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ABSTRACT

Shared micromobility - the shared use of a bicycle (i.e., bikesharing), scooter (i.e., scooter sharing), or other low-speed mode - can enable short-term access to a transportation service on an as-needed basis. The objectives of this study are to understand: 1) if shared micromobility complements or competes with public transportation; 2) the relationship between shared micromobility service models; 3) how different shared micromobility services impact safety; and 4) how the impacts of shared micromobility on public transportation are measured. This study examines the impacts and relationships between shared micromobility and public transportation through a multi-method qualitative and quantitative approach including a literature review of over more than 135 sources, interviews with 19 experts, analysis of activity data from four California communities (Los Angeles, Sacramento, San Jose, and San Francisco), and a survey of n=1,029 shared micromobility users. The study finds that shared micromobility users tend to be Caucasian, higher-income, younger, and male. Shared micromobility can also impact pedestrian and public transit safety when users improperly park and ride devices, and engage in unsafe or erratic behavior, such as failing to follow traffic laws and not wearing helmets. Shared micromobility safety can be improved through changes such as supportive infrastructure (e.g., protected bike lanes), standardizing permissible riding areas, and speeds, sharing incident data, and locating devices in safer areas. The study also suggests that bike and scooter sharing may complement public transit by bridging first- and last-mile gaps. The activity data analysis reveals that bikesharing and public transit connections ranged from 7.9 percent in San Jose to 18.6 percent in San Francisco. However, experts interviewed believe that more research and data are needed to confirm the relationships and impacts of shared micromobility on public transportation through improved data collection and metrics. Future metrics should focus on understanding why some trips replace others and leverage data from sources, such as data dashboards, ridership data, and stated preferences for mode choices.

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PUBLIC TRANSIT AND SHARED MICROMOBILITY INTERACTIONS IN CALIFORNIA

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ABSTRACT

Shared micromobility - the shared use of a bicycle (i.e., bikesharing), scooter (i.e., scooter sharing), or other low-speed mode - can enable short-term access to a transportation service on an as-needed basis. The objectives of this study are to understand: 1) if shared micromobility complements or competes with public transportation; 2) the relationship between shared micromobility service models; 3) how different shared micromobility services impact safety; and 4) how the impacts of shared micromobility on public transportation are measured. This study examines the impacts and relationships between shared micromobility and public transportation through a multi-method qualitative and quantitative approach including a literature review of over more than 135 sources, interviews with 19 experts, analysis of activity data from four California communities (Los Angeles, Sacramento, San Jose, and San Francisco), and a survey of n=1,029 shared micromobility users. The study finds that shared micromobility users tend to be Caucasian, higher-income, younger, and male. Shared micromobility can also impact pedestrian and public transit safety when users improperly park and ride devices, and engage in unsafe or erratic behavior, such as failing to follow traffic laws and not wearing helmets. Shared micromobility safety can be improved through changes such as supportive infrastructure (e.g., protected bike lanes), standardizing permissible riding areas, and speeds, sharing incident data, and locating devices in safer areas. The study also suggests that bike and scooter sharing may complement public transit by bridging first- and last-mile gaps. The activity data analysis reveals that bikesharing and public transit connections ranged from 7.9 percent in San Jose to 18.6 percent in San Francisco. However, experts interviewed believe that more research and data are needed to confirm the relationships and impacts of shared micromobility on public transportation through improved data collection and metrics. Future metrics should focus on understanding why some trips replace others and leverage data from sources, such as data dashboards, ridership data, and stated preferences for mode choices.

Table of Contents

Abstract **2**
List of Tables 5
List of Figures 5
Executive Summary **6**
Introduction **7**
Methodology **3**
Literature Review **5**
User Demographics 5
Station-Based Bikesharing Demographics 15
Race and Ethnicity 15
Gender 15
Income 15
Age 15
Scooter Sharing Demographics 16
Race and Ethnicity 16
Gender 17
Income 17
Age 17
Shared Micromobility and Public Transit Interactions 17
Impacts of Station-Based Bikesharing on Bus Ridership 20
Impacts of Station-Based Bikesharing on Rail Ridership 20
Impacts of Public Transportation on Station-Based Bikesharing Use 20
Impacts of Scooter Sharing on Public Transportation 20
Impacts of Shared Micromobility on Safety 21
Station-Based Bikesharing Safety Impacts 22
Scooter Sharing Safety Impacts 23
Summary 23
Expert Interviews **24**
Impacts of Shared Micromobility on Public Transit 26
Evaluation Metrics to Enhance Understanding of Shared Micromobility's Impact on Public Transportation 26
Shared Micromobility and Public Transit Interactions 28
Summary 29

Shared Micromobility Activity Data **31**
Background on Data and Data Processing 31
Categorizing Rail Transit Connection Trips 34
Distance of Origin or Destination from Start from a Rail Transit Station Entrance 35
Identifying Trips that Substitute for Rail Transit Trips 37
Identifying Trips that Fall within GTFS-defined Schedule of Rail System Operation 37
Results and Discussion 39
Weekly Patterns of Travel 39
Daily Travel Patterns 40
Patterns of Distance and Time Traveled 41
Percentage of Trips Connecting to Public Transit with Bikesharing 43
Spatial Distribution of Public Transit Connections 44
Characteristics of Trips that Connect to Public Transit 46
Summary 48
Shared Micromobility Survey **50**
Bikesharing Connections to Public Transit 52
Summary 58
Conclusion **60**
Shared Micromobility and Public Transit 60
Shared Micromobility Safety Impacts 60
Shared Micromobility Performance Metrics 60
User Surveys 60
Appendix A: Expert Interview Protocol **63**
References **651**

List of Tables

Table 1. Station-Based Bikesharing, Scooter Sharing, and Public Transit User Demographics 11
Table 2. Race/Ethnicity of Scooter Sharing Users in Chicago, IL; Portland, OR; and San Francisco, CA...... 16
Table 3. Shared Micromobility and Public Transit Impacts 18
Table 4. Shared Micromobility Safety Impacts.. 21
Table 5. Summary of Expert Affiliations... 25
Table 6. Potential Data Sources for Integration Assessment 27
Table 7. Integration Strategies 29
Table 8: GBFS Data Structure 31
Table 9. System Types and Start/End Times of the Four U.S. Cities... 32
Table 10: GTFS Data Structure 33
Table 11. Rail Transit Agencies in the Four U.S. Cities 34
Table 12. Statistics of Trip Distance 46

List of Figures

Figure 1. Generalization of Public Transit Access and Egress Trips... 36
Figure 2. 100m Radius around Downtown Berkeley Station 36
Figure 3. Transit Connecting Station Assignment when Connecting Radii of Two Stations Overlap 37
Figure 4. Generalization of Trip where Bikesharing Substitutes for Public Transit 37
Figure 5. Criteria on Incorporating Transit Schedules for Access Trips (left) and Egress Trips (right) 38
Figure 6. Distribution of Station-Based and Dockless Trips in the Four U.S. Cities 39
Figure 7. Trip Distribution by Day of Week 40
Figure 8. Trip Distribution by Time of Day 41
Figure 9. Distribution of Trip Distance 42
Figure 10. Distribution of Trip Duration 42
Figure 11. Percentage of Connection Trips by City 43
Figure 12. Percentage of Connection Trips by City with GFTS Measures.. 44
Figure 13. Spatial Distribution of Connections by Station 45
Figure 14. Trip Distribution by Day of Week with GTFS Measures (Connections) 47
Figure 15. Trip Distribution by Time of Day with GTFS Measures (Connections) 48
Figure 16. Distribution of Survey Sample and Population Income 50
Figure 17. Distribution of Survey Sample and Population Education 51
Figure 18. Distribution of Survey Sample and Population Age 52
Figure 19. Distribution of Race/Ethnicity 52
Figure 20. Distribution of Mode Use of the Survey Sample 53
Figure 21. Frequency of Use of Shared Micromobility Modes.. 54
Figure 22. Mode Substitution from Shared Micromobility 55
Figure 23. Frequency of Shared Micromobility Connecting to Public Transit... 56
Figure 24. Distribution of Distance Traveled to Connect to Public Transit 57
Figure 25. Distribution of Time Traveled to Connect to Public Transit 58

EXECUTIVE SUMMARY

Shared micromobility - the shared use of a bicycle (i.e., bikesharing), scooter (i.e., scooter sharing), or other low-speed mode - presents an opportunity to provide first- and last-mile connections to public transportation. Existing literature on shared micromobility fairly consistently shows that bike and scooter sharing users tend to be disproportionately Caucasian, male, higher-income earners, and younger. These findings may be due to a number of factors, such as safety concerns by female users and device placement that underrepresents low-income and minority communities. Literature on shared micromobility modal behavior suggests that bike and scooter sharing have the potential to serve first- and last- mile trips to public transportation but may also compete with transit depending on context. Shared micromobility may also impact the safety of users and non-users when riders travel in the opposite direction of traffic, at high speeds, and/or engage in traffic violations (e.g., running stop signs and red lights). Supportive infrastructure (e.g., protected bike lanes); slower speed limits; curbspace management; and enforcement have the potential to improve safety outcomes. The literature also revealed that shared micromobility may cause safety concerns when devices are not used properly, ridden at high speeds, and/or used without proper protective equipment (e.g., helmets). These behaviors can cause safety concerns for travelers, including transit riders waiting, accessing, or egressing transit stops. The objectives of this study are to understand: 1) if shared micromobility complements or competes with public transportation; 2) the relationship between different shared micromobility services; 3) how different shared micromobility services impact safety; and 4) how the impacts of shared micromobility on public transportation are measured.

The experts (n=19) interviewed in Fall 2019 indicated that there is early evidence to suggest that shared micromobility may impact public transit by both increasing ridership by filling service gaps and decreasing ridership by replacing public transit trips, depending on the context of where these services are deployed. For example, shared micromobility may be more likely to compete with public transportation if shared micromobility is employed in an environment with limited spatial or temporal coverage. These experts suggest that shared micromobility may offer a more suitable alternative for replacing transit than connecting to an out-of-the-way route with infrequent service. However, more research is needed to examine this dynamic. The experts offered insight on performance metrics for continued research, monitoring, and evaluation. The metrics included connections to and from public transit, public transit trips replaced by shared micromobility, shared micromobility trips that did not connect to public transit, and difficult to classify shared micromobility trips. However, the data used to support these metrics (e.g., Global Positioning System information) may be limited and/or inaccurate. The experts also suggest that understanding shard micromobility’s relationship to public transportation may be far less important than understanding its impact on private vehicle ownership and use.

Bikesharing ridership and public transit interactions were also analyzed using trip activity data for four of the largest California cities with rail systems – San Francisco, Los Angeles, Sacramento, and San Jose for between October 2019 and February 2020. The data revealed that bikesharing, both station-based and dockless, was used most frequently in the middle of the week with a sharp decrease in use from Friday to Saturday. In Sacramento, Los Angeles, and San Jose, most bikesharing activity occurred during the daytime (i.e., between 8:00 AM and 6:00 PM). However, dockless bikesharing appeared to be more popular later at night and earlier in the morning. Trips in San Francisco tended to be the longest (2,198 m), followed by San Jose (1,630 m), Los Angeles (1,229 m), and Sacramento (1,179 m). Researchers applied criteria to identify trips that were likely to connect to public transit (e.g., origin or termination near the station, trip time, nearness of trip to train arrival or departure, etc.). The analysis included 1,191,560 trips and revealed that an estimated 18.6 percent, 14.9 percent, 14.6 percent, and 7.9 percent of bikesharing trips connected to and from public transit in San Francisco, Los Angeles, Sacramento, and San Jose, respectively.

The user surveys included 1,029 respondents in the San Francisco Bay Area; they were collected between August 2020 and February 2021. The respondents were relatively representative of the region's demographic makeup, with slight variations from the male to female split, income brackets between $100,000 to $150,000 and over $200,000 per year, as well as the share of high school/GED attainment. The surveys revealed that shared micromobility users constituted about 6.7 percent of all respondents. Relative to the population overall, shared micromobility users were more likely to be younger, more likely to be male, somewhat more likely to be white, and had slightly higher incomes and educational attainment levels. The usage data showed that shared micromobility a large share (at least 50%, depending on the mode) users tend to do use these modes rather regularly (i.e., at least one to three times per week). If shared micromobility was not available most users would have driven alone in a personal vehicle, taken a transportation network company or taxi, walked, or taken a personal bicycle. The responses revealed that shared micromobility connections to public transit was a trip purpose used at some point by the vast majority of respondents. For example, all of the respondents using conventional bikesharing reported using it to connect to public transit at some point, while 95% of those using electric bikesharing, and 97% of those using scooter sharing reported the same. On average, this connection to public transit was about 1.9 miles or about 15 minutes.

Shared micromobility may not only impact public transit ridership, but also safety. This can include the safety of public transit riders (particularly those accessing and egressing vehicles), vehicle operators, and pedestrians. For example, shared micromobility can impact pedestrian and public transit safety when users improperly park and ride devices, as well as engage in unsafe or erratic behavior, including failing to follow traffic laws and not wearing helmets. While the study suggests that bike and scooter sharing may complement public transit by bridging first- and last-mile gaps (, experts interviewed believe that more research and data are needed to confirm this relationship and impacts of shared micromobility on public transit through improved data collection methods and metrics. Future metrics should focus on understanding why some trips replace others and leverage data from sources, such as data dashboards, ridership data, and stated preferences for mode choices.

INTRODUCTION

Public transit agencies throughout California are facing challenges such as increased operating costs and competition from shared mobility (e.g., transportation network companies [TNCs][1]), decreased ridership and revenue due to COVID-19 (and even prior to the pandemic), and greater accessibility of personal vehicles for riders (Taylor et al., 2020). These agencies are looking at innovative strategies to help address these challenges. Some public transit agencies are experimenting with mobility services for first- and last-mile connections to public transportation, such as shared micromobility. Shared micromobility is the shared use of a bicycle, scooter, or other low-speed mode that enables short-term access to a transportation service on an as-needed basis (Shaheen et al., 2019). Today, shared micromobility includes a growing number of device types and form factors (e.g., electric bicycles [e-bikes], moped scooters). Shared micromobility typically encompasses two modes: bikesharing and scooter sharing. Shared micromobility is usually deployed using one of three common service models Shaheen and Cohen (2019):

1. **Station-Based Services:** Systems in which users access bicycles or scooters via unattended stations offering one-way station-based service (i.e., bicycles/scooters can be returned to any station).
2. **Dockless Systems:** Systems in which users may check out a bicycle/scooter and return it to any location within a predefined geographic region. Dockless systems can include business-to-consumer or peer-to-peer systems enabled through third-party hardware and applications.
3. **Hybrid Systems:** Systems in which users can check out a bicycle/scooter from a station and end their trip by either returning it to a station or a non-station location. Alternatively, users can pick up any dockless bicycle/scooter and either return it to a station or any non-station location.

COMMON TERMS AND DEFINITIONS

Bikesharing provides users with on demand access to bicycles at a variety of pick up and drop off locations for one way (point to point) or roundtrip travel. Bikesharing fleets are commonly deployed in a network within a metropolitan region, city, neighborhood, employment center, and/or university campus (Shaheen, et al., 2020).

Scooter sharing allows individuals access to scooters by joining an organization that maintains a fleet of scooters at various locations. Scooter sharing models can include a variety of motorized and non motorized scooter types. The scooter service typically provides gasoline or electric charge (in the case of motorized scooters), maintenance, and may include parking as part of the service (Shaheen et al., 2019).

The National Association of City Transportation Officials (NACTO) estimates that between 2010 to 2019 people in the United States took over 343 million shared micromobility trips. In 2019, approximately 136

[1]Transportation Network Companies also referred to as TNCs, ridesourcing, and ridehailing) provide prearranged and on-demand transportation services for compensation in which drivers of personal vehicles connect with passengers. Digital applications are typically used for booking, electronic payment, and ratings.

shared micromobility trips were made in the U.S., more than a 60 percent increase from 2018 (NACTO, 2019). Over 40 million (almost 30 percent) and 10 million (approximately seven percent) of 2019 shared micromobility rides were taken on station-based and dockless bikesharing systems, respectively. Dockless scooter sharing made up 86 million (roughly 63 percent) of shared micromobility trips.

Shared micromobility presents a number of potential opportunities and challenges for public transportation. For example, shared micromobility has the potential to provide additional mobility in a variety of built environments and may also complement public transit by bridging first- and last-mile connections to public transit (City of Austin, 2019; Denver Public Works, 2019). However, there are concerns that shared micromobility could also compete with public transit. More research is needed to understand the relationship between and impacts of shared micromobility on public transportation. Research is also needed to understand how the global pandemic may impacting these relationships and long-term ridership trends. As mobility evolves through the pandemic recovery, changes in travel behavior will need to be monitored to inform future transportation planning decisions.

This study attempts to answer the three research questions:

- Do station-based and dockless shared micromobility services complement or compete with public transportation?
- What is the relationship between different shared micromobility services (e.g., station-based and dockless services; bike and scooter sharing)?
- How do different shared micromobility services impact safety?
- How are the impacts of shared micromobility on public transportation measured?

The goal of this report is to help inform transportation planning decision-making by increasing the understanding of the relationship between shared micromobility and public transit through a variety of research approaches. The report is organized into six sections:

1. **Methodology:** This section provides an overview of how each of the research approaches were completed.
2. **Literature Review:** This section summarizes and analyzes recent literature on shared micromobility and public transit user demographics and equity considerations, interactions between shared micromobility and public transit, and safety considerations.
3. **Expert Interviews:** This section provides a summary and analysis of interviews with 19 experts on shared micromobility and public transit experts from the public, private, non-profit sectors, and community-based organizations completed in Fall 2019.
4. **Activity Data Analysis:** This section includes an analysis of bikesharing and public transit data to estimate the number of trips that connected the services.
5. **User Surveys:** This section evaluates survey findings from a survey of 1,029 shared micromobility users.
6. **Conclusion:** The final section concludes with a summary of key takeaways and recommendations for additional research.

METHODOLOGY

This study employed a multi-method qualitative and quantitative approach to researching the relationship and impacts of shared micromobility and public transit. Researchers employed four methods:

1. **Literature Review:** The authors reviewed 135 reports and peer-reviewed journal articles on shared micromobility and public transit that included user demographics, equity considerations, interactions between shared micromobility and public transit, and safety impacts. The literature review was also supplemented with an Internet search for emerging practices and trends in response to COVID-19 and emerging transportation technologies. Literature that did not specify the shared micromobility service model (e.g., station-based, dockless, or hybrid) or the type of transit system (e.g., rail, bus, etc.) were excluded. Key findings from this review informed the expert interviews and survey design. However, given this emerging topic and the vast number of industry developments, it is possible that some literature may have been inadvertently omitted.

2. **Expert Interviews.** In September and October 2019, researchers conducted interviews with 19 experts on shared micromobility (bikesharing and scooter sharing) and public transit. The experts interviewed represented a variety of stakeholders representing the public and private sectors, academia, non-profits, and community-based organizations. The experts were identified through their publication of academic papers, development of innovative micromobility and/or equity programs, operation of shared micromobility services, and/or for responsibility with integrating micromobility into the broader transportation network. The purpose of the expert interviews was to better understand the impacts of shared micromobility services on infrastructure, public transit, equity, and safety; obtain feedback on metrics to evaluate public transit and micromobility integration; and discuss strategies to encourage integration between these modes. Interviews were conducted remotely (e.g., via phone), lasted approximately one hour, and used an interview protocol (available in Appendix A: Expert Interview Protocol). The findings from the expert interviews were used to inform the survey implementation.

3. **User Surveys.** To better understand how people use micromobility to connect to public transit, a general population survey was deployed to people within the San Francisco Bay Area between August 2020 and February 2021. Data collection occurred over the course months because of the need to meet population quotas. Initial data collection was relatively quick, but as quotas were filled, the pace of collecting respondents with increasingly rare attributes slowed considerably. The survey contained questions about respondent demographics, home and work location, use of different transportation modes, travel impacts related to the COVID-19 pandemic, connections with public transit, and other questions related to interactions with urban infrastructure. The response to these questions helped inform the behavioral side of understanding how micromobility modes are used to make connections to public transit. At total sample size of 1,029 respondents were collected during the survey deployment. The survey deployment was designed to align with the American Community Survey distributions of the key attributes of the populations within Oakland and San Francisco. The quotas served to align the sample demographics with that of population as closely as possible. As quotas were filled, recruitment targeted demographic attributes that remained unfulfilled. The attributes for which quotas were defined included age, gender, race/ethnicity, income, and education. These quotas were met with some nearness to the population demographics, but even with management of the recruitment process, some departure from the quotas was necessary. This can happen towards the end of

recruitment as quotas box in the need to find respondents with rare demographics. For example, if quotas remain open for respondents of high income and low education, but closed for most other categories, then qualifying respondents for remaining recruitment must simultaneously meet both attributes at the same time. This dynamic can enforce the recruitment of rare individuals that ultimately becomes intractable over reasonable time. Hence, the final sample population ultimate exhibits some departure from the general population. A couple limitations exist with respect to the survey analysis. The first is to the survey analysis stem from the limited sample size. While the general population survey is useful for understanding the relative size of the population of shared micromobility users relative to the overall population, this can lead to small subsample sizes when the user population is relatively small. The small subsample can limit the capacity for further disaggregation. Additionally, the survey data faces the standard limitations associated with self-reported responses on activity. Such reporting can be subject to inaccuracy and uncertainty associated with respondent self-estimation and recollection.

4. **Activity Data.** Shared micromobility data from four of the largest California cities with rail systems (Los Angeles, Sacramento, San Jose, and San Francisco) were analyzed. The data included basic trip activity information (e.g., start and end points, start and end times) and were collected from October 2019 to February 2020. All vehicle types operating within these systems were included in the analysis, including docked and dockless bikesharing as well as dockless scooter sharing. Electric bikes and scooters were included alongside pedal-assist bikes within the data. Public transit data were also collected and analyzed. Both data were derived from the structures of the General Bikeshare Feed Specification and the General Transit Feed Specification. The evaluation attempted to identify the percentage of bikesharing trips that connected to and from public transit by developing a method for evaluating the number of connected trips.

   There are some noted limitations to the analytical methods applied to the activity data. The data evaluation only included the origin and destination of devices, not travelers. As a result, it is possible that some trips that were estimated as connections to public transit were not accurate (e.g., the public transit stop was not the traveler's destination). Similarly, some trips that were not included as transit connections could have connected to transit (e.g., if riders were willing to walk further to public transit stops or stations). The data evaluation was also limited by the fact that in most environments the method works reasonably well with public transit rail services, but not local public buses. Additionally, measuring a percent of transit connecting trips relies on consistency within the public transit system and these systems may not have consistence service. Despite these limitations, the evaluation offers an approach to measure bikesharing trips connecting to public transit.

LITERATURE REVIEW

According to the North American Bike Share Association, shared micromobility was available in 264 United States cities as of 2019 (NABSA, 2020). Shared micromobility has the potential to help bridge transit service gaps and also compete with public transportation. A key goal of this study is to better understand the interactions between public transit and shared micromobility, including whether or not shared micromobility is a competitor or complement to public transit. Additionally, the California Department of Transportation (Caltrans) wants to explore the impacts of shared micromobility, particularly on equity and safety.

This section summarizes the review of approximately 135 peer-reviewed and industry articles, reports, and documents that examine the relationship between, and impacts of shared micromobility on public transportation. This review is organized into three subsections including:

1. **User Demographics and Equity:** Demographics of public transit, station-based bikesharing, and dockless scooter sharing users with equity considerations;
2. **Impacts of Shared Micromobility on Public Transit**: Impacts of shared micromobility on public transit use; and
3. **Impacts of Shared Micromobility on Safety:** Safety impacts of shared micromobility on users and non-users.

User Demographics

Understanding who and who is not using shared micromobility may lend insight into whether or not these services are being equitably deployed, and accessible to a broad population. While studies of dockless micromobility are more limited, a number of studies of station-based bikesharing have documented user demographics (Shaheen et al., 2012; Shaheen et al., 2014). Lazarus et al. (2020) used the Spatial Temporal Economic Physiological (STEPS) framework to analyze data from two bikesharing companies in San Francisco, California. The analysis identified opportunities and challenges to improve service equity, including locations where the services could be expanded. Other studies have also examined the demographics of shared micromobility users. Table 1 summarizes the demographics of public transportation, station-based bikesharing, and dockless scooter sharing users. However, it should be noted that many of these studies were conducted prior to the global pandemic and service availability and the demographics of riders may have changed due to broader changes in travel patterns. For example, during the initial phase of the pandemic, some service providers removed devices or closed docking stations (Galehouse, 2020; Citi Bike, 2020). However, anecdotal evidence throughout the recovery phase suggests that some travelers may also be shifting to shared micromobility as a way of maintaining social distance and avoiding public transportation. Moreover, during the recovery a number of service providers have increased the availability of devices and are offering incentives (e.g., free trials, memberships), such as programs for essential workers (e.g., police officers, first responders) (Galehouse, 2020; Citi Bike, 2020; Bay Wheels, 2020; Capital Bikeshare, 2020).

Table 1. Station-Based Bikesharing, Scooter Sharing, and Public Transit User Demographics

Mode	Source *Location*	Race and Ethnicity	Gender	Household Income	Educational Attainment	Age
Public Transit	**U.S. Census Bureau (2017)** *North America*	50% Caucasian 24% Black 23% Hispanic 13% Asian	49.9% male 50.1% female	20% > $75,000 35% < $25,000		50% 25-44
Station-Based Bikesharing	**Shaheen et al. (2012)** *North America*	79% Caucasian 6% Asian 5% Other 4% Hispanic 4% Prefer not to answer 2% Black		133% > $100,00 15% <$35k	88% with a degree 11% without a degree	48% 25-34 21% 35-44 11% 18-24 10% 45-54 8% 55-64 1% 65+
	Uraski and Aultman-Hall (2015) *Arlington, Virginia; Boston, Massachusetts; New York City, New York; Seattle, Washington; Washington, D.C.*	**Arlington, VA** 35.4% Caucasian 5.2% Black **Boston, MA** 42.6% Caucasian 7.1% Black **Chicago, IL** 18.8% Caucasian 5.2% Black **Denver, CO** 19% Caucasian 1.6% Black **New York City, NY** 7.1% Caucasian 1.4% Black **Seattle, WA** 14% Caucasian 1.3% Black **Washington, D.C.** 41.5% Caucasian 42.6% Black		**Arlington, VA** 24.6% > $100,000 4% < $20,000 **Boston, MA** 18.6% > $100,000 14.8% < $20,000 **Chicago, IL** 8.7% > $100,000 6.1% < $20,000 **Denver, CO** 5.8% > $100,000 5.2% < $20,000 **New York City, NY** 4.3% > $100,000 2.2% < $20,000 **Seattle, WA** 4.7% > $100,000 4.8% < $20,000 **Washington, D.C.** 31.7% > $100,000 17% < $20,000	**Arlington, VA** 38% with a degree 13.6% without a degree **Boston, MA** 40.3% with a degree 22.3% without a degree **Chicago, IL** 18.1% with a degree 11.4% without a degree **Denver, CO** 14.4% with a degree 8.5% without a degree **New York City, NY** 7.2% with a degree 4.1% without a degree **Seattle, Washington** 13.3% with a degree 6.2% without a degree **Seattle, WA** 13.3% with a degree 6.2% without a degree **Washington, D.C.**	**Arlington, VA** 5.9 % 60+ **Boston, MA** 6.7% 60+ **Chicago, IL** 4% 60+ **Denver, CO** 3.4% 60+ **New York City, NY** 1.9% 60+ **Seattle, Washington** 2.7% 60+ **Seattle, WA** 2.7% 60+ **Washington, D.C.** 14.3% 60+

Mode	Source *Location*	Race and Ethnicity	Gender	Household Income	Educational Attainment	Age
					52.1% with a degree 41.5% without a degree	
	Shaheen et al. (2014) *Minneapolis and St. Paul, Minnesota and Salt Lake City, Utah*	**Minneapolis & St. Paul, MN** 92% Caucasian 5% Asian 2% Hispanic 1% Black 0% Other **Salt Lake City, UT** 89% Caucasian 5% Hispanic 3% Asian 1% Black 1% Other	**Minneapolis & St. Paul, MN** 55% male 45% female **Salt Lake City, UT** 66% male 34% female	**Minneapolis & St. Paul, MN** 25% > $100,000 8% < $15,000 **Salt Lake City, UT** 20% > $100,00 3% < $15,000	**Minneapolis & St. Paul, MN** 87% at least 2- or 3-year college **Salt Lake City, UT** 83% at least 2- or 3-year college	**Minneapolis & St. Paul, MN** 31% 25-34 28% 35-44 23% 45-54 8% 55-64 6% 16-24 4% 65+ **Salt Lake City, UT** 26% 25-34 21% 16-24 16% 35-44 15% 45-54 12% 55-64 10% 65+
	Buck et al. (2012) *Washington, D.C.*	**Annual Users** 81% Caucasian 7% Asian 5% Hispanic 5% Other 3% Black **Short-Term Users** 78% Caucasian 8% Asian 5% Black 4% Hispanic 3% Other 41.5% Caucasian 42.6% Black	**Annual Users** 55% male 45% female **Short-Term Users** 52% female 48% male			**Annual Users** 55% 25-34 20% 35-44 12% 16-24 10% 45-54 5% 55+ **Short-Term Users** 43% 25-34 17% 35-44 17% 16-24 16% 45-54 7% 55+

Mode	Source *Location*	Race and Ethnicity	Gender	Household Income	Educational Attainment	Age
Dockless Scooter Sharing	**City of Chicago (2020)** *Chicago, Illinois*	72% Caucasian 12% Hispanic 8% Asian 6% Black 3% Other 1% American Indian	61 to 69% male	52 to 64% > $75,000		
	Denver Public Works (2019) *Denver, Colorado*		61 to 69% male	52 to 64% > $75,000		47% < 35 4% > 55
	City of Portland (2018) *Portland, Oregon*	71% Caucasian 10% Hispanic 7% Asian 6% Black 5% Other 1% American Indian	61 to 69% male	36% > $75,000		
	City of Santa Monica (2019) *Santa Monica, California*		61 to 69% male	52 to 64% > $75,000		33% > 55
	SFMTA (2019) *San Francisco, California*	61% Caucasian 16% Asian 11% Other 7% Hispanic 2% Black	81% male	9% low-income (i.e., identify for government assistance)		

Station-Based Bikesharing Demographics

Studies on station-based bikesharing have generally found that users tend to be Caucasian, male, and younger (typically 25 to 44 years old) and have higher incomes and levels of educational attainment (North America Bikeshare Association, 2020). This section summarizes existing research documenting the demographics of station-based bikesharing users, including race/ethnicity, gender, income, and age.

Race and Ethnicity

A number of studies from multiple North American cities have found that station-based bikesharing users are often disproportionately Caucasian in comparison to the general population of each city where the service was studied. In a study of station-based bikesharing in seven U.S. cities, Ursaki and Aultman-Hall (2015) found that only New York City (NYC)'s bikesharing system served African-American and white residents similarly. In the other cities (Arlington, Virginia; Boston, Massachusetts; Chicago, Illinois; Denver, Colorado; Seattle, Washington; and Washington, D.C.) predominantly served Caucasians. However, another study by the NYC Department of Transportation found that bikesharing was primarily used by white residents (NYC, 2018). Similar socio-demographic findings have also been documented in studies of Capital Bikeshare in Washington, D.C. and Indego in Philadelphia (LDA Consulting, 2017; Indego, 2018). Earlier, multi-city North American studies of station-based bikesharing also documented a disproportionate use by white households (Shaheen et al., 2012; Shaheen et al., 2014).

Gender

Existing North American studies have generally found that that station-based bikesharing users tend to be disproportionately male (LDA Consulting, 2017; NYC DOT, 2018; Shaheen et al., 2014). A study of station-based bikesharing users found that in five cities (Minneapolis, Minnesota; Montreal, Canada; Salt Lake City, Utah; Saint Paul, Minnesota; and Toronto, Canada) only the bikesharing system in Montreal, Canada were 50 percent of users female. In the other locations users tended to be male, ranging from 55 to 70 percent (Shaheen et al., 2014). It is hypothesized that women may use bikesharing less due to safety concerns, such as cycling around vehicle traffic (Kaufman et al., 2014). Women may also be less likely to use bikesharing due to differences in typical household roles that may contribute to women having shorter commute distances, completing more non-work trips, and traveling at off-peak hours (International Transport Forum, 2018).

Income

Studies of station-based bikesharing have found that users tend have higher incomes than the general population (Indego, 2018; NYC DOT, 2018; Shaheen et al., 2014). However, the placement of bikesharing stations in more affluent neighborhoods may contribute to this dynamic. Ursaki and Aultman-Hall (2015) found that bikesharing service areas in major American cities tended to be in more affluent areas, with service areas in six out of seven cities comprised of higher percentages of households earning more than $100,000. Another study found that only 11.9 percent of bikesharing stations were located in census tracts with high levels of economic hardship (Smith et al., 2015). However, in some North American studies the lower income respondents were proportionately represented in surveys, possibly due to the lower cost of season and annual memberships of station-based programs, and income-based equity programs offered by a number of micromobility service providers (North American Bikeshare Association, 2020).

Age

Studies have found station-based bikesharing use is higher among younger adults (LDA Consulting, 2017; NYC DOT, 2018; Shaheen et al., 2014). A study of Capital Bikeshare users found that 51 percent were under 35 years old (LDA Consulting, 2017). Higher use among younger adults may also be related to service areas and station placement. Similarly, Ursaki and Aultman-Hall (2015) found that only 1.9 to 14.3 percent of residents were over 60 years old, lower than the general population in the seven cities studied.

Scooter Sharing Demographics

Several city governments have analyzed the impacts of their scooter sharing pilot programs providing some early insight into the user demographics of these demonstrations. Broadly, these studies have found that scooter sharing users tend to have similar demographic profiles to station-based bikesharing users (often Caucasian, young, male, and higher income). This section reviews key findings of the demographics (race/ethnicity, gender, income, and age) of scooter sharing users.

Race and Ethnicity

Studies in Chicago, Portland, and San Francisco found that 61 to 73 percent of scooter sharing users identified as Caucasian (City of Chicago, 2020; City of Portland, 2018; SFMTA, 2019). Table 2 compares the user demographics from these scooter sharing demonstrations to the 2017 American Community Survey (ACS) data in each location. Portland's user demographics most closely align with the general population whereas the Chicago study found a disparity between the 72 percent of scooter sharing users who are Caucasian yet only comprise of 33 percent of the city's population.

Do Bikesharing and Scooter Sharing Users Overlap?

The City of Oakland (2019) analyzed shared mobility operator data (scooter sharing, bikesharing, and free-floating carsharing) for the year 2018 and concluded that the introduction of scooters had little impact on the use of other shared modes. The city hypothesized that scooter sharing was used by different users or for different types of trips than bikesharing and carsharing. The City of Austin (2019) found some overlap between scooter sharing and dockless bikesharing users. Of 9,560 respondents to a community survey, 25 percent used only scooter sharing, three percent used only dockless bikesharing, and 13 percent used both. In Portland, PBOT (2019) found that 74 percent of scooter users had never used the station-based bikesharing and 42 percent had never cycled.

Table 2. Race/Ethnicity of Scooter Sharing Users in Chicago, IL; Portland, OR; and San Francisco, CA

Race/Ethnicity	San Francisco		Chicago		Portland*	
	Users	2017 ACS	Users	2017 ACS	Users	2017 ACS
Caucasian	61%	38%	72%	33%	73%	71%
Black	2%	6%	6%	30%	3%	6%
Hispanic	7%	39%	12%	29%	8%	10%
Asian	16%	14%	8%	7%	9%	7%
American Indian /Alaska Native	n/a	1%	1%	1%	2%	1%
Other and/or Mixed	11%	3%	3%	1%	n/a	5%

**Includes only Respondents who live and/or work in Portland*

However, other studies suggest that non-white riders may be more likely to try scooter sharing (Sanders et al., 2019). The Portland Bureau of Transportation (PBOT) completed two focus groups (n=22) with black residents of Portland and East Portland, Oregon. The majority of focus group participants viewed scooters positively, although some concerns regarding policing and racial profiling were also raised (Portland Bureau of Transportation, 2019). However, the focus recruitment process and selection criteria was not published making it difficult to validate the research findings.

PBOT also distributed an online survey (n=301) to understand scooter sharing ridership trends and perspectives among different demographic segments. The survey found that more than 70 percent of people of color had a positive perception of scooter sharing (Portland Bureau of Transportation, 2019). Scooter sharing demonstrations that target historically underserved communities may be expanding access to these communities. For example, a four-month long scooter sharing pilot in Chicago, Illinois required the operators to locate 50 percent of micromobility devices in “Priority Sub-Areas” (i.e., locations that were historically under-resourced) (City of Chicago, n.d.). The Application Programming Interface (API) used on one day of the pilot to analyze device locations verified that an average of 48.7 percent of devices were located in the Priority Sub-Areas (Smith and Schwieterman, 2019).

Gender

Studies have found that the majority of scooter sharing users tend to be male (e.g., 81 percent in San Francisco and 61 to 69 percent in Chicago, Portland, Santa Monica, and Denver) (City of Chicago, 2020; City of Portland, 2018; City of Santa Monica, 2019; Denver Public Works, 2019; SFMTA, 2019). Women may also be encouraged to use shared electric scooters due to the relatively low physical effort needed to operate them. However, shared micromobility user surveys from San Francisco, California found that more females used dockless bikesharing than scooter sharing (26 and 17 percent, respectively) (Barnes, 2019), perhaps due to safety concerns associated with scooter sharing (Sanders et al., 2019).

Income

Studies have generally found that users of scooter sharing tend to have higher household incomes. In San Francisco, California, only nine percent of users were low-income. In Chicago, Illinois; Santa Monica, California; and Denver, Colorado, 52 to 64 percent of users had a household income greater than $75,000 (City of Chicago, 2020; City of Santa Monica, 2019; Denver Public Works, 2019; SFMTA, 2019). Portland, Oregon was an exception, however, with only 36 percent of users have a household income greater than $75,000 (City of Portland, 2018). One study in Arlington, Virginia showed higher use from households with incomes below median incomes suggesting that scooter sharing may be an attractive option for lower-income residents (Arnell, 2019).

Age

Studies have found that scooter sharing tends to be used more by younger adults. For example, 47 percent of users in Denver and approximately two thirds of users in Santa Monica were under 35 years old. In contrast, only four percent of users in Denver and five percent in Santa Monica were over 55 years old (City of Santa Monica, 2019; Denver Public Works, 2019).

Shared Micromobility and Public Transit Interactions

Shared micromobility presents an opportunity to complement public transit by filling service gaps, such as offering first- and last-mile connections. However, shared micromobility may compete with or replace public transit trips. The impacts of shared micromobility on public transportation likely vary by service model, device type, built environment, and location of program deployment, and other context-specific variables. Table 3 summarizes existing studies that document the relationships between shared micromobility and public transit. However, the impacts of COVID-19 on traveler behavior, transit service frequency, geographic coverage, and fares may impact the relationship between micromobility and public transportation. Service reductions and social distancing may be impacting travelers' willingness to use the services, trip lengths, frequency of use, and the types of trips used for micromobility and public transportation.

The following section is organized into two subsections. The first section details the relationships between station-based bikesharing and public transit. The second section describes scooter sharing's impacts on public transit.

Table 3. Shared Micromobility and Public Transit Impacts

Study *Location*	**Methodology**	**Findings**
Station-Based Bikesharing's Impacts on Bus Ridership		
Campbell and Brakewood (2017)* *New York City, New York*	Difference-in-differences regression model	Every thousand bikesharing docks along a bus route were associated with a 2.42% reduction in daily unlinked trips and a 1.69% reduction in bus trips when the presence of bike lane infrastructure was controlled for. Bus routes with the mean number of bikesharing docks had a 3.3% reduction in unlinked trips.
Shaheen et al. (2015)*, Shaheen et al. (2016)* *North America*	Two-part bikesharing study	Bikesharing in larger cities competed with bus systems but complemented bus systems in smaller cities.
Station-Based Bikesharing's Impacts on Rail Ridership		
Ma et al. (2019)* *Washington, D.C.*	Origin-destination spatial analysis by year and season Ordinary Least Squares Regression analysis	A 10% increase in annual bikesharing ridership contributed to a 2.8% increase in average daily rail ridership. About 60% of bikesharing members used metro rail less often after joining bikesharing.
Public Transit's Impacts on Station-Based Bikesharing		
Kaufman et al. (2015)* *New York City, New York*	ArcGIS software analysis using spatial, ridership, station activity, and station location data	The busiest bikesharing stations were adjacent to major public transit hubs. A correlation existed between existing transit infrastructure and bikesharing use.
Kaviti et al. (2018)* *Washington, D.C.*	Two-tailed t test	Transit maintenance and cheaper one-ride fare options increased first-time casual bikesharing ridership by 79% and monthly ridership by 41%, but this did not last long after transit maintenance projects were done.
Dockless Scooter Sharing's Impacts on Public Transit		
Barnes (2019) *San Francisco, California*	User survey and crosstab analysis, quantitative estimates, comparative descriptive analysis, and content analysis	Scooter sharing induced transit trips 5 times faster than they replaced them. A user survey showed that nearly 30% of all scooter trips induced new transit trips. Around 6% of scooter users would have taken transit for their trip if a scooter wasn't available.
City of Austin (2019) *Austin, Texas*	Online and paper survey to community members that includes members and non-members	Users found that scooter sharing made using public transit easier.

Study *Location*	**Methodology**	**Findings**
Denver Public Works (2019) *Denver, Colorado*	Online survey of a total of 2,000 users and non-users	The frequency with which users accessed public transit with scooter sharing included: • 44% never accessed transit with a scooter, • 37% occasionally accessed transit with a scooter, • 12% accessed transit one to three times per week with a scooter, and • 7% accessed transit three or more times per week with a scooter.
Lime (2018) *San Francisco, California*	User survey distributed to 7,000 users with 600 responses	About 39% of users combined Lime scooters with public transit.
Portland Bureau of Transportation (2019) *Portland, Oregon*	Survey of 4,500 users	The survey asked "How often do you use electric scooters [i.e., standing electric scooters] to access a bus, MAX, or streetcar?" and received the following responses: • 61% never used them for access, • 27% used them occasionally but less than once per week, • 8% used them one to three times per week, • 2% used them three to six times per week, • 1% used them daily, and • 0.42% used them more than once per day.
Scoot (2019) *San Francisco, California*	Survey of 3,000 moped riders	An estimated 19% of moped users said their top use of scooter sharing is to connect to public transit.
SFMTA (2019) *San Francisco, California*	Evaluation of ridership impacts based on five principles: 1) pilot progress, 2) safety and accessibility, 3) complaints and citations, 4) inclusive and equitable service, and 5) ridership and demand	On their last trip, 34% of survey respondents used the service to get to or from public transportation. Nearly 28% of respondents would not have taken transit if a scooter was not available but used the service to connect to transit. About 7% of respondents would have taken transit had a scooter not been available and did not use the service to connect to transit.
Skip (2019) *San Francisco, California*	User survey	A reported 61% of Skip riders use public transportation in their day-to-day lives.

**Denotes peer reviewed literature.*

Impacts of Station-Based Bikesharing on Bus Ridership

A number of pre-pandemic studies have documented the impacts of station-based bikesharing on public transit ridership and use. Campbell and Brakewood (2017) used a difference-in-differences regression model to measure how the introduction of bikesharing in New York City impacted bus routes. The researchers found that every thousand bikesharing docks along a bus route was associated with a 2.42 percent reduction in daily unlinked bus trips. A second model that controlled for new bike lane infrastructure found a 1.69 percent reduction in bus trips. Examining full fare, unlinked bus trips, the researchers found a 3.13 percent reduction. Bus routes with the mean number of bikesharing docks saw a 3.3 percent reduction in unlinked bus trips.

Unlinked trips (also known as boardings) refer to the number of times passengers board public transit vehicles. Passengers are counted each time they board vehicles no matter how many vehicles they use to travel from their origin to their destination and regardless of whether they pay a fare, use a pass or transfer, ride for free, or pay in some other way (APTA, n.d.).

Shaheen et al. (2015 and 2016) studied the impacts of station-based systems on mode choice in North America. The results of a comparative analysis of the Twin Cities and Washington D.C. suggested that station-based bikesharing in larger cities competed with bus systems, but possibly provided first- and last-mile connections to public transit in smaller cities. Respondents reported that rail usage decreased in larger cities due to faster travel speeds and cost savings from bikesharing (Shaheen and Chan, 2016).

Impacts of Station-Based Bikesharing on Rail Ridership

The impacts of station-based bikesharing's on public transit may vary between bus and rail services. A study by Ma et al. (2019) quantified bikesharing's impacts on rail ridership in Washington, D.C. using: 1) origin-destination spatial analyses by year and season to investigate trip patterns, and 2) Ordinary Least Squares regression analysis. The researchers found that a 10 percent increase in annual Capital Bikesharing (CaBi) ridership contributed to a 2.8 percent increase in average daily Metrorail ridership. The researchers found a large demand for CaBi in suburban areas. Ma et al. (2019) also examined bikesharing-transit interactions through a survey of CaBi users. The study found that 54 percent of respondents reported that a Metrorail station was their trip origin or destination. Sixty-one percent of respondents reported that they used Metrorail less often and four percent more often after joining the CaBi program. Finally, 17 percent stated that they would support expansion of the CaBi program near Metrorail stations.

Impacts of Public Transportation on Station-Based Bikesharing Use

While bikesharing may impact public transit, public transit may similarly impact station-based bikesharing use. Kaviti et al. (2018) studied changes in bikesharing ridership and revenue in Washington, D.C. after the introduction of regular transit disruptions. Using a two-tailed t test, the authors found that transit maintenance and a cheaper one-ride fare option increased first-time casual bikesharing ridership by 79 percent and monthly casual ridership by 41 percent. Kaufman et al. (2015) also examined the impacts of public transit on station-based bikesharing using geographic information systems (GIS) to analyze connections between Citi Bike and public transit in New York City. The study found that the highest use bikesharing stations were adjacent to large transit hubs. The authors also found that bikesharing trips tended to correlate with the morning and evening commutes.

Impacts of Scooter Sharing on Public Transportation

A number of public agencies and service providers have conducted pre-pandemic exploratory studies to understand the relationship and impacts of scooter sharing on public transit use. SFMTA (2019) studied the impacts of scooter sharing by analyzing data collected by two scooter sharing operators. The data showed that standing electric scooters induced public transit trips at approximately four times the rate that they replaced transit trips, suggesting that scooter sharing has the potential to complement public transit. The City of Austin (2019) examined the impacts of scooter sharing on public transit through a survey of residents (n=9,299). Common survey responses regarding scooter sharing characteristics included making bus and/or rail use easier, offering easier and more reliable public transit connections, and improving access to public transit stops and stations.

Impacts of Shared Micromobility on Safety

Shared micromobility may not only impact public transit ridership, but also safety. This can include the safety of public transit riders (particularly those accessing and egressing vehicles), vehicle operators, and pedestrians. A number of exploratory studies can help to inform potential safety concerns related to the interaction between transit and micromobility. Table 4 summarizes these studies.

Table 4. Shared Micromobility Safety Impacts

Source **Location**	**Methodology**	**Finding**
Station-Based Bikesharing		
Ballus-Armet et al. (2014) *Minneapolis, Minnesota and Washington, D.C.*	Cross-sectional analysis of bicycle counts and crash data	Strategically located bikesharing stations can address rising bikesharing collisions.
Langford et al. (2015) *Knoxville, Tennessee*	Naturalistic GPS-based safety study between traditional and electric bicycle riders	Traditional bicycle users rode the wrong way on 45% of street segments, at 6.5 miles per hour (mph) on roads, and at 7.8 mph on greenways. E-bike users rode the wrong way on 44% of street segments, at 8.3 mph on roads, and at 6.8 mph on greenways. Higher speeds were correlated with higher stop sign violations.
Martin et al. (2016) *San Francisco Bay Area, California*	Focus groups, expert interviews, and an analysis of bicycle and bikesharing activity data	Strategically located bikesharing stations and education and outreach efforts can help increase safety.
Moon-Miklaucic et al. (2019) *Multiple national and international locations*	Review of bikesharing growth and review of recent technology, data, and business model developments	Safety considerations, including data set evaluation, were critical for bikesharing success.
Si et al. (2019) *Multiple national and international locations*	Scientometric review of 208 bikesharing related articles analyzed through a co-occurrence, time zone, view, and cluster analysis	Infrastructure supports were critical components to improving safety.
Reese (2020) *North American Cities*	Research conducted through roundtables, workshops, and webinars	Infrastructure investments could support safe bikesharing. Improved bikesharing safety could improve ridership and encourage drivers to adopt safer behaviors.

Source Location	Methodology	Finding
Kim et al. (2021) *Honolulu, Hawaii*	Descriptive statistics and logistic regression models to identify and model relationships between bicyclist characteristics and traffic violations	Users were more likely than other cyclists to commit traffic violations, potentially impacting surrounding rights-of-way users. Traffic safety could be improved through regulation enforcement, rights-of-way engineering, and bikesharing management.
Dockless Scooter Sharing		
Anderson-Hall (2019) *United States cities*	Review of shared micromobility policies, news articles, and reports	Safety considerations may impact where devices are ridden. Standardized operations could improve scooter sharing safety.
Todd et al. (2019) *Los Angeles, California*	Observational study of scooter sharing users whose behaviors were quantified and reviewed according to local policies	While scooter sharing users may be licensed to operate motor vehicles, they may have no or limited experience operating scooters. The presence of scooters around high traffic volumes increased the risk of interactions between different road users.
Puzio et al. (2020) *Indianapolis, Indiana*	Multicenter, retrospective study conducted at two Level 1 trauma enters	Scooter sharing accidents were caused by a lack of protective gear and use of alcohol.
Cicchino et al. (2021) *Washington, D.C.*	Interviews with 105 adults injured while riding scooters supplemented with charts and evaluated through a logistic regression	Scooters ridden on the road presented more severe injuries to riders, but devices ridden on the sidewalk could lead to more conflicts with rights-of-way users.
Iroz-Elardo and Currans (2021) *North American cities*	Systematic review of scooter articles through November 2019 and analysis of data	Age and lack of helmet use contributed to scooter sharing accidents. Data standardization and sharing between stakeholders could improve safety. Specific hours of availability could improve safety.

Station-Based Bikesharing Safety Impacts

A number of studies have examined the safety of station-based bikesharing in a variety of contexts. Research on Hawaii's Biki system found that bikesharing users were more likely than other cyclists to commit traffic violations, potentially contributing to safety-related concerns (Kim et al., 2021). Research on bikesharing at the University of Tennessee, Knoxville identified unsafe behavior and high numbers of traffic violations from bikesharing users (Langford et al., 2015). The study found that standard and electric bicycle riders rode the wrong way on 45 and 44 percent of street segments, respectively. E-bike users had typically higher on-road speeds (8.3 mph) than traditional bike riders (6.5 mph). Bicycle and e-bike riders ran red lights at similar rates, approximately 70 percent of the time (Langford et al., 2015). Research has helped identify bikesharing challenges and strategies to address them (Si et al., 2019). Infrastructure investments (e.g., separated bike lanes, well-marked intersections) can support safe bikesharing use (Reese, 2020; Ballus-Armet et al., 2014). Additionally, strategically locating bikesharing stations can address increased bikesharing collisions resulting from an increase in cyclists (Ballus-Armet et al., 2014). Stations located in dense, urban environments and on roads with lower speeds and higher levels of pedestrian activity are typically accompanied by motorists who look out for pedestrians and bicyclists.

This can reduce potential collisions between bicyclists and drivers (Martin et al., 2016). These changes can potentially increase safety for surrounding rights-of-way users. Awareness of traffic safety can also be supported by improving enforcement, rights-of-way, and curbspace management (Kim et al., 2021; Martin et al., 2016). Permit processes and regulatory standards can help public agencies better address bikesharing safety concerns.

Scooter Sharing Safety Impacts

Similar to bikesharing, scooter sharing growth is leading to concerns regarding safely integrating these modes. Standing electric scooters, which are commonly used in scooter sharing, are unique because they are small enough to maneuver around pedestrians but fast enough to cause safety concerns if ridden on the sidewalk. However, scooters are not fast enough to operate on roadways. These characteristics may cause a scooter rider to suddenly change where they ride based on their surrounding environment (e.g., move from the sidewalk to a traffic lane to avoid pedestrians). This could catch motorists off-guard and increase the risk of an accident. Additionally, scooter users may be licensed to drive passenger vehicles, they may have limited or no experience operating scooters, particularly around vehicle traffic (Todd et al., 2019). An observational study of scooter rider behavior in Los Angeles, California showed that the presence of scooters and high traffic volumes increased the risk of interactions between scooters, pedestrians, and vehicles (Todd et al., 2019).

Unsafe rider behavior and injuries from scoter sharing users may be caused by a lack of helmet use and age (Iroz-Elardo and Currans, 2021). In an Indiana-based study, researchers found that the accidents were caused, in part, by a lack of use of safety equipment (no riders wore protective gear) and use of alcohol (33 percent of patients used alcohol prior to their admittance) (Puzio et al., 2020). Safety can also be impacted by when and where devices can be ridden (Anderson-Hall et al., 2019). For example, while riding in a roadway may present more severe injuries for scooter riders, riding on the sidewalk with pedestrians could lead to greater pedestrian risks when collisions occur (Cicchino et al., 2021). Implementing policies for permissible location and hours of use can help address some safety concerns, such as prohibiting users from riding on a curb or at nighttime with limited visibility (Cicchino et al., 2021).

Summary

Studies of shared micromobility have generally found that users tend to be Caucasian, higher-income, younger (e.g., under 35), and male. However, some exceptions do exist. A few studies have found that non-white and low-income households have positive perceptions of scooter sharing. Establishing equity programs may help increase service availability and use by lower-income households and communities of color. For example, research has found that bikesharing service area locations (e.g., stations and corrals) may contribute to the high number of higher-income and younger users.

Shared micromobility may impact the safety of users and surrounding individuals (e.g., people waiting at public transit stops) if users improperly ride and park devices. Shared micromobility may impact public transit by filling first- and last-mile gaps to increase ridership. However, in some instances shared micromobility may replace transit trips. Early and exploratory research tends to indicate that station-based bikesharing may decrease bus ridership while increasing rail use. Early research also suggests that scooter sharing may complement public transit, however more research is needed.

EXPERT INTERVIEWS

The research team conducted 19, hour-long interviews in Fall 2019 with experts in a variety of industries in the academia and community-based organizations and nonprofit, private, and public sectors to gain insights on the relationship between public transportation and shared micromobility. These experts represent numerous professional perspectives, such as employees of shared micromobility companies, equity interests, policymakers, public transit operators, urban planning professors, and city planners.

Table 5 provides further information on the affiliations of each expert. The statements, recommendations, and findings of the expert interviews reflect personal views and are not necessarily representative of the experts' respective organizations.

Table 5. Summary of Expert Affiliations

Sector	Organization	Location	Affiliation
Academic	University of Maryland	College Park, Maryland	National Center for Smart Growth
	University of Texas at San Antonio	San Antonio, Texas	Department of Urban and Regional Planning
	University of Georgia	Athens, Georgia	School of City and Regional Planning
Community-Based Organizations	Greenlining Institute	Oakland, California	Staff
	Transform	Oakland, California	Staff
Non-Profit	North American Bikeshare Association	Portland, Maine	Executive Board
Private Sector	JUMP	San Francisco, CA and Washington, D.C.	Policy
	SPIN	Seattle, Washington	Government Partnerships
Public Sector	Alameda County Transit (AC Transit)	Alameda County (Oakland), California	Service Planning
	Bay Area Rapid Transit (BART)	San Francisco Bay Area, California	Transit and Curb Management
	Chicago Department of Transportation	Chicago, Illinois	Commissioner's Office
	Dallas Area Rapid Transit (DART)	Dallas, Texas	Planning and Development
	District Department of Transportation	Washington, District of Columbia	Parking and Ground Transportation
	Golden Gate Transit	San Francisco, California	Service Planning
	Oakland Mayor's Office	Oakland, California	Mobility and Interagency Relations
	Pinellas Suncoast Transit Authority	St. Petersburg, Florida	Planning
	San Francisco County Transportation Authority (SFCTA)	San Francisco, California	Executive Board
	San Francisco Metropolitan Transportation Authority (SFMTA)	San Francisco, California	Sustainable Streets, Parking and Curb Management
	San Mateo County Transit (SamTrans)	San Mateo County, California	Service Planning

The expert interview summary is organized into three subsections: 1) impacts of shared micromobility on public transit, including research and knowledge gaps; 2) evaluation metrics to help enhance understanding of the impacts of shared micromobility on public transit; and 3) strategies for integrating shared micromobility and public transportation.

Impacts of Shared Micromobility on Public Transit

Many of the experts noted the sparsity of literature on the impacts of shared micromobility on public transit. Two academic and one public sector expert stated that there is not conclusive research yet on this topic nor is there much evidence about impacts of shared micromobility in general. One non-profit expert offered an anecdotal example of the lack of conclusive understanding of shared micromobility's impacts: when reading media articles about shared micromobility one article suggested micromobility cannibalized public transit ridership, while another suggested it facilitated ridership. Several of the experts identified a large knowledge gap regarding research on electric standing scooters specifically. However, as scooter sharing pilots and programs grow this gap may be closed.

To supplement sparse empirical data, several respondents offered anecdotal observations on shared micromobility's impact on public transportation. Two respondents – from the academic and public sectors - noted that based on trip data, bikesharing use is high around public transit stations. Analysis of activity data also shows extensive use around public transit stations. Notably however, this can be partly driven by such stations being located in high density downtown areas. In addition, the public sector expert observed many scooters parked around a heavy rail station. However, the academic representative was careful to point out that this could be a product of operators placing devices in high density public transit areas to maximize revenue.

Despite the sparse literature, experts provided insight on the potential impacts of shared micromobility on public transit ridership. The experts noted that there is limited understanding about the impacts of shared micromobility on public transportation, and that more data and research are needed to understand the relationship between micromobility and transit.

Evaluation Metrics to Enhance Understanding of Shared Micromobility's Impact on Public Transportation

To inform future research on the impacts of shared micromobility on public transit, the experts were asked to evaluate the following performance metrics: 1) connection to public transit, 2) connection from public transit, 3) public transit trips replaced by micromobility, 4) micromobility trips that did not replace or connect to or from public transit, and 5) difficult to classify micromobility trips.

Overall, experts thought these metrics are a good starting point for measuring the impacts of micromobility on public transit. Seven of the nine respondents had a positive reaction, but improvements were also suggested. One academic expert cautioned that with the available data these metrics are not measurable and difficult to use outside of the research context. The same expert also stated that it may be challenging to say with statistical significance whether users are using transit or not based on Global Positioning System (GPS) or origin-destination data alone. This caution was furthered by a private sector expert who warned against the inaccuracy of GPS data, which would be a barrier to accurately determining trip purpose and whether or not a trip connects to public transit. This expert also advised against making assumptions without knowing what a complete trip looks like for a user but was supportive about analyzing trip data in general.

Four respondents voiced concerns on measuring successful integration based on these metrices. Both private sector experts and a public sector expert thought it was more important to understand why people might be substituting transit trips rather than the number of substitutions itself. An academic and a private sector expert prioritized measuring the number of single-occupancy vehicle (SOV) trips replaced rather than the impact of a shared micromobility program on public transit ridership. In their opinion, the long-term reduction of SOV trips is a better metric for sustainability. In addition, in the long run, these findings could show whether or not shared micromobility supports an ecosystem of various mobility options that encourage reducing vehicle ownership.

In addition to their feedback on the proposed metrics, the experts also offered additional metrics that could be important for evaluating public transit and micromobility integration. The experts also provided data sources to supplement shared micromobility and public transit integration metrics. These recommended data sources are summarized in Table 6 with their data type defined.

Table 6. Potential Data Sources for Integration Assessment

Data Source	Activity Data	Public Transit Data	Surveys	Third-Party Data
App users		X		X
Data dashboards	X			X
Open data portals from cities	X			
Radio-frequency identification (RFID) data	X			X
Ridership data		X		X
Shared micromobility and public transit transfers	X	X	X	X
Stated preferences for mode choices			X	
Trip data	X		X	X

Evaluation Metrics for Shared Micromobility and Public Transit

A number of local, state, and federal agencies have developed metrics to evaluate public transit and shared mobility performance. The Federal Transit Administration (FTA), in a report developing a new metric system for emerging mobility services (described below), has developed an extensive review of existing metric frameworks (Transit Center, 2020).

In February 2020, the FTA developed new mobility performance metrics (MPM) to supplement existing public transit-oriented performance metrics. The FTA's MPM framework is meant to evaluate emerging mobility services including: bikesharing, carsharing, transportation network companies/ridesourcing, and other on-demand and shared modes. FTA has developed a tiered framework of 65 metrics consisting of core indicators and three tiers:

- **Core:** Metrics measuring how well the integrated mobility system meets the needs of individual travelers;
- **Tier 1:** Metrics measuring how effectively and efficiently the integrated mobility system performs while meeting the needs of individual travelers;
- **Tier 2:** Metrics measuring how the integrated mobility system impacts the region in terms of sustainability, accessibility, environment, workforce, etc.; and
- **Tier 3:** Metrics measuring how the integrated mobility system impacts national goals for societal benefits, economic benefits, return on infrastructure investment, etc.

These metrics measure performance in three stages – pre-trip, trip, and post-trip. They also measure five categories of the traveler experience: time, budget, reliability, availability, and safety. Following the Development Phase, the FTA has entered a Testing phase in which it will develop a roadmap to operationalize the metrics (Transit Center, 2020). In conjunction with feedback from the experts on preliminary performance metrics, more robust measures can be developed.

Shared Micromobility and Public Transit Interactions

A common theme throughout the interviews was the benefit of more mobility options. Providing travelers with more modes to choose from could allow them to find options that better fit their mobility needs. On expert specifically noted the importance of integration in supporting multimodal travel. To support multimodal travel, experts offered suggestions for improving shared micromobility integration with public transit. These strategies are summarized in

Table 7. In addition to the suggestions in the table, two of the experts noted the need for an equity focus of shared micromobility services. In particular, they noted the need for public and private operators to work together to improve transportation for people with restricted mobility and/or low incomes. Finally, a number of experts indicated that more research is needed to improve the safety of shared micromobility, particularly at locations where the services interact with public transportation (e.g., curbside management and intersections).

Table 7. Integration Strategies

Strategy	Description	Public Transit Agency	Micromobility Provider	City or Planning Agency
App Integration	App integration, allowing travelers to plan and book complete journey in one app	X	X	
Charging Stations	Installing charging stations for electric devices near public transit stations		X	
Device Availability	Make sure micromobility devices are available at both ends of the trip for commuters (e.g., in both urban and suburban areas)		X	
Incentives	Monetary incentives to encourage users to position micromobility devices around public transit stations		X	
Infrastructure	Safe infrastructure (i.e., protected bike lanes, bike paths, pothole-free roads)			X
Integrated Fare Payment	Integrated fare payment, preferably with a fare card that does not require a bank or smartphone	X	X	
Mobility as a Service	Platform that allows users to bundle mobility services	X	X	X
Parking	Providing parking for micromobility devices throughout a geographical area, perhaps staggered at every block	X		X
Partnerships	Collective of mobility partners to make unified proposals to communities	X	X	X

When asked about measures their companies plan to take to integrate with public transit, the two private industry experts mentioned payment integration, providing services in the same app, and placing scooter charging stations near transit stations. Examples of these efforts include integrating public transit routing and ticket information into existing apps in select markets. To support these integration efforts, a public sector employee suggested the requirement of shared micromobility providers to make General Bikeshare Feed Specification feeds public so that public transit could integrate real-time micromobility data into third-party apps, such as public transit apps.

Summary

While there are some emerging studies on the impacts of shared micromobility on public transit, the experts interviewed believe this research is not conclusive. Existing findings are often mixed about whether micromobility complements or competes with public transit. Some evidence has shown that shared micromobility complements public transit as bikesharing use tends to be higher around public transit, and scooters are often also observed around these locations. However, it is unclear if devices are connecting to public transit rides or if the operators are rebalancing the devices at these locations. In addition to the relationship between shared micromobility and public transportation, a number of experts indicated the need for additional research on how to improve the safety of shared micromobility near and around public transportation operations.

When presented with metrics to evaluate the impacts of shared micromobility on public transit, the experts recommended ensuring that data are available to measure the metrics (i.e., connection to public transit, connection from public transit, public transit trips replaced by micromobility, micromobility trips that did not replace or connect to or from public transit, and difficult to classify micromobility trips), particularly given the limitations of GPS data and understanding the cause of trip substitutions. In addition to the metrics suggested, experts also recommended exploring why people may be substituting transit trips and considering the impact of micromobility on single occupant vehicle use.

SHARED MICROMOBILITY ACTIVITY DATA

The objective of the analysis was to better understand shared micromobility trip patterns, including docked bikesharing, dockless bikesharing, and scooter sharing, to evaluate appropriate metrics that characterize bikesharing interaction with public transit. The main metric identified for this analysis was the percentage of bikesharing trips connecting to and from public transit. This simple metric offers an easy-to-interpret measure of the degree to which bikesharing is facilitating connections to or from the broader public transit system. This metric requires a method for identifying which trips connect to or from public transit. In the case of this analysis, a method is developed for evaluating the number of trips that likely connect to or from rail public transit from system activity data. This approach, when applied consistently across system data sets over time, can be used to monitor and evaluate the degree to which bikesharing systems are facilitating connections to and from public transit systems.

Background on Data and Data Processing

A key source of activity data for study was derived from the General Bikeshare Feed Specification (GBFS), which is a standardized data structure for real-time shared micromobility trip data (NABSA, 2020). The data structure enables the deduction of basic information on trip activity including trip start and end points, trip start and end times, and bike IDs. User information is not included in this structure. Table 8: GBFS Data Structure Table 8 shows the structure of pertinent fields that are rendered by the GBFS data structure.

Table 8: GBFS Data Structure

Variable	Type	Description
Bike ID	String	Encrypted unique identifier of bikes.
Start time	Datetime	The trip start time.
Start Latitude	Float	Latitude of trip origins.
Start Longitude	Float	Longitude of trip origins.
End time	Datetime	The trip end time.
End Longitude	Float	Longitude of trip destinations.

For this study, the period of analysis include data rendered from the GBFS structure from October 2019 to February 2020 and for systems within four of the largest cities in California with rail systems. This included San Francisco (748,605 trips), Los Angeles (212,447), Sacramento (97,281), and San Jose (46,205). Data for San Diego included a smaller number of trips from the GBFS structure, and fewer rail transit stations covered by the bikesharing systems operating at the time. For this reason, the four cities above were selected for the study of dynamics of bikesharing connections to public transit. The bikesharying system start and end times for the four cities are listed in Table 9.

Table 9. System Types and Start/End Times of the Four U.S. Cities

	San Francisco	Sacramento	Los Angeles	San Jose
Shared Micromobility Systems	• JUMP Scooter • JUMP Bike • Bay Wheels	• JUMP Scooter • JUMP Bike	• JUMP Scooter • JUMP Bike • Lime • Breeze • Metro Bike Share	• Bay Wheels
First Trip	1/1/2020	1/6/2020	10/3/2020	1/1/2020
Last Trip	2/29/2020	2/28/2020	2/29/2020	2/29/2020

In addition to information derived from the GBFS data structure, this study used information derived from the General Transit Feed Specification (GTFS). The GTFS is a similar data standard that structures transit data reported by public transport providers (GTFS, n.d.). The GTFS data structure is summarized in Table 10.

Table 10: GTFS Data Structure

Variable	Type	Description
trip_id	String	Identifies a trip.
arrival_time	Datetime	Arrival time at a specific stop for a specific trip on a route.
departure_time	Datetime	Departure time at a specific stop for a specific trip on a route.
stop_id	String	Identifies the serviced stop.
stop_name	String	Name of the location.
stop_lat	Float	Latitude of the location.
stop_lon	Float	Longitude of the location.
route_id	String	Identifies a route.
route_type	Int	Indicates the type of transportation used on a route. 0 - Tram, Streetcar, Light rail. 1 - Subway, Metro. 2 - Rail. 3 through 12 – Other route types out of our interest.
start_date	Date	Start service day for the service interval.
end_date	Date	End service day for the service interval.

Both the geographic and the schedule information in the GTFS are used to identify connection trips. The geographic information is used to measure the proximity of transit stations to shared micromobility trip origins and destinations. The schedule information is used to check if a bike or scooter trip accessing the station ends near a rail transit departure time. It is also used to check if a bike or scooter trip departs right after a rail transit arrival time. Table 11 summarizes the public transit agencies in the four U.S. cities.

Table 11. Rail Transit Agencies in the Four U.S. Cities

	San Francisco	Sacramento	Los Angeles	San Jose
Public Transit Agencies	• Caltrain • Bay Area Rapid Transit (BART) • San Francisco Municipal Railway (Muni)	• Sacramento Regional Transit District (SACRT)	• Metrolink • LA Metro Rail	• Valley Transportation Authority (VTA)

In addition to data derived from the GBFS and GFTS data structures, additional information about road networks is needed to define the routes and distances traveled. We used OpenStreetMap data and network files to estimate routes and distances that were taken to complete the trip.

Data cleaning was done to process the raw trip data for use in this analysis. Three types of trips were removed from the dataset before connections were identified. They included the following:

a) Trips with zero distances (i.e., those that start and end at the exact same geographic location),

b) Trips with average speeds over 30 kilometers per hour (km/h), and

c) Trips that took longer than 60 minutes.

The parameterization of these cleaning criteria was defined by several references. The extraction of zero distance trips needed no further justification. Regarding the speed criteria, several resources defined reasonable speeds for cycling. For example, cyclists in Copenhagen are reported by the city to ride at 15.5 km/h on average (City of Copenhagen website, 2013). In addition, Road Bike Rider (2019) reports most cyclists (beginners and more experienced riders) ride between 10 to 18 miles per hour (16.1 to 29.0 km/h). This informs the upper bound of removing trips according to their speed.

Finally, Martens (2004) studied three European countries (the Netherlands, Germany, and the United Kingdom) and found most bicycle trips accessing public transit to be less than six kilometers (4.7 miles). While the cycling environment is notably different in these countries relative to California, it informs a conservative bound of 60 minutes for removing trips that connect to transit. Such very trips with bikesharing are often not continuous in nature, but involve stops and breaks, while the vehicle remains checked out.

Categorizing Rail Transit Connection Trips

The activity data defining the trips offers the opportunity to character trips that are likely connecting to public transit. This approach has a few limitations. One limitation of exclusively using activity data for this purpose is that we cannot definitively know where a user went after they ceased using bikesharing. But using a set of logical criteria we can make reasonable suppositions of which trips are likely to be public transit connecting trips. We can further eliminate a large number of trips that we can reasonably conclude are not connecting to rail transit. Another limitation is more practical, in that the method can only be used to identify trips that connect to rail transit systems in metropolitan major regions. This is because bus stations are simply too ubiquitous within the urban landscape to attribute the location of origin or destination to the connection of a given bus line. While connections to bus systems from bikesharing inevitably happen, they are likely far less frequent than connections to rail transit given the longer distances of travel and greater speed gained when connecting to rail. Given these caveats we consider the following criteria to identify trips that are likely connecting to rail transit:

1) Distance of the trip origin from a rail transit station entrance (for egressing trips);

2) Distance of the trip destination from a rail transit station entrance (for accessing trips);

3) Trips that substitute for a travel pattern that would otherwise be served by rail transit; and

4) Trips that meet criteria 1) or 2) and 3) and fall within the GTFS-defined schedule parameters of the rail system operation (e.g., scheduled arrival and departure times of vehicles).

If the attributes of a bikesharing trip meet the parameters of these criteria (discussed in detail below), then we classify the trip as likely connecting to rail transit. Otherwise, we consider the bikesharing trip to exhibit attributes that are not connecting to rail transit. The subsections that follow discuss the logic and parametrization of these criteria in greater detail.

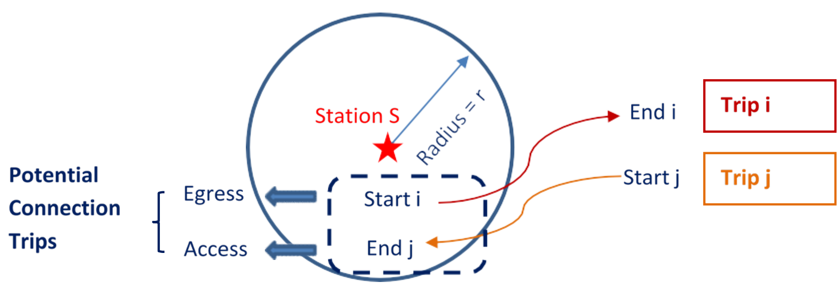
Distance of Origin or Destination from Start from a Rail Transit Station Entrance

To illustrate this generalized concept, suppose that there is a circle centered at a given station SS and a radius of rr, access and egress bikesharing trips can then be defined as follows (see **Figure 1**).

a) If trip ii starts within this circle, it is likely to be an egress trip from public transit.

b) Likewise, if trip jj ends within this circle, it is likely to be an access trip to public transit.

Figure 1. Generalization of Public Transit Access and Egress Trips



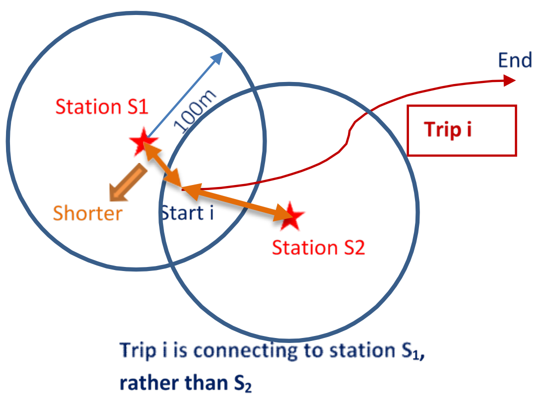
It is crucial to find a reasonable radius from the station that reasonable identify trips that could be plausibly connecting to public transit. Guerra et al. (2012) has suggested a transit catchment radius of 0.25 miles (400 meters) for jobs and 0.5 miles (800 meters) for the residential population. In studying the intervention of Capital Bikeshare (CaBi) and Metrorail in Washington, D.C., Ma et al. (2015) also considered Capital Bikeshare stations located within 0.25 miles of a transit station.

But catchment areas suggest the radius of a region that use a specific transit station. When considering specific bikesharing trips, users have an ability (and incentive) to terminate a trip relatively close to the point of entry. Given the specific origin and destination information in trip data, we can evaluate which trips start and end within an arbitrarily tight area around a station. Hence, this study implements a more restrictive criteria than those observed of general catchment areas. We only consider trips that terminate or start within 100-meter radius as possibly transit connecting. Other criteria (to be explained below) are also required to be met before the trip is classified as a transit connecting bikesharing trip. To provide a visual context for this radius, Figure 2 shows an overlay a 100m-radius coverage around the Downtown Berkeley Station.

Figure 2. 100m Radius around Downtown Berkeley Station

While the rules above propose a buffer zone around each transit station with a radius of 100 meters, there are exceptional circumstances that require treatment. For example, if either end of a trip falls within multiple buffers, we assume that the trip connects to the closer station. Figure 3 shows a generalized illustration of this situation for an egress trip. The start point of trip ii is found in both buffers of station $\mathbb{SS}_1$ and $\mathbb{SS}_2$. In this situation, the trip is classified as a potential egress trip of $\mathbb{SS}_1$, given that the trip starts closer to $\mathbb{SS}_1$.

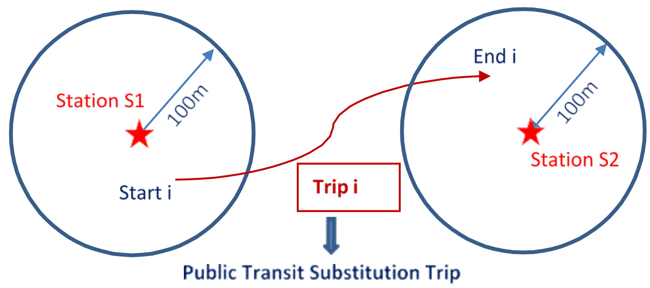
Figure 3. Transit Connecting Station Assignment when Connecting Radii of Two Stations Overlap



Identifying Trips that Substitute for Rail Transit Trips

The alignment of the trip relative to the existing rail transit system also informs the likelihood the trip is serving to access or egress to public transit. In this capacity, we evaluate whether the origin and destination of the trip could have been served by rail network itself. We consider such a trip to be a substitution to (rather than a complement of) public transit when a trip both starts and ends within 100m access and egress zones identified previously. Such trips conducted via the bikesharing system are occurring despite the fact that equivalent service is offered through the public transit system as well (see Figure 4).

Figure 4. Generalization of Trip where Bikesharing Substitutes for Public Transit

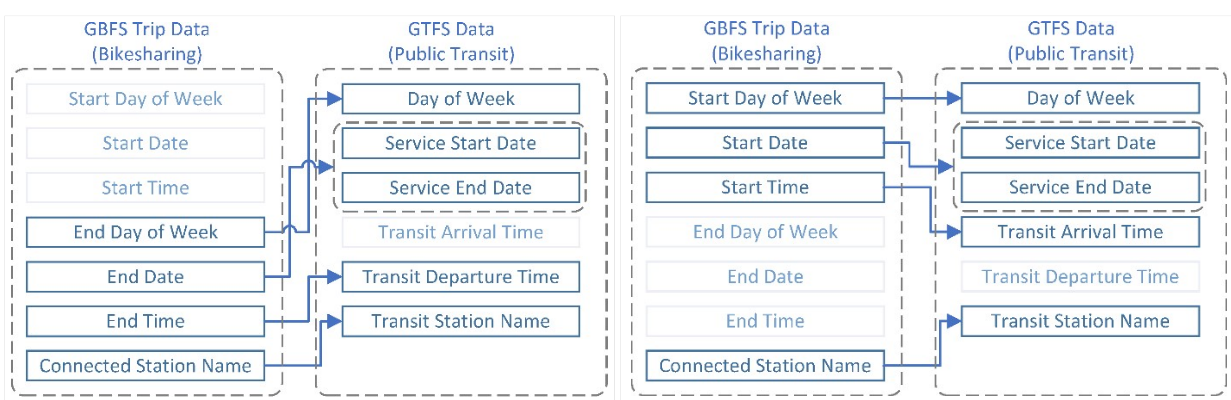


Identifying Trips that Fall within GTFS-Defined Schedule of Rail System Operation

Trips that meet the spatial criteria of access and egress can be further assessed as to whether they meet temporal criteria as well. For example, trips that connect outside of operating hours, even if passing all other criteria, are not connecting to public transit. Additional considerations can be made using information from known arrival times and departure times. That is, access trips are likely to arrive at a station within some margin of time before the next train departure, and egress trips are likely to occur within a similar margin of time after departure.

Incorporating information from the General Transit Feed Specification into the identification method can provide additional restrictions on trips that would qualify is likely connecting to rail transit. As shown in Table 10 the GTFS data provide the arrival and departure times of each train, as well as the locations of transit stations and the service dates. Figure 5 below illustrates the way in which transit schedules are added to strengthen the identification rules.

Figure 5. Criteria on Incorporating Transit Schedules for Access Trips (left) and Egress Trips (right)



Based on this structure, we define a 10-minute time interval for connections to happen, which means the following requirements should hold:

- For Access Trip ii connecting to transit station SS:

For all schedules at station SS, there should exist at least one schedule which makes

$$EEEEEE\ TTiiTTTT\ oooo\ AAAAAATTAAAA\ TTrriiTT\ ii \in [TTrrTTiiEE\ EETTTTTTrrddddrrTT\ ddiiTTTT - 10\ TTiiEEddddTTAA, TTrrTTiiEE\ EETTTTTTrrddddrrTT\ ddiiTTTT]$$

- Egress Trip ii connecting to transit station SS:

For all schedules at station SS, there should exist at least one schedule which makes

$$SSddTTrrdd\ TTiiTTTT\ oooo\ EEEErrTTAAAA\ TTrriiTT\ ii \in [TTrrTTiiEE\ TTrrrriiaaTTaa\ ddiiTTTT, TTrrTTiiEE\ TTrrrriiaaTTaa\ ddiiTTTT + 10\ TTiiEEddddTTAA]$$

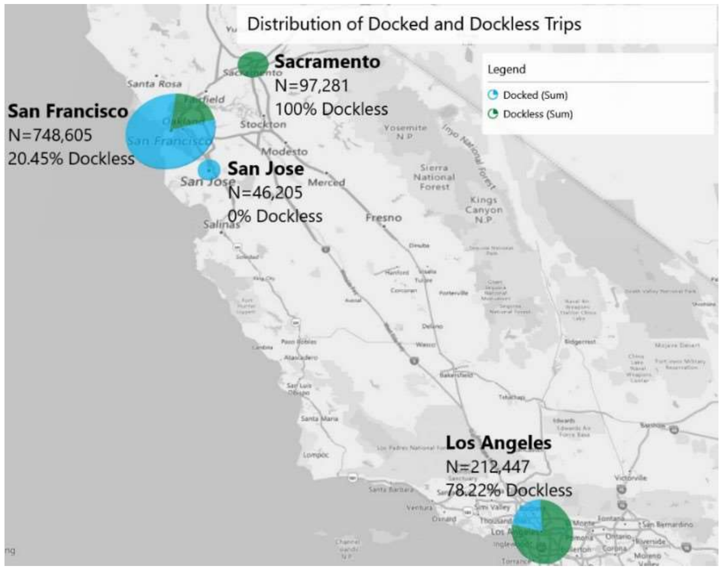
That is, access trips should terminate with 10 minutes of the arrival of a train and egress trips should begin within 10 minutes after a train has departed. This restriction naturally eliminates any trips that occur outside of rail transit systems operating hours and also eliminate trips that would happen to occur within the dead space of train headways. The 10-minute bound is naturally an arbitrary boundary, and it can be tightened or relaxed. As part of this study, we evaluate the impacts that additional temporal criteria have on the identification of transit-connecting trip candidates versus just using the spatial criteria and data processing filters. Taking these rules together, the heuristic describes within this methodology defines transit connecting trips as those: 1) taking no longer than 60 minutes, 2) are not faster than 30 km/h, 3) fall within the spatial bounds of the station, 4) do not exhibit a pattern substituting for public transit, and 5) fall within the temporal criteria informed by the integration of GTFS data.

We use these criteria to identify trips that are likely candidates of bikesharing trips connecting to rail transit. While data does not presently exist to definitively know which users truly connected to or from public transit, trips that do connect to public transit would generally need to align with the attributes of spatial and temporal proximity to rail system operations. Trips characterized by this collection of criteria can be evaluated as a percent of total trips, which can be used to quantify the degree to which transit connections are likely being made across systems and over time. The computation and measurement of these connections are presented in the results section that follows for four major cities with rail and bikesharing operations in California.

Results and Discussion

Among the four cities evaluated in this study, only San Francisco and Los Angeles had both station-based and dockless systems present in the dataset. All systems in Sacramento were dockless (both bike and scooter), whereas San Jose has only one station-based system (docked bike). All vehicle types operating within the system were included in the analysis. Across all four cities, one million trips were evaluated for connection criteria. Figure 6Table 5 shows how the station-based and dockless trips are distributed geographically.

Figure 6. Distribution of Station-Based and Dockless Trips in the Four U.S. Cities

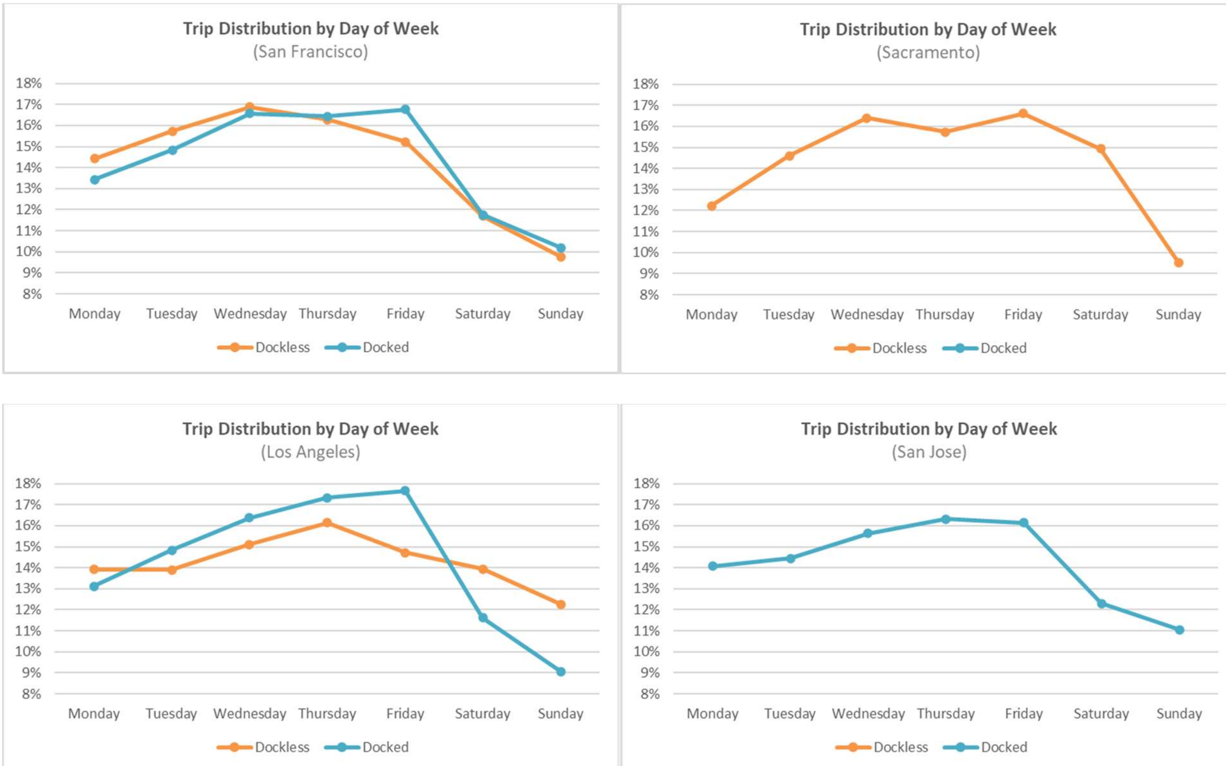


The overall data collection period started from October 2019 to February 2020, before the COVID-19 pandemic and the California Stay Home Order announced on March 19, 2020 (State of California, 2020). Individual start and end dates vary across systems and cities as shown in Table 9.

Weekly Patterns of Travel

Before studying the patterns of the bikesharing trips connected to public transit, we conducted a temporal analysis by summarizing all bikesharing trips by both day of week (Figure 6) and time of day (Figure 7) as distinguished by station-based and dockless systems. Results are presented as in within-city percentages.

Figure 7. Trip Distribution by Day of Week



According to Figure 7, the bikesharing service was most frequently used in the middle of the week, and was the least frequently used on Sunday, regardless of city or service model (i.e., station-based and dockless systems). In San Francisco, dockless systems outperformed station-based systems in terms of the total percentages of trips in the first three days of the week, and vice versa toward the end of the week. Los Angeles witnessed a different pattern with station-based systems dominating the trips from Tuesday to Friday. Overall usage was generally highest on Wednesday, Thursday, or Friday across the four systems.

In all the station-based systems listed above, there was a sharp drop from Friday to Saturday. This was usually not as much the case for dockless trips except for San Francisco, where similar usage patterns were observed in both systems. In Sacramento and Los Angeles, dockless trips remained stable from Tuesday to Saturday, with at least 13.9 percent taken on Saturday, while station-based trips on Saturday always dropped below 12.5 percent. In Los Angeles, there is a steep drop in dockless bike usage relative to station-based bikes. One possibility explanation for this separation is that people were slightly more inclined to use station-based bikes for commute trips, which have very fixed start and end points, while dockless systems retain their utility for recreational trips during the weekend.

Daily Travel Patterns

We took a closer look at the hourly variations in the four cities as well. Figure 8 shows the distribution of diurnal patterns of activity at 30-minute intervals.

Figure 8. Trip Distribution by Time of Day

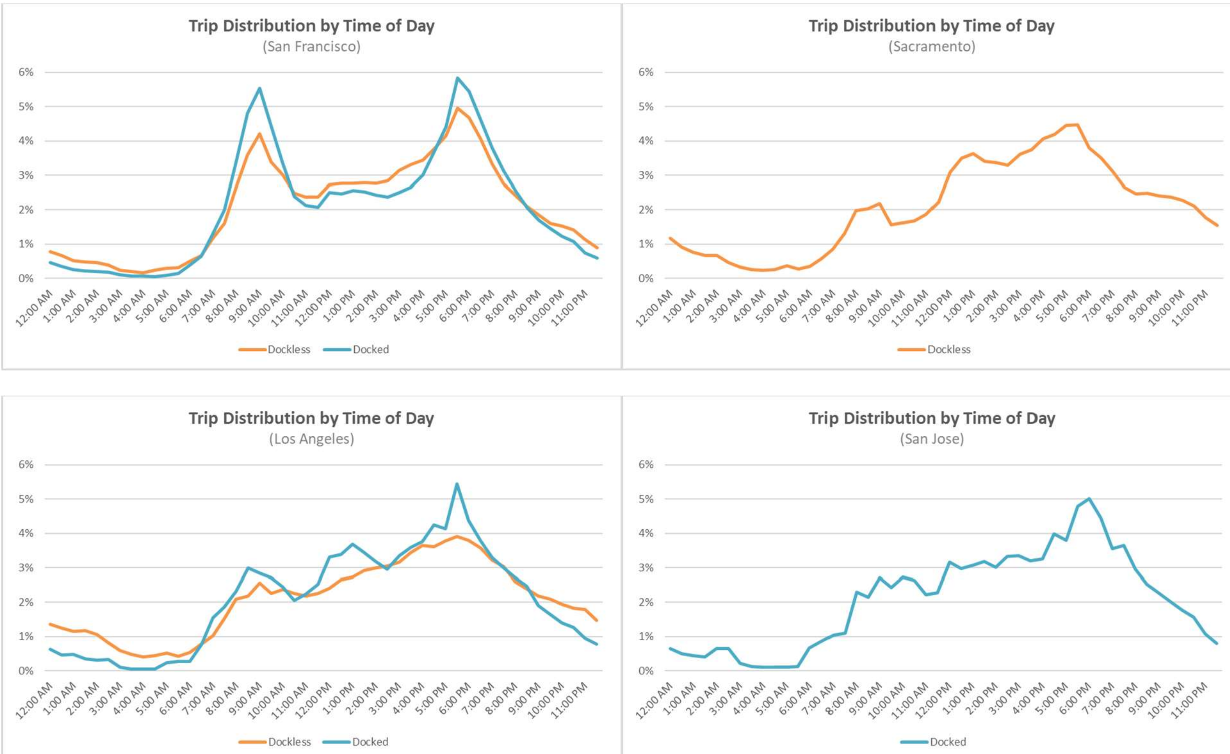


Figure 8 shows that there were usually about one percent of trips at midnight, and as expected, the lowest trip activity occurred during 3:00AM and 6:00AM. San Francisco is the only city where we observed clear commute-driven spikes in both morning (9:00AM) and afternoon (5:30PM) rush hours that traditionally accompany commute patterns. Consistent with the earlier observation in Los Angeles, there is a slighted prevalence for station-based bikesharing to be used for commuting. Given that bikesharing services were less frequently used on Saturday and Sunday in San Francisco (see Figure 7), it might be the case that commute was the major trip purpose in that city.

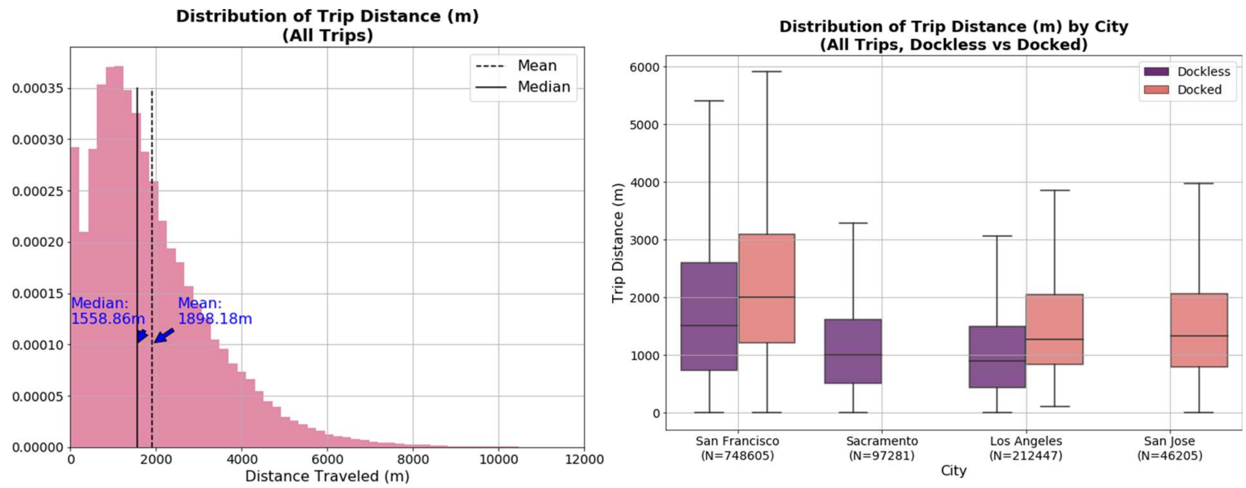
In contrast, most activities in Sacramento, Los Angeles, and San Jose took place during the daytime (between 8:00AM and 6:00PM) following an ascending trend, but peaks were not obvious. However, slight increases during morning (8:00AM – 9:00AM), noon (12:00PM – 1:00PM), and evening (5:00PM – 6:00PM) times were seen in both dockless Sacramento trips and station-based Los Angeles trips.

Another finding is that dockless bikes seemed to be more popular later at night and earlier in the morning. In both San Francisco and Los Angeles, the percentages of dockless trips exceeded station-based trips during 9:00PM and 5:00AM. In Sacramento and Los Angeles, about 1.5 percent of the dockless trips remained active at 11:30PM, while station-based trips were often found to drop below one percent at the same time.

Patterns of Distance and Time Traveled

As noted in the methodology, the data permitted an imputation of trip distances traveled by bikesharing vehicles as the shortest street network-based distance between the origin and destinations. The distribution of these bikesharing trip distances observed within the data is skewed to the right. People traveled with a bikesharing device for 1,898 m on average, but this average number was greater than median distance (1,559 m), while the longest trip was as far as 24,597 meters (see Figure 9).

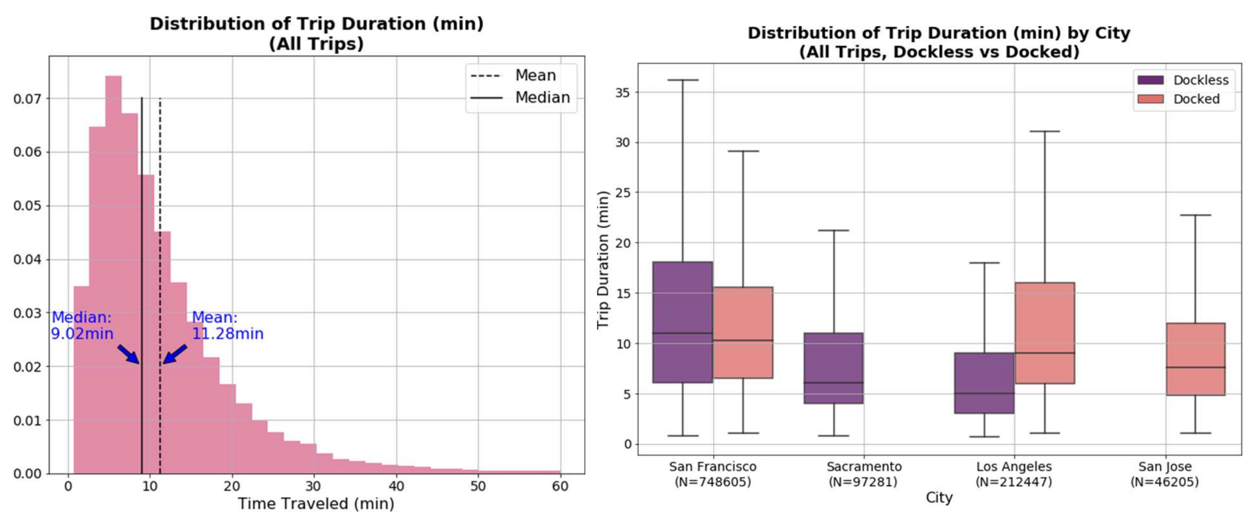
Figure 9. Distribution of Trip Distance



In general, station-based bikesharing trips appeared to be much longer in both San Francisco (2,296 m vs 1,818 m) and Los Angeles (1,602 m vs 1,125 m). One factor potentially contributing this is that when riding a dockless bikesharing device, people were not obliged to return it to a fixed dock. This freedom may have enabled more trips of shorter range. Trips in San Francisco were on average the longest (2,198 m), followed by San Jose (1,630 m), Los Angeles (1,229 m), and Sacramento (1,179 m).

Similar to the distance traveled, the distribution of time has a heavy right tail. The average trip duration was 11 minutes, greater than the median at nine minutes. Given that we only kept the trips under 60 minutes for the purposes of this analysis, the maximum duration observed bounded by this value. This information is visualized in Figure 10.

Figure 10. Distribution of Trip Duration



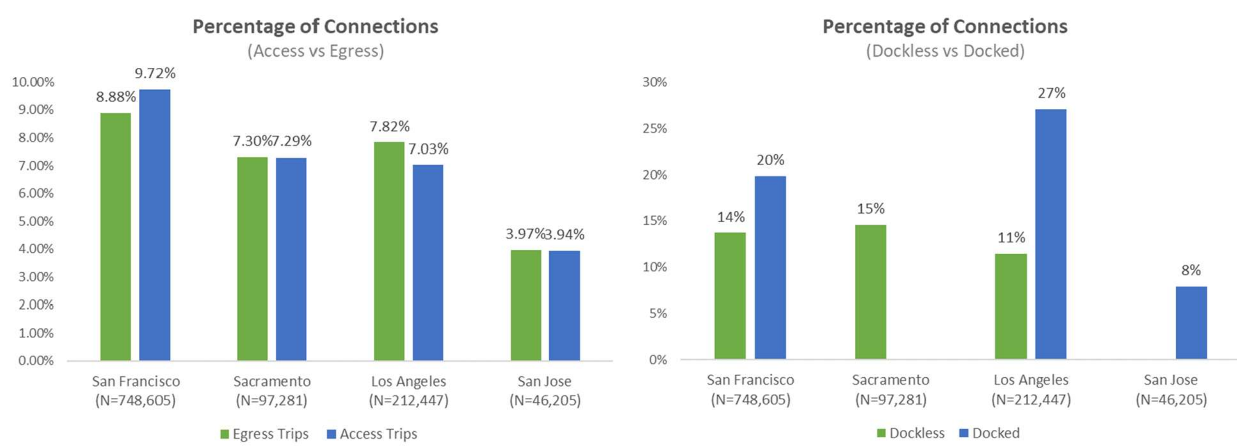
Although station-based trip distances were on average longer than dockless ones, trip durations did not follow a similar pattern. An average dockless trip in San Francisco was almost 14 minutes, compared to

12 minutes for station-based trips. While the measured distances traveled are a generally lower bound (shortest path between two points), the trip time is measured as it actually occurred. The station-based trips in Los Angeles were longer in both distance and duration. The difference in duration was even more apparent because the median duration of station-based trips was the same as the 75th percentile of dockless trips (nine minutes), while the 75th percentile of dockless trips was as great as 16 minutes. San Francisco had the longest average time spent (12 minutes), while trips in Sacramento, Los Angeles, and San Jose only took around eight and nine minutes.

Percentage of Trips Connecting to Public Transit with Bikesharing

For each city, two subsets of access and egress trips were generated following this methodology. The analysis used 1,191,560 trips, which were retained after cleaning. Two identification procedures were evaluated. The first employed all the criteria outlined in the methodology except for consideration of transit schedules as provided in the GTFS data. The second approach incorporates GTFS data, and considers trips that meet the spatial requirements, but also fall within the connection-associated 10-minute window of arrival or departure (e.g., 10 minutes after departure for egress, 10 minutes before arrival for access). The first methodology (absent GTFS information) found that access and egress trips accounted for 8.62 percent and 8.24 percent of all trips respectively. Notably, the total numbers of trips significantly varied across cities (from 46,205 in San Jose to 748,605 in San Francisco), but the percentages of connections are comparable (see Figure 11).

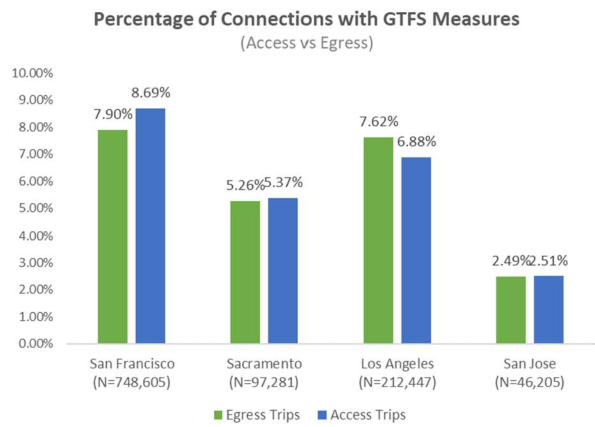
Figure 11. Percentage of Connection Trips by City

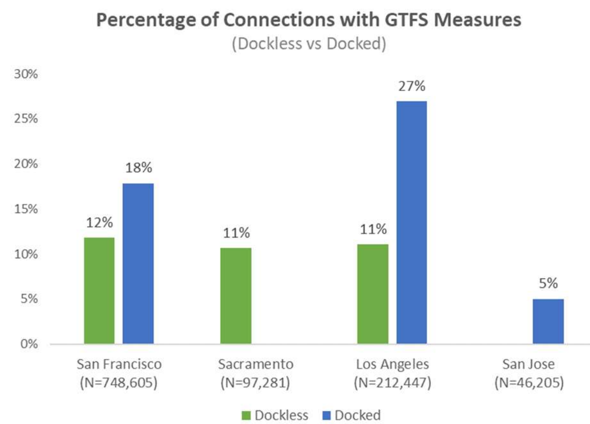


When considering access and egress trips together, San Francisco was found to have the highest percentage of connection trips (18.60 percent) while San Jose had the lowest (7.91 percent). The lower percentage in San Jose is possibly due to the lower population density and the greater auto-orientation of the surrounding land use. When the results are grouped by station-based and dockless system trips, different insights emerge. In San Francisco and Los Angeles, where both station-based and dockless systems are present, the results show that a much greater percentage of station-based trips were connecting to public transit, especially in Los Angeles where the percentage on connecting trips was 27 percent relative to 11 percent to 15 percent range for dockless trips.

The results presented to this point consider trips classified as connections based on the spatial criteria defined for rail transit-connecting trips. These results do not take into consideration alignment with transit schedules, and thus may overestimate the actual number of connections to transit. Following the GTFS-incorporated methodology where only trips occurred within the 10-minute time interval were included, Figure 12 presents the percentages of connection trips that were identified after the constraints defined by GTFS transit schedules are applied.

Figure 12. Percentage of Connection Trips by City with GFTS Measures



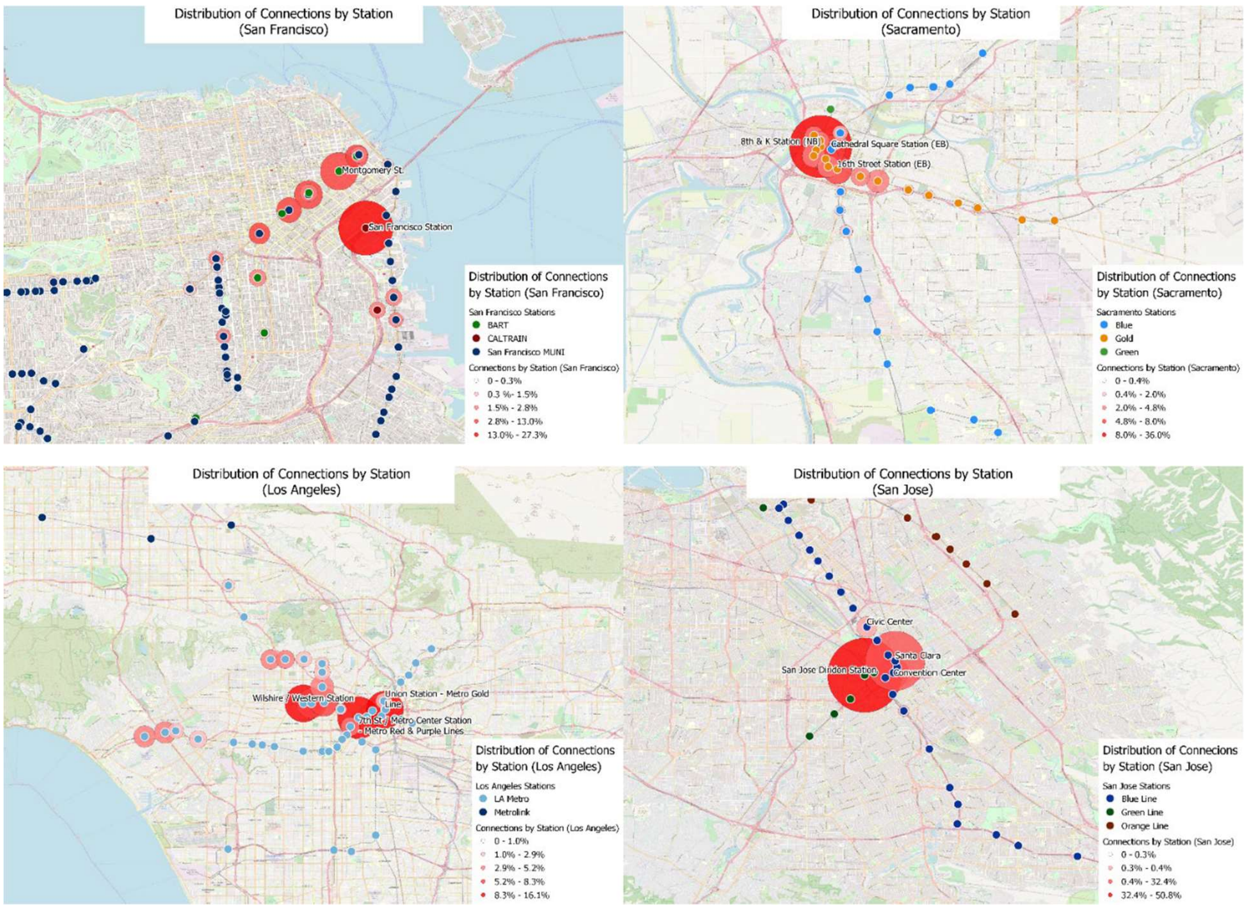


Compared to Figure 11, percentages in Figure 12 are smaller given that the incorporation of GTFS information can only reduce the number of trips that could be identified as transit connecting. However, the degrees to which these percentages shrank varies among cities. For example, Los Angeles turned out to have almost all (at least 96 percent) of the connections identified by the spatial criteria retained, followed by San Francisco at over 85 percent. However, larger reductions were found within less rail transit-rich environments. Only about 71 percent of spatially-defined connections in Sacramento and 62 percent in San Jose occurred with the schedule time-defined constraints. An important caveat to this finding is a discovered data limitation related to some GTFS data. In San Jose, GTFS information contained some missing arrival (arrival_time) and departure (departure_time) times in GTFS for the VTA system, which led to a lower reliability in this city's estimates. This issue raises a caveat that needs to be understood with respect to the utilization of GTFS information through this methodology. Naturally, the method is reliant on quality GTFS data available from the operator, and this may not always be the case. Through the exploration of incorporating GTFS information into the methodology, some limitations in the completeness of the GTFS information were encountered. This limitation may mean that methods evaluating transit connections should rely more on spatial criteria for consistency within environments where GTFS information is more limited.

Spatial Distribution of Public Transit Connections

With the subset of trips identified as connecting to rail transit stations using the previously discussed spatial and schedule constraints, we can further interpret dynamics of these trips through a variety of visualizations. Figure 13 presents a series of maps that shows the geographic distribution of trips that both connect to and from the rail systems within the four respective cities. Almost every station logged at least one connecting trips, but a few logged a significant share of trips. Not surprisingly, the stations with the largest share of connecting trips occurred within the downtown regions, but also at key rail transit hubs and terminals, such as Caltrain's San Francisco Station. In other cities such as Sacramento, rail transit connecting trips were identified as occurring with relatively consistent and notable frequency along the string of light rail stations servicing the city's gold line. Despite the various shapes of transit route and sizes of bikesharing fleet among cities, one thing in common is that the most popular station was often 1) located in the downtown area, or 2) a station where multiple transfers were available.

Figure 13. Spatial Distribution of Connections by Station



For each city, the bubbles in graduated red scales represent the percentages of trips connecting to a given station as a percentage of the total connections in the city (note that this is percentage of connections, not the percentage of all trips as reported earlier). Since the percentages varied greatly among stations (e.g., from 0.3 percent to 50.8 percent in San Jose), a square root operation was applied to all the numbers so that smaller bubbles were still visible. The fixed sized dots, on the other hand, represent the transit systems/lines that the stations belong to.

In San Francisco, almost 30 percent of connections occurred around the San Francisco Station of Caltrain, situated right next to Highway 101 and a Muni station (4th St and King St). The BART stations along the Market Street, such as Montgomery Station (13.0 percent) and Embarcadero Station (4.8 percent) had a large share of connections as well. Few trips connected to Muni stations, except for those close to BART or Caltrain stations.

In Sacramento, about 36 percent of all connections identified were to or from 8th and K Station (northbound) of the Gold Line. Unsurprisingly, this station was in the center of Downtown Sacramento. Another observation is that nine out of top ten stations where most connections took place were in the Gold Line that extended along Highway 50, and one of the nine stations was a connection to the Amtrak Sacramento Valley Station at 3.1 percent.

The station that attracted the most connections in Los Angeles was the 7th St and Metro Center Station at 16.1 percent also located in the downtown. Several stations around the downtown area, such as Wilshire and Western Station (12.8 percent) and Union Station (12.7 percent) were just as popular. Except for Union Station, no connections were found to Metrolink. The reason might be that Metrolink is a commuter rail that mainly serves longer-distance travels compared to LA Metro that consists of rapid transit and light rail lines, and the Metrolink stations are much less densely distributed, especially in the urban core and can be distant from bikesharing systems in Los Angeles. Unlike other cities, a considerably large number of connections were found toward the ends of several transit lines. On west end, for example, about 4.3 percent of connections connected to Expo and Bundy Station, which was the closest to both Santa Monica Beach and Santa Monica Airport. On the northwest, the Hollywood and Highland Station next to West Hollywood attracted 3.6 percent of the trips. This dynamic is in part driven by the unique multi-hub nature of the Los Angeles metropolitan region.

In San Jose, identified connections were far more concentrated. Trips connecting to San Jose Diridon Station took up as much as 50.8 percent in San Jose. Serving Caltrain, Altamont Corridor Express, VTA, and Amtrak, this central passenger depot plays a critical role in delivering passengers to downtown San Jose. Similarly, about 32.4 percent of the identified connections were at the Santa Clara Depot. These two stations have both been planned to be part of the Silicon Valley BART extension program into Santa Clara County (VTA, 2009). Additionally, Convention Center Station (8.8 percent) and Civic Center Station (3.9 percent) had a notable share of identified bikesharing connections as well.

Characteristics of Trips that Connect to Public Transit

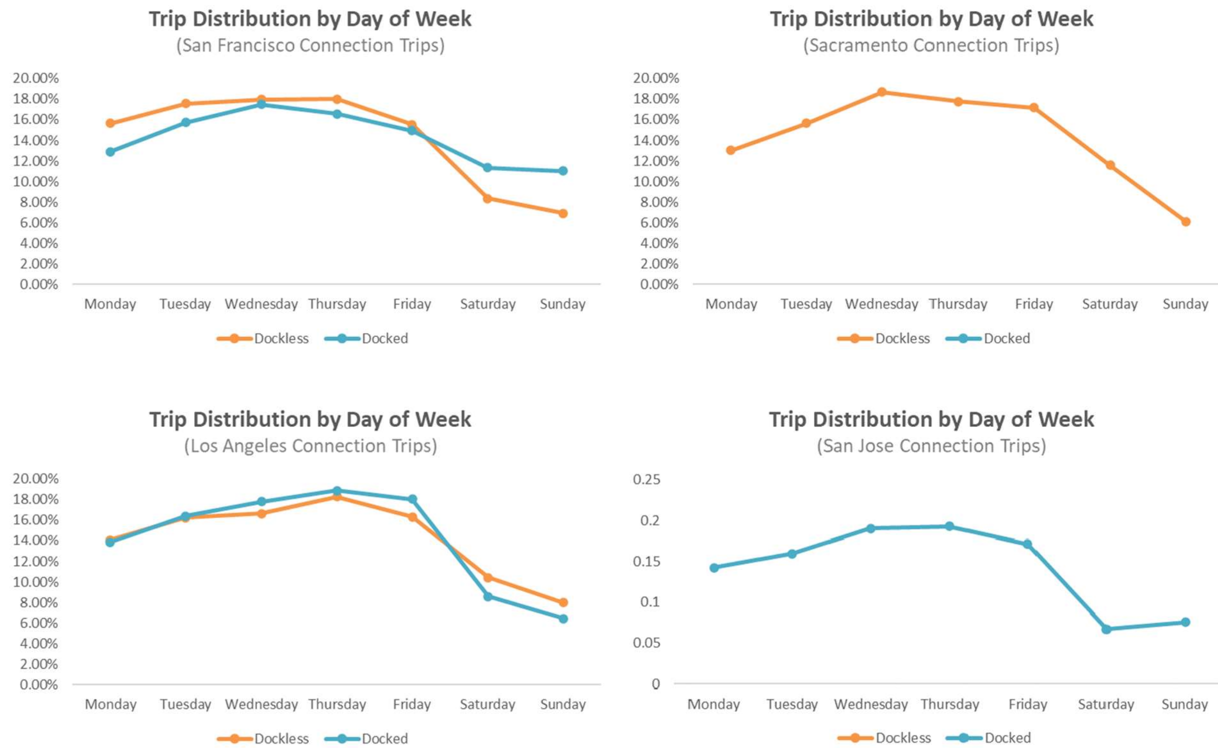
The characteristics of trips identified as connecting to transit were also explored. As with the broader distribution of all trips, a right tail was observed in the distance distribution of all identified connection trips. Station-based trips were on average much longer (2,208 meters) than dockless ones (1,540 meters). These connections, however, had a greater mean (2,022 meters) and median (1,681 meters) length but a shorter right tail (see Figure 12). Trip distance statistics are provided in Table 12.

Table 12. Statistics of Trip Distance

	Average Distance (m)	Median Distance (m)	Maximum Distance (m)
All Trips	1,898	1,559	24,597
Connections (with GTFS)	2,022	1,681	17,546

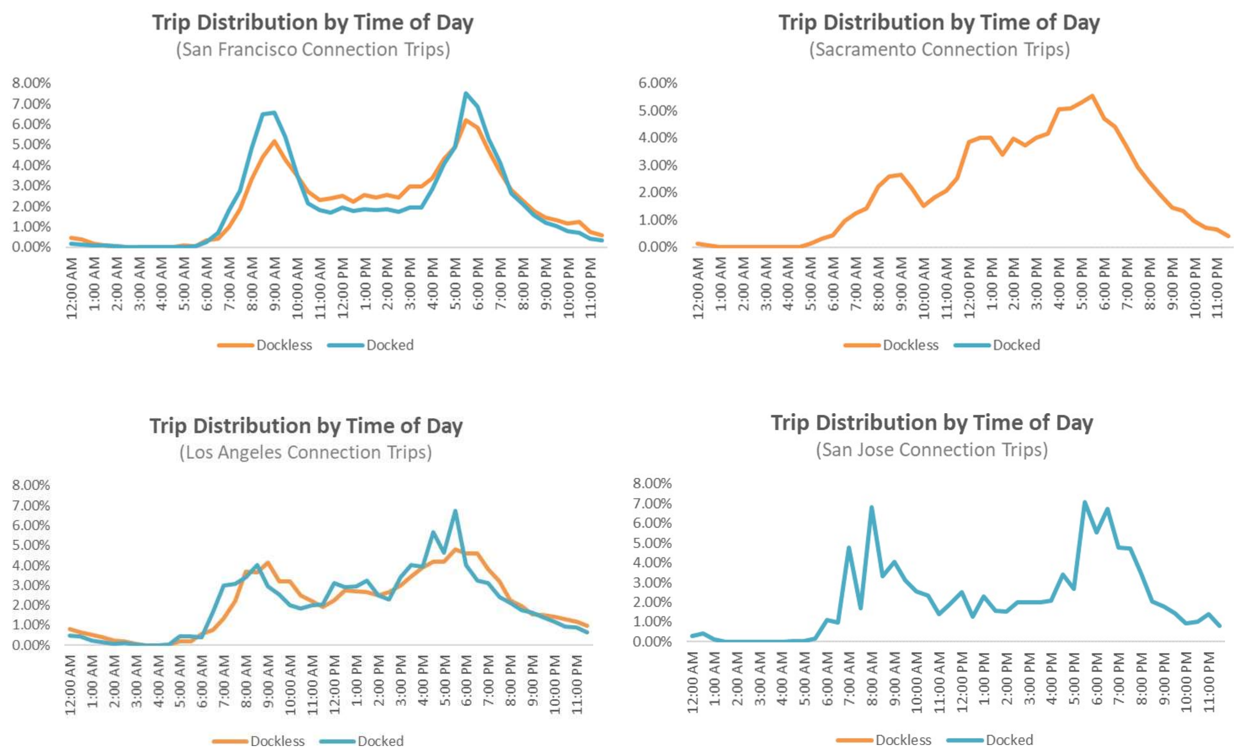
The distribution by day of week for connection trips is shown in Figure 14, and reveals a very similar pattern as in Figure 7 for all trips among which most occurred on weekdays.

Figure 14. Trip Distribution by Day of Week with GTFS Measures (Connections)



However, differences between the two figures are still observable. Unlike Figure 7 where dockless and station-based trips peaked on different days, no great distinctions were found from the graphs of San Francisco and Los Angeles in Figure 14. We also found that the most connections in Los Angeles and San Jose took place slightly later (i.e., on Thursday) than San Francisco and Sacramento where peaks were usually on Wednesday. Additional comparison is made on the time of day of trip occurrence between all trips (Figure 8) and connection trips (Figure 15).

Figure 15. Trip Distribution by Time of Day with GTFS Measures (Connections)



The general patterns in Figure 15 are not significantly different from Figure 8. However, since the GTFS approach eliminated trips that were nowhere near a transit arrival or departure, especially during 1:00AM and 5:00AM when few transit lines were operating, the peaks of these distributions were boosted higher and thus became more prominent in all cities shown in Figure 15. For example, in San Francisco, the station-based trips during the afternoon rush hour (5:30PM) took up 5.83 percent of all trips in a day, but the station-based trips connecting to transit during the same period took up 7.51 percent.

In Figure 8, an ascending trend of identified connection trips was observed between 8:00AM and 6:00PM in Sacramento, Los Angeles, and San Jose. This trend is not as prominent in Figure 15, particularly in San Francisco and San Jose. Notably, identified connections in San Jose exhibit a two-peak pattern showing up in San Jose connection trips that is not present with the broader activity plotted in Figure 8. This distinction is likely driven by the fact that most popular stations in San Jose were the main rail passenger depots that attracted about 80 percent of the city's bikesharing access and egress trips.

Summary

The bikesharing activity data analysis provides insights on the magnitudes of transit connection activity that could be enabled by bikesharing and detected through a logical set of spatial and temporal criteria. It is important to note that the data evaluates the origin and destination of the vehicle and not the user. Therefore, it is quite possible (indeed likely) that not that all trips identified as transit connecting had the rail station as the user's origin or destination. It is similarly likely that some trips excluded from the transit connecting identification were in fact transit connections, where the user walked a little father to get to or from the rail station.

Despite these limitations, there are fundamentals to transit connections that are embedded in the identification heuristic that are useful to evaluate over different systems and over time. Transit connecting trips must be terminating or starting within some reasonable proximity of the station, and they must occur during system operating hours. Other factors, such as the 10-minute window around GTFS arrival times may be more restrictive, since it is possible that some users will arrive exceptionally early to a station before a train's arrival or depart exceptionally late. However, a consistent method that can identify bikesharing connection activity that is likely serving as public transit connections can be useful for monitoring the health of the interaction of the two systems over time.

In this analysis, a spatial radius of 100 meters about the station entrance is rather tight, leaving limited alternative destinations of interest in many areas. Naturally, in downtown areas, the capacity for greater volatility in true identifications exist, even though these areas would be reasonably suspected to have the largest access and egress activity. This is likely to remain even if additional criteria is added and such criteria could end up being too restrictive (e.g., discarding more true connections than false ones). One discovery of this exercise is that while GTFS does provide a logical restriction on transit connecting trips and further discards those trips that occur outside of operating hours, its impact on the overall spatially derived measurement is somewhat muted. This is a useful insight because incorporating GTFS information into the identification heuristic can be time consuming and hindered by incomplete information. Because of its logical criteria, it is considered to better and more accurate overall, but it was found to not be necessary to get a good general picture of the relative amount of connection activity. Naturally, this may vary over systems, but the effect was found to be relatively consistent within this exercise.

Overall, the method has a couple of additional limitations to note. One is that the method at defined can only reasonably work with rail and not with local buses in most environments. This is because bus stations are simply too ubiquitous to attribute the termination of a nearby bikesharing trip to a transit connection. Another limitation relates to the metric of the *percentage* of trips identified as connecting to transit. This metric, while directly measurable and easy to interpret, relies on a certain consistency of the system. That is, if the system expands in areas not associated with transit connections, the percentage of trips identified as connecting to transit will drop, even though there is no aggregate change in transit connecting activity. Thus, for the interpretation of connections over time, additional metrics may be useful, such as the aggregate number of trips identified as connecting to transit, alongside the percentage of trips identified. At the same time, percentages remain useful for the purposes of provide a relative measure of connection activity in the context of the broader system activity.

To conclude, the methodology presented here provides an approach to generate a measurement of trips that are likely connecting for transit when accounting for proximity, trip time, trip alignment with the transit line, and the transit schedule. The method, and further enhancements of it, can be applicable to estimating the relative magnitude of bikesharing connections to transit over time. The findings of this analysis suggest that bikesharing connections to transit are a minority of overall activity and vary with land-use. Most bikesharing activity serves isolated point-to-point travel within the city or even serves as substitution for public transit. The role of bikesharing in supporting public transit within several corridors is found to be sizeable, and at the scale of these systems represents hundreds of thousands of connections over a relatively short period of time.

SHARED MICROMOBILITY SURVEY

The general population were categorized by the demographic distributions of income, education, age, race/ethnicity, and gender. The population statistics were drawn from the latest available (2019) U.S. Census American Community Survey data. The statistics of San Francisco and Oakland were combined to produce the population distribution shown in this section for comparison. In general, the quota management implementation of the survey served to align the sample with the population rather well, but there were some departures, particularly at the edges of certain distributions. The gender split of the survey was one attribute where a more sizeable departure with the sample occurred relative to the population. The male to female split of the survey sample was 45 percent to 55 percent, whereas the split within the population was 50/50. This departure may be the result of a general predilection of females to take surveys relative to males. The next distribution was that of income, shown in for the both the sample and population. The distribution shows that the survey sample matched the population distribution rather well for all income categories at $50,000 and below. There is greater departure at the upper end of the distribution, where the survey sample is over-represented from $100,000 to $150,000, but significantly under-represented for income levels of $200,000 or more.

Figure 16. Distribution of Survey Sample and Population Income

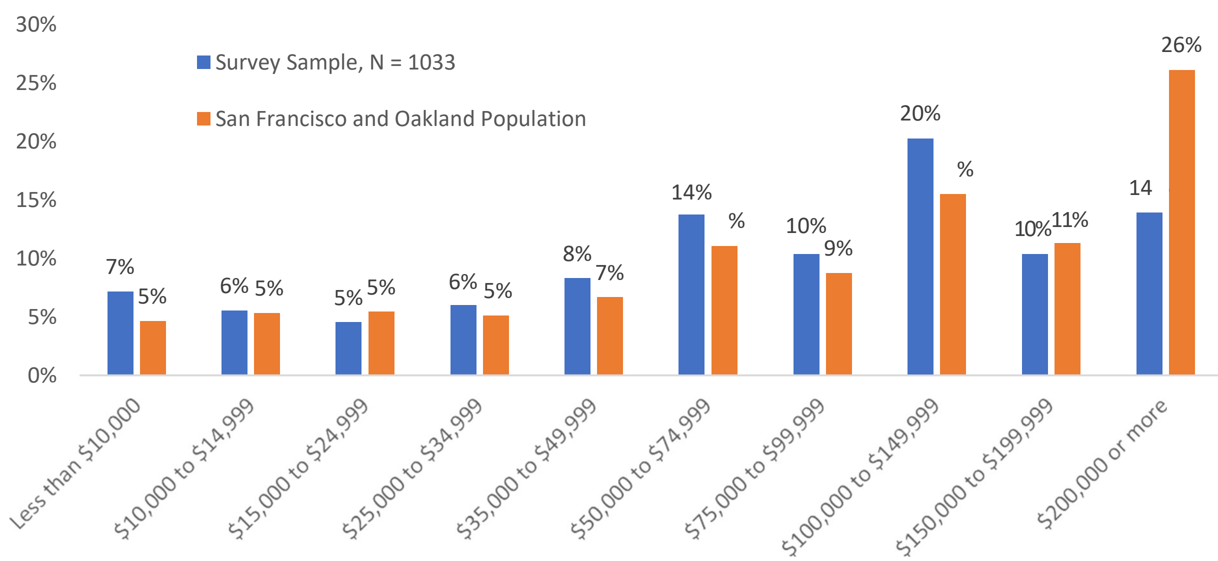


Figure 17 shows the distribution of educational attainment for the survey sample and population. The distribution of the survey matched the population rather well. In particular, upper education levels of the sample matched the population very closely. The survey sample also matches very well with the population share of high school/GED attainment. One category of with notable separation was the category of some college no degree. This was in part due to way the survey sample categorized those taking the survey who were students. These would include respondents who were studying for a degree but had not yet attained it. Overall, however the education distribution of the survey sample matched the population relatively well.

Figure 17. Distribution of Survey Sample and Population Education

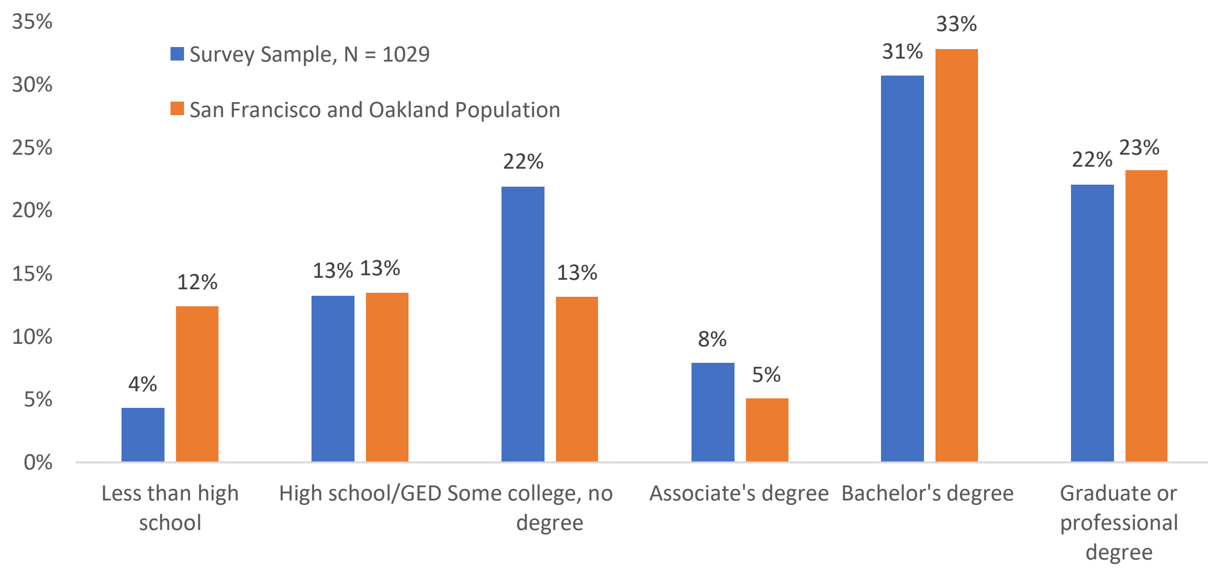


Figure 18 shows the distribution of age for both the survey sample and the population. The distribution of the survey sample matches the population rather well within the middle age brackets. The sample slightly over represents younger populations, likely due to a greater inclusion of students (which was also noted as apparent in the educational distribution), and slightly underrepresents senior populations over the age of 75. Finally, Figure 19 shows the comparative distribution of race/ethnicity for the sample and for the population. This survey sample distribution was found to match the population rather well across five main categories, including White, Asian, Black, Hispanic/Latino, and Other. The largest departure was only by about four percent for Hispanic/Latino. All other categories within the sample aligned within margin less than four percent. Overall, the distributions of the five major demographic categories found that the survey sample aligned relative well with the general population.

Figure 18. Distribution of Survey Sample and Population Age

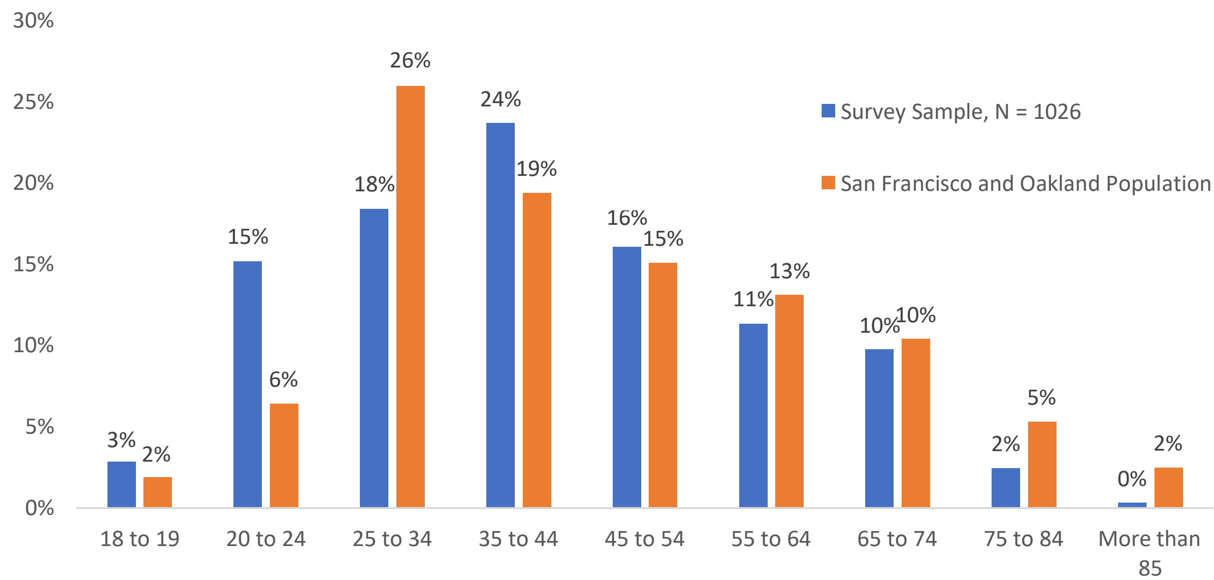
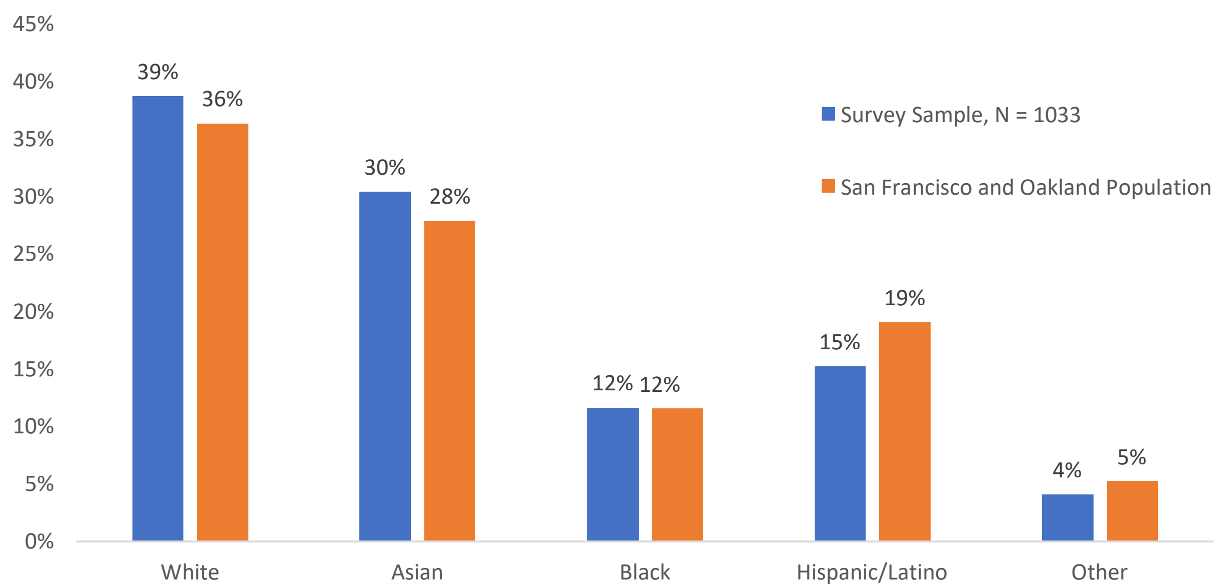


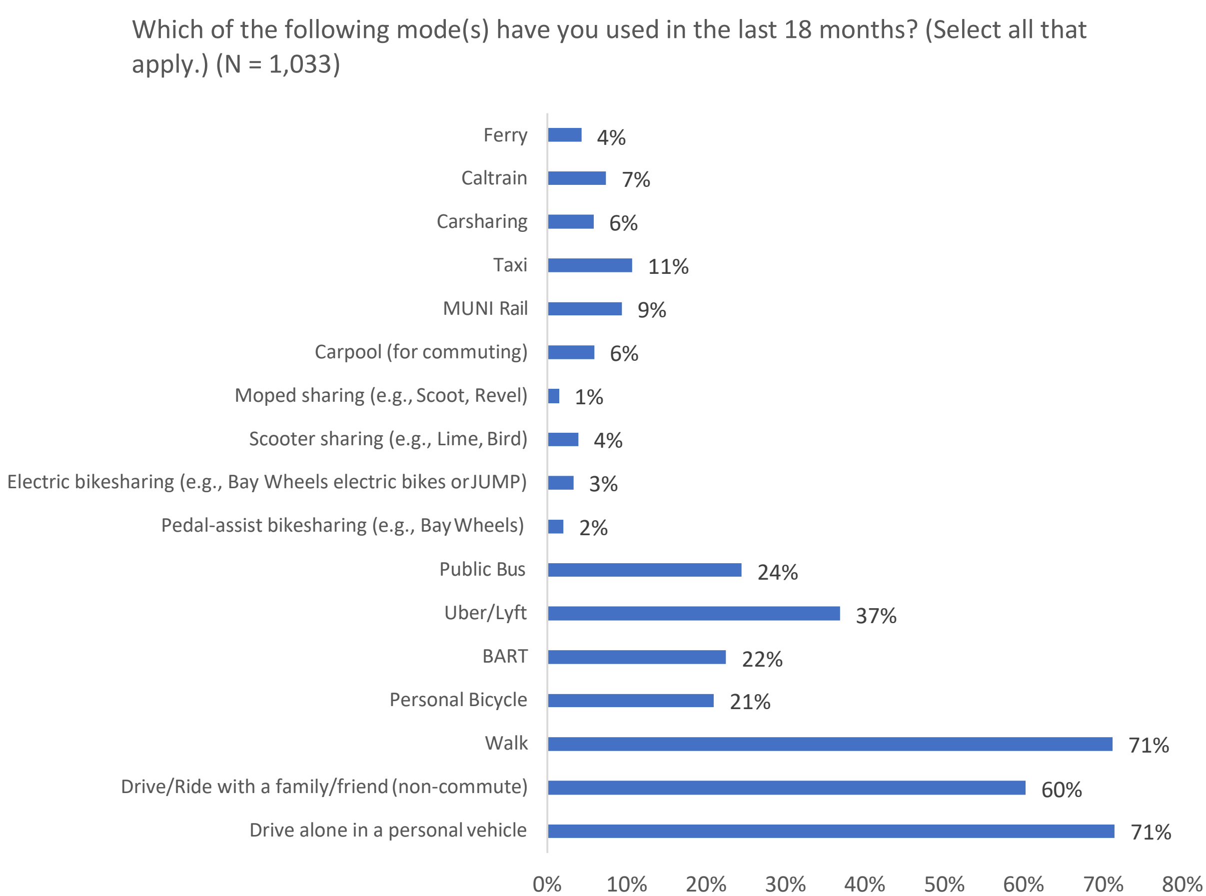
Figure 19. Distribution of Race/Ethnicity



Bikesharing Connections to Public Transit

The survey asked a number of questions that identified bikesharing users and shared micromobility users more broadly. Those who had reported using bikesharing or another shared micromobility mode (e.g., scooters) were asked additional questions about their activity with the mode, including the propensity to connect to and from public transit with it. Figure 20 shows the distribution of all modes taken by respondents during the 18 months prior to the survey deployment. The distribution shows an expected emphasis on driving alone, where 71 percent of respondents had reported driving alone during the last 18 months. Walking to a destination received an equal response, while driving or riding with a family or friend was the third most frequently selected response. A collection of public transit options along with TNCs make up the next collection of response. BART and public bus were selected by 22 percent and 24 percent respectively, while Uber and Lyft were selected by 37 percent. Personal bicycle followed with 21 percent of respondents reporting having used the mode. The shared micromobility modes of "Pedal-assist bikesharing" (Bay Wheels), Electric bikesharing (JUMP), Scooter sharing (JUMP, Bird, etc.), and "Moped sharing" (Scoot, Revel), were selected by 70 respondents or 6.7 percent of the sample. While there are other approaches to measuring the number of shared micromobility users, since the sample was stratified to match the general population, this percentage may be considered close to the actual percentage of shared micromobility users within the of these two cities population. However, it may be biased slightly upward given the noted tilt of the sample towards younger student demographics. Many shared micromobility users reported using more than one micromobilty mode, so the sum of percentages of shared micromobility modes exceeds 6.7 percent in Figure 20.

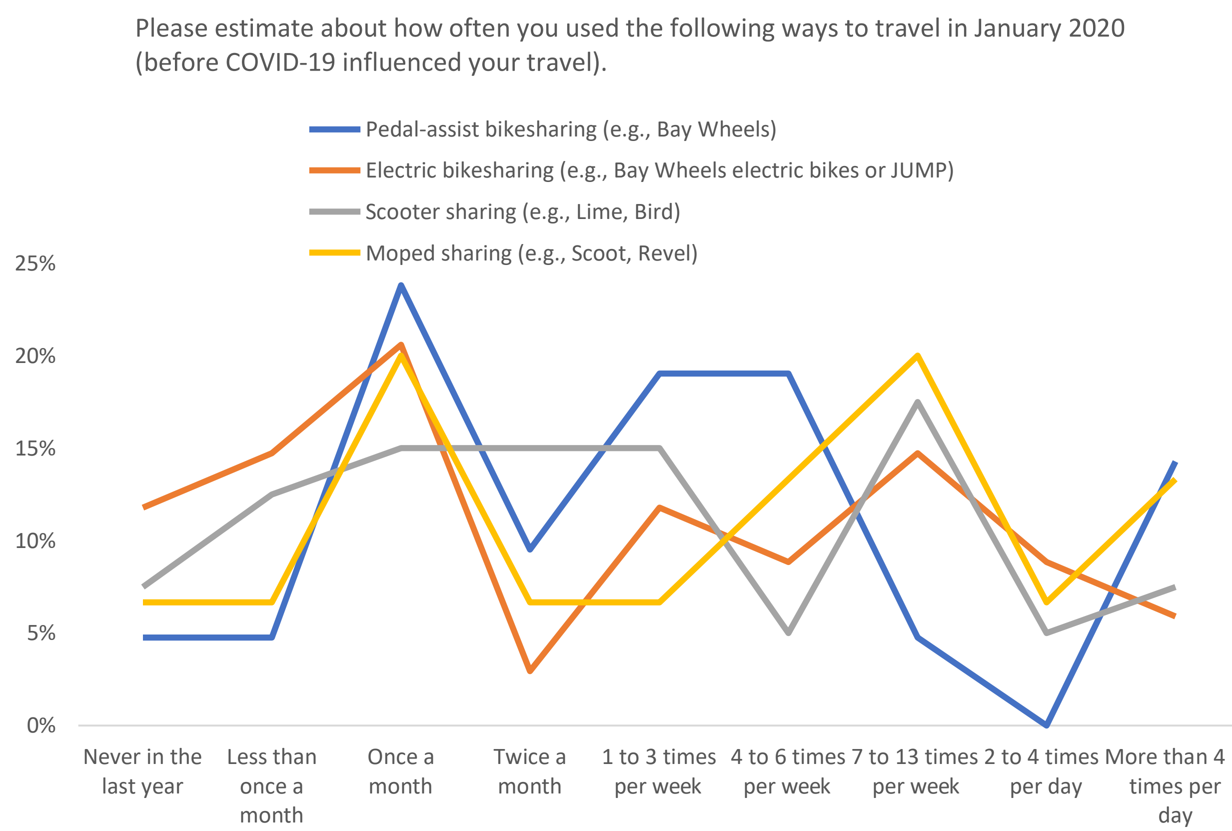
Figure 20. Distribution of Mode Use of the Survey Sample



Demographically, shared micromobility users were found to be younger than population sample, of a slightly higher income distribution, and a slightly higher education. With respect to income and education, the differences between shared micromobility users and the broader sample were relatively limited, with slightly higher representations of upper incomes and educations relative to the survey sample. The gender balance of shared micromobility users exhibited the largest departure. While males represented 45 percent of the general population, they represented 62 percent of the shared micromobility user subsample. Finally, with respect to race/ethnicity, shared micromobility users were found to be more white than the sample. Whites represented 39 percent of the survey sample but represented just over 50 percent of shared micromobility users. This increased White representation among shared micromobility users came at the expense blacks and Asians, but not Hispanic/Latinos, where the representation held steady with the survey sample.

Among those who used shared micromobility, the distribution of frequency of use was found to be rather uniformly distributed. That is, a fair share of shared micromobility users reported using the mode frequently, on the order of one to three times per week or more. Numerically, between 50 percent to 60 percent of users of each mode reported using it at least one to three times per week. This suggests that for those who use the mode, it is a routine component of their mobility portfolio. Figure 21 provides further information on the frequency of shared micromobility use.

Figure 21. Frequency of Use of Shared Micromobility Modes



Mode substitution resulting from the shared micromobility is an important consideration as well for understanding how it interacts with public transit. Respondents that used shared micromobility were asked what they mode they would have used to make the trip had shared micromobility not been available, the results are shown in Figure 22.

Figure 22. Mode Substitution from Shared Micromobility

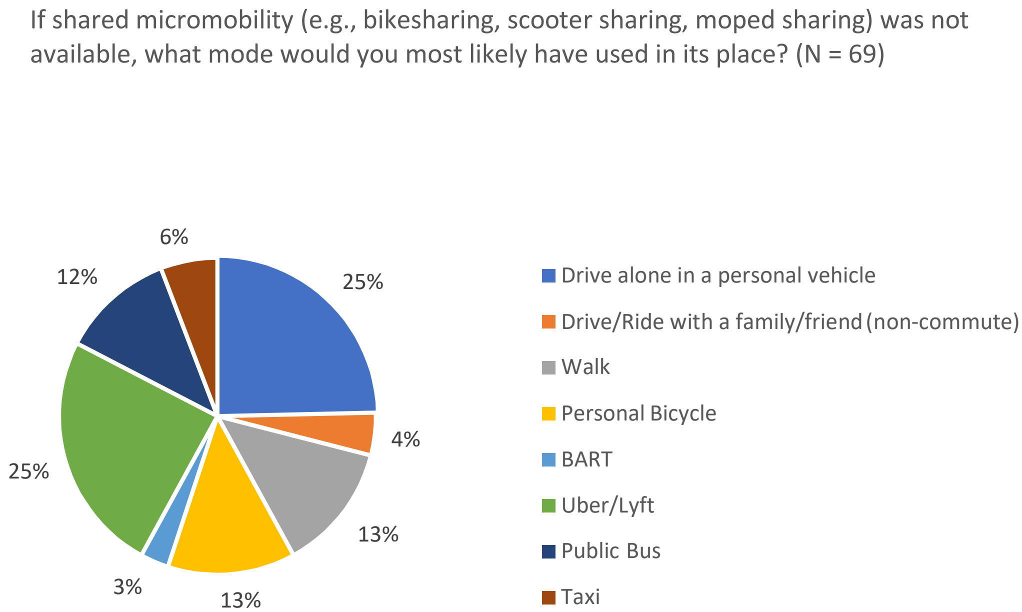


Figure 22 shows that shared micromobility users substituted for a variety of a wide variety of modes. Notably, the share of respondents reporting substitution of public transit is relatively low, where 12 percent of respondents substituted for public bus and only three percent substituted for BART. MUNI rail was an option that could be selected by respondents, but it was not reported by anyone. It is expected that with a larger sample size, other public transit modes would also be represented. However, the results suggest that shared micromobility substitution with Oakland and San Francisco is predominantly of personal vehicle modes including "Drive alone in a personal vehicle" (25 percent), "Drive/Ride with a family/friend (non-commute)" (three percent), and Uber/Lyft (25 percent). Broadly, Figure 22 reports a limited a substitution of public transit. These encouraging results may in part be due to the survey being a general population survey versus a user survey. A user survey, which collects a large number or respondents that use a specific mode (such as bikesharing), can be effective at evaluating mode substitution with higher sample sizes. However, a report released by NABSA in 2020 averaged mode substitution questions across a series of user surveys taken across the North America found similar order of magnitudes within the average response. The unweighted average of mode substitution responses found that 20 percent of bikesharing substituted for public transit, while only eight percent of scooter trips substituted for public transit trips.

The survey contained questions that evaluated the frequency with which users of shared micromobility connected to public transit. Figure 23 reports on an ordinal scale of frequency that respondents reported connecting to or from public transit. The results show some variation by mode, but notably a minority (<20 percent) of respondents of each mode reported rarely using shared micromobility to connect to or from public transit.

Figure 23. Frequency of Shared Micromobility Connecting to Public Transit

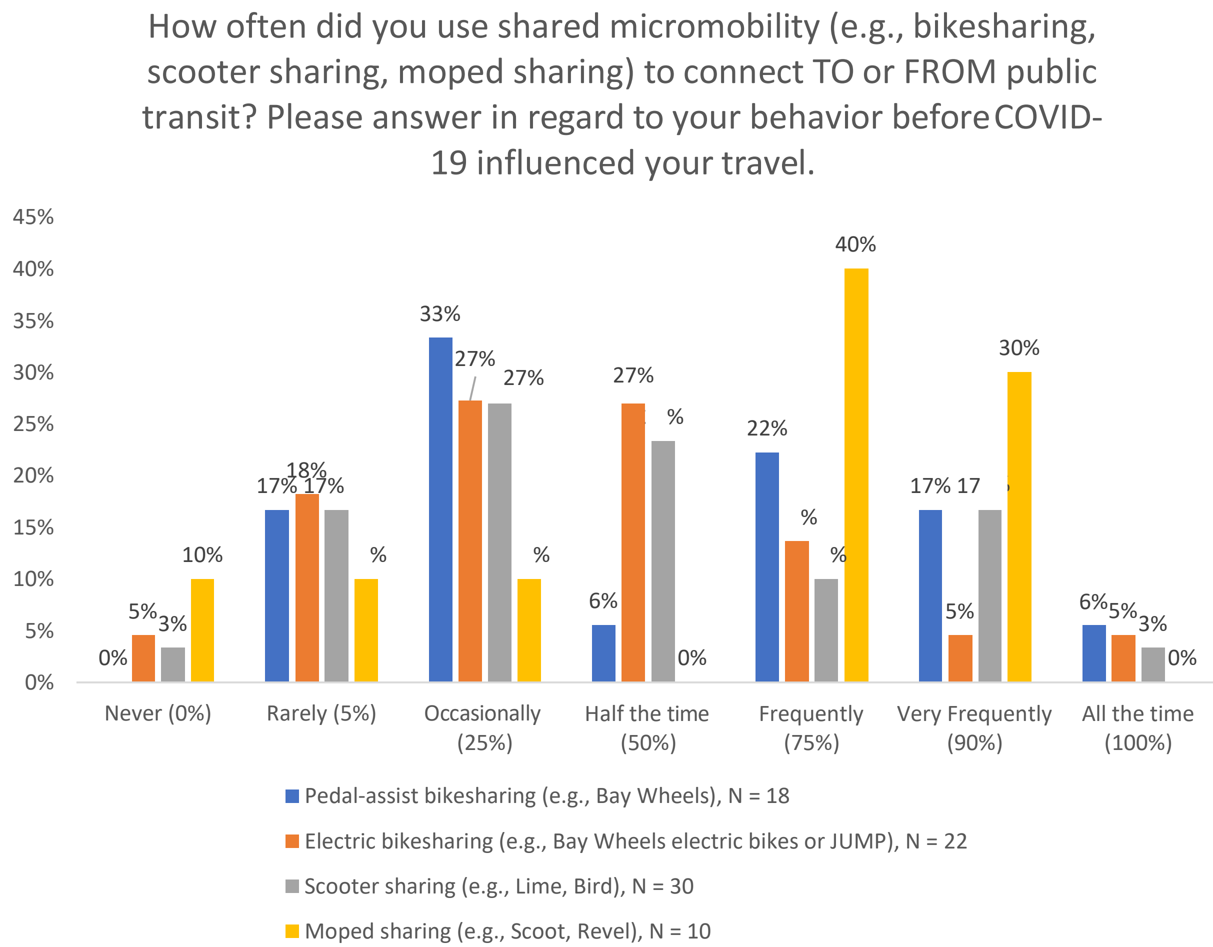
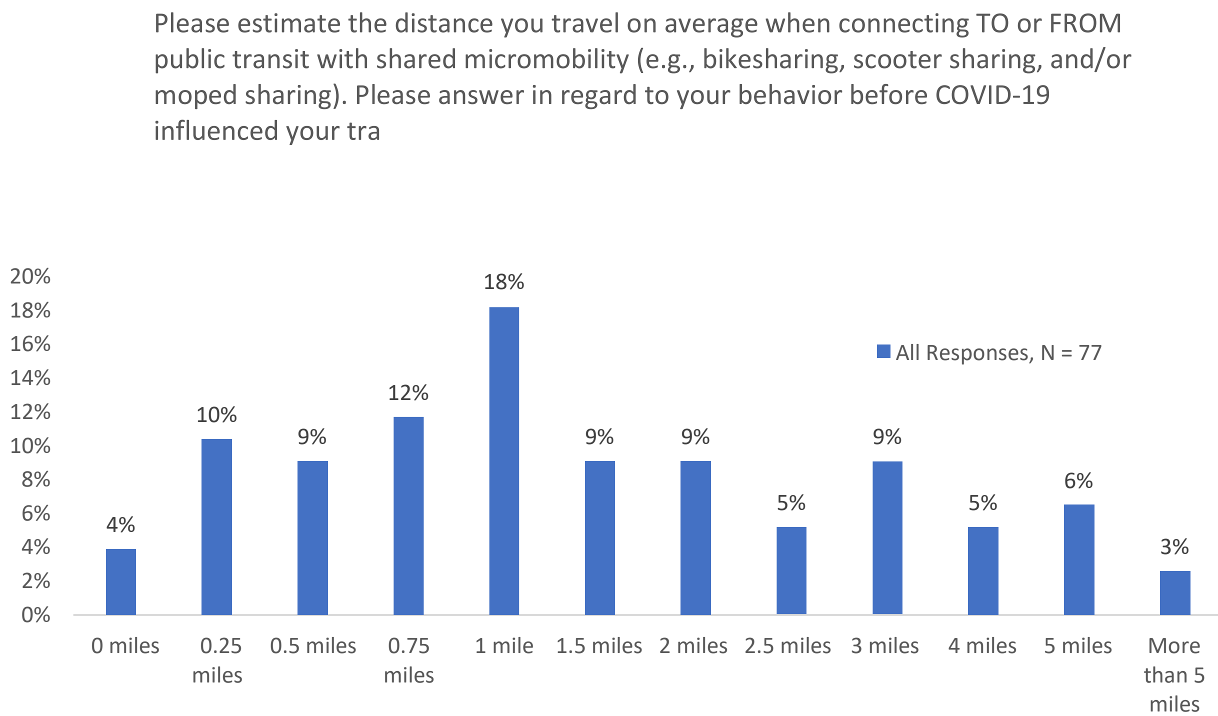


Figure 23 shows that those using "Moped sharing" seemed to use the mode with the greatest frequency to connect public transit. At the same time, this was the shared micromobility mode with the smallest sample size of responses. The more commonly used scooter sharing and electric bikesharing were predominantly used to connect to public transit "Occasionally" (25 percent) or "Half the time" (50 percent), by about half of the respondents reporting use of the mode. The percentage in the parenthetical was meant to be a numerical approximation of the percentage of times they connected with public transit as a percent of the total number of uses of that mode. About 39 percent of respondents using pedal bikesharing reported that they connected with public transit frequently or very frequently. Broadly, the results from Figure 23 suggest that connections to public transit using shared micromobility (including bikesharing) was a relatively common trip purpose among respondents that used the mode.

Finally, the survey asked questions about the distance traveled for shared micromobility trips connecting to public transit as well as the time traveled during trips connecting to and from public transit. Figure 24 shows the distribution responses as aggregated across all shared micromobility modes.

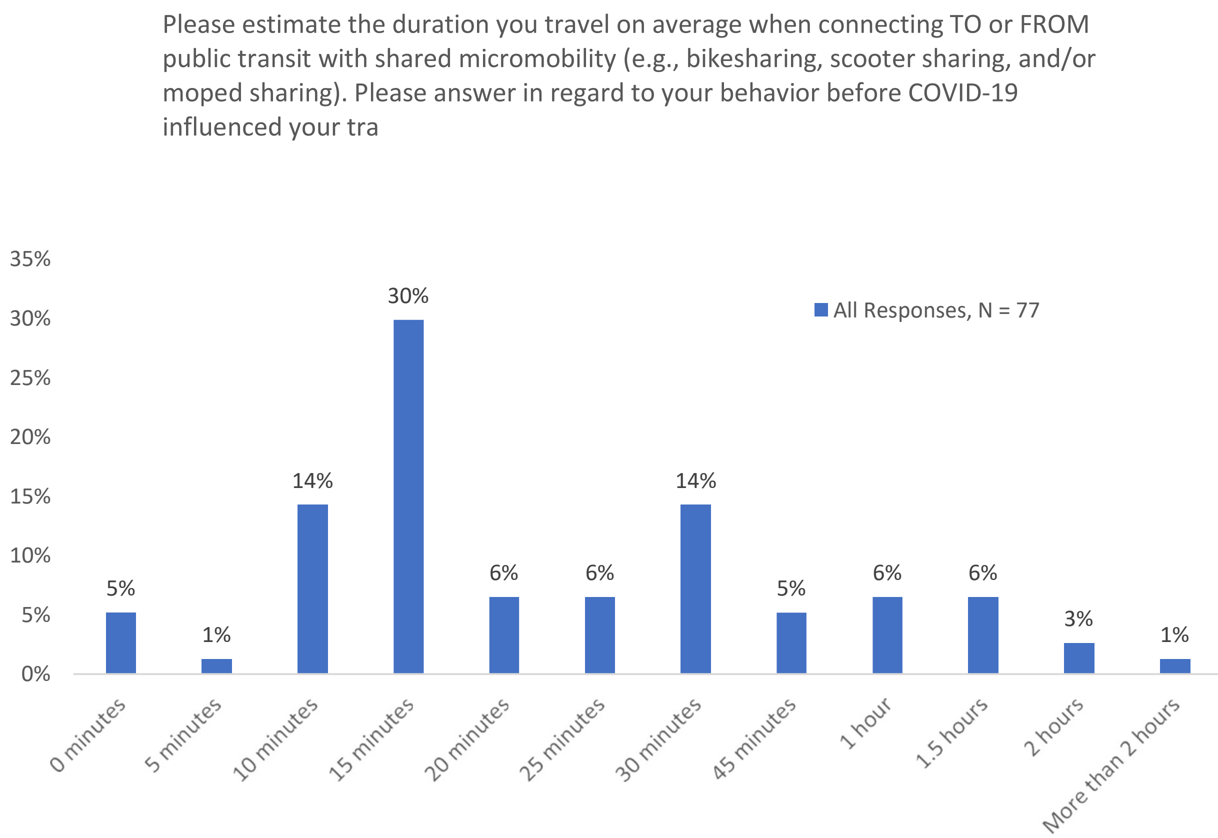
Figure 24. Distribution of Distance Traveled to Connect to Public Transit



The numerical average distance of the distribution is about 1.8 miles. But this sensitive to the value assigned to the “More than 5 miles category.” With an assumed value between six to nine miles, the average is 1.8 rounded to the nearest tenth. At an assumed value of 10 miles for this category, the average rises to 1.9. Overall, the results suggest that while reasonable share of transit connecting exceed two miles, trips connecting to transit are on average about two miles as reported by respondents.

Similar to the analysis of distance, respondents were asked about the duration of travel that they typically experience when connecting to public transit using shared micromobility. Figure 25 presents the distribution of aggregated responses by shared micromobility users. The results suggest a relatively widespread in travel times reported by respondents. About half of the respondents reported travel time of 15 minutes or less. The remaining half of respondents were spread over times extending from 20 minutes to more than two hours. The upper echelons of this range may seem implausible or unlikely, but nonetheless were reported by respondents. The results suggest that the vast majority (78 percent) of users believe that their travel to public transit via shared micromobility fell within 30 minutes or less.

Figure 25. Distribution of Time Traveled to Connect to Public Transit



Summary

The results of the survey analysis showed that the general population survey aligned well with population statistics reported by the U.S. Census American Community Survey. The robust alignment of the sample to population provided a good foundation for extracting shared micromobility user attributes and behaviors. The subsample of shared micromobility users within the sample amounted to 70 respondents (6.7 percent) of the total general population sample. A comparison of their demographics to the broader sample suggests that shared micromobility users are most distinguished as being predominantly male (at 62 percent of the subsample), whereas men represented 45 percent of the broader survey sample. The subsample of shared micromobility users was also more likely to be white relative to the general population. Finally, shared micromobility users were more likely to be younger relative to the general population. The distributions of education and income skewed slightly higher for shared micromobility users, but not significantly so. The broader behavioral findings of the survey found that shared micromobility users would use the collection of services to substitute for a number of modes, and that substitution for public transit was relatively infrequent as compared to modes based on personal automobiles. The survey suggested that those that do connect to public transit do so with some regularity. Only about 20 percent of respondents reporting that they used their given shared micromobility mode “Rarely” or “Never” to connect to public transit. Far more common were responses of “Occasionally” or “Half the time,” suggesting that the use of shared micromobilty modes to connect to public transit was a common use case. Pedal bikesharing (in contrast to e-bikes) in particular was found to have a high frequency of use for this purpose among respondents, possibly due to the fact that docked infrastructure is routinely positioned near transit stations. Overall, the survey results suggest that users of bikesharing and scooter sharing are active in using the mode to connect to public transit systems. The results also suggest that this is generally routine for a fair share of users. These and related findings in other sections support the conclusion bikesharing and shared micromobility are generally playing a positive role in supporting connections to public transportation.

CONCLUSION

This research attempted to answer four questions on the relationships and impacts between shared micromobility and public transit using a multi-method qualitative and quantitative approach. The approach included a literature review of over 135 resources, interviews with 19 shared micromobility and public transit experts, analysis of survey data from 1,029 respondents, and an evaluation of survey data from four California cities. Key findings to each of the research questions can be found below.

Shared Micromobility and Public Transit

The relationship between shared micormobiltiy and public transit is unclear but early and exploratory research tends to indicate that station-based bikesharing may decrease bus ridership while increasing rail use. Early research also suggests that scooter sharing may complement public transit, however more research is needed. The experts interviewed also agreed that current findings on shared micromobility impacts are not conclusive and often have mixed results. For example, early findings show that shared micromobility use tends to be high around public transit locations, but it is unclear if devices are being picked-up and dropped-off at public transit or if the operators are rebalancing the devices at these locations.

The activity data analysis similarly demonstrated inconclusive results regarding bikeshairng and transit connections. The analysis showed that bikesharing connections to transit are a minority of overall activity and vary with land-use. Most bikesharing activity serves isolated point-to-point travel within the city or even serves as substitution for public transit. The role of bikesharing in supporting public transit within several corridors is found to be sizeable, and at the scale of these systems represents hundreds of thousands of connections over a relatively short period of time.

Shared Micromobility Safety Impacts

While research on shared micromobility safety impacts is emerging, existing literature suggests that shared micromobility may impact the safety of users and nearby individuals (e.g., people waiting at public transit stops). Common safety challenges include riders improperly operating devices (e.g., riding at high speeds or in the incorrect direction on streets) and not wearing helmets. However, implementing supportive infrastructure, standardizing regulations, and sharing safety data can help address these challenges.

Shared Micromobility Performance Metrics

Developing insightful performance metrics are key for supporting the growth of shared micromobilty. The experts interviewed said more data are needed to understand trip substitution and the impact of micromobility on single occupant vehicle use. Experts also recommended ensuring that data is available to measure for performance metrics given the limitations of GPS data.

The analysis of activity data revealed challenges measuring shared micromobility impacts and performance. These challenges, and future considerations include:

- **Vehicle Origin and Destination Considerations:** The data evaluated the origin and destination of the vehicle and not the user. Therefore, it is possible that not that all trips identified as transit connecting had the rail station as the user's origin or destination. It is similarly likely that some trips excluded from the transit connecting identification were in fact transit connections, where the user walked a little father to get to or from the rail station.

- **Time Windows:** To address concerns with trip exclusions or incorrect inclusions the methodology included considerations for public transit operating hours and 10-minute windows around GTFS arrival times. While the window can be more restrictive in the future, a consistent method that can identify bikesharing connection activity that is likely serving as public transit connections can be useful for monitoring the health of the interaction of the two systems over time.
- **Geographic Restrictions:** The analysis also included a tight spatial radius of 100 meters about the station entrance, leaving limited alternative destinations of interest in many areas. However, in downtown areas, the capacity for greater volatility in true identifications exist, even though these areas would be reasonably suspected to have the largest access and egress activity. This is likely to remain even if additional criteria is added and such criteria could end up being too restrictive (e.g., discarding more true connections than false ones).
- **Rail Versus Bus Limitation:** The method can only reasonably work with rail and not with local buses in most environments because bus stations are too ubiquitous understand the termination of a bikesharing trip.
- **Percentage of Trips Limitation:** This metric is directly measurable and easy to interpret but relies on a certain consistency of the system (i.e., if the system expands in areas not associated with transit connections, the percentage of trips identified as connecting to transit will drop, even though there is no aggregate change in transit connecting activity). Thus, additional metrics may be useful (e.g., aggregate number of trips identified as connecting to transit).

The lessons learned can help inform the development of future shared micromobility performance metrics and research.

APPENDIX A: EXPERT INTERVIEW PROTOCOL

Intro

The purpose of these interviews is to provide a policy context for the research. We would like to know how various transport providers, policymakers, and other interest groups view the relationship between shared micromobility (bikesharing and scooter sharing) and public transportation, and what you see as the most important policy issues.

Interview Questions

1. Can you describe your role in your organization its relevance to shared micromobility (bikesharing/scooter sharing)/public transportation?
2. Do you have information on the frequency and types of trips micromobility is being used for (e.g., short trips connecting to transit, longer commutes to work)?

Micromobility Impacts

3. In what ways do you think micromobility has impacted the use of curbspace by other modes (e.g., pedestirans)?
4. In what ways do you think land use and micromobility impact each other?
5. Have you encountered any challenges with managing curbspace because of the presence of micromobility? If so, what kinds of challenges?
6. What type of infrastructure do you think would support a safer use of micromobility?
7. In what ways do you think the introduction of shared micromobility has impacted public transportation, if at all?
    a. Can you talk more specifically about public transit ridership?
    b. Can you talk more specifically about public transit operations?
    c. How do you think micromobility has changed the market for transportation?
8. Do you see differences in impacts on public transportation between dockless modes and station-based modes?
9. Do you see differences in impacts on public transportation between bikesharing and scooter sharing?
10. What types of issues (e.g., safety, congestion, etc.) are you seeing with the growing number of shared micromobility devices? What are the greatest issues and concerns from your point of view?

Measuring Micromobility

11. What do you think of our preliminary metrics for measuring bikesharing/scooter integration with public transit? How would you improve upon them?
    a. Connection to public transit
    b. Connection from public transit
    c. Public transit trips replaced by micromobility

d. Micromobility trips that did not replace or connect to or from public transit
e. Difficult to classify micromobility trips
f. Operational systems

12. What types of metrics do you think are important for consideration?
13. What types of data sources do you think can be used to are needed to assess these metrics?
14. How do you think public agencies should respond to shared micromobility, particularly for curbspace management?

Micromobility Integration

15. What practices do you think are best for managing curbspace between micromobility and other modes?
16. What is your long-term vision for curbspace management?
17. What is the role of mobility integration in supporting or impeding the relationship of micromobility and other modes? (e.g., smartphone apps, mobility-as-a-service (MaaS), integrated fare payment, etc.)
18. What would you recommend for integrating micromobility moving forward?
19. How do you think shared mobility will fit in with other forms of transportation, such as public transit?
20. What is the role of policy and/or public private partnerships in negotiating/coordinating this relationship among modes?
21. What operations and system design measures do you take (or plan to take) to integrate bikesharing/scooter sharing systems with public transit (asked of both bikesharing/scooter and transit operators)?
22. Do you see differences between agency operated micromobility programs and private sector micromobility services with respect to their impacts on public transportation?
23. What is your long-term vision with respect to shared micromobility and public transportation?

Final Questions

24. Is there anything else you would like to share that we haven't discussed?
25. Do you have anyone else you recommend we talk to for this study?
26. Is it alright for us to contact you again if we have any follow-up questions?

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