 2018, the Bird Graveyard has displayed photos and videos submitted by users of such acts of vandalism as scooter on fire, in trash cans, in tangled piles, and in various bodies of water (Blocker, 2018).

While fans of the account find it amusing, this is not only problematic for scooter providers, but also for the bystanders and the public. Environmental issues are created when the e-scooters are dumped in bodies of water as well as when they are set on fire. While e-scooter providers are generally responsible for retrieving the scooters from bodies of water within a specified amount of time, this can still be damaging for water quality. There is no remediation for the air quality damage caused by setting these devices on fire. Another serious form of vandalism is cutting brake lines, which can be dangerous to both riders and bystanders if the riders do not notice before beginning their rides (Prior, 2019). Another dangerous issue is devices being thrown off buildings (Calise, 2019).

Potential solutions: Facilitate Community Engagement, Form Meaningful Partnerships with Micromobility Providers, Lock-To Systems

Solutions

Collect Data

In order to understand needs for micromobility users and bystanders, data are required to describe how people are using the services. This can include dimensions such as accidents, how many devices are used in a day, where the devices being and end, trip length, and time of day. Contact information for riders may also be important so that rider surveys can be conducted. Shaheen and Cohen (2019) recommend collecting quantifiable performance metrics for safety, congestion, equity, and environment. Congestion measures include non-vehicle mode share and travel time to work. Equity measures include user demographics, average distance to nearest device, percentage of population/geography served, and increase in users of equitable access programs. Environmental performance measures include carbon dioxide footprint of the vehicles and vehicle/battery life span. The New Urban Mobility Alliance (NUMO; n.d.) provides a useful tool describing what types of data can be collected at https://policydata.numo.global/data-sources/

It is important to consider which data may be needed and specify that in the agreements with micromobility providers. However, it is also important to consider how to protect personal data. Striking the correct balance between the needs of different groups is an ongoing challenge, and research to better understand the needs and implications of these data is necessary.

Economic Equity Plans

The majority of cities surveyed offered some form of financial equity initiatives, including discounted fares or membership options, flexible payment options, cash access or options for the unbanked, access for those with digital impoverishment (having to use a smart phone with high speed data), combined bikeshare and transit passes; however, as stated in the report from the City of Portland Bureau of Transportation (2020), people who are eligible for programs often do not know that they are available to them. In addition, some systems for receiving assistance may be difficult to navigate. One solution that the Los Angeles Department of Transportation (2020) has identified is to introduce price capping for trips that begin/end in an equity zone. Another solution, deployed by the City of Portland Bureau of Transportation (2020) has been to leverage existing alliances with community organizations. They partnered with affordable housing providers to include e-scooter memberships in existing transportation subsidies, and supported property managers of these properties to help residents gain access to these options. This multi-lingual program was the primary source of low-income plan signups for e-scooters. While many cities and micromobility providers are making efforts at improving equity for micromobility users, these efforts have not been completely successful. Research is needed to better understand how to engage underserved communities and provide options that lead to equitable access.

Educate Riders and Bystanders

Riders cannot follow the rules if they do not know what they are. Unfortunately, people often do not pay full attention to materials provided to them, making it the accessibility of these materials crucial. Shadel Fischer (2020) recommends providing riders “consistent, simple, and easy-to-understand rules that promote safety”. Having a simple message can also be helpful. For instance, Los Angeles, CA collaborated on a safety campaign with Santa Monica to establish a unified message around safe riding and commonsense parking practices. The Los Angeles Department of Transportation purchased space on DASH and Metro buses and bus shelters to deliver the “Take the Friendly Road” campaign message. Hundreds of Metro and DASH buses display interior bus cards.

Communicating with Riders

- Easily digestible printed materials such as posters, fliers, hang tags popular for illustrating dos and don’ts
- In app training with verification (such as a short quiz)
- Require information on the provider’s website
- Provide information on the devices

- On street messaging indicating where to (and where not to) ride

Communicating with Bystanders

- Community/neighborhood events
- Discuss micromobility in driver education programs
- Micromobility providers can hire and deploy existing community members
- Train law enforcement on rules and how they should be enforced
- Public service announcements

Facilitate Community Engagement

Community engagement can be facilitated through a number of methods, including community education, community meetings, and user and rider surveys. Los Angeles Department of Transportations (2020) uses community engagement "as a tool to understand issues and opportunities related to program design, policy gaps, and product-market fit." They also organized and hosted quarterly community meetings to provide general information on the permit program and to facilitate dialogue between the public and the providers. Meetings typically consisted of a brief presentation on program updates from Los Angeles Department of Transportations' staff and a period for comments and questions. They also organized and hosted quarterly community meetings to provide general information on the permit program and to facilitate dialogue between the public and the providers. Baltimore, MD used well-known community members to develop a public service announcement (Baltimore City Department of Transportation, 2020).

In their guide for engaging with communities, the National Association of City Transportation Officials Better Bikeshare Partnership (2018) recommended strategies, including:

- Actively look for opportunities to engage with people. Cities, advocates, and providers need to invest in engagement by hiring people who can connect in meaningful and respectful ways; this can take many forms to reach people in ways that are clear, convenient, and accessible to them.
- Recognize that many people do not attend meetings, and their perspectives will be missed. Oversample in key communities to combat historic inequities and avoid missing vulnerable populations.
- During planning, ensure that the public understands how decisions will be made regarding system coverage and resource placement.
- Ambassador programs leverage existing relationships with community members, and provide a deeper understanding of community wants and needs.
- Employing people from within the neighborhoods that the systems serve, youth training, workforce development programs, focus on under-employed populations, can facilitate long-term community investment.
- Marketing campaigns should be inclusive and include multilingual ads and outlets.

Community engagement is generally a difficult proposition, so gaps exist in how to reach a broad segment of communit members. Research into this problem is recommended.

Form Meaningful Partnerships with Micromobility Providers

Treating the relationships with micromobility providers as meaningful community partnerships rather than just contracts with service providers can improve the relationship between the communities and providers.

The City of Portland Bureau of Transportation (2020) suggests that as the e-scooter industry grows, it will be able to better meet transportation goals, shifting their relationship from regulation to partnership. For this reason, they are focusing their attention on creating deeper relationships. One way of doing this is by limiting the number of providers. They also recommend having clearly stated shared goals between community and micromobility providers. Similarly, Yanocha and Allan (2019) recommend developing a vision for the role of micromobility as part of achieving broader transportation goals. It is important to remember that e-scooters and other micromobility do not operate in a vacuum, but rather coexist with all of the other transportation infrastructure users. Anderson-Hall, Bordenkircher, O'Neill & Scott (2019) recommend choosing scooter providers whose missions align with the values of the community by asking questions such as:

- Will e-scooters provide greater environmental performance?
- How can e-scooters help to alleviate shortfalls in the existing transportation systems, such as the last mile problem?
- To what extent can e-scooters be equitably distributed?
- How will the program offer opportunities for economic development within the community?
- What are the safety standards and how can providers communicate the rules with riders and community members to emphasize safe riding?

The Shared-Use Mobility Center (2019). recommends building trusted relationships, creating a shared vision, conducting thorough research on the companies and needs of the community, keeping lines of communication open, accepting unsolicited proposals, employing performance based selection processes where appropriate, treating partnership as the start of a longer process, staying current with the mobility industry, and effectively engaging with the community. Van Audenhove and colleagues (2020) recommend fostering innovation through public-private collaborations, including technology and business model development, technology development and implementation, innovative business models. They also recommend promoting innovation schemes, competitions and projects. This can be especially beneficial in communities with inadequate transportation infrastructure for safe micromobility operation.

Another effective way to form and leverage partnership is by take public feedback through existing systems available to the public. For instance, many cities now integrate 311/City service numbers with e-scooter providers to allow the public to more quickly and easily deal with complaints. Another method is by collecting rider and community survey data regarding shared micromobility perceptions and behaviors through the local government websites (link to facilitate community engagement).

While mutually beneficial partnerships are built on trust, verification may also be a necessary component. To verify provider reporting, Los Angeles Department of Transportation (2020) completed monthly audits on deployment, user parking, vehicle condition, unpermitted providers, and location accuracy. They have developed a mobile app to streamline auditing by allowing staff to verify that providers are accurately registering and reporting devices. To ease the burden of collecting compliance data, Los Angeles Department of Transportation has also developed a mobile app to track various components of compliance.

Limit Device Speeds

Like any other type of mobility, micromobility devices are more dangerous at higher speeds. However, unlike other modes of transportation, micromobility device speed can be controlled by the provider. Further, it is possible to limit speeds for specific areas using geofencing, which uses GPS, RFID, and/or Wi-Fi signals to automatically trigger a device behavior such as speed reduction.

Some cities that allow sidewalk riding mandate a different speed limit for sidewalk riding than for other infrastructure, such as streets and bike lanes. In Arlington County, VA the initial maximum speed was 10 miles per hour, but through discussions with providers and staff, they realized 10 was too fast for sidewalks and too slow for streets. For this reason, they adopted two speed limits: 15 miles per hour on streets, and 6 miles per hour on sidewalks (Arlington County Mobility Lab, 2020). Similarly, Denver asks that riders use bike lanes whenever possible, or if there are no bike lanes, to use roads that have speed limits under 30 miles per hour. If sidewalks must be used then the speed limit on the sidewalk is 6 miles per hour (Kenney, 2019).

Limiting speed for first time users may improve safety. To explore this, the City of Seattle, WA has employed a speed limit for first-time users. Whereas the speed limit for scooters in Seattle is normally 15 miles per hour, first-time users are capped at 8 miles per hour (Seattle Department of Transportation, 2020).

Over time, general device speed limits have become somewhat standard (10-15 mph) based on cities' experiences. However, continuing research is necessary to determine whether the solutions of lowering speed limits on sidewalks and for first time users are effective for improving safety.

Lock-To Systems

Lock-to systems are locks connected to micromobility devices that allow riders to lock them to infrastructure features. Lock-to systems have been implemented in a number of cities, including Minneapolis, MN (Minneapolis Public Works, 2020), Chicago, IL (Claffey & Hofer, 2020), Denver, CO (City and County of Denver, 2020), and Washington D.C (Pascale, 2020). This solution can reduce sidewalk obstruction, dumping, and vandalism, but also has its drawbacks. According to Natalie Sawyer, a spokesperson for Bird, "There's no evidence to support that lock-to meaningfully improves parking compliance," stating that lock-to implementation in Denver only increased compliance by 1-2 percent. Further retrofitting scooters to add the necessary capabilities could cost millions of dollars, which would be difficult given the current market climate (Lazo, 2020). Not surprisingly, Guaquelin (2020) states that most scooter providers are against this solution, and that it could cause other problems because bike racks could no longer be available to cyclists. The Los Angeles Department of Transportation (2020) reports they intend to require lock-to technologies, but will also be increasing the number of bike racks to deal with this issue. As the transportation landscape continues to change, research will continue to be necessary to understand optimal parking solutions and how they vary by location.

Manage Number of Devices And Distribution

To meet the goal of promoting spatial and geographic equity, it is important to manage where devices are deployed and rebalanced. Many cities (including Portland, OR, and Chicago, IL) include specific rebalancing requirements in vendor contracts. This can promote access in areas where people may otherwise have limited transportation options, and ensure other areas are not overcrowded with devices. Limiting the number of devices allowed in an area can reduce the competition for space for both parking and riding.

Parking Corrals

Parking corrals are clearly marked designated scooter parking zones. They are typically marked by using pavement decals or paint, making them a low-cost method for curb-space management. They can be implemented on the sidewalk or in the street itself. This solution is becoming a popular way to deal with parking and curb-space management issues. According to the City of Portland Bureau of Transportation (2020), Phoenix, AZ; Toronto, ONT; and San Diego, CA have reported success using this solution. This solution is attractive to scooter providers because it also gives them a designated area for deployment. However, in their rider surveys. The City of Portland Bureau of Transportation found that (76%) riders they surveyed were not aware of the corrals, which would obviously lead to compliance issues. Another issue with this solution is that unlike lock-to systems, parking corrals do not protect devices from dumping and vandalism. As the transportation landscape continues to change, research will continue to be necessary to understand optimal parking solutions and how they vary by location.

Penalties For Improper Use

Since the responsibility for parking appropriately must ultimately be on the rider, some cities have enacted penalties for parking improperly. For instance, the city of Seattle, WA charges a $20 fee onto the riders' bills if they do not park according to regulations (Seattle Department of Transportation, 2020). As the transportation landscape continues to change, research will continue to be necessary to understand optimal parking solutions and how they vary by location.

Protect Personal Data

With the introduction of the Mobility Data Specification, the Los Angeles Department of Transportation began collecting a considerable amount of data beyond what was being collected in the Global Bikeshare Feed Specification (GBFS). Los Angeles, CA Portland, OR, and Seattle, WA have protocols around the collection, protection, and sharing of information as well as their digital rights of way. Shaheen and Cohen (2019) recommend data standards that include data accessibility, data license (ensure it's available for public use), data quality and timeliness. Further, guiding principles for establishing data exchanges include conditions for use, data management policies, and data dashboards.

The City of Portland Bureau of Transportation is a founding member of the Open Mobility Foundation (OMF) to engage in conversation regarding mobility data and data privacy. This has allowed them to engage with stakeholders regarding best-practices for managing and protecting mobility data. Detailed aggregation methods are described in the City of Portland Bureau of

Transportation 2019 E-Scooter Findings Report. Additional guidance can be found in NACTO Policy 2019, Managing Mobility Data.

Provide a Variety of Device Configurations

While scooters may be accessible to a different population than traditional bicycles, many people are still unable to use them. Different types of scooters may be leveraged to reach a wider audience. After identifying that "not everyone is physically able to ride an e-scooter" as a 2018 pilot concern, the City of Portland Bureau of Transportation (2020) began offering priority in the permitting process to providers offering seated e-scooters. Continuing research is necessary to understand how micromobility can meet the needs of users with various abilities.

Provide Infrastructure

When considering the implementation or expansion of micromobility programs, it is necessary to consider whether current infrastructure is adequate for all users in the transportation environment. The Los Angeles Department of Transportation (2020) used a data driven approach to determine that protected infrastructure is important to travelers using mobility movement data. NACTO (2016) reported that the majority (53%) riders in Alexandria, VA reported preferring to ride bikes in bike lanes over other options (trails, sidewalks or streets), and 88% of e-scooter riders in Hoboken, NJ stated they would feel safer riding in streets if bike lanes were present.

Shadel Fischer (2020) reported that separating transportation modes is the most effective way to reduce the risk of accidents, and similarly Yanocha and Allan (2019) reported that crashes can be decreased by designing safe, inclusive street infrastructure. The National Association for City Transportation Officials published a report in 2016 (before the deployment of shared e-scooters) suggesting that protected bike lanes are essential to equity and mobility efforts in transportation.

Unfortunately, dedicated protected infrastructure is not widely available, and current U.S. surface transportation funding law does not include dedicated funding for micromobility. A further financial constraint is that fees collected by these programs are inadequate to cover administrative costs or the costs of educating riders and other road users on how to interact safely (Shadel Fischer, 2020). At the federal level, the North American Bikeshare Association (n.d.) recommends including shared micromobility as federally-recognized methods of public transportation in a Surface Transportation Reauthorization Bill. While planning for the influx of micromobility into shared transportation infrastructure is important, it is also important to communicate that information to riders.

While providing infrastructure may increase safety, it comes at a cost to other transportation users. For instance, existing streets and sidewalks would have to be altered in most places to allow for more bike lanes. More research is necessary to understand the cost-benefit landscape of increased infrastructure for micromobility.

Regulation Harmonization

Relationships between regulatory areas can be complicated. Regulation harmonization refers to an approach bringing uniformity of regulations/policies between two or more political jurisdictions. Harmonization can occur at various levels of government. There are regulations at the city, county and state level, and there can be differing rules in abutting jurisdictions, which can be confusing for both riders and bystanders. Policies at local levels can allow support the desires of individual communities. Policies at the state level can support uniform policy development but do not address unique local concerns. At the same time, federal-level guidance is a primary driver of transportation policy.

Areas with abutting jurisdictions often have similarities, but invariably there will also be differences between the wants and needs of their populations. It can be challenging to accommodate the policy desires of all involved municipalities and result in policies that don't fully meet anyone's desires. There is a risk of deadlock between municipalities who disagree on the proper course of action. Additionally, feedback from any given constituency can be diluted, increasing the risk that specific populations may go unheard. Another danger is that harmonization of e-scooter regulations may inhibit experimentation, thus preventing novel solutions from being implemented. It is important that all cities sharing boundaries be aligned in terms of public communications oversight, data standards, and small vehicle standards for shared use contexts (Rayaprolu, McCarthy, & Gifford, 2020).

Federal, state, and local regulations and policies all govern not only micromobility but transportation in general, leading to a complex legislative structure. More research should be conducted to better understand who should regulate each aspect and how these regulatory structures can best be communicated with community members.

Safety Data Reporting And Standardization

Arlington Mobility Labs (2019) stated that when comparing micromobility accidents to other modes, it is important to look at "normalized measures of crashes that reflect the difference in exposure between the modes given the variation in speed, distance traveled and trip counts" (p. 43). They recommend be measures of 1) crashes/1,000 miles; 2) crashes/1,000 trips; or 3) crashes/1,000 people". Of these, crashes per mile may provide the most consistent measure and is easiest to compare to other modes of transportation, but more research is needed to fully understand how to best standardize and report these data.

In a report for the Governor's Highway Safety Association, Shadel Fischer (2020) recommends that state crash reporting systems include a unique field for all micromobility devices that are permitted, such as has been proposed for the Model Minimum and Uniform Crash Criteria (MMUCC). Since the FARS was modified in 2020 to indicate whether indicate whether the personal conveyance was motorized, non-motorized or unknown, including these important details on state crash forms would allow the change to FARS to be fully realized.

Socially Inclusive Outreach

In order to appropriately communicate with members of a community, it may be helpful to use socially appropriate outreach. In some cases, deployment of multilingual communication in written and spoken materials can help communities reach a larger segment of the population. More research should be conducted to better understand communicating with diverse communities.

Support Helmet Use

While there is debate on whether helmets should be mandated, helmet use has been shown to decrease the occurrence of traumatic brain injuries in other domains, including motorcycles, bicycles, and skateboards. One specific example is from Michigan, where they repealed a mandatory helmet law for motorcycles and observed a dramatic decrease in helmet use and a crash mortality rate that increased fourfold (Striker, Chapman, Titus, Davis & Rodriguez, 2016). Another indication comes from the Austin Public Health (2019) study, where nearly half the participants suffered head injuries and 15% suffered traumatic brain injuries.

Lack of helmet use is especially concerning given that nearly one-third of e-scooter injury patients evaluated in a recent study had head or neck injuries, which is more than double the rate of head injuries experienced by bicyclists (Namiri 2020). Austin Public Health (2019) found that only one person of the 190 evaluated for their study was wearing a helmet. In Salt Lake City, Badeau and colleagues (2019) that none of the 58 injured were wearing helmets. Another study by Kobayashi reported that 98% of riders in the records they evaluated were not wearing helmets.

Helmets are mandated for e-scooters in few cities (e.g. Seattle, WA and Portland, OR). While some researchers (e.g. Namiri 2020; Kobayashi, et al. 2019) strongly advocate for laws mandating helmet use to increase safety, some organizations such as CalBike (n.d.) suggest that mandating helmets is a barrier to use for shared systems, and these mandates themselves may not result in higher helmet use. In the cycling domain, advocates usually oppose mandating helmets since it potentially limits access. Encouraging helmet use through such mechanisms as helmet giveaways and educational campaigns is likely to be more productive (Yanocha & Allan, 2019). Shadel Fischer (2020) recommends encouraging competitive funding to spur the development of collapsible helmets or helmets designed for shared use. As this is a somewhat contentious issue, more research is recommended into the importance of helmet use for various forms of micromobility, how to communicate that with the public, and how best to provide helmets and encourage their use.

Conclusion

This report provides information about micromobility (specifically e-scooters), focusing on of bystanders. Using information collected through an environmental scan, discussions with subject matter experts, and review of academic literature, the needs and responsibilities of bystanders are described, the history and present state of e-scooter deployments and regulations are detailed, and benefits, challenges and solutions are provided. This paper is accompaniment to the website, https://micromobility.mitre.org.

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Appendix A: Regulations by City

City	Maximum Devices/Provider	Minimum Devices/Provider	Fees	Speed Limit	Sidewalk Speed Limit	Helmet Required	Street Operation
Los Angeles, CA	10500		$10,000 permit + variable device fee	15		18 years of age	Streets 25 mph
Chicago, IL	3333		$250 permit + $120/device	15		Not required	
San Antonio, TX	1000		$500 application + $10/device			Not required	Streets 35 mph
San Diego, CA			$5141 permit + $150/device	15		18 years of age	Streets 25 mph
San Jose, CA	1000	50	$2500 permit + $97/device	12		18 years of age	Streets 25 mph
Austin, TX	Variable based on usage		$30/device	20		18 years of age	Streets 35 mph
Columbus, OH	500		$500 permit + $75/device	20		18 years of age	Streets 35 mph
Charlotte, NC	Variable based on usage	50		15		16 years of age	
San Francisco, CA	1000 - 2500		$25000 permit + $5000 application + $10000 endowment	15		18 years of age	Streets 25 mph
Indianapolis, IN	1000		$15,000 permit + $1/device/day	20		Not required	
Seattle, WA	Variable based on permit	2000	$232 permit + $296/hr review + $150 per scooter	15		Required	Streets 25 mph
Denver, CO			$15000 permit + $30/device	20		18 years of age	Streets 30 mph
Washington D.C.	Variable based on usage	500	$250 permit + $33/month/device	10		Not required	Allowed
Baltimore, MD	2000	150	$70000/permit + $0.10/device	20	6	16 years of age	Allowed
Arlington County, VA	2000		$8000 permit	15	6	14 years of age	Allowed
City of Alexandria, VA	200		$1000 permit + $80/device	15		14 years of age	Allowed
Fairfax City, VA	250		$5000 permit + $0.05/trip	10		14 years of age	Allowed
Montgomery County, MD	500 (includes ebikes)			15		18 years of age	Streets 50 mph
College Park, MD	150					Required	Low traffic areas
Portland, OR	2500		$500 application + $80/scooter + $0.25/trip + $0.20 right of way use	15		Required	Allowed
Santa Monica, CA	Variable based on usage		$20,000/year + $105/device/year + $0.20/trip	15		18 years of age	Allowed
Grand Rapids, MI						19 years of age	Allowed
New York, NY				15		18 years of age	Streets 30 mph

City	Sidewalk Operation	Licensure	Age Req.	Report Link	Program Website
Los Angeles, CA	Prohibited	Required	16	https://ladot.lacity.org/sites/default/files/documents/ladot-dockless-year-one-report.pdf	https://ladot.lacity.org/projects/transportation-services/shared-mobility/micromobility

Chicago, IL	Prohibited	Required	18	https://www.chicago.gov/content/dam/city/depts/cdot/Misc/EScooters/E-Scooter_Pilot_Evaluation_2.17.20.pdf	https://www.chicago.gov/city/en/depts/cdot/supp_info/escooter-share-pilot-project.html
San Antonio, TX	Prohibited	Not required	16		https://www.sanantonio.gov/ccdo/DocklessVehicles
San Diego, CA	Prohibited	Required	18		https://www.sandiego.gov/bicycling/bicycle-and-scooter-sharing
San Jose, CA	Prohibited	Required	18		https://www.sanjoseca.gov/your-government/departments-offices/transportation/micro-mobility
Austin, TX	Allowed	Not required			http://austintexas.gov/department/shared-mobility-services
Columbus, OH	Prohibited	Not required	16		https://smart.columbus.gov/playbook-asset/multimodal-and-alternative-transportation/regulating-dockless-scooters-and-bikes#playbook-resources
Charlotte, NC	Allowed	Required			https://charlottenc.gov/Transportation/Programs/Pages/EScooterSharePilotProgram.aspx
San Francisco, CA	Prohibited	Required	18		https://www.sfmta.com/projects/powered-scooter-share-program-permit
Indianapolis, IN	Prohibited (also specifies pedestrian paths are prohibited)				https://www.indy.gov/activity/shared-mobility-devices
Seattle, WA	Prohibited	Not required	16	https://sdotblog.seattle.gov/2019/12/18/moving-forward-with-scooter-share-pilot/	http://www.seattle.gov/transportation/projects-and-programs/programs/new-mobility-program/scooter-share
Denver, CO	Prohibited	Required	16		https://www.denvergov.org/content/denvergov/en/transportation-infrastructure/programs-services/dockless-mobility.html
Washington D.C.	Locational	Not required	16		https://ddot.dc.gov/page/dockless-vehicle-permits-district
Baltimore, MD	Locational				https://transportation.baltimorecity.gov/bike-baltimore/dockless-vehicles
Arlington County, VA	Allowed	Not required		https://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/19/2019/11/ARL_SMD_Evaluation-Final-Report-1112.pdf	https://transportation.arlingtonva.us/scooters-and-dockless-bikeshare/
City of Alexandria, VA	Prohibited				https://www.alexandriava.gov/DocklessMobility
Fairfax City, VA	Prohibited				https://www.fairfaxva.gov/government/public-works/transportation-division/dockless-mobility
Montgomery County, MD	Locational	Required			https://www.montgomerycountymd.gov/DOT-DIR/commuter/bikesharingCSS.html
College Park, MD	Allowed	Required	18		https://www.collegeparkmd.gov/188/Transportation#bikeshare
Portland, OR	Prohibited		16	https://www.portlandoregon.gov/transportation/article/689879	https://www.portland.gov/transportation/escooterpdx
Santa Monica, CA	Prohibited	Required	16	https://www.smgov.net/uploadedFiles/Departments/PCD/Transportation/SantaMonicaSharedMobilityEvaluation_Final_110419.pdf	https://www.smgov.net/departments/pcd/transportation/shared-mobility-services/
Grand Rapids, MI	Allowed		18		https://www.grandrapidsmi.gov/Government/Programs-and-Initiatives/Shared-Mobility
New York, NY	Prohibited	Not required	16		https://www1.nyc.gov/html/dot/html/bicyclists/ebikes.shtml

Note that there may be errors in this spreadsheet as the rules are changing regularly and not all changes to the rules are published.