September 2024

# Shared Micromobility Systems for Connecting to Regional Transit Services

*prepared for* Metrolinx
*by* Daniel Romm* *at the* Platial Analysis Lab**, McGill University

* daniel.romm@mail.mcgill.ca
** https://platial.science

Executive Summary ........ 2

1 The Last-Mile Problem and Shared Micromobility Systems ........ 6

2 Benefits and Disbenefits of Shared Micromobility ........ 14

3 Considerations for Implementing Shared Micromobility Systems ........ 18

4 Summary Table of Considerations for Implementing Shared Micromobility Systems . 28

5 Resources ........ 31

6 References ........ 31

# Executive Summary

Solving the last-mile problem of connecting travellers from their home to a public transit system, and from the transit system to their final destination, is crucial for enabling the mass adoption of public transit for commuting. Shared micromobility systems, such as municipal-run docked bikeshare, hold great potential in addressing this challenge. Shared micromobility systems may be implemented in different ways, varying by the type of vehicle(s) used, and where users can access and park them, each variation with its own advantages and disadvantages.

The benefits and disbenefits of shared micromobility systems for connecting to regional transit services are discussed, in terms of strategic, financial, economic, and operational factors. The successful implementation of these systems requires forethought, and so considerations to keep in mind when implementing shared micromobility systems are presented, with an eye for amplifying the benefits and limiting the disbenefits of these systems. With careful implementation, shared micromobility systems have the potential to improve the adoption of regional transit services using a transport mode that produces fewer greenhouse gas emissions and is more space efficient than car use.

The following summary table presents considerations for the successful implementation of shared micromobility systems:

## The Operator(s)

| | |
|---|---|
| **1. Owner/operator structure** | • Who will own the system?<br>• Who will operate the system?<br>• How will the system by funded? |
| **2. Number of permitted operators and operator selection** | • How many operators/systems will be permitted?<br>• Which operators will be chosen? |
| **3. Transit connectivity and integration** | • How can shared micromobility systems be set up to encourage connectivity and integration with public transit systems? |
| **4. Establishing cooperative relationships** | • What relationships will be present between stakeholders, and how can these be set up to support the functioning of the system for all stakeholders? |
| **5. Operational/program fees** | • What fees will be charged to operators by municipalities, in cases where operators are external? |
| **6. Legal policies and insurance** | • What legal policies will be set up to permit the systems and ensure they function well and that users are safe?<br>• What insurance policies are necessary, and for which stakeholders? |
| **7. Policy learning** | • What examples from other already existing implementations are available to learn from?<br>• What guides and resources are available to prepare? |
| **8. Data availability, sharing, and privacy** | • What data is the operator permitted and required to collect, how is it stored, how will it be managed, and with whom will it be shared?<br>• How will data be made available to the municipality and other stakeholders, including the public?<br>• How will users' data privacy be respected? |

## The Vehicles

| | |
|---|---|
| **9. Parking system** | • What parking system will be implemented: docked, dockless, or hybrid? |
| **10. Vehicles deployed** | • Which vehicles will the system deploy, including potentially bicycles, e-bikes, e-scooters, and cargo bikes? |
| **11. Vehicle durability, maintenance, and battery certification** | • What is the build of the vehicles to be deployed, how durable are they, and how will they be maintained?<br>• In the case of electric vehicles, what battery certification is required? |

## The Fleet

| | |
|---|---|
| **12. System balance, fleet size, and equitable siting** | • How will rebalancing be performed, so that good system balance is maintained?<br>• How many vehicles will be in the fleet?<br>• What equitable siting policies will be in place to ensure that equity-deserving areas are adequately served by the system? |
| **13. Service area boundaries** | • Where will users be allowed to ride, and how will this be enforced? |
| **14. User fees and equitable fee policies** | • What fees will users be charged for use of the system?<br>• What equitable fee policies will be in place to promote affordability for equity-deserving users? |

## Safety and Compliance

| | |
|---|---|
| **15. Safety rules, speed limits, helmet use** | • What are the applicable rules, policies, and laws for the safe riding and parking of micromobility and shared micromobility systems?<br>• What are the speed limits for these vehicles, and will speed limiters be used?<br>• What are the applicable rules for helmet use, and how will this be promoted and/or enforced? |
| **16. Compliance penalties, monitoring, and enforcement** | • How will municipalities promote, monitor, and enforce compliance with applicable rules, policies, and laws, for both users and operators? |
| **17. Socializing the system, public education and engagement** | • How can public education and engagement campaigns be carried out by stakeholders to promote the safety, orderliness, and utility of the system? |
| **18. Protected micromobility lanes** | • What supportive infrastructure is in place for micromobility use, and how can further infrastructure be installed? |

# 1 The Last-Mile Problem and Shared Micromobility Systems

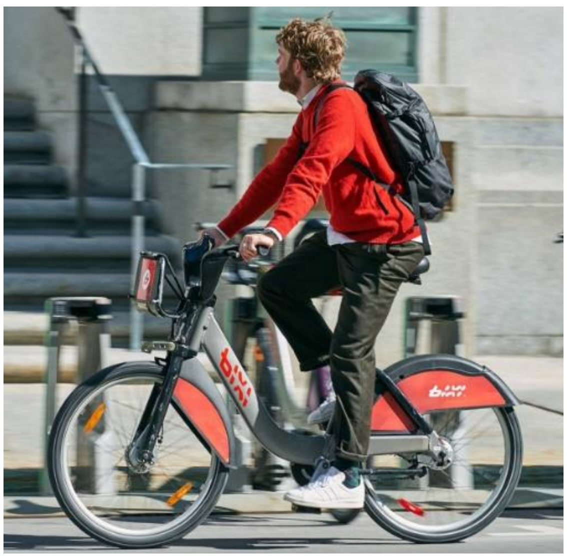
One of most pernicious challenges to the mass adoption of public transit systems is good options for commuters to get from their homes to transit stations, and then from the final public transit stop on their trip to their destination. Taking public transit generally requires another travel mode (*multimodal* travel) for this purpose. This is referred to as the *last-mile problem*[1]; a train that takes a passenger from their home transit station to their work transit station is less appealing without a convenient option for the commuter to get from their home to the closest transit station in the first place. The Metrolinx *2041 Regional Transportation Plan*[2] sets the goal of "designing an easy, safe, accessible, affordable and comfortable door-to-door travel experience that meets the diverse needs of travellers", and under Strategy 3 ("optimize the transportation system"), the plan emphasizes the need for multimodal options for addressing this challenge. The *GO Rail Station Access Plan*[3] similarly underlines the importance of supporting all transport modes, setting the policy of focusing investments on "increasing ridership and sustainable modes of access for both new and existing riders" (section 3.3.2.a). An added hurdle to solving the last-mile problem, given that a significant proportion of national carbon emissions results from transportation,[4] is doing so using transport modes that produce fewer greenhouse gas emissions than automobiles.

A growing body of research attests to the promise of using shared *micromobility*, meaning lightweight vehicles (bicycles, e-scooters)[5] to connect to public transit,[1,6] as a potentially more sustainable and cheaper travel mode, compared with personal automobile use or a city investing in transit routes feeding into regional transit hubs.[7,8] The *modal share* (proportion of total travel) of micromobility is increasing internationally[9,10] and micromobility sharing systems are growing dramatically in number and size, demonstrating their promise.[11] Supporting micromobility use for connecting to public transit systems may be a low-cost policy solution to extend the *catchment area* (from which persons travel to a station) of transit systems, allowing more people to travel without using cars.[12,13]

# 1.1 Implementation Varieties

## *1.1.1 Types of Vehicles*

There are three varieties of vehicles used in nearly all shared micromobility systems globally: pedal-powered bicycles, e-bikes, and e-scooters. In North America in 2023, there were 172 million trips made using shared micromobility systems, with 37% made using pedal-powered bicycles, 23% with e-bikes, and 40% with e-scooters.[14] It is also possible for shared micromobility systems to use several vehicle types at once, for example having both pedal-powered bicycles and e-scooters available to users.

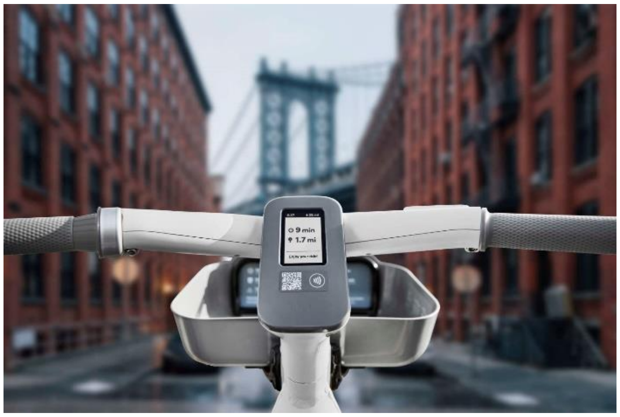



Pictured: Montréal's *BIXI* system.
(Source: https://bixi.com/)

### *The pedal-powered bicycle*

The pedal-powered bicycle is the traditional vehicle used in shared micromobility systems. Typically, the bicycle is heavier, sturdier, and clunkier than personal bicycles, designed to withstand constant use with relatively little maintenance. Vehicles may have baskets attached to place belongings when riding.

The principal advantage of the pedal-powered bicycle is in its low cost relative to other vehicles, and in not requiring charging infrastructure or operations that would be required with electric vehicles. Additionally, many travellers are already familiar with bicycles. There are also health benefits associated with riding pedal-powered bicycles.[15,16] The disadvantages of the pedal-powered bicycle are in the effort required for pedalling, which may dissuade some users. They are also less suitable for hilly terrain, since elevation drastically increases the physical effort needed to pedal.

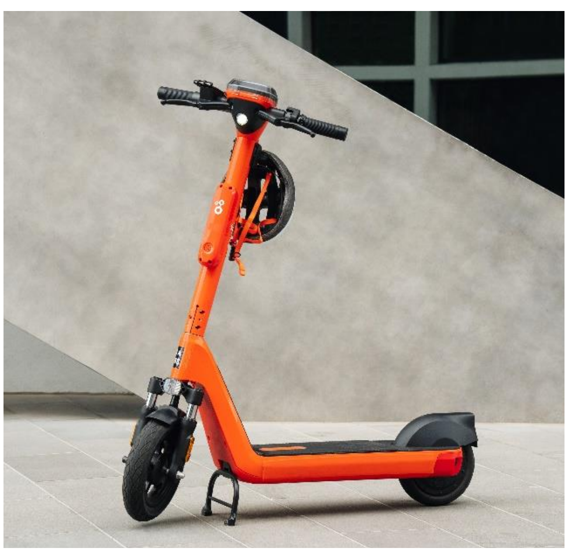


Pictured: E-bike in New York City's *Citi Bike* system.
(Source: https://citibikenyc.com/)

### *The e-bike*

E-bikes are typically "pedal-assisted", meaning that an electric motor amplifies the power of each pedal of the traveller, so that less effort is needed to use the vehicle, especially when encountering elevation. Batteries in e-bikes require charging by the system operator.

The advantage of e-bikes is in significantly reducing the physical exertion needed to use the system. For potential travellers who are dissuaded by the effort needed to ride a bicycle, whether because of disability, fitness, not wanting to sweat, etc., e-bikes are an attractive option. Additionally, e-bikes are more able to navigate hilly terrain than pedal-powered bicycles, with the motor assisting climbing elevation. The main disadvantage of e-bikes is that their batteries require constant charging by the system operator. E-bikes can also more easily reach high speeds, and are heavier than pedal-powered bicycles, potentially posing a safety risk to others, though operators are able to place speed limiters on the vehicles to cap the speed at which users can travel.

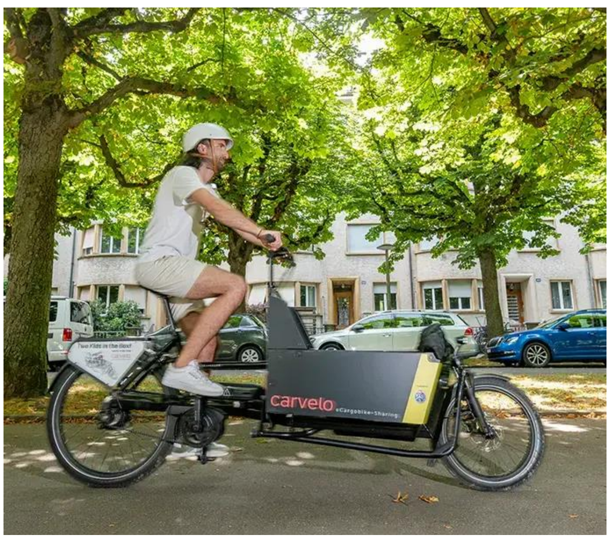


Pictured: E-scooter in Edmonton's *Neuron* system.
(Source: https://rideneuron.com/)

### *The e-scooter*

E-scooters are the newest entrants to shared micromobility systems and typically are used in dockless systems, but can also be used with docks. E-scooters can be two-, three-, or four-wheeled, and wheel thickness can vary as well, affecting the stability of the vehicle. Travellers stand on the board and use triggers at the handles of the vehicle to control an electric motor to propel and brake the vehicle. E-scooters are usually significantly lighter than both pedal-powered bicycles and e-bikes.

E-scooters have an advantage of being lightweight and small, both increasing the ease of use for some travellers and making it easier for operators to transport the vehicles when compared to bicycles. They are user-friendly and intuitive, making the use of the system possible to those who do not know how to ride a bicycle. They also occupy less public space, both when not in use and when in motion. The disadvantages of e-scooters largely mimic those of e-bikes: because they are electric, they require constant charging. There also are safety concerns associated with e-scooters, both to the users and those around them, resulting from falls and collisions with other road users.[17–19] By virtue of their size and light weight, they can be less stable than bicycles, especially on poorly maintained pavement surfaces. E-scooters may also struggle on steep inclines, though they typically handle fine with most hills in cities.



Pictured: E-cargo bike in the C*arvelo* system, found in Switzerland.
(Source: https://carvelo.ch/)

### *The cargo bike*

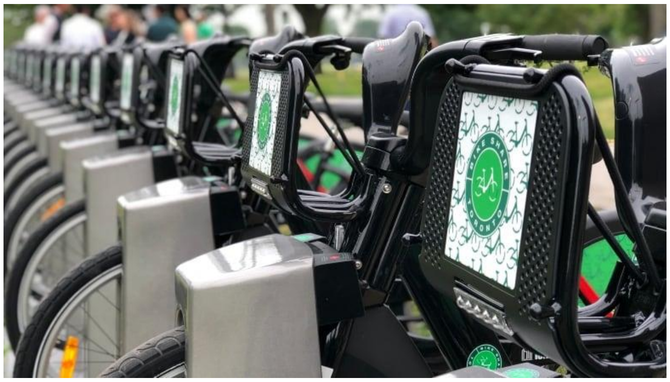
The use of cargo bikes in shared micromobility systems is new in many parts of the world. Cargo bikes may be either pedal-powered or electric, and include a basket or wagon to allow travellers to haul cargo on their trip. They can be added as one potential vehicle option to complement a shared micromobility system.

The principal advantage of cargo bikes is in their added function of carrying cargo. Travellers who need to haul items for their trip (e.g., for buying groceries), who would otherwise not use a shared micromobility system, may be attracted by the option of cargo bikes. This may especially encourage mode shift away from automobiles. The disadvantage of cargo bikes is that they are larger and occupy more space.

### *1.1.2 Types of Parking Systems*

In addition to the type of vehicle used, systems may be characterized their parking system: where are travellers allowed to park vehicles after use? In 2023, 421 cities in North America had at least one shared micromobility system, including 41 in Canada. In these cities, 55% had a docked parking system, 28% had a dockless system, 11% a hybrid system (combining features of both the docked and dockless form), and 6% had multiple system types.[14] Hybrid systems are increasing in popularity.

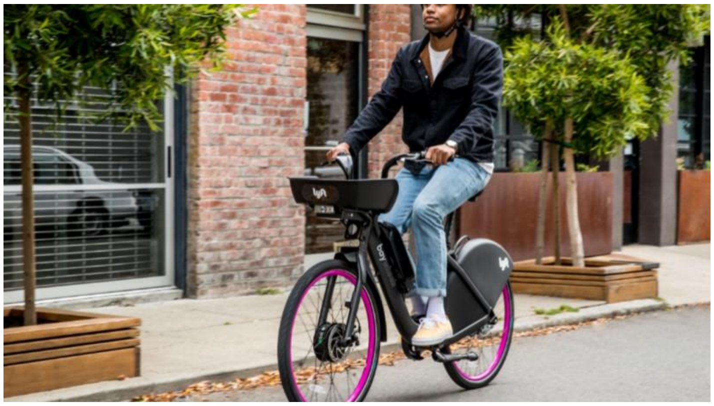
Shared micromobility systems must be “balanced”, meaning that vehicles are optimally placed to meet user demand, with minimal distance between where a person's demand begins, and where the vehicle is parked. If a system is poorly balanced, the system may not serve users’ needs well. Ensuring system balance is necessary, which means that operators perform “rebalancing” operations, hauling their vehicles to different areas to meet changing user demand.


Pictured: Docked *Bike Share Toronto* system.
(Source: Taylor Simmons, https://cbc.ca/news/canada/toronto/toronto-bike-share-ridership-1.6946281)

### *Anchor-based "docked" system*

These are the conventional system type and the one most people and municipalities are familiar with. In anchor-based, or "docked", systems, vehicles are accessed from and returned to anchors or docks (stations), which typically lock, secure, and provide a mechanism for users to access the vehicles. There are usually terminals located at each dock to allow the user to pay and access the vehicle, but other mechanisms, such as QR codes attached to the vehicles themselves, are also possible.

The main advantage of docked systems over alternatives is that when not in use, vehicles are orderly, parked in docks where space is already set aside for them. Operators conducting rebalancing may also benefit from vehicles being already grouped for pickup. The disadvantages of docked systems include the cost of the docking infrastructure, which also adds a significant spatial and financial cost to expanding the system, as doing so requires finding space for and procuring additional docks. Another disadvantage is that docks are subject to constrains on the available parking space in docks, and if there is an unplanned-for spike in demand for either renting a vehicle from a particular location, or parking a vehicle at a certain location, travellers may be faced with either a lack of available vehicles, or insufficient available docks to conclude their trip. Both scenarios sharply reduce the utility of the shared micromobility system and may be difficult for an operator of a docked system to address through rebalancing.

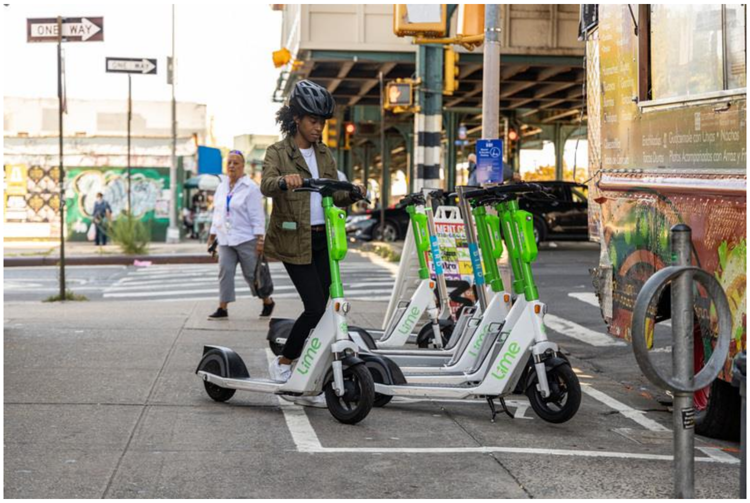


Pictured: Lyft-operated *Bay Wheels* system in the San Francisco Bay area.
(Source: Lyft)

### ***Free-floating "dockless" system***

Free-floating, or "dockless", systems remove the need for fixed docking infrastructure, instead using "smart lock" mechanisms that usually interface with smart devices, allowing the vehicle to be unlocked and locked at any location. Vehicles are embedded with a location tracking system, so that operators can track the location of their fleet. Users can locate vehicles and unlock them through the operator's app, and later use the app to lock the vehicle.

The advantage of dockless systems is in increased flexibility and accessibility. A user's demand for a micromobility trip does not usually start and end exactly at a docking station, but elsewhere, and by distributing vehicles over space, a well-balanced system more likely has vehicles placed closer to where travellers' demand begins. Operators benefit from not needing docking infrastructure, as they can expand the system without incurring the cost of installing new docks. The inherent flexibility of a dockless system also allows operators to relocate vehicles to address spikes in demand or supply, and there is no risk of travellers not finding an available dock in which to park their vehicle. The disadvantage of dockless systems is in the disorder they may bring to city streets, as vehicles are not contained neatly in docking stations but spread out over public space. Neat parking relies partly on good user behaviour, and when users park haphazardly, they risk disrupting public space, creating obstacles which especially pose a hazard to the visually impaired or those with mobility disabilities.




Pictured: Painted corrals for scooter parking in New York City.
(Source: https://nycdotscootershare.info/)

### *Hybrid systems*

Hybrid systems combine some features of docked and dockless systems, with numerous options available for how the system may be hybridized. The simplest version of a hybrid system is including docking stations, but also allowing users park vehicles outside of docks, in the manner of a dockless system. Alternatively, operators may affix an extendable bike lock to the vehicle, requiring that users lock the vehicle to already-available fixed infrastructure on streets, effectively transforming existing infrastructure into "anchors" for vehicles. Another option is to paint or otherwise indicate "virtual" docks (or "corrals") on sidewalks or streets, and require users to leave vehicles in these, verifying that they have done so with a picture or using geofencing technology. Geofencing refers to virtual geographic boundaries in which a vehicle must be parked, using GPS and/or RFID (Radio-Frequency Identification) to determine if a vehicle is within a geofence.

The advantage of hybrid systems is that, if well-designed, they combine the advantages of both systems and ameliorate the challenges that exist with docked and dockless systems. A hybrid system allows for the convenience, flexibility, and accessibility of dockless systems while encouraging orderly parking around docking stations. The operator can more cheaply and easily expand the system without the requirement of the fixed infrastructure of docks. The challenge of docking stations having enough capacity to receive vehicles in the case of unexpected demand can also be addressed, in part, with hybridity, as users need not rely on docks, though operators must still perform rebalancing operations. The disadvantages of hybrid systems depend on the manner in which a system is hybridized, but often is ensuring users adhere to the rules of the system, parking vehicles where operators allow, otherwise risking the disadvantages of dockless systems. Operators have options for enforcing these rules (including geofencing, verifying orderly parking by requiring users take a photo of the parked vehicle, or imposing heavy penalties for user misbehaviour), but their effectiveness may vary depending on the particular circumstances of implementation.

# 2 Benefits and Disbenefits of Shared Micromobility

## 2.1 Strategic

| Benefits | Disbenefits |
| --- | --- |
| • *Health benefits* are associated with using micromobility, especially when replacing automobile travel,[15,16] though it should be noted that some, but not all, of these benefits result from the physical activity needed for pedal-powered vehicles, and will not be conferred to the same extent with electric vehicles. Car travellers also experience negative health effects from their travel,[20–22] which can be avoided in part by using other modes of travel.<br>• Shared micromobility systems can *support multimodal connections* to public transit, providing a convenient option for travellers to get to transit stations from the point of origin for their trip, and from transit stations to their destination.[7,8,13,23,24] With shared micromobility, versus using personal micromobility vehicles, travellers need not worry about securely storing their vehicle, or carrying it on public transit. In effect, micromobility systems extend the catchment area of public transit, improve overall accessibility, and reduce travel times.[12]<br>• Shared micromobility systems *improve access to transport and overall mobility*, and may be an effective policy solution to do so *for equity-deserving groups*.[25–28] | • A key, unsolved question about shared micromobility systems is their effect on *mode shift*: how does the use of the shared micromobility system affect the number of trips made using other transport modes? In particular, are shared micromobility trips replacing public transit trips, thereby potentially reducing fare revenues? The evidence for this is mixed, with some studies finding shared micromobility complements public transit use, increasing ridership;[29–32] others finding it competes with public transit, reducing ridership;[33,34] and others findings no substantial effect.[35] The effect can also vary geographically, with systems competing where transit coverage is high, and complementing where coverage is low.[36] The type of public transit matters, as micromobility tends to serve short distance trips, which may be poorly served by public transit anyways; it is less likely that micromobility replaces longer distance subway or train trips.[37,38] |

## 2.2 Financial

| Benefits | Disbenefits |
| --- | --- |
| • Installing shared micromobility systems may results in *cost savings to* travellers, as the cost of their use may be lower than alternatives. If micromobility trips can replace automobile trips, the cost savings can be significant.<br>• Shared micromobility can confer *cost savings to municipalities*, especially when the costs of micromobility systems are offset by private firms. If the micromobility system reduces automobile use, the costs of expensive automobile infrastructure (i.e., road maintenance, parking, etc.) may be reduced.<br>• For *transit agencies* seeking to facilitate multimodal connections, supporting micromobility is a lower-cost alternative than expensive parking infrastructure, or expensive feeder bus routes.[13] | • Depending on how a shared micromobility system is implemented, and whether and how costs are borne or offset by private firms, there may be *financial costs* associated with setting up a system, building supportive infrastructure, and operating the system.<br>• Different stakeholders, including micromobility operators and municipalities, have to purchase *liability insurance* coverage for shared micromobility systems.[39] |

## 2.3 Economic

| Benefits | Disbenefits |
| --- | --- |
| • If shared micromobility systems encourage mode shift from private automobiles, there are significant *environmental benefits* from reducing the pollution from car use.[4,40,41]<br>• There are associated *economic benefits* from shared micromobility systems by generating economic activity.[42,43]<br>• There are *time savings* conferred by using micromobility over walking.<br>• *Reducing injuries and deaths from automobile collisions* is an important and widespread policy objective.[44,45] Decreasing car use contributes to this objective.<br>• Car infrastructure has an extremely high spatial cost and occupies much of a city's public space, especially contrasted to the much *more spatially efficient* micromobility travel mode.[46–48] By supporting micromobility travel and reducing the dependence on automobile travel, shared micromobility systems can more efficiently use space in cities. | • The *risk of injury* from micromobility travel is a substantial concern, especially with the e-scooter vehicles, with many studies examining harm resulting from e-scooters in particular.[18,19,49–53] Elevation changes, pavement quality, and user demographics are important factors affecting injury incidence and severity.[54] Many injuries occurred especially when micromobility users were inebriated.[55–57]<br>• The material inputs of vehicles used in shared micromobility systems have an *environmental cost*, especially if policies are not put in place to conduct life-cycle assessments (LCAs) of these costs, and mitigate them through improved vehicle durability, repair policies, and good battery disposal processes.[58–60] |

## 2.4 Operational

| Benefits | Disbenefits |
|---|---|
| • Shared micromobility systems can *reduce road traffic* when car travellers opt to use micromobility instead.<br>• Shared micromobility systems are often *externally operated* through private firms with experience and expertise in doing so, alleviating the burden of daily operations from municipalities. | • In the case of dockless micromobility systems, there may be *messiness or disorder* from haphazardly parked vehicles, infringing upon the public right-of-way and posing hazards to other travellers, especially those with visual or mobility disabilities.<br>• Users of shared micromobility systems may not use them as expected or required by the operator and municipality, for example, by riding vehicles on sidewalks where prohibited. Addressing this requires *additional efforts in compliance and enforcement* by the operator and municipalities.<br>• *Ensuring adequate paving quality and safe road conditions*, for example through protected micromobility infrastructure, is important for micromobility traveller comfort and avoiding injuries. This poses additional costs and obligations to municipalities and other landowners.<br>• There is a *reputational risk* to shared micromobility systems from travellers (mis)using personal micromobility vehicles that may be challenging to manage. The public may associate shared micromobility systems with these others travellers' poor behaviour. |

# 3 Considerations for Implementing Shared Micromobility Systems

The successful implementation of shared micromobility systems requires thoughtful cooperation among stakeholders, including:

- municipalities,
- provincial agencies,
- municipal and regional transit agencies,
- micromobility operators,
- large landowners (e.g., universities),
- business owners, and
- residents.

While the particulars may vary, typically a municipality enters into an agreement with a micromobility operator to launch a shared micromobility system, and there sets the rules, policies, guidelines, etc. that govern the system and also define the relationships between operators and other stakeholders. It is particularly important to foster a good relationship with the system operator and ensure that the terms of the agreement are favourable to the other stakeholders involved. There is opportunity to support multimodal connection between shared micromobility and transit agencies, for example by integrating fares and payment systems between micromobility and public transit systems. To foster beneficial relationships and successful micromobility systems, it may be useful to set up advisory boards with key stakeholders from different sectors to inform shared micromobility policy and development. Public communication and engagement are vital to bringing residents onboard with changes to their mobility landscape, especially as people may be sensitive and reactionary to micromobility projects and proposals.[61–63]

The following considerations are arranged into four categories: those related to the operator(s) and the relationship between them and other stakeholders, the vehicles used in the system, the fleet deployed in the system, and safety and compliance.

## *3.1 The Operator(s)*

### *1. Owner/operator structure*

There are a variety of possible implementations with regards to the structure of ownership, operations, and funding. The system(s) and fleet can be owned by the municipality, a private firm, or an arms-length agency. The operations may be performed by the municipality, a contracted private firm, or consigned to an arms-length agency. Systems can be funded in whole or in part by government agencies, private firms through ownership, private firms through sponsorship, or other arrangements.

For example, Montréal's *BIXI* system is run by a non-profit organization created by the city of Montréal, funded in part by sponsors including Loto Québec, Fizz (telecommunications), Tangerine (banking), Beneva (insurance and financial services), and Rachelle Bery (groceries). *Bike Share Toronto* is owned by the Toronto Parking Authority, a city agency, but works with *Shift Transit* and *PBSC Urban Solutions* for operations, and is sponsored by Tangerine (banking). Meanwhile, *Neuron* operates an e-scooter sharing service in Edmonton (and many other locations), and wholly owns and operates the system apart from the city, only working with the city to have a permit to run their system.

The owner/operator structure affects the distribution of control, financial costs, risks, and financial benefits. When establishing a shared micromobility system, the municipality can decide the structure of this distribution, with consequences along these four aspects. At one extreme, the municipality owns, operates, and funds a shared micromobility system: they retain complete control of all implementation and operation decisions, but also must absorb and financial costs of the system and any associated risk (e.g., financial, reputational). At the other extreme, a private firm owns, operates, and funds a shared micromobility system with a minimally restrictive permit from a municipality: the municipality has limited control on implementation and operations, but eschews all of the financial costs and financial benefits, and most of the risk. For example, with an implementation such as the *Bird* system in Calgary, the private firm Bird owns, operates, and finances the system, but the city retains some control through the permitting process, including specifying safety requirements and operator fees, which provides an additional revenue source to the city.

### 2. *Number of permitted operators and operator selection*

A municipality can opt to allow only one operator, or several. For example, Waterloo allows *Neuron* alone to operate a shared micromobility system, whereas Washington, D.C. permits *Lime*, *Lyft*, *Spin*, and *Veo* to operate shared micromobility systems in addition to its own *Capital Bikeshare* program. The prospective benefits of multiple operators in the same municipality are the potential benefits of firm competition, including competition over prices and quality of service.

The disadvantage of multiple operators is that they compete for the same public space. A shared micromobility system works well when vehicles are located conveniently near where a traveller wishes to begin their trip, meaning that there must be a certain density and distribution of vehicles to ensure that demand is well met (system balance). Typically, when multiple operators are permitted, each individual operator is allowed fewer vehicles to be deployed than if there were only one operator, meaning that there are likely to be insufficient vehicles in any individual system to deliver a convenient and accessible service to its users. This means that users have to use multiple systems to achieve the same level of service, and this may pose an inconvenience that dissuades prospective travellers. There is some evidence that multiple systems with different characteristics (e.g., an e-scooter system and a bikeshare system, or a dockless system and a docked system) can complement one another,[31,64,65] while other studies find that systems compete with one another.[29] It is likely that the particulars of implementations and local context is important to determining the effects of having multiple operators.

### 3. *Transit connectivity and integration*

While shared micromobility systems have the potential to support multimodal connections to public transit systems, there are opportunities for improving connectivity to transit. Operators and transit agencies can coordinate over micromobility station and hub planning, or vehicle placement, and transit agencies can serve on advisory boards for operators, participate in funding micromobility systems, integrate trip planning between the systems in mobile applications, share data, and participate in joint marking and promotion activities. Operators and transit agencies can also pursue payment integration, so that travellers can pay for both with the same card. For example, Montréal's *BIXI* system allows payment with the public transit agency's fare card. Micromobility operators and agencies can also coordinate to provide discounts for multimodal trips that connect between the two systems, or offer bundled passes.[14]

### 4. *Establishing cooperative relationships*

It is vital for the well-functioning of a shared micromobility system for stakeholders to establish and maintain cooperative relationships. Part of this is through the permitting process, where municipalities define some of the expectations and responsibilities of their relationship with operators, but constructive professional relationships between personnel working in the municipality and for operators are also important. The success of an implementation can rely on whether municipalities listen to operators, operators respect city's guidelines, travellers follow operator policies, etc. Transit agencies also have the opportunity to establish productive relationships with operators, either directly or through the municipality, to promote connectivity and integration between systems.

### 5. *Operational/program fees*

When permitting external operators, municipalities can attach fees to operate their systems. They can do this on a per-trip basis, per-vehicle basis, annually, one-time, or on some other basis. Government also benefits from sales taxes on user fees, in addition to operator or program fees. Operating a shared micromobility system usually requires some form of subsidy, since they typically do not generate revenue on their own in excess of their costs. In cases where private firms function as owners and operator, rather than municipalities, the additional costs are borne by operators, and municipalities can absorb some revenue. When working with private operators in this way, fees allow municipalities to financially benefit from permitting micromobility systems, but this also drives costs up for operators, which may threaten the financial viability of their business and also result in costs being passed on to users. In the United States, fees vary widely and can result in revenues for cities, but this also means that shared micromobility services are sometimes taxed at much higher levels than other transport modes, including private automobile use.[66]

### 6. *Legal policies and insurance*

There are relevant legal policies at several levels of government, including those pertaining to the use of micromobility in general (e.g., where can a bicycle legally ride), and specifically to operators, usually via municipal by-laws. It may be necessary to purchase liability insurance, as is the case in Ontario.[39] Policies, permits, and regulations provide the opportunity for municipalities to define the relationship between the municipality and the operator(s).

### *7. Policy learning*

There have been thousands of shared micromobility systems deployed across the world, across a variety of contexts, providing valuable learning opportunities, both from successes and failures. It may be valuable to consult reports from other municipalities, speak to relevant personnel, and consult compiled shared information (see *Resources*).

### *8. Data availability, sharing, and privacy*

Operators typically collect data on vehicles, including their real-time location, historical locations, and user data. The industry standard for data collection and reporting is the Mobility Data Specification (MDS),[1] which provides a standard format for reporting mobility data as well as a suite of application programming interfaces (APIs) to facilitate data transfer between operators, municipal agencies, and other parties. The MDS uses the General Bikeshare Feed Specification (GBFS)[2] standard, a real-time, read-only data feed, intended to be publicly available for travellers to see vehicle locations.

This data is enormously valuable for research and policy, as it provides some of the best data on people's mobility. Many important insights about micromobility systems are from studies that use micromobility system data made publicly available. Washington, D.C. is an example of a municipality that provides good public access to data[3], and, as a result, there are many academic research papers that have investigated the mobility system in Washington and drawn valuable insights for the city and for micromobility in general.[67–70] In the context of the growing Open Data movement, sharing this data also has important implications for data transparency. In the permitting process, municipalities can define policies around data availability and sharing.

It is also important for municipalities and operators to consider data privacy protection, as data on people's mobility is enormously valuable and potentially dangerous. Some degree of anonymization is necessary and common practice, through the aggregation of trips, fuzzing of locations, and anonymization of user data. There may be legal implications or requirements for data privacy depending on the jurisdiction.

---

[1] https://www.openmobilityfoundation.org/about-mds/
[2] https://gbfs.org/
[3] https://ddot.dc.gov/page/dockless-api

## *3.2 The Vehicles*

### *9. Parking system*

Municipalities and operators must decide on the desired parking system for any shared micromobility system, ranging from fully docked to fully dockless parking, or some hybrid system in between the two. There are advantages and disadvantages to any option, though hybrid systems may allow municipalities and operators to optimize the advantages of both systems, achieving the orderliness of docked systems, and the convenience and flexibility of dockless systems.

### *10. Vehicles deployed*

Shared micromobility systems typically work with either pedal-powered bicycles, e-bikes, or e-scooters. It is also possible for systems to have multiple vehicle types. Different vehicles are better-suited to different purposes, with each vehicle having its own advantages and disadvantages, and being better suited to different trip distances (with e-scooters being suited to shorter trips and e-bikes being suited to longer trips).[64,65] There is also the consideration of whether and how to include cargo vehicles (cargo bikes or e-bikes, typically) in the fleet, as doing so could further attract travellers.

If electric vehicles are deployed, the electric charging process and any requisite infrastructure must be considered. This can range from having operators collect vehicles and charge them in separate facilities, having users collect and charge vehicles at home for some incentive, or having docking stations capable of charging the vehicles.

### *11. Vehicle durability, maintenance, and battery certification*

Vehicles in shared micromobility systems see heavy use, and so they need to be exceptionally durable and receive regular maintenance. This is especially important from the perspective of sustainability, with poor vehicle quality severely increasing the total emissions and waste of the micromobility transport mode.[60,71] Municipalities can set policies with operators so that vehicles in poor repair must be picked up in a timely manner. Vehicle build also must be considered, in relation to pavement quality, elevation, and so on. E-scooters can be outfitted with thicker or more wheels to increase stability, for example. For electric vehicles, battery certification and regular maintenance is crucial to ensure safety.

## 3.3 The Fleet

### *12. System balance, fleet size, and equitable siting*

Shared micromobility systems work as viable options for travellers when accessing a vehicle is sufficiently convenient. A prospective user does not want to walk too long to access the vehicle, and they want to be able to park the vehicle as close as possible to their destination. Vehicles must be distributed such that they meet user demand as it occurs, with minimal distance between where a person's demand for a micromobility trip begins, and where the vehicle is parked. The dynamic (meaning over time) spatial distribution of vehicles in a system is referred to as system balance. If a system is poorly balanced in the manner that there are prospective travellers who do not have a vehicle readily available, the system may not be attractive to users, especially if it is perceived as unreliable. It is essential for operators to ensure that system balance is well maintained, which means they also perform rebalancing operations, hauling vehicles to different destinations, usually using a truck, to better meet demand.

To ensure good system balance, the operator must deploy a certain number of vehicles in their fleet. With too few vehicles in the fleet, it will not be possible to position them in a way that reliably meets demand. When a shared micromobility system is permit-based, meaning the municipality issues a permit to an operator, the municipality often sets a minimum and/or maximum for fleet size. For a well-functioning system, the municipality must ensure that the fleet size is sufficiently large to accommodate demand, otherwise the system is unlikely to succeed. Determining the appropriate fleet size requires tailored research of the context around an implementation, and can be done by commissioning an external research team or by consulting with external operators with expertise and, often, in-house teams to conduct such studies. In this process, the municipality should emphasize important policy priorities, related to the number of operators, transit connectivity, equity, and other factors related to system balance and fleet size. The municipality can also set policies to ensure that vehicles are equitably distributed, meaning that operators must place a given number of vehicles in equity-deserving areas. If implemented well, shared micromobility systems can improve the equitable access to the transportation system and opportunities.[25,26,72,73]

### *13. Service area boundaries*

Municipalities can designate the boundaries of the service area of a shared micromobility system, so that it only operates where appropriate. For dockless vehicles, this is commonly enforced with geofencing technology, tracking the location of vehicles and preventing them from functioning outside of the service area (stopping their wheels, for instance, or not allowing users to end their trip). For example, Parc Jean-Drapeau in Montréal has shared dockless e-scooters,[4] but they are disallowed outside of the park. For a docked system, this is mostly enforced by the requirement to return the vehicle to the docking station, located in the service area. There may be stakeholder private landowners (e.g., universities) who refuse shared micromobility services on their property; this can be done using geofencing. When permitting, the municipality must consider what service area is appropriate for the system.

### *14. User fees and equitable fee policies*

Municipalities and operators must decide on the appropriate fee to charge users for access to the system. If the fee is too high, the system may not provide a sufficiently valuable proposition to travellers when compared with other transport modes. However, it is usually desirable for the fee to be high enough to either cover operating costs or make a profit, especially in the case of private operators. The question of user fees is a question of priorities: if the principal objective of the system is to encourage non-automobile transportation, then lower fees will better attract users. Municipalities and/or operators may also want to deliver equitable fee policies, providing discounted or free travel to equity-deserving populations. For example, Grand Rapids Michigan partnered with micromobility operator *Lime* to launch a program that provides free access to low-income travellers.

[4] https://www.parcjeandrapeau.com/en/electric-scooters-at-parc-jean-drapeau-montreal/

## 3.4 Safety and Compliance

### *15. Safety rules, speed limits, helmet use*

Safety rules are set by the municipality and other levels of government regulate how shared micromobility systems are used, usually following the rules of micromobility travel in general. This involves determining where micromobility vehicle are allowed to be used and whether they can be used on the sidewalk. The speed and weight of the vehicle are the most significant factors in the dynamics of a collision, and so these are important regulatory determinations. This may involve placing speed limiters on vehicles to cap their speed at some safe limit, when the vehicles are electric. Regulations around distractions (i.e., phone/headphone use) and intoxication are also important.

Another important consideration is around the promotion or mandate of helmet use. While it is established that helmets are vital in mitigating injuries in collisions and falls, they may also discourage ridership.[50,52,74] The relevant governing authority will have to decide on whether helmet use is mandatory, and, if it is not, what policies and programs could be implemented to encourage helmet use. Operators are sometimes required to distribute helmets along with their vehicles to encourage use.

### *16. Compliance penalties, monitoring, and enforcement*

While municipalities may set policies to regulate micromobility operators and micromobility use, they must also establish procedures for monitoring compliance and assigning penalties to noncompliance. This is especially important for dockless and hybrid systems, where compliance is essential for maintaining orderly public space. Municipalities often charge fees to operators when vehicles are left out of place, which also encourages operators to fine users when they inappropriately park their vehicles.

### *17. Socializing the system, public education and engagement*

It takes time for the public to acclimate to the installation of any new system in a city; this is true for mobility systems as well, as people decide whether or not to change their travel patterns to use the new system. For shared micromobility systems, which can be contentious, it is also expected that it will take time for travellers and non-travellers to get used to the change, and until that point, growing pains may be anticipated. This also means that user behaviour and public response during the initial launch period of a system may not be reflective of how the system will be used and how the public feels about the system a year or two years later. Stakeholders should expect a period of "growing pains" for a system to become well-established. A common strategy for mitigating the shock and protecting reputational risk is to implement new micromobility systems through "pilot projects", allowing a system to operate for a finite period of time, after which the pilot is evaluated, and a decision may be made on whether to renew the pilot or install a more permanent system.

Public education and engagement campaigns may be helpful in speeding up this initial socializing the system period and get people on-board with the change. Public education efforts are also important for instructing users on legal and safety rules when travelling, and promoting good behaviour. These campaigns can be delivered by municipalities, operators, or other partners to best reach users.

### *18. Protected micromobility lanes*

Shared micromobility systems exist in the wider context of how micromobility functions in a given area. Better protections for micromobility in general also mean greater protections for shared micromobility travellers, and vice versa. There is also evidence that there is a "safety-in-numbers" effect for micromobility, with more micromobility travellers conferring more safety for other micromobility travellers.[75] If a shared micromobility system increases overall use of micromobility, this has benefits for those who do not use the system as well. Protected micromobility lanes are necessary infrastructure to enhance road safety,[76,77] and should be considered when implementing shared micromobility systems to protect new users.

# 4 Summary Table of Considerations for Implementing Shared Micromobility Systems

## The Operator(s)

| | |
|---|---|
| **19. Owner/operator structure** | • Who will own the system?<br>• Who will operate the system?<br>• How will the system by funded? |
| **20. Number of permitted operators and operator selection** | • How many operators/systems will be permitted?<br>• Which operators will be chosen? |
| **21. Transit connectivity and integration** | • How can shared micromobility systems be set up to encourage connectivity and integration with public transit systems? |
| **22. Establishing cooperative relationships** | • What relationships will be present between stakeholders, and how can these be set up to support the functioning of the system for all stakeholders? |
| **23. Operational/program fees** | • What fees will be charged to operators by municipalities, in cases where operators are external? |
| **24. Legal policies and insurance** | • What legal policies will be set up to permit the systems and ensure they function well and that users are safe?<br>• What insurance policies are necessary, and for which stakeholders? |
| **25. Policy learning** | • What examples from other already existing implementations are available to learn from?<br>• What guides and resources are available to prepare? |
| **26. Data availability, sharing, and privacy** | • What data is the operator permitted and required to collect, how is it stored, how will it be managed, and with whom will it be shared?<br>• How will data be made available to the municipality and other stakeholders, including the public?<br>• How will users' data privacy be respected? |

## The Vehicles

| | |
|---|---|
| **27. Parking system** | • What parking system will be implemented: docked, dockless, or hybrid? |
| **28. Vehicles deployed** | • Which vehicles will the system deploy, including potentially bicycles, e-bikes, e-scooters, and cargo bikes? |
| **29. Vehicle durability, maintenance, and battery certification** | • What is the build of the vehicles to be deployed, how durable are they, and how will they be maintained?<br>• In the case of electric vehicles, what battery certification is required? |

## The Fleet

| | |
|---|---|
| **30. System balance, fleet size, and equitable siting** | • How will rebalancing be performed, so that good system balance is maintained?<br>• How many vehicles will be in the fleet?<br>• What equitable siting policies will be in place to ensure that equity-deserving areas are adequately served by the system? |
| **31. Service area boundaries** | • Where will users be allowed to ride, and how will this be enforced? |
| **32. User fees and equitable fee policies** | • What fees will users be charged for use of the system?<br>• What equitable fee policies will be in place to promote affordability for equity-deserving users? |

## Safety and Compliance

| | |
|---|---|
| **33. Safety rules, speed limits, helmet use** | • What are the applicable rules, policies, and laws for the safe riding and parking of micromobility and shared micromobility systems?<br>• What are the speed limits for these vehicles, and will speed limiters be used?<br>• What are the applicable rules for helmet use, and how will this be promoted and/or enforced? |
| **34. Compliance penalties, monitoring, and enforcement** | • How will municipalities promote, monitor, and enforce compliance with applicable rules, policies, and laws, for both users and operators? |
| **35. Socializing the system, public education and engagement** | • How can public education and engagement campaigns be carried out by stakeholders to promote the safety, orderliness, and utility of the system? |
| **36. Protected micromobility lanes** | • What supportive infrastructure is in place for micromobility use, and how can further infrastructure be installed? |

# 5 Resources

NACTO. (2019). Guidelines for regulating shared micromobility. https://nacto.org/sharedmicromobilityguidelines/

ITDP. (2021). Maximizing micromobility. https://itdp.org/publication/maximizing-micromobility/

Shaheen & Cohen. (2019). Shared micromobility policy toolkit. https://escholarship.org/uc/item/00k897b5

TransLink Tomorrow. (2019). Shared micromobility guidelines. https://www.translink.ca/plans-and-projects/programs-and-studies/translink-tomorrow

# 6 References


1. Tilahun N, Thakuriah P (Vonu), Li M, Keita Y. Transit use and the work commute: Analyzing the role of last mile issues. *Journal of Transport Geography*. 2016;54:359-368. doi:10.1016/j.jtrangeo.2016.06.021

2. Metrolinx. *2041 Regional Transportation Plan For the Greater Toronto and Hamilton Area*. Metrolinx; 2018.

3. Metrolinx. *GO Rail Station Access Plan*. Metrolinx; 2016.

4. Environment and Climate Change Canada. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada*. Environment and Climate Change Canada; 2023.

5. Dediu H. The Micromobility Definition. Micromobility. February 23, 2019. https://micromobility.io/news/the-micromobility-definition

6. Razak SY. Last mile commute: An integral sustainability component for passengers accessibility within city's transport fabric. *Cities*. 2022;125:103667. doi:10.1016/j.cities.2022.103667

7. Ma T, Liu C, Erdoğan S. Bicycle Sharing and Public Transit: Does Capital Bikeshare Affect Metrorail Ridership in Washington, D.C.? *Transportation Research Record: Journal of the Transportation Research Board*. 2015;2534(1):1-9. doi:10.3141/2534-01

8. Park K, Farb A, Chen S. First-/last-mile experience matters: The influence of the built environment on satisfaction and loyalty among public transit riders. *Transport Policy*. 2021;112:32-42. doi:10.1016/j.tranpol.2021.08.003

9. NACTO. *Shared Micromobility in the US: 2019*. NACTO: National Association of City Transportation Officials; 2020.

10. Ensor M, Maxwell O, Bruce O. *Mode Shift to Micromobility*. Waka Kotahi NZ Transport Agency; 2021:111.

11. O'Brien O, DeMaio P, Rabello R, Chou S, Benicchio T. *The Meddin Bike-Sharing World Map Report: 2022 Edition*.; 2022.

12. Ferguson B, Sanguinetti A. Facilitating Micromobility for First and Last Mile Connection with Public Transit through Environmental Design: A Case Study of California Bay Area Rapid Transit Stations. In: *Proceedings of the Design Society*. ; 2021:1577-1586. doi:10.1017/pds.2021.419

13. Shaheen S, Chan N. Mobility and the Sharing Economy: Potential to Facilitate the First- and Last-Mile

Public Transit Connections. *Built Environment (1978-)*. 2016;42(4):573-588.

14. North American Bikeshare & Scootershare Association (NABSA). *5th Annual Shared Micromobility State of the Industry Report, 2023*. North American Bikeshare & Scootershare Association (NABSA); 2024. https://doi.org/10.7922/G2DF6PKP

15. de Hartog JJ, Boogaard H, Nijland H, Hoek G. Do the Health Benefits of Cycling Outweigh the Risks? *Environmental Health Perspectives*. 2010;118(8):1109-1116. doi:10.1289/ehp.0901747

16. Pérez K, Olabarria M, Rojas-Rueda D, Santamariña-Rubio E, Borrell C, Nieuwenhuijsen M. The health and economic benefits of active transport policies in Barcelona. *Journal of Transport & Health*. 2017;4:316-324. doi:10.1016/j.jth.2017.01.001

17. Sikka N, Vila C, Stratton M, Ghassemi M, Pourmand A. Sharing the sidewalk: A case of E-scooter related pedestrian injury. *The American Journal of Emergency Medicine*. 2019;37(9):1807.e5-1807.e7. doi:10.1016/j.ajem.2019.06.017

18. Traynor MD, Lipsitz S, Schroeder TJ, et al. Association of scooter-related injury and hospitalization with electronic scooter sharing systems in the United States. *The American Journal of Surgery*. Published online June 2021:S0002961021003342. doi:10.1016/j.amjsurg.2021.06.006

19. Shah NR, Aryal S, Wen Y, Cherry CR. Comparison of motor vehicle-involved e-scooter and bicycle crashes using standardized crash typology. *Journal of Safety Research*. 2021;77:217-228. doi:10.1016/j.jsr.2021.03.005

20. Christian TJ. Trade-Offs Between Commuting Time and Health-Related Activities. *J Urban Health*. 2012;89(5):746-757. doi:10.1007/s11524-012-9678-6

21. Ding D, Gebel K, Phongsavan P, Bauman AE, Merom D. Driving: A Road to Unhealthy Lifestyles and Poor Health Outcomes. *PLoS One*. 2014;9(6):e94602. doi:10.1371/journal.pone.0094602

22. Petrunoff N, Crane M, Rissel C. A Case Study Exploring Associations of Quality of Life Measures with Car and Active Transport Commute Modes in Sydney. In: Friman M, Ettema D, Olsson LE, eds. *Quality of Life and Daily Travel*. Applying Quality of Life Research. Springer International Publishing; 2018:183-198. doi:10.1007/978-3-319-76623-2_10

23. Guo Y, He SY. Built environment effects on the integration of dockless bike-sharing and the metro. *Transportation Research Part D: Transport and Environment*. 2020;83:102335. doi:10/ggxgvr

24. Li Y, Zhu Z, Guo X. Operating Characteristics of Dockless Bike-Sharing Systems near Metro Stations: Case Study in Nanjing City, China. *Sustainability*. 2019;11(8):2256. doi:10/gfzzbs

25. Palm M, Farber S, Shalaby A, Young M. Equity Analysis and New Mobility Technologies: Toward Meaningful Interventions. *Journal of Planning Literature*. 2021;36(1):31-45. doi:10.1177/0885412220955197

26. Meng S, Brown A. Docked vs. dockless equity: Comparing three micromobility service geographies. *Journal of Transport Geography*. 2021;96:103185. doi:10.1016/j.jtrangeo.2021.103185

27. Tokey AI. E-scooter's Availability and Social Equity in Minneapolis, MN: A Spatial Modeling Approach. *Findings*. Published online October 20, 2021. doi:10.32866/001c.29149

28. McNeil N, MacArthur J, Broach J. Making Equity a Sustainable Part of Bike Share. *Institute of Transportation Engineers Journal*. 2020;90(5):16-18.

29. Nawaro Ł. E-scooters: competition with shared bicycles and relationship to public transport. *International Journal of Urban Sustainable Development*. Published online October 11, 2021:1-17. doi:10.1080/19463138.2021.1981336

30. Fan Y, Zheng S. Dockless bike sharing alleviates road congestion by complementing subway travel: Evidence from Beijing. *Cities*. 2020;107:102895. doi:10/ghbw4h

31. Lu M, Traut EJ, Ilgin Guler S, Hu X. Analysis of spatial interactions among shared e-scooters, shared bikes, and public transit. *Journal of Intelligent Transportation Systems*. 2024;28(4):587-603. doi:10.1080/15472450.2023.2174803

32. Mohiuddin H, Fukushige T, Fitch-Polse DT, Handy SL. Does dockless bike-share influence transit use? Evidence from the Sacramento region. *International Journal of Sustainable Transportation*. 2024;18(2):146-167. doi:10.1080/15568318.2023.2252757

33. Ma X, Yuan Y, Van Oort N, Hoogendoorn S. Bike-sharing systems' impact on modal shift: A case study in Delft, the Netherlands. *Journal of Cleaner Production*. 2020;259:120846. doi:10/ggsf8v

34. Campbell KB, Brakewood C. Sharing riders: How bikesharing impacts bus ridership in New York City. *Transportation Research Part A: Policy and Practice*. 2017;100:264-282. doi:10.1016/j.tra.2017.04.017

35. Ziedan A, Shah NR, Wen Y, Brakewood C, Cherry CR, Cole J. Complement or compete? The effects of shared electric scooters on bus ridership. *Transportation Research Part D: Transport and Environment*. 2021;101:103098. doi:10.1016/j.trd.2021.103098

36. Luo H, Zhang Z, Gkritza K, Cai H. Are shared electric scooters competing with buses? a case study in Indianapolis. *Transportation Research Part D: Transport and Environment*. 2021;97:102877. doi:10.1016/j.trd.2021.102877

37. Cao Z, Zhang X, Chua K, Yu H, Zhao J. E-scooter sharing to serve short-distance transit trips: A Singapore case. *Transportation Research Part A: Policy and Practice*. 2021;147:177-196. doi:10.1016/j.tra.2021.03.004

38. Fukushige T, Fitch DT, Handy S. Factors influencing dock-less E-bike-share mode substitution: Evidence from Sacramento, California. *Transportation Research Part D: Transport and Environment*. 2021;99:102990. doi:10.1016/j.trd.2021.102990

39. Government of Ontario. Ontario e-scooter pilot program: guidelines for municipalities. Accessed August 16, 2024. http://www.ontario.ca/page/ontario-e-scooter-pilot-program-guidelines-municipalities

40. Ritchie H, Roser M. Cars, planes, trains: where do CO2 emissions from transport come from? *Our World in Data*. Published online 2020. Accessed January 24, 2024. https://ourworldindata.org/co2-emissions-from-transport

41. Kou Z, Wang X, Chiu SF (Anthony), Cai H. Quantifying greenhouse gas emissions reduction from bike share systems: a model considering real-world trips and transportation mode choice patterns. *Resources, Conservation and Recycling*. 2020;153:104534. doi:10.1016/j.resconrec.2019.104534

42. Buehler R, Hamre A, Virginia Tech. Urban Affairs and Planning. *Economic Benefits of Capital Bikeshare: A Focus on Users and Businesses*. United States Department of Transportation; 2014. Accessed August 16, 2024. https://rosap.ntl.bts.gov/view/dot/27421

43. Bullock C, Brereton F, Bailey S. The economic contribution of public bike-share to the sustainability and efficient functioning of cities. *Sustainable Cities and Society*. 2017;28:76-87. doi:10.1016/j.scs.2016.08.024

44. World Health Organization. Road traffic injuries. World Health Organization. December 13, 2023. Accessed January 24, 2024. https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

45. Transportation Association of Canada. *Vision Zero and the Safe System Approach: A Primer for Canada (2023)*. Transportation Association of Canada; 2023. Accessed January 29, 2024. https://www.tac-atc.ca/en/publications/prm-vzss-e

46. Creutzig F, Javaid A, Soomauroo Z, et al. Fair street space allocation: ethical principles and empirical insights. *Transport Reviews*. 2020;40(6):711-733. doi:10.1080/01441647.2020.1762795

47. De Gruyter C, Zahraee SM, Young W. Understanding the allocation and use of street space in areas of high people activity. *Journal of Transport Geography*. 2022;101:103339. doi:10.1016/j.jtrangeo.2022.103339

48. Gössling S, Schröder M, Späth P, Freytag T. Urban Space Distribution and Sustainable Transport. *Transport Reviews*. 2016;36(5):659-679. doi:10.1080/01441647.2016.1147101

49. Uluk D, Lindner T, Dahne M, et al. E-scooter incidents in Berlin: an evaluation of risk factors and injury patterns. *Emerg Med J*. Published online June 7, 2021:emermed-2020-210268. doi:10.1136/emermed-2020-210268

50. Toofany M, Mohsenian S, Shum LK, Chan H, Brubacher JR. Injury patterns and circumstances associated with electric scooter collisions: a scoping review. *Inj Prev*. Published online March 11, 2021:injuryprev-2020-044085. doi:10.1136/injuryprev-2020-044085

51. Stigson H, Malakuti I, Klingegård M. Electric scooters accidents: Analyses of two Swedish accident data sets. *Accident Analysis & Prevention*. 2021;163:106466. doi:10.1016/j.aap.2021.106466

52. Schneeweiss M, Hassan-Ali M, Kam A. Safety and risk factors associated with electric scooter use globally: A literature review. *McMaster University Medical Journal*. 2021;18(1):13. doi:10.15173/mumj.v18i1.2588

53. Nielsen KI, Nielsen FE, Rasmussen SW. Injuries following accidents with electric scooters. *Danish Medical Journal*. 2021;68(2):A09200697.

54. Fang K. Micromobility injury events: Motor vehicle crashes and other transportation systems factors. *Transportation Research Interdisciplinary Perspectives*. 2022;14:100574. doi:10.1016/j.trip.2022.100574

55. McGuinness MJ, Tiong Y, Bhagvan S. Shared electric scooter injuries admitted to Auckland City Hospital: a comparative review one year after their introduction. *New Zealand Medical Journal*. 2021;134(1530):10.

56. Lavoie-Gagne O, Siow M, Harkin W, et al. Characterization of electric scooter injuries over 27 months at an urban level 1 trauma center. *The American Journal of Emergency Medicine*.

2021;45:129-136. doi:10.1016/j.ajem.2021.02.019

57. Moftakhar T, Wanzel M, Vojcsik A, et al. Incidence and severity of electric scooter related injuries after introduction of an urban rental programme in Vienna: a retrospective multicentre study. *Arch Orthop Trauma Surg*. Published online August 27, 2020. doi:10/ghbw4v

58. Calan C, Sobrino N, Vassallo JM. Understanding Life-Cycle Greenhouse-Gas Emissions of Shared Electric Micro-Mobility: A Systematic Review. *Sustainability*. 2024;16(13):5277. doi:10.3390/su16135277

59. Calão J, Lemos Marques D, Godinho Completo A, Cabrita Coelho M. Life Cycle Thinking Approach Applied to a Novel Micromobility Vehicle. *Transportation Research Record*. 2022;2676(8):514-529. doi:10.1177/03611981221084692

60. de Bortoli A. Environmental performance of shared micromobility and personal alternatives using integrated modal LCA. *Transportation Research Part D: Transport and Environment*. 2021;93:102743. doi:10.1016/j.trd.2021.102743

61. Wild K, Woodward A, Field A, Macmillan A. Beyond 'bikelash': engaging with community opposition to cycle lanes. *Mobilities*. 2018;13(4):505-519. doi:10.1080/17450101.2017.1408950

62. Gössling S. Why cities need to take road space from cars - and how this could be done. *Journal of Urban Design*. 2020;25(4):443-448. doi:10.1080/13574809.2020.1727318

63. Field A, Wild K, Woodward A, Macmillan A, Mackie H. Encountering bikelash: Experiences and lessons from New Zealand communities. *Journal of Transport & Health*. 2018;11:130-140. doi:10.1016/j.jth.2018.10.003

64. Lazarus J, Pourquier JC, Feng F, Hammel H, Shaheen S. Micromobility evolution and expansion: Understanding how docked and dockless bikesharing models complement and compete – A case study of San Francisco. *Journal of Transport Geography*. 2020;84:102620. doi:10/ggxgvs

65. Reck DJ, Haitao H, Guidon S, Axhausen KW. Explaining shared micromobility usage, competition and mode choice by modelling empirical data from Zurich, Switzerland. *Transportation Research Part C: Emerging Technologies*. 2021;124:102947. doi:10.1016/j.trc.2020.102947

66. MacArthur J, Fang K, Thigpen C. *Taxing Shared Micromobility: Assessing The Global Landscape Of Fees And Taxes And Their Implications For Cities, Riders, And Operators*. Portland State University Transportation Research and Education Center (TREC); 2024. https://trec.pdx.edu/news/taxing-shared-micromobility-how-cities-respond-emerging-modes-and-whats-next

67. McKenzie G. Docked vs. Dockless Bike-sharing: Contrasting Spatiotemporal Patterns. In: *Leibniz International Proceedings in Informatics (LIPIcs)*. Vol 114. Schloss Dagstuhl--Leibniz-Zentrum fuer Informatik; 2018. doi:10.4230/LIPIcs.GISCIENCE.2018.46

68. McKenzie G. Urban mobility in the sharing economy: A spatiotemporal comparison of shared mobility services. *Computers, Environment and Urban Systems*. 2020;79:101418. doi:10/gghbh6

69. Zou Z, Younes H, Erdoğan S, Wu J. Exploratory Analysis of Real-Time E-

Scooter Trip Data in Washington, D.C. *Transportation Research Record*. Published online May 17, 2020:036119812091976. doi:10/ggxxcd

70. Yan X, Yang W, Zhang X, Xu Y, Bejleri I, Zhao X. A spatiotemporal analysis of e-scooters' relationships with transit and station-based bikeshare. *Transportation Research Part D: Transport and Environment*. 2021;101:103088. doi:10.1016/j.trd.2021.103088

71. Luo H, Zhao F, Chen WQ, Cai H. Optimizing bike sharing systems from the life cycle greenhouse gas emissions perspective. *Transportation Research Part C: Emerging Technologies*. 2020;117:102705. doi:10/gg4kkx

72. Qian X, Jaller M, Niemeier D. Enhancing equitable service level: Which can address better, dockless or dock-based Bikeshare systems? *Journal of Transport Geography*. 2020;86:102784. doi:10/gg4kkn

73. Johnston K, Oakley DA, Durham A, Bass C, Kershner S. Regulating Micromobility: Examining Transportation Equity and Access. *Journal of Comparative Urban Law and Policy*. 2020;4(1):682-720.

74. Serra GF, Fernandes FAO, Noronha E, de Sousa RJA. Head protection in electric micromobility: A critical review, recommendations, and future trends. *Accident Analysis & Prevention*. 2021;163:106430. doi:10.1016/j.aap.2021.106430

75. Elvik R, Bjørnskau T. Safety-in-numbers: A systematic review and meta-analysis of evidence. *Safety Science*. 2017;92:274-282. doi:10/gfppm7

76. Pucher J, Buehler R, Seinen M. Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. *Transportation Research Part A: Policy and Practice*. 2011;45(6):451-475. doi:10.1016/j.tra.2011.03.001

77. Pucher J, Buehler R. Cycling towards a more sustainable transport future. *Transport Reviews*. 2017;37(6):689-694. doi:10.1080/01441647.2017.1340234