# Transportation Planning, Policy, and Electric Micro-Mobilities:

# A Knowledge Synthesis of Recent Publications


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January 2022


SSHRC Knowledge Synthesis Grants – Mobility and Public Transit (2020)
Grant # 972-2020-1009

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# INTRODUCTION

Developments in battery technology and mobile computing have allowed electric micro-mobilities (EMMs) to develop as a popular means of a short-distance and urban mode of transportation across various localities (Abduljabbar et al., 2021). E-bikes – that is, both electric pedal assist (pedelec) and scooter-style – as well as stand-up e-scooters, e-unicycles, and e-skateboards are the most popular forms of EMMs. These EMMs can be further categorized into shared or private usage, with the former referring to companies like Lime and Bird that offer e-scooter rentals in cities around the world.

Although in the initial months of COVID-19 there was decreased usage of shared EMM services compared to previous years, the pandemic has since provided an opportunity for EMMs to grow market share, as people decreased transit and shared car usage, and, especially in periods of strict shelter-in-place orders, re-imagined what city streets with fewer private vehicles could look like (Bubbers, 2020; Tchir, 2020). During the pandemic, Ottawa, for example piloted shared scooter service Bird, while the company reported growth in both Calgary and Edmonton. Even the UK, which formerly banned e-scooters on roads, is reconsidering this approach largely due to the pandemic (House of Commons, Transport Committee, 2020; Tchir, 2020).

With interest in EMMs growing once again, we undertook a synthesis of existing research (2010-2021) to consider the emerging wide and disparate body of research related to EMMs on themes such as: rider demographics, usage, and motivations; mobility justice; benefits of and barriers to EMM use; safety and injuries; comparison to other modes of transport; environmental impact; conflict and controversy; EMM pilot programs; and integration, legislation, and policy recommendations. Aside from scholarship, media reports were also included in this literature search, in order to speak to the environment in which the research takes place.

# METHODS

As the wide-ranging and non-cohesive nature of the literature on this topic makes a traditional systematic review of limited value (Munn et al., 2018, p. 2), this report is based on a scoping review model. A scoping review maps an emerging topic of interest, identifies knowledge gaps, and provides recommendations for future research (Tricco et al., 2016). This process relies on the staged approach set out by Arksey and O'Malley (2005) and further refined by Levac et al. (2010), Colquhoun et al. (2014), and Tricco et al. (2018). Under the guidance of an academic librarian from May-August 2021, research assistants (RAs) searched for relevant literature using four strategies: (1) discovery-layer searches, (2) database-specific searches, (3) Google Scholar searches and citation examination, and (4) internet searches. All four types of searches were necessary in order to achieve literature saturation (i.e., the point at which no new literature emerges in searches).

(1) Discovery layer Searches: A discovery layer is a software application that is used to conduct multiple searches across article databases and other library holdings (i.e., books, datasets, A/V materials) at the same time. Not limiting the scope to particular databases at the outset allows the interdisciplinary shape of a particular topic to emerge. For example, in initial literature searches for youth and transit, we found relevant scholarship in health and social science databases via discovery layer searching that would not have emerged had we only searched transportation-themed databases. We also found books and datasets that are part of academic library holdings (i.e., not indexed within proprietary databases, and would thus be missed if conducting only database-specific searches). The primary search phrase was: ("e-bike" OR "electric bike" OR "electric bicycle" OR "electric scooter" OR "e-scooter" OR "micromobility" OR "micro-mobility" OR "micro mobility" OR "micromobilities"). Two other terms tested were "personal electric vehicle" and "electric two-wheel," but neither were used frequently by authors.

(2) Database-Specific searches – While discovery layer searches allow for breadth, database specific searches are focused on depth. Individual databases are organized around particular subjects and include search tools that are not available through discovery layer searching. 44 different databases were searched.[1]

(3) Google Scholar searches and citation examination– Having concluded database specific searches, RAs turned their attention to Google Scholar to seek grey literature (i.e., materials not published through regular academic channels, such as government reports, position papers, pilot project reports, conference presentations, etc.). The same search terms used in discovery layer searching were used, but updated for the proper way to search within the Google environment (i.e., no AND OR NOT Boolean logic). Google Scholar also allowed for citation chaining – the practice of seeing who cites a particular document – which enabled RAs to find the most recent literature in a subject area, including materials not yet available via library systems.

(4) Internet Searches – While Google Scholar will return some grey literature, pilot projects involving youth and transit, as well as some advocacy group and governmental reports, are often only found using general internet searching. RAs explored the first 100 search results in a general Google search for resources related to EMMs. They also conducted an advanced Google search for filetype:PDF, which limits the search to PDFs only. This technique helps surface grey literature reports.

[1] Databases include: TRID, JSTOR, Project MUSE, Sociological Abstracts, Taylor & Francis Online, Proquest Dissertations & Theses, SAGE Journals, Web of Science, Wiley, GEOBASE, Social Sciences Citation Index, Associated Press, Canadian Newsstream, Associated Press, Nexis Uni, Proquest Newspapers, and multiple EBSCO databases (Academic Search Premier, AgeLine, Alternative Press Index Archive, America: History & Life, Anthropology Plus, Applied Science & Technology Index, Bibliography of Asian Studies, Bibliography of Native North Americans, Business Source Complete, CINAHL Complete, Communications & Mass Media, Criminal Justice Abstracts, eBook collection, EconLit, Education Source, Environment Complete, ERIC, General Science Abstracts, Global Health, Humanities Source, International Political Science Abstracts, Maclean's Magazine Archive, MEDLINE, Military & Government Collection, Political Science Complete, APA PsycArticles, APAPsycInfo, Social Science Full Text, SPORTDiscus, Women's Studies International).

During all four types of searches, PhD and MA RAs reviewed titles, abstracts, and full-text of resources found using established criteria for relevance (i.e., subject is EMMs, source is credible). If criteria were met, the resource was logged in a Google Spreadsheet, and imported and tagged in Zotero, a free open-source citation management software. Zotero tags were used to organize results and allowed team members to analyze the literature found. To enhance accuracy, regular team meetings were held to discuss issues that arose and consider examples of materials with questionable relevance.

323 scholarly journal articles, 51 reports, 167 news/magazine stories, 12 academic theses, 1 book, 9 book chapters, 3 academic letters to journal editors, 10 conference papers were included as relevant. A spreadsheet of all literature included may be found at http://summit.sfu.ca/item/21709. In addition to this list of all included literature, the authors can provide the specific details of each database search upon request.

## EMM RIDER DEMOGRAPHICS, USAGE, AND MOTIVATIONS

Electric micro-mobility riders hail from a wide range of socio-demographic and experiential backgrounds with varying motivations for choosing to use electric micro-mobilities. E-scooters and e-bikes attract users of distinct socio-demographic characteristics, and user demographics differ depending on location and access. But, in general, EMM users are mostly men with relatively high income and education levels, ranging in age from their twenties to their forties (Liao & Correia, 2020; Reck & Axhausen, 2021), although users between the ages of 40 and 65 are overrepresented in studies on e-bike usage (Marincek et al., 2020). Because of financial and physical limitations, users younger than 25 and older than 75 are very underrepresented in e-bike research (Marincek et al., 2020). Riders represented in the literature on e-bikes and EMMs also tend not to travel by car as much as public transportation and bicycle, many of them being multimodal and located in more urban areas or working within the city (Liao & Correia, 2020; Marincek et al., 2020). However, while e-scooter use often clusters around shorter-distance city trips and tourist attractions, replacing walking and public transit trips (Bieliński & Ważna, 2020; Caspi et al., 2020; Kopplin et al., 2021; Nikiforiadis et al., 2021), e-bike riders more often live in suburban or rural areas, likely because the e-bike aids these riders in traversing the long distances of their commutes (Rérat, 2021).

EMM rider demographics reflect more diversity, or at least the potential for more equity, among users than conventional cycling. As e-bikes carry the capacity to overcome some of the barriers posed by conventional cycling, such as distance, gradient, and physical exertion, they demonstrate the ability to get people who previously did not cycle, or who previously could not (Boland et al., 2020), to actively participate in cycling (Haustein & Møller, 2016). E-bikes could empower "more people to cycle, across social groups (women, couples with children, people over 40, people with a lower physical condition) and spatial contexts (suburban and rural areas)" (Rérat, 2021, p. 2). In one study, access to e-bikes decreased age differences in self-reported cycling frequency and increased differences in self-reported distances traversed (Haustein & Møller, 2016).

Countries with established cycling cultures and strong biking infrastructure, such as the Netherlands, enjoy more diversity among their e-bike user base while countries more centered around car transportation and without as much cycling infrastructure in place, such as many parts of the United States, see less diversity between users (Marincek et al., 2020). In a Netherlands dataset, for instance, women are represented slightly more than men are, and have conducted more trips on both bike and e-bike (Dane et al., 2020). Rérat's (2021) study in Switzerland found a higher percentage of women among e-bikers (49.4%) than among conventional cyclists (40.8%), as well as a higher percentage of riders older than 40 (75.9% among e-bikers and 57.4% among other cyclists). Meanwhile, studies in the US find that men make up the majority of e-bike users (Marincek et al., 2020). With regard to income, e-bike users in Switzerland "are slightly overrepresented among those with the lowest income (5.5% vs 4.1%) as well as the highest (17.5% vs 16.8%)" (Rérat, 2021, p. 7), which may be explained by the cost of the e-bike — the device can be a budget-friendly alternative to buying a car, or it can be purchased as a mobility option in addition to other costly means of transportation (Rérat, 2021).

E-bike users tend to be significantly older, with higher education levels and larger households, than non-users — and they use cars more, compared to non-users (Simsekoglu &

Klöckner, 2019b). In contrast, e-scooter users are more often young (younger than e-bike users on average), able, male, and highly educated, across various localities (Bieliński & Ważna, 2020; Curl & Fitt, 2020; Laa & Leth, 2020; Merlin et al., 2021; Reck & Axhausen, 2021). In studies conducted in Greece and Texas, e-scooter users tended to be located downtown or close to the city center (Caspi et al., 2020; Nikiforiadis et al., 2021). These findings are consistent with studies in other locations. Interestingly, Reck & Axhausen found that in Switzerland, shared e-scooter users, although younger, were “more representative of the general population in terms of education, full-time employment, income, and gender than bike-sharing users” (2021, p. 1). But although shared e-scooters could contribute to transportation equity, these contributions may be skewed (Reck & Axhausen, 2021); Curl and Fitt point out that e-scooter users are still more likely to be young, able, or male, which raises “questions surrounding equity of this emerging mode” (2020, p. 194).

E-bikes and e-scooters appeal to such different sets of users perhaps because the devices inspire distinct transportation and trip styles. E-bikes are usually ridden as part of a commute, whether directly to places of interest or as first- or last-mile transport within a larger transit journey (Bieliński & Ważna, 2020). E-bike riders use e-bikes as a means to 1) get back into or increase cycling, especially when conventional cycling has become a less viable option due to age, health problems, or other factors; 2) maintain an existing cycling practice and supplement the use of the conventional bicycle as an alternative to driving despite contextual changes or physical difficulties such as moving farther away from work or moving to a hilly area; or 3) go on irregular, long-distance recreational trips (Haustein & Møller, 2016; Marincek et al., 2020). Simsekoglu and Klockner (2019b) found that although there was a negative relationship between e-bike and conventional bike use, there was a positive relationship between e-bike and car use — drivers were more likely to use e-bikes than were conventional bicycle users. As such, e-bikes often replace trips that users would otherwise have taken by car.

While e-bikes are used for longer trips, for sport, for commuting, and to replace car trips, e-scooters are seen as fun objects that replace walking and public transit trips much more than car trips according to most research studies with the exception of some from US cities (Bieliński & Ważna, 2020; Kopplin et al., 2021; Laa & Leth, 2020; Nikiforiadis et al., 2021). This is why cycling experience is not strongly related to e-scooter use (Curl & Fitt, 2020). A Seoul study offers another alternative finding that shared e-scooter users preferred to use the shared services for commuting and for first- and last-mile trips, although preferred trip purposes could vary depending on socio-demographic factors (Lee et al., 2021). Generally, e-scooters are currently used more for leisure and social trips, shopping, and tourism or sight-seeing (Bieliński & Ważna, 2020; Kopplin et al., 2021). Indeed, street segment analysis reveals that tourist sites, hotels, and transit stops are the most popular e-scooter trip destinations (Merlin et al., 2021). E-scooter usage is also highly associated with areas with bicycle infrastructure (Caspi et al., 2020), which aligns with the common finding that users and non-users of both e-scooters and e-bikes cite lack of infrastructure as a major impediment to their frequent use or adoption of these EMMs, and that better cycling infrastructure would enhance usage (Curl & Fitt, 2020; Edge et al., 2018; Laa & Leth, 2020; Mayer, 2020; Nikiforiadis et al., 2021).

Besides individual convenience, environmental concerns constitute another significant motivation driving both e-bike and e-scooter use (Flores & Jansson, 2021; Kopplin et al., 2021; Liao & Correia, 2020; Simsekoglu & Klöckner, 2019b), especially in the US and Australia (Marincek et al., 2020). Positive attitudes about the health benefits and environmental impact of e-bikes were important predictors of e-bike use (Simsekoglu & Klöckner, 2019b). However, Edge et al. (2018) found that participants' perceptions of these health and environmental benefits depended on which transportation mode their e-bike use replaced — sedentary modes such as driving or transit versus conventional cycling. The environmental effect of mode choice is discussed below. Some participants related "positive feelings or [a] sense of stewardship" that came with choosing an e-bike over transportation modes powered by fossil fuels (Edge et al., 2018, p. 393).

Some authors note that rider demographics and usage patterns exhibited in the current literature may reflect the behaviour and demographics of the early adopters of this technology, who tend to take more risks and who tend to reflect more normative demographic characteristics, i.e., male, white, upper-middle class (Liao & Correia, 2020; Lo et al., 2020). Users of both e-bikes and e-scooters "consider themselves innovative and perceive [these transportation modes] as relatively green, while non-users do not" (Flores & Jansson, 2021, p.

1). The less innovative a person is, the less likely they are to own an e-bike (Simsekoglu & Klöckner, 2019b). This early adopter lens could explain how although EMMs demonstrate the capacity for greater transportation equity, the current demographic research on EMM use reveals that users are those with more social and financial power as opposed to those who could benefit most from access to EMMs.

## MOBILITY JUSTICE

The framework of mobility justice is particularly helpful for assessing the potential of EMMs as a path toward equitable transportation. Mobility justice is a lens that considers "how power and inequality inform the governance and control of movement, shaping the patterns of unequal mobility and immobility in the circulation of people, resources and information" (Sheller, 2018, p. 23). Concerns about equity have grown alongside the rapid increase in scholarly and media attention to EMMs. Fitt & Curl surmise that "individuals who are initially excluded from a practice of e-scootering are, on balance and without intervention, likely to become more excluded over time" (Fitt & Curl, 2020, p. 9). A mobility justice framework supports the emphasis that inclusion must be built into EMM use from the outset if it is to become an equitable form of transportation.

EMMs are heralded as useful to increasing transit equity due to their ability to address the first/last mile problem (Milakis et al., 2020) and transit deserts (Ecola & Fraade-Blanar, 2021), while doing so at a relatively low price (Stowell, 2020). EMMs, however, can only enhance mobility justice if they are both in proximity and accessible to underserved communities; physical proximity and access (not necessarily requiring a credit card, for example) to shared services is particularly important for people of colour and low-income individuals (Dill & McNeil, 2021). Evidence to date suggests that this is not necessarily the case (e.g., Clewlow et al., 2018; Fitt & Curl, 2020; McKenzie, 2019). Multiple authors (Reck & Axhausen, 2021; Reinhardt & Deakin, 2020) suggest that cities require shared EMM providers to position their vehicles based on population density and within transit deserts, in a bid to both improve equity and assist in integrating EMMs into broader transit networks. For example, Washington, DC requires that EMM vendors deploy a set number of vehicles to "equity zones" in underserved areas, which is similar to city policies in Santa Monica (Stowell, 2020), Kansas City and Denver (Blickstein et al., 2019). In addition to location of vehicles, whether they are docked or dockless matters, with the latter found easier to access and thus better in meeting the needs of low-income areas (Populus, 2018; Stowell, 2020; Swanson, 2020). Also necessary are non-credit-card options and subsidized or low cost services (Blickstein et al., 2019).

However, shared EMMs are not without their issues in terms of equity. They largely require physical ability, a credit card, smart phone, and enough technical literacy to install an app (Ecola & Fraade-Blanar, 2021; Fitt & Curl, 2020; Milakis et al., 2020). In some locales, a driver's license is required (Fang et al., 2019). They are also perceived by many in the public as being a form of entertainment rather than a serious mode of transportation, and thus best left to tourists (Kopplin et al., 2021; Stewart, 2019), "tech bros" (Swanson, 2020, p. 74), and other white, affluent young men (Fitt & Curl, 2020; Reck & Axhausen, 2021). Still, in surveys in Portland and Washington, DC, some of the highest support for shared e-scooter schemes came from low-income residents (City of Portland, 2018; Populus, 2018), and in Washington, DC, African Americans adopted dockless vehicles at a rate of 2.6:1 compared to 1.2:1 among white people (Populus, 2018). Likewise, Sanders et al. (2020) found that African American and Hispanic/Latinx non-riders expressed significantly more intent to try participating in an e-scooter pilot, but that a perceived lack of available e-scooters also impacted willingness to try them.

While e-scooters have potential to increase transportation equity, it is critical to remember that they are connected to broader systems of inequity. For example, racial profiling by police was a serious concern among a focus group of Black Portlanders, who feared that they would be targeted by police enforcing riding laws more so than e-scooter riders of other racial backgrounds (City of Portland, 2018). Swanson (2020) suggests that one way of decreasing the risk to Black riders is to build more bike lanes and allow e-scooters to ride in them, thus decreasing the possibility of riders coming into contact with police who stop them for minor infractions like riding on sidewalks. Expanding infrastructure and legalizing personal EMMs is also identified as a mechanism for reducing the likelihood of low-income riders being fined (Murphy, 2019).

In addition to racial/ethnic background, other axes of difference such as gender and age should be considered. Fitt and Curl (2020) suggest that e-bike sharing may be a better option than e-scooters for older adults and women, due to the public image of e-scooter riders being wealthy white young men. Sanders et al. noted that women participating in an e-scooter pilot program expressed significantly more traffic and personal safety concerns (Sanders et al., 2020).

Although EMMs may increase transportation equity, it is also important to consider how they may detract from justice in other ways, including the precarious labour contracts of those working for shared service companies (Kopplin et al., 2021) and the fact that shared services mean "allowing a private company to use public space (sidewalks) in order to serve the common good (mobility)" (Stolte, 2019). Fleisher et al. (2020) dispute the notion of a common good, noting that providers prioritize shareholders and customers over the general public, thus leading to instability of services and pricing. A final concern in the literature is the possible gentrification that may accompany the expansion of EMM shared services (Swanson, 2020).

## BENEFITS

Aside from their potential to advance transportation equity, EMMs are cited in the literature for multiple other benefits. As e-bikes can be operated with less or even no physical exertion, users can travel longer distances with higher payloads compared to biking with conventional bicycles or walking (Leger et al., 2019; Rérat, 2021). Additionally, higher speeds and greater acceleration can be achieved with e-bikes compared to bicycles, which allows for travel time reductions (Popovich et al., 2014), and the ability to travel more easily across difficult terrain such as hills (Nematchoua et al., 2020). From a Belgium survey of 1496 users, Nematchoua et al. (2020) found that "topographical relief is the most important limitation with respect to the use of the conventional bikes" (p. 13), a limitation that e-bikes allow riders to overcome.

Being able to travel further with less effort is particularly important for older age groups who may have reduced physical mobility, ailments, or conditions that limit accessibility to cycling (Leger et al., 2019; Popovich et al., 2014). E-bikes act as a convenient mode of transportation for older age groups and for users with injuries/disabilities; in this context, e-bikes were seen as a replacement for conventional bicycles and not cars but are a means for riders to continue riding rather than shifting more trips to car travel (Leger et al., 2019; Spencer et al., 2019).

Reduced physical exertion also allows users across all demographics to arrive at their destination less tired and less sweaty, an important consideration that was highlighted by many e-bike commuters (Mayer, 2020; Plazier et al., 2017a). Commuting by e-bike was also seen as beneficial because riders could avoid the hassle of finding and paying for parking, while navigating heavily congested roads with greater ease than they would in a car (Thomas, 2021).

E-bikes also provide numerous social benefits as well for older age groups. For those with limited mobility, Leger et al. (2019) found that e-bikes allow for participation in group rides or cycling clubs, with many older interview participants reporting increased satisfaction and enjoyability. Some users even reported that the social benefits of "weekly interaction, friendships, leadership and belonging" outweighed the physical benefits (p. 251). An e-bike pilot in the United Kingdom with participants over the age of 50 noted that not only did e-bike riding increase confidence and skills, it created ample opportunities for participants to ride with more physically capable partners (Spencer et al., 2019).

In contrast to e-bikes, e-scooters were found to be used more often for recreational purposes (Bieliński & Ważna, 2020), although substantial time savings were perceived as well on a campus of university students, where e-scooter usage acted as a mode replacement primarily for walking (Buehler et al., 2021). Almannaa et al. (2021) find that if shared e-scooters were to be implemented in Saudi Arabia, most participants would utilize them for entertainment purposes, with a smaller subset indicating commuting and changing to another transportation mode as motivation.

To further realize the benefits of EMMs, significant improvements could be made to road infrastructure, in terms of developing more robust separate bike lanes and crossroads that are cycling oriented. One specific benefit of EMMs that should be considered in depth relates to their ability to bring about transportation equity.

# BARRIERS

While there are numerous benefits to EMM adoption, significant barriers remain. Safety considerations resulting from unsuitable road infrastructure for EMMs is ranked as the highest barrier to adoption by respondents surveyed from various jurisdictions (Almannaa et al., 2021; Arsenio et al., 2018; Leger et al., 2019; Mayer, 2020; Nematchoua et al., 2020). Depending on the locale, separate bike lanes are either non-existent or must be retrofitted to be larger in width to facilitate higher perceptions of safety (Leger et al., 2019). In a study on student commuting behaviour using e-bikes, Arsenio et al. (2018) found that the odds of using an e-bike was 6.5 times higher in a scenario where students were given the option of having dedicated bike lanes compared to no cycling infrastructure. Current designs of traffic intersections and crossroads are also problematic for many e-bike users, as shown by Rérat (2021), through a survey of 14,000 bike and e-bike commuters in Switzerland, where over 70 percent reported that existing crossroads did not meet their cycling needs.

The availability of shared e-bikes due to the low number of units was also found to be a significant barrier to usage, particularly in metropolitan core areas (Bieliński et al., 2020; Populus, 2018). In the same study, users from suburbs were found to face different barriers such as long distances to docking stations and lack of modifications to support the transportation of children.

As outdoor transportation modalities, poor weather conditions are shown to negatively impact riding decisions for e-bike and e-scooter users (Noland, 2021; Simsekoglu & Klöckner, 2019a). The presence of low air temperatures, high winds, rain, ice and snow decrease average rider uptake in terms of both time and distance; however, experienced users and avid cyclists are less likely to be influenced by such conditions (Edge et al., 2018; Leger et al., 2019). In a longitudinal study of e-bike users in the Netherlands, respondents indicated that “snow and ice on the cycle path had the highest impact on the choice not to commute to work by e-bike” (de Kruijf et al., 2021, p. 312).  In other cold climates such as Canada, Edge et al. (2018) find that although e-bikes were particularly useful to replace cars for short trips, most survey respondents communicated that full car replacement with e-bikes would be difficult due to concerns with weather and safety when travelling with children. Additionally, extremely high temperatures represent another deterrent to EMM usage in hot climates such as Saudi Arabia, where weather was found to be the second largest obstacle to e-scooter usage after poor infrastructure (Almannaa et al., 2021).

Aside from weather conditions, price can act as another barrier to e-bike adoption, particularly for students (Plazier et al., 2017a) and residents of suburbs (Bieliński et al., 2020). In an e-bike pilot trial with Dutch university students, e-bikes were favoured for their speed, convenience, and capacity to reduce dependence on public transportation (Plazier et al., 2017a). However, the high cost of purchasing an e-bike was considered not worth these benefits due to the availability of affordable public transportation and low-cost conventional bicycling. In contrast, in the United States, the purchasing of an e-bike was considered to be a money-saver by adult respondents surveyed by Mayer (2020). Through 47 semi-structured interviews, the author found that e-bikes allowed participants with cars to reduce spending on insurance, fuel, and maintenance, with some completely replacing their car with an e-bike.

Shared e-scooter implementations may be perceived as providing insufficient quantities of units and/or even distribution across urban landscapes, with many experienced users surveyed by Sanders et al. (2020) indicating that a major obstacle for riding was finding an available e-scooter unit. The authors also noted that units requiring repair was also a factor that inhibited shared e-scooter use.

## SAFETY AND INJURIES

The adoption of electric micro-mobilities has introduced a new dynamic to safety concerns and injury prevention and holds important implications for transportation and urban policy makers. A flurry of studies in medical journals have been published detailing injury rates in cities around the world, often based on emergency room/hospital admission records (e.g. Badeau et al., 2019; Bekhit et al., 2020; Brownson et al., 2019; Dhillon et al., 2020; DiMaggio et al., 2020; Du et al., 2014; English et al., 2020). However, the problem with many EMM-related injury studies is that the total number of rides is not reported, nor is the injury rate of EMMs compared to other types of transportation (Yue, 2019).

Lack of helmet use was often reported among those who ended up crashing and being taken to the hospital for treatment (e.g. English et al., 2020; Gross et al., 2018; Karepov et al., 2019; Kim et al., 2021; Tan et al., 2019; Yuan et al., 2017). Conversely, wearing a helmet was reported to reduce the risk of brain and head trauma (Baschera et al., 2019; X. Li et al., 2017). From a survey of dockless e-scooter riders in Berlin, Siebert et al. (2021) found that self-reported helmet use was extremely low and that many riders would choose not to ride an e-scooter if helmets became mandatory. Haworth et al. (2021) observed similar helmet use rates in Brisbane, where shared e-scooter riders had the lowest rate of helmet use compared to private e-scooters and conventional bicycles.

In addition to the issue of helmets, lack of knowledge regarding traffic laws and high propensity for risky riding behaviour are reported safety concerns and injury factors among e-scooter and e-bike riders (C. Ma et al., 2019; Siebert et al., 2021; Wang et al., 2018). However, research has found differences between EMM type and user demographics as they relate to injuries and risky behaviour. There is a significant distinction between riders of e-scooters and e-bikes in terms of safety and injury characteristics, with the former identified with higher rates of injury and risk behaviour. E-scooter riders are also more likely to engage in other risky behaviour such as riding in car lanes and against traffic compared to e-bike riders and conventional bicyclists (Bai et al., 2015). In field observations of traffic intersections in Nanjing and Kunming, China, risky riding behaviour was significantly higher for males compared to females, as well as for younger riders compared to older (Bai et al., 2015).

Injuries sustained during e-scooter trips were often found on the arms, upper legs, face, and head (English et al., 2020; Kim et al., 2021; Wüster et al., 2021) and tended to occur the most on sidewalks, followed by on the road (Cicchino et al., 2021b). A significant minority of riders reported that they had used e-scooters after consuming alcohol (Siebert et al., 2021) or had been riding under the influence at the time of their accident (Cicchino et al., 2021a; Wüster et al., 2021).

There is greater risk of injury from riding an e-bike vs. a conventional bike because users of e-bikes ride at higher rates of speed compared to riding on conventional bicycles (Huertas-Leyva et al., 2018). Due to high rates of speed, e-bike users are at more risk of serious accidents and accidents overall occur more frequently compared to cyclists (Fyhri et al., 2019; Hertach et al., 2018; C. Ma et al., 2019). A high rate of speed was cited as the most common factor for accidents by e-bike users (Haustein & Møller, 2016; Hertach et al., 2018; Panwinkler & Holz-Rau, 2021). Additionally, e-bikes tend to be heavier than bicycles which contributes to more incidents of accidents involving losing balance, particularly among older users (Fyhri et al., 2019; Haustein & Møller, 2016). Uneven and slippery surfaces also contribute significantly to crash circumstances and increased riding speeds make it more difficult to maneuver against such hazards (Hertach et al., 2018; Van Cauwenberg et al., 2019).

Recommendations for improved safety of EMMs include increased public education campaigns for traffic rules and safe EMM operation, mandatory helmet laws, and improved cycling and e-scooter infrastructure.

## MODAL SHIFT AMONG FORMS OF TRANSPORTATION

As EMM pilots and new programs continue to expand in cities around the globe, researchers are considering which transportation modes are being displaced by EMMS. Studies with this focus report varied results. Most research agrees that shared and private e-bike usage reduce conventional bicycle ridership (de Haas et al., 2021; Kroesen, 2017; Sun et al., 2020). However, agreement on e-bikes displacing car usage is more fraught, with researchers publishing mixed results. Car mode-substitution for short trips are reported as more frequent in Northern Europe, North America, and Australia compared to China (Bigazzi & Wong, 2020). However, de Haas et al. (2021) suggest that the effects of e-bikes on car-mode substitution may be overstated, as their longitudinal analysis of Netherland e-bike riders showed only small substitution effects for commuting car trips specifically. In Sacramento, Fitch et al. (2021) make similar observations and find that shared e-bike usage does not necessarily decrease car usage significantly, in contrast to self-reported trip statistics. Also in the Netherlands, Sun et al. (2020) found that e-bike usage had a minor effect on reducing car usage, although not ownership.

Aside from competing with private vehicle use for mode share in China, e-bikes tended to replace buses in cities with robust public transportation infrastructure, whereas in cities with less amenable public transportation, e-bikes tended to replace bicycles (Kroesen, 2017).

E-scooters are also not likely to routinely replace cars for short trips, as the majority of participants in several studies indicated they would have walked if e-scooters were not available (Buehler et al., 2021; Hollingsworth et al., 2019; Laa & Leth, 2020). For example, Hollingsworth et al. (2019) found that 50 percent of trips made using shared dockless e-scooters would have been made by biking or walking, 34 percent would have used a car, 11 percent would have taken public transportation, and only 7 percent would not have made the trip otherwise.

## RIDER SATISFACTION WITH MODE CHOICE

Aside from calculating how often various types of transportation are utilized, researchers have also considered how satisfied travellers are with their mode choice. Compared to driving, travel satisfaction was notably higher for e-bike commuters in the Netherlands, where de Kruif et al. (2019) observed "an increase of about 1.4. on a 7-point scale, […] suggest[ing] that a shift from car to e-bike generates a considerable increase in commute satisfaction, and therefore possibly in overall well-being" (p. 198). Factors contributing to satisfaction were related to route attractiveness, presence of greenery, and liveliness of the environment. E-bike users are also able to travel longer distances with less effort, reduce sweating, and reduce commute times (Leger et al., 2019; Plazier et al., 2017b), making e-bikes a more attractive option compared to pedal bikes. Preferences for e-bikes are also influenced by perceived environmental benefits, particularly among younger age groups (Ling et al., 2017) and the mobility they provide for older users who may have disabilities or long-term health conditions (Leger et al., 2019).

## ENVIRONMENTAL IMPACT

Although EMM usage is generally perceived as a sustainable mode of transportation, findings have been mixed with recent research calling into question its sustainability impact (Abduljabbar et al., 2021; de Bortoli, 2021; McQueen et al., 2021; Weiss et al., 2015). The true environmental burden of EMMs depend on a multitude of region-specific variables and factors such as manufacturing, end-of-life disposal, type of transportation mode it displaces, usage lifetime, shared or private use, electricity generation and charging methods, and public policy interventions.

As noted above, EMMs have an influence on mode share, and this has environmental effects. In a study on private e-bike usage in Sweden that compared urban and rural usage, Hiselius and Svensson found that users from both tended to use e-bikes mainly in place of cars for short-term travel and in doing so, reduced “14-20% of the average total $CO_2$ emissions per person from transportation in Sweden” (2017, p. 823). Comparable figures were reached by McQueen et al. (2020), where the authors used North American survey data to model e-bike person miles traveled (PMT) in relation to different levels of mode share penetration. Focusing only on usage scenarios and not manufacturing or disposal processes, they concluded that a 15 percent e-bike mode share, based on Portland’s mode share and emission profiles, could lead to a 12 percent reduction in $CO_2$ emissions.

However, although EMMs emit no greenhouse gas emissions while being used, battery manufacturing, other related production processes, shipping from point of manufacture to point of sale, re-charging, and recycling heavily influence total environmental impact. With regards to shared dockless e-scooters, current life cycle assessment (LCA) estimates indicate that, with the exception of cars, they do not reduce greenhouse gas emissions relative to the transportation modes they displace (Hollingsworth et al., 2019; Kazmaier et al., 2020; Moreau et al., 2020). Estimates from Hollingsworth et al. (2019), based on the shared dockless e-scooter program in Raleigh, North Carolina, found that e-scooters are responsible for 202 g $CO_2$-eq/passenger mile (50% from materials and manufacturing, 43% from daily collection for charging, and 7% other). In comparison, the authors found 414 g $CO_2$/mi for cars, 82 g $CO_2$/mi for buses with high ridership, 40 g $CO_2$/mi for private electric bicycles, and ) 8g $CO_2$/mi for bicycles.

Although the findings are not directly comparable, research on e-scooters completed in Germany (Kazmaier et al., 2020) and Brussels, Belgium, yields similar figures with the conclusion that in their current state of usage, e-scooters have a greater global warming potential (GWP) compared to the modes they displace. For example, dockless e-scooters in Paris were found to have “increased greenhouse gas emissions by 12,000 of tonnes per year”

(Moreau et al., 2020, p. 9) because the city operates a fleet of renewable-energy buses while the e-scooters drew energy from non-renewable sources (Abduljabbar et al., 2021, p. 9). In this case, overall bus usage dropped significantly due to increased e-scooter utilization and environmental benefits from EMM usage were unable to be realized.

However, in other locations such as Sydney and Melbourne where short-term travels are dominated by private car usage, making even small modal shifts to e-scooter usage could provide significant environmental benefits (Abduljabbar et al., 2021). Sun et al. (2020) reached a similar conclusion with e-bike adoption in these cities, arguing it provides a net environmental benefit because the distance travelled by cars often far exceeds that of bicycles. Incentivizing EMM mode substitution for cars, then, may help realize net greenhouse gas emission reductions.

Attention to manufacturing, end-of-life disposal, and electricity generation are critical in understanding total emissions generated from e-bike adoption. In China, where lead-acid batteries are primarily used, lead pollution is significant to calculating life cycle emissions (Cherry et al., 2009; Machedon-Pisu & Borza, 2019)**.** In contrast, e-bikes in Europe tend be priced higher and use lithium-ion batteries, which provide higher energy density and do not contribute to lead pollution (Weiss et al., 2015). Additionally, Weiss et al. found that "Gross electric energy production in the EU-27 (442 g CO2 kW $h^{-1}$) is 40% less carbon intensive than the gross electric energy production in China (790 CO2 kW $h^{-1}$) (p. 354). They argue that local electricity generation infrastructure and battery type are the "two single most critical variables in determining the life cycle impact of electric two-wheelers" (2015, p. 358).

Although shared EMMs currently do not merit their hype as sustainable modes of transportation, several authors point out optimistically that with ongoing development and targeted interventions, EMMs may evolve as an environmentally friendly transportation option (Abduljabbar et al., 2021; McQueen et al., 2021; Weiss et al., 2015). For example, despite current negative environmental impacts of dockless e-scooters, significant improvements and optimizations can be made to better realize their ecological potential. Hollingsworth et al. (2019) makes several recommendations; 1) increasing usage lifetime by addressing vandalization and misuse, 2) optimizing vehicle distribution and re-collection of e-scooters for charging, and 3) implementing city policies that would allow e-scooters to remain in public overnight to decrease re-collection for charging vehicle usage. Shared dockless e-scooters remain a convenient option for short-distance travel and to reduce congestion, but without interventions, it is highly likely that they increase net greenhouse gas emissions compared to the modes they displace (Hollingsworth et al., 2019; Kazmaier et al., 2020; Moreau et al., 2020). In contrast to the energy consumption involved in charging a shared fleet, personally owned EMMs that are charged at home may reduce $CO_2$ emissions.

## CONTROVERY AND CONFLICT

While controversy is attached to all EMMs (e.g., Cheney, 2013), e-scooters (kick scooters with an electric motor and battery) – particularly shared e-scooters – are a lightning rod for debate in the media (e.g., Nowak, 2019; Spurr, 2021b; Stewart, 2019; Tchir, 2019; Van Dongen, 2020), among the public (Kostareli et al., 2020), and in provincial/state and municipal policy (e.g., “Allowing E-Scooters on Roads Risky: Diodati,” 2019; “Cuomo Vetoes NY State Bill to Legalize E-Scooters and e-Bikes,” 2019; “Transportation Committee Backs 2023 E-Scooter Pilot,” 2021; City of Toronto, 2021; Rider, 2020; Rodriguez, 2019).

Proponents laud e-scooters for their low cost, smaller physical footprint, environmental sustainability and quietness compared to private vehicles, their ability to solve the first/last mile problem and for potential to reduce traffic congestion (Spurr, 2021a; Tchir, 2020). Cities such as Calgary, Edmonton, Waterloo, Portland, Seattle, Austin, and Chicago embraced this new mode of transportation, implementing pilot programs (“E-Scooters on the Road Back to Calgary, but with New Rules,” 2020; Jackson, 2019; Nowak, 2018, 2019).

However, municipalities such as Toronto, San Francisco, Nashville, Chattanooga, and Beverly Hills, have banned e-scooters, citing concerns including injury/death, unsightliness, liability and lack of insurance, lack of resources to enforce rules, and improper use and parking impeding sidewalk traffic (City of Toronto, 2021; Spurr, 2021a; Stewart, 2019; Yue, 2019). To counter safety concerns, shared e-scooter companies have implemented safety training, send pop-up reminders about helmets, and issued free helmets (“E-Scooters: Lime Urges Montreal Riders to Write to City Hall,” 2019). In Portland’s pilot, the city provided shared e-scooter companies incentives for performance targets related to curbing illegal riding and improving safety (Wright, 2020).

The most frequent criticism of shared e-scooter programs is improper parking and riding on sidewalks, an argument that is frequently linked to concerns about sidewalk safety for disabled people and seniors (e.g., City of Toronto, 2021; Flaccus, 2019; Rider, 2020; Van Dongen, 2020). For example, a focus group of Ottawa residents with vision impairments reflected on the city's pilot program and raised safety concerns related to unsafe riding, improper parking, and difficulty reporting infractions (CNIB Foundation, 2020). Several studies report the rate of improper e-scooter parking that directly impeded pedestrian thoroughfares, with 11 of 530 e-scooters (2%) found by Fang et al. (2018) in San Jose, and 36 of 606 (6%) observed by James et al. (2019) in Rosslyn, VA. Improper parking that did not impede pedestrian movement was higher in both studies. Shared e-scooter companies responded to criticism by adding braille to the devices, helping to ensure that visually impaired individuals can report infractions (Lazo, 2019). Wright (2020) interviewed officials involved with successful pilot programs for their feedback on the issue of e-scooters and accessibility; his article stresses the importance of early outreach and consideration of people with disabilities from the outset in considering shared EMM services.

Negative attitudes toward e-scooters is a cause of concern to those that ride the devices and experience aggressive behaviour from pedestrians (Che et al., 2020; James et al., 2019; Tuncer & Brown, 2020) and car drivers (Jie & Richburg, 2009). E-scooter riders must balance safety, riding practices, and accountability to other members of society (Tuncer et al., 2020).

While not fully accepted, pedelec e-bikes have garnered more public and government support than e-scooters. Toronto-area decision-makers and stakeholders generally supported the inclusion of e-bikes (Edge et al., 2020; Edge & Goodfield, 2017), while a survey of 546 trail users in Manitoba (Trails Manitoba, 2020) found a majority of respondents favoured e-bikes on bike paths (77%), multi-use paths (55%), and mountain bike trails (57%). Still, there are reports of e-bike riders facing abuse (e.g., Ussner, 2014) and social stigma. While the latter was not a significant obstacle to actual e-bike usage for the majority of riders, it was found that receiving negative comments from conventional cyclists, pedestrians, and drivers was a common experience (Mayer, 2020; Popovich et al., 2014; Thomas, 2021). The majority of comments centred on the perceived “cheating” of e-bike usage (Mayer, 2020) and in some cases for e-bike cargo users, criticisms were directed to the “danger” of exposing children on cargo bikes to the dangers of the road (Thomas, 2021). However, for older adults (60+ years of age), social stigma may act as a real obstacle for adoption due to general attitudes perceiving e-bikes “as a ‘lesser than’ mode of transportation” (Leger et al., 2019, p. 252).

## EMM PILOTS

Much of the controversy discussed above comes about through the implementation of pilot programs in cities around the world. Across various locales, pilot programs for shared e-scooters and e-bikes have been implemented to provide an assessment of their benefits, community impact, and long-term effects. Despite the controversy, in-person and online surveys, in combination with real-time data provided by vendors, have indicated largely positive results for shared e-scooters overall (City of Calgary, 2020; MacArthur et al., 2017; Smith, 2020). Usage statistics show that demand for shared e-scooters exceeded that for shared e-bikes in Ottawa, cumulating in a total of 238,000 e-scooter rides across 600 units between July 16, 2020, and October 31, 2020 (Manconi, 2021). In Portland, similar observations were made during a pilot program from July 2018 to November 2018, where 700,369 e-scooter rides were made using 2,043 units (MacArthur et al., 2017). The average trip distance in both cities was approximately 1.9 kilometres. Peak riding times were between 3pm and 9pm, with most users indicating their reason for usage being for leisure (Manconi, 2021) or for transportation (MacArthur et al., 2017). Commuting was not a significant portion of riding usage. However, participants from Ottawa and Portland indicated that they drove far less, with six percent of users from Portland getting rid of their cars and 16 percent considering it (MacArthur et al., 2017). Walking was also a significant mode of transportation that was displaced, with 37 percent of respondents from Portland indicating that they would have walked instead if e-scooters were not available (MacArthur et al., 2017).

Users and non-users have indicated that shared e-scooters were a positive addition to local transportation needs (City of Calgary, 2020; MacArthur et al., 2017) and a modeling using

Chicago's e-scooter pilot program found that significant time savings could be made in multimodal transportation scenarios (Smith, 2020)**.** However, a minority of survey respondents from Calgary's shared e-scooter pilot program indicated that riders could be more considerate when utilizing sidewalks. Findings from the pilot program in Portland also noted that e-scooters were observed to be too fast for sidewalk use and posed a hazard for pedestrians and would be more suitable for bike lanes or low-volume roads. Concerns with awareness of e-scooter regulations and rules were also common (MacArthur et al., 2017; Manconi, 2021) among survey respondents, particularly with respect to improper parking. Concerns regarding safety were less significant, with minimal injuries being reported and no severe injuries occurring at all (MacArthur et al., 2017; Manconi, 2021). However, staff in Portland observed that only 10 percent of riders wore helmets.

In regards to private e-bikes, pilot programs in Europe have measured significant reduction in car usage for commuting to work and school, and increased inclinations to cycle and purchase e-bikes (A. S. f.k.a. Andersson et al., 2021; Cairns et al., 2017; Fyhri & Fearnley, 2015; Moser et al., 2018; Ton & Duives, 2021). In Brighton, UK, Cairns et al. (2017) conducted a study to assess the impact of e-bikes on long-term commuting and travel behaviour – by loaning 80 e-bikes to employees from two major firms over a six to eight week period. They state that the "the biggest effect of borrowing the bike was on car driving, with a 20% reduction in car miles driven averaged across all participants" (p. 14). After the trial ended, 70 percent of participants indicated they would commute at least one day a week if they had an e-bike and would be more likely to cycle as a means of inner-city transportation.

In 2019, Delft University of Technology implemented an e-bike pilot for employees and students to assess commuting and travel behaviour. 100 e-bikes were distributed to frequent car users over a period of six to eight weeks. Findings show that at the end of the trial, car use for commuting had decreased by 25 percent, and some users had started to commute by e-bike entirely (Ton & Duives, 2021).

In Sweden, a 2021 randomized control study of 98 frequent drivers found that those given an e-bike decreased their car usage by 37% – an average of 14km per person per day, and increased their cycling by 25% (A. S. f.k.a. Andersson et al., 2021). Nearby in Norway, 66 participants were loaned an e-bike and compared to a control group. The study found that those in the e-bike group increased their bike mode share from 28% to 48%, a rate that increased with time after a learning effect (Fyhri & Fearnley, 2015).

While the pilots and studies cited above found an increase in e-bike use, there are questions if this persists post-intervention. In Switzerland, a pilot program was undertaken in which car owners traded in their keys for a loaned e-bike over a two-week period. Researchers followed up with participants one year later, and found significant a decrease in car use overall – regardless of whether the individuals had gone on to purchase their own e-bikes or not (Moser et al., 2018).

Overall, pilot programs for EMMs have been successful in changing travel behaviour, generating positive responses from users, and reducing car usage. However, results should be contextualized to local transportation infrastructure, climate, costs, and geography.

## EMM INTEGRATION, LEGISLATION, AND POLICY RECOMMENDATIONS

The integration of electric micro-mobilities (EMMs) into everyday transportation has encountered both logistical challenges and public pushback across the globe. This section outlines the main challenges associated with EMM adoption and integration, lessons learned from past pilot projects and policymaking, and policy recommendations arising from the study of these obstacles and experiences.

Arguably the most significant hurdle that cities have come up against in the effort to integrate new mobilities, including EMMs, is the built environment. From physical and legislative limitations of urban landscapes shaped for car use to the aforementioned conflicts with other road users and pedestrians, it is difficult to circumvent the structures built into the foundations of how we navigate spaces in day-to-day living. E-scooters, for instance, have the ability to be ridden on different surfaces, including sidewalks and bike lanes (Q. Ma et al., 2021). With the existing built environment shaped for cars and pedestrians, it is a challenge to regulate the terms of scooter and e-scooter road use (Hedglin, 2019). Because of this flexibility, and in the absence of clear restrictions regarding e-scooters, other road users find it hard to anticipate the movements and behaviour of e-scooters in motion (Tuncer et al., 2020) – and e-scooter riders themselves encounter hazards, for example in the form of poorly-paved sidewalks (Q. Ma et al., 2021). Conflicts, collisions, and falls often occur as a result of this unpredictability and competition for space (Gössling, 2020; Q. Ma et al., 2021). Conflicts also arise from “irresponsible” e-scooter practices such as inappropriate speeds, reckless or rule-bending riding, and the clutter of e-scooters parked inappropriately or left on sidewalks (Gössling, 2020; Tuncer et al., 2020), leading to public anger as evidenced in news media (Gössling, 2020) and explored more above. Similarly, e-bikes face conflict with regular cyclists in competition for lane space because of speed differentials (Dill & Rose, 2012).

A main criticism emerging from the literature on the difficulties of working with the built environment is that a lack of bicycle infrastructure is a major impediment and that better infrastructure would likely aid in the adoption and integration of micro-mobilities across the board (Edge & Goodfield, 2017; Hedglin, 2019; Oeschger et al., 2020; Yue, 2019). In particular, having dedicated parking spaces for micro-mobilities as well as safe, convenient infrastructure for micro-mobilities around public transport stations would motivate commuters to use EMMs and contribute to a smoother and more user-friendly integration of micro-mobilities (Hedglin, 2019; Oeschger et al., 2020). Making room for micro-mobility-oriented infrastructure would also ultimately reduce the need for car parking space — according to Hedglin, if “just one percent of attendees at a sports game switched from traveling by car to riding scooters to games, this could reduce the number of required parking spaces by 592; it takes 2.32 acres of land to accommodate this many parking spaces” (2019, p. 61).

Another concern involves the digitization of mobilities, or so-called smart mobilities. The smart mobility transition is currently driven by the private sector for the most part (Wallsten et al., 2021). With many mobility and EMM sharing services being operated over smart technology, information privacy and data sharing are presenting as growing problems that policymakers and stakeholders need to deal with. An analysis by Li et al. (2021) reveals that despite the integration of consumer privacy acts and regulations such as the California Consumer Privacy Act and the European Union’s General Data Protection Regulation, e-scooter service users still report that they experience privacy concerns for traceable information (PCTI) while they use these services. These anxieties are not unfounded, as governments using data to shape policy and mobility-sharing corporations using large amounts of user data for commercial purposes have much more to gain from this data than do users themselves (L. Li et al., 2021).

That being said, the management of this data raises its own set of problems for governmental agencies, who are not accustomed to dealing with data in such great volume and detail from a variety of vendors (Hedglin, 2019). There are challenges associated with balancing user privacy and the data sharing needed to gain insight into the behaviour of mobility users — cities must also be meticulous with the anonymization and distribution of such valuable data, as some geographical data, even when anonymized, is subject to public records requests and can be “combined with other data sources to reveal sensitive information about users” (Hedglin, 2019, p. 64). Policymakers and those who manage EMM sharing services should therefore consider users’ concerns about privacy and minimize the collection of unnecessary or irrelevant data as well as implement clear policies to notify users about data sharing by the government or third parties (L. Li et al., 2021).

The inequality of benefits gained from data collection is only one of many equity concerns smart mobility brings up. For example, geofence coverage — the use of virtual geographic boundaries for private operators to constrain access to their fleets — is inadequately regulated (Moran, 2021). Operators’ emphasis on cities’ densest areas can result in clustering in higher-income and gentrifying neighbourhoods as well as the subsequent neglect of other areas and neighbourhoods, even though low-income and racialized communities have voiced their dissent and their desire to access shared micro-mobilities (Moran, 2021). Limits to EMM access in the form of restrictions such as geofences may explain why some North American cities such as San Francisco have e-scooter user bases that are mostly white, high-income males (Edge & Goodfield, 2017; Field & Jon, 2021; Moran, 2021). However, having “an abundance of shared modes of car, bike, and e-scooter that are linked to public transport can improve transport accessibility to meet specific public preferences, reduce social inequality, and minimize dilemmas from the demand side” (Meng et al., 2020, p. 670). Moran (2021) suggests that cities 1) provide clear geofence-specific guidance and regulations to operators in order to reach people outside of central business districts and high-income neighbourhoods and 2) devise incentives for operators that link geofences to vehicle caps, for example, with a sliding scale that allows larger geofences to use more vehicles, or reduce fees and taxes on operators with larger geofences.

The relationships between government and private operators can and should include equity and sustainability goals in order to expand low-income, racialized communities' access to EMMs and prioritize the use of smart mobilities for long-term sustainability objectives over commercial interests (Field & Jon, 2021; Wallsten et al., 2021). For example, San Francisco and Seattle learned from research results and are implementing a minimum number of scooters for operators to deploy in disadvantaged communities and regulations allowing for reduced rates in low-income communities respectively (Field & Jon, 2021). However, Wallsten et al. find that with commercial actors shaping smart mobility as they are now, and with municipalities' "laissez-faire" neoliberal approaches to governing smart mobility enabling these commercial actors, the development of these mobilities are more likely focused on "finding paying customers, rather than achieving a sustainable sound transport system" (2021, p. 12). Though these findings come from the Stockholm Metropolitan Area, and Field and Jon's from Brisbane, Australia, authors in the US and Canada echo similar difficulties with the fragmentation and inconsistency of the governance and regulation of EMMs, gauging the willingness and capacity of governance stakeholders to integrate EMM usage, and weighing the interests of multiple parties involved in technological innovations and planning (Edge & Goodfield, 2017; see also Hedglin, 2019).

One reason that governments have trouble with balancing interests in regulating EMMs is the way new mobility technologies, especially shared, enter urban landscapes abruptly, leaving governments scrambling to catch up and cope with these developments as well as anticipate where they are going next (Field & Jon, 2021). In Canada, for example, provincial Highway Acts were written prior to EMM technology development, which poses a regulatory impediment to their use (Frew, 2019; *Who Needs a Car?*, 2020) that is also related to helmet rules, licensing, and insurance. Many cities, such as San Francisco and Seattle as detailed above but also those in other cities around the globe, have gone through trial-and-error stages with policymaking (Field & Jon, 2021; Gössling, 2020). Different cities approach EMMs in different ways, as legislation and rules surrounding EMMs must take into consideration the context of the region and its geography (Field & Jon, 2021; Q. Ma et al., 2021). It is difficult to both coordinate across departments within the same government and synchronize effective regulations across different municipalities, especially given how each department and stakeholder, not to mention cities' unique transportation contexts, has varying goals and responsibilities with regard to the integration of EMMs (Edge & Goodfield, 2017; Hedglin, 2019). Some policy issues may also fall outside of cities' jurisdictions and under national jurisdiction instead (Gössling, 2020).

In addition, planners are encouraged to take into account the matter of public opinion, power struggles, and social and cultural resistance, as "global newspaper reports would seem to suggest that public opinion is the most significant challenge" for e-scooters (Gössling, 2020, p. 3) and multimodal shared mobility in general (Meng et al., 2020). In a report to policymakers regarding establishing regulations for dockless e-scooters, Wood et al. (2019) suggest that media sensationalism not be allowed to set the tone for policymaking; policy makers should focus on advancing community goals instead of responding to creating rules based on media criticism. This can be particularly difficult advice to follow, given the substantial negative perception that accompanies free-floating e-scooters reports in media (Lipovsky, 2020) that can be considered a moral panic (Kolaković-Bojović & Paraušić, 2019).

According to Ma et al. (2021), US cities with large populations but lacking e-scooter guidelines or policies point to a need to not only improve the quality of e-scooter policies but also make those policies accessible. The authors identify that a unified platform would be helpful in aiding cities with diverse guidelines to share policies and practices with each other (Q. Ma et al., 2021). As new mobilities continue to develop and change, knowledge sharing among municipalities will be a helpful process in continuing to adapt policies to support these mobilities (Meng et al., 2020). In general, municipalities are encouraged to understand the characteristics of e-scooter (or EMM) users, be clear about where riders may park and ride, provide guidelines for sharing and navigating road spaces with others, clarify restrictions and requirements such as minimum riding ages and helmets, set speed limits, and exchange lessons and knowledge with other municipalities (Q. Ma et al., 2021). These steps may help cities to avoid conflicts, negative public opinion, and integrate EMMs into their transportation systems (Gössling, 2020).

A range of authors identify that finding ways to not only improve access to EMMs but also attract individuals to them would help to achieve many of the benefits associated with EMM as a mode of transport (Cairns et al., 2017; Ton & Duives, 2021). Habit formation surrounding established transportation modalities and the high cost of e-bikes is working against the uptake of modes such as e-bikes and EMMs (Ton & Duives, 2021). Spreading costs of EMM purchase over time instead of having a one-time payment[2] is one way to mitigate this barrier (Ton & Duives, 2021). Comparisons to the promotion of electric cars are made (Cairns et al., 2017; Dill & Rose, 2012) – some e-bike owners who were interviewed proposed that tax incentives and feebate schemes like those for electric cars could be useful applied to e-bikes as well, though the study itself could not address the efficacy of this strategy (Dill & Rose, 2012). An analysis of China's and Taiwan's e-bike and e-scooter policies suggests that subsidies alone may not be enough to bolster the growth of EMM use, but that limiting access to fossil-fuel alternatives could be an effective tool to foster the use of electric vehicles (Yang, 2010). However, this strategy may have consequences for those whose accessibility needs require a reliance on cars for travel. E-bike owners also advocated for policies that would promote bicycle use in general, including better biking infrastructure and disincentives for car use (Dill & Rose, 2012). Providing appropriate riding facilities for improved riding conditions is similarly important for e-scooter riders (Q. Ma et al., 2021). Local authorities may strategize to improve the built environment by promoting developments "with mixed land-use and micro-mobility- and pedestrian-friendly environments" (Oeschger et al., 2020, p. 15).

## RECOMMENDATIONS FOR POLICY AND PRACTICE

- As lack of bicycle infrastructure is a major impediment, better infrastructure would likely aid in the adoption and integration of micro-mobilities across the board (Edge & Goodfield, 2017; Hedglin, 2019; Oeschger et al., 2020; Yue, 2019).

[2] In Canada and the USA there are a number of EMM dealers who provide customers with payment plans.

- Dedicated parking spaces and secure lockup facilities for micro-mobilities as well as safe, convenient infrastructure for micro-mobilities around public transport stations will motivate commuters to use EMMs and contribute to a smoother and more user-friendly integration of micro-mobilities (Hedglin, 2019; Oeschger et al., 2020).

- Allowing EMMs on transit will enhance integration with public transportation systems.

- The relationships between government and private operators of shared EMMs can and should include equity and sustainability goals in order to expand low-income, racialized communities' access to EMMs and prioritize the use of smart mobilities for long-term sustainability objectives over commercial interests (Field & Jon, 2021; Wallsten et al., 2021). Specific suggestions on how to do this include 1) provide clear geofence-specific guidance and regulations to operators in order to reach people outside of central business districts and high-income neighbourhoods, and 2) devise incentives for operators that link geofences to vehicle caps, for example with a sliding scale that allows larger geofences to use more vehicles, or reduce fees and taxes on operators with larger geofences (Moran, 2021).

- In much of the reporting and literature, those who use EMMs and those who have disabilities are often held up as opposing communities, with an underlying assumption that the two groups are mutually exclusive. This should not be assumed to be the case. Wright (2020), for example, considers how to make EMMs accessible, noting that Oakland requires some e-scooters to be more accessible, with seats and wider wheel-bases.

- A range of authors identify that finding ways to not only improve access to EMMs but also attract individuals to them would help to achieve many of the benefits associated with EMM as a mode of transport (Cairns et al., 2017; Ton & Duives, 2021). Various researchers suggest ways to accomplish this:

- Spread costs over time instead of having a one-time payment is one way to mitigate this (Ton & Duives, 2021).
- Some e-bike owners proposed that tax incentives and rebate schemes like those for electric cars could be useful applied to e-bikes (Dill & Rose, 2012).
- An analysis of China's and Taiwan's e-bike and e-scooter policies suggests that subsidies alone may not be enough to bolster the growth of EMM use, but that limiting access to fossil-fuel alternatives could be an effective tool to foster the use of electric vehicles (Yang, 2010). However, this strategy may have consequences for those with accessibility needs that include a reliance on cars for travel.
- E-bike owners also advocated for policies that would promote bicycle use in general, including better biking infrastructure and disincentives for car use (Dill & Rose, 2012).
- Providing appropriate riding facilities for improved riding conditions are important for e-scooter riders (Q. Ma et al., 2021). Local authorities may strategize to improve the built environment by promoting developments "with mixed land-use and micro-mobility- and pedestrian-friendly environments" (Oeschger et al., 2020, p. 15).

- Policymakers and those who manage EMM sharing services should consider users' concerns about privacy and minimize the collection of unnecessary or irrelevant data as well as implement clear policies to notify users about data sharing by the government or third parties (L. Li et al., 2021).

- Planners are encouraged to take into account the matter of public opinion, power struggles, and social and cultural resistance, as "global newspaper reports would seem to suggest that public opinion is the most significant challenge" for e-scooters (Gössling, 2020, p. 3) and multimodal shared mobility in general (Meng et al., 2020). Media sensationalism should not be allowed to set the tone for policymaking; policy makers should focus on advancing community goals instead of responding to creating rules based on media criticism (Wood et al., 2019).

- Ma et al. (2021) found that improvement the quality and accessibility of municipal e-scooter policies should be improved. The authors identify that a unified platform would be helpful in aiding cities with diverse guidelines to share practices with each other.

- One of the key problems with EMM-related scholarship and policy is that there is no universal agreement on specific terms and definitions. For example, Edge & Goodfield (2017) report Ontario decision-makers noting a need for definition between electric pedal-assist (pedelec) e-bikes in which the rider provides some muscle and e-scooters that resemble a traditional moped. A differentiation between e-scooter types – moped and stand-up style – should also be made. Regional terms, such as “electric two-wheeler” to mean a moped-style e-bike in China, are not widely used elsewhere. While researchers generally do define the type of EMM(s) they are referencing, there needs to be better differentiation between various types of e-scooters and e-bikes.

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