Integrating Micromobility with Public Transit: A Case Study of the California Bay Area

February 2023

A Research Report from the National Center for Sustainable Transportation

Beth Ferguson, University of California Davis

Angela Sanguinetti, University of California Davis

National Center for Sustainable Transportation

UC DAVIS Institute of Transportation Studies

Technical Report Documentation Page

1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**
NCST-UCD-RR-23-08	N/A	N/A

4. Title and Subtitle Integrating Micromobility with Public Transit: A Case Study of the California Bay Area	**5. Report Date** February 2023 **6. Performing Organization Code** N/A
7. Author(s) Beth Ferguson, Design MFA, https://orcid.org/0000-0001-7319-2590 Angela Sanguinetti, Ph.D., http://orcid.org/0000-0002-9008-7175	**8. Performing Organization Report No.** UCD-ITS-RR-22-117
9. Performing Organization Name and Address University of California, Davis Institute of Transportation Studies 1605 Tilia Street, Suite 100 Davis, CA 95616	**10. Work Unit No.** N/A **11. Contract or Grant No.** Caltrans 65A0686 Task Order 068 USDOT Grant 69A3551747114
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590 California Department of Transportation Division of Research, Innovation and System Information, MS-83 1727 30th Street, Sacramento, CA 95816	**13. Type of Report and Period Covered** Final Report (October 2021 – November 2022) **14. Sponsoring Agency Code** USDOT OST-R Caltrans DRISI

15. Supplementary Notes

DOI: https://doi.org/10.7922/G2J38QV7

16. Abstract

Micromobility is well-suited to address first- and last-mile connectivity with public transit by extending the catchment area around transit stations and bridging gaps in the existing transit network, ultimately facilitating access to jobs and services. However, the uptake of micromobility depends on a variety of factors including environmental design features at and around public transit stations that support or inhibit access. This research covered environmental audits at 18 BART stations to count arrivals, departures, and parked personal and shared micromobility vehicles, an online survey of BART and micromobility users, and interviews with government, industry, and community stakeholders. This research showed that in the California Bay Area, the prevalence of personal micromobility currently dwarfs rates of shared micromobility use, and that includes a burgeoning segment of transit users connecting with their own e-bikes and e-scooters. Successes and challenges were highlighted, and recommendations made for station design, including greater availability of shared micromobility vehicles, more affordable secure parking for personal micromobility vehicles, better signage and wayfinding. Beyond the station proper, there is a need for protected bike lanes and consistent design standards for bike facilities throughout the region.

17. Key Words	**18. Distribution Statement**
Micromobility, public transportation, shared mobility, scooter, bike	No restrictions.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	62	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

About the National Center for Sustainable Transportation

The National Center for Sustainable Transportation is a consortium of leading universities committed to advancing an environmentally sustainable transportation system through cutting-edge research, direct policy engagement, and education of our future leaders. Consortium members include: University of California, Davis; University of California, Riverside; University of Southern California; California State University, Long Beach; Georgia Institute of Technology; and University of Vermont. More information can be found at: ncst.ucdavis.edu.

Disclaimer

Acknowledgments

This study was funded, partially or entirely, by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) and the California Department of Transportation (Caltrans) through the University Transportation Centers program. The authors would like to thank the NCST, the USDOT, and Caltrans for their support of university-based research in transportation, and especially for the funding provided in support of this project. The authors would like to thank students Emily Searl and Jovita Wattimena for their contributions.

NCST

Integrating Micromobility with Public Transit: A Case Study of the California Bay Area

A National Center for Sustainable Transportation Research Report

February 2023

Beth Ferguson, Department of Design, University of California, Davis

Dr. Angela Sanguinetti, Institute of Transportation Studies, University of California, Davis

[page intentionally left blank]

NCST

TABLE OF CONTENTS

List of Tables

List of Figures

Integrating Micromobility with Public Transit: A Case Study of the California Bay Area

EXECUTIVE SUMMARY

Micromobility (bikes/scooters) is well-suited to address first- and last-mile connectivity with public transit by extending the catchment area around transit stations, enabling users to travel more quickly and easily to stations from further away and bridging gaps in the existing transit network (Shaheen & Chan, 2016), ultimately facilitating access to jobs and services (NABSA 2020; DuPuis et al. 2019; Smith & Schwieterman 2018). However, the uptake of micromobility depends on a variety of factors including environmental design features at and around public transit stations that support or inhibit access. These issues are considered through a case study of the Bay Area Rapid Transit (BART) heavy rail system in the California Bay Area.

The present research builds upon a previous project in which the research team conducted environmental audits of 18 BART stations inventorying physical environmental features supportive of micromobility and mapped micromobility providers and bike lanes surrounding the stations (Ferguson & Sanguinetti, 2021). This seed grant supported additional environmental audits focusing on micromobility user behavior (documenting arrivals and departures and parking), updates to the micromobility map and city, community, and industry stakeholder interviews.

Station audits counted arrivals to and departures from the stations on personal or shared micromobility vehicles and number and types of micromobility vehicles parked at each type of parking facilities. Results revealed use of personal micromobility nearly tenfold higher than the use of shared micromobility, including nearly three times as many personal electric vehicles (e-bikes and e-scooters) than shared electric vehicles. Most types of secure personal micromobility parking facilities were relatively well-used, but outdoor racks were mainly used for shared micromobility. Interesting anecdotal observations during the audits included that many travelers took their personal bikes onboard BART trains rather than storing them and (non-folding) scooters were often brought into stations despite a policy against it (currently only folding scooters are allowed).

An online survey of BART and micromobility users (focusing on shared micromobility users) explored the influence of environmental design features at and around stations on facilitating first and last mile connections. Personal safety and security emerged as the key challenges. Participants conveyed the need for better bike lanes in station neighborhoods and better lighting and visibility of pathways and less crime at stations.

Another challenge is shared vehicle availability. A large majority of users said they had on occasion been unable to find a vehicle to get to the station or get home from the station. Nearly half said shared vehicles were always difficult to find around their destination stations and more than half said there was insufficient parking at their destination stations for shared micromobility.

Interviews with government, industry, and community stakeholders were conducted to gather more context for understanding the audit and survey results. For example, stakeholders explained the issues with access to shared vehicles at stations seem to mainly center on market challenges for the industry. It is costly for operators to rebalance vehicles to ensure adequate numbers at transit stations and other strategies are more profitable. Government and industry stakeholders recognized a need for greater subsidies for operators or other service models to streamline micromobility and transit connection and make it more affordable.

The micromobility landscape continues to evolve as shared micromobility business models and private-public partnerships gain experience and travel behaviors find a new normal in the wake of the pandemic. This research showed that in the California Bay Area the prevalence of personal micromobility currently dwarfs rates of shared micromobility use, and that includes a burgeoning segment of transit users connecting with their own e-bikes and e-scooters. Further research can establish the degree to which better access to shared vehicles might change this balance and the degree to which shared services play a role in allowing users to test out the technology leading them to ultimately invest in their own bicycle or e-vehicle.

Regardless of the shape it takes (personal or shared vehicles; scooters, bikes, or other), micromobility holds tremendous promise for facilitating first and last mile connections with public transit. Taking the California Bay Area Rapid Transit system as a case study, this research documented current micromobility use patterns at stations, examined transit station environmental design features, and explored stakeholder experiences with respect to the integration of micromobility and public transit. Successes and challenges were highlighted and recommendations made for station design, including greater availability of shared micromobility vehicles, more affordable secure parking for personal micromobility vehicles, better signage and wayfinding. Beyond the station proper, there is a need for protected bike lanes and consistent design standards for bike facilities throughout the region. Further research and design solutions focused on facilitating micromobility connections with BART can help California continue to demonstrate leadership in supporting low carbon transportation options.

Introduction

Revolutionizing urban transportation on a massive scale is necessary to meet the climate goals set by the Paris Agreement and mitigate global warming (Santos, 2017). Industry stakeholders, policymakers, and academicians are imagining a more sustainable transportation system where mobility-as-a-service (MaaS), including micromobility, shared mobility, and public transit, supplants personal cars as the dominant model (Shaheen & Cohen, 2018; Sheller & Urry, 2016; Sperling, 2018). However, public transit use in the US has decreased in recent years (Mallet, 2018) and faces further challenges due to the COVID-19 pandemic (Zheng et al., 2020).

For this study we have used the U.S. Department of Transportation's definition of micromobility to be: "any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances." Micromobility technologies (i.e., e-bikes and e-scooters) and shared service models (i.e., on-demand docked and dockless fleets of bikes, e-bikes and e-scooters) present an opportunity for increasing public transit use. In particular, micromobility is well-suited to address first- and last-mile connectivity with public transit by extending the catchment area around transit stations, enabling users to travel more quickly and easily to stations from further away (e.g., not relying on less flexible feeder buses), and bridging gaps in the existing transit network (Shaheen & Chan, 2016), ultimately facilitating access to jobs and services (NABSA 2020; DuPuis et al. 2019; Smith & Schwieterman 2018). Recognizing this potential, shared micromobility companies and public transit agencies have formed partnerships (e.g., Bizjak, 2018).

Private ownership of light electric vehicles has also increased in recent years in the US (they have been popular in Asia since the 2000s; An et al., 2013, Dekker, 2013, Fishman and Cherry, 2016), especially since the pandemic. According to Bennett and MacArthur (2022) e-bikes sold annually in the US increased from less than 300,000 to over 1 million between 2018 and 2021, and the boom that occurred during the pandemic has been sustained for e-bikes whereas traditional bike sales have returned to pre-pandemic rates. Another benefit of personally owned micromobility can be a lower carbon footprint. Life cycle assessments of shared versus personal e-scooters, e-bikes, and e-mopeds have found that the latter generate less CO_2-equivalent emissions, due to the longer vehicle lifespan of personal micromobility (De Bortoli, 2022; Moreau et al., 2020).

The potential for personal and shared micromobility as a solution for first- and last-mile connectivity with public transit depends on a variety of factors related to shared service accessibility, ease of use, and safety, including user education and training; vehicle fleet size and charging and deployment practices; safe facilities for riding and parking; weather and road conditions; fitness of vehicles for diverse ages and abilities; and pricing. Many of these issues relate to the design of the built environment, which is the focus of this research. Specifically, this research is concerned with environmental design features at and around public transit stations that support or inhibit micromobility access. These issues are considered through a case study of the Bay Area Rapid Transit (BART) heavy rail system in the California Bay Area. We consider micromobility broadly, to include personal and shared non-motorized and electric bikes and scooters.

The rest of this report proceeds as follows. A brief literature review and background to the research are presented followed by four sections describing the aims, methodology, and results of each of four research efforts: BART station observational study, BART and micromobility user online survey, stakeholder interviews, and ArcGIS Bay Area Micromobility Map. These sections are followed by a Discussion section that interprets the findings across the four efforts and a conclusion section that suggests practical implications and future research needs.

Literature Review

A good deal of attention has been given to built environment features that promote traditional active modes (walking, non-motorized bicycling, and public transit) for healthy and sustainable cities. These include designing secure networks of active travel paths and making active travel enjoyable by creating safe and attractive neighborhoods with convenient access to affordable public transit (Giles-Corti et al., 2016). For bikes in particular, separated bike lanes, mixed-use neighborhoods, and connectivity between local streets have been found to promote use (Zhao, 2014).

The same features support newer forms of micromobility (shared and personal light electric vehicles), though other affordances are also important. For docked bikesharing, the proximity of docking stations to work and home strongly predict adoption (Bachand-Marleau et al., 2012; Fishman et al., 2013; Fishman et al., 2014). Bikesharing service design recommendations include real-time bike and parking availability information technologies, reliable bike maintenance and locking mechanisms, extended operational hours, and dense vehicle availability in multiple nearby locations to create a network effect (Cohen & Shaheen, 2016; Shaheen et al., 2011).

E-bikes and e-scooters may have unique needs for built environment supports regarding where users can and cannot ride and park, including the infrastructure itself and signage that communicates the rules. Some of these innovations are non-conforming to mainstream street designs, presenting challenges for cities tasked with regulating them, e.g., e-scooters sharing sidewalks with pedestrians (potentially dangerous for pedestrians) or riding in the street (potentially dangerous for scooter riders). Best practice guides have been developed to assist cities (National Association of City Transportation Officials, 2019; Transportation 4 America, 2020), but limited research exists on actual impacts of built environment factors and related policies. Exceptions include an evaluation of an e-scooter pilot in Portland (Portland Bureau of Transportation), which revealed a strong public preference for protected bicycle and/or scooter infrastructure and found that more protected infrastructure and lower street speed limits were associated with reduced illegal use of e-scooters on sidewalks. The study also found community concerns about dangerous and illegally parked scooters; however, in an observational study in San Jose, CA, researchers found that 97% of e-scooters were parked appropriately, not interfering with pedestrians (Fang et al., 2018).

Transit Station Design

There is also literature on the specific topic of transit station design, including general best practice guidelines (not specifically on strategies to facilitate micromobility and active transportation connections to public transit). Much of this literature, including one relatively seminal source (Griffin, 2004), predates micromobility. Furthermore, such considerations may have historically been framed as low priority in the US. For example, one source that overviewed guidelines for transit station design (Beimborn et al., 1993) contained only one mention of bikes and the advice was tentative: “Bicycle access to transit centers, park-and-ride lots, freeway flyer stops, and other major bus stops should be encouraged by local jurisdictions. Wide curb lanes (13 ft, minimum) or striped bike lanes should be considered for major streets leading to transit facilities” (p.169-170).

Some station design best practice studies have devoted more detailed attention to facilitating micromobility. For example, Kumar et al. (2010) developed a framework (Multi Modal Oriented Design) for designing multimodal transit stations in Delhi. The framework recommended: safe and convenient bicycle routes in the neighborhoods surrounding the station; well-lit and well-marked bicycle parking facilities protected from weather, theft, and conflicts with other modes. To avoid theft, they recommended parking be located in areas with high pedestrian activity or staffed with station attendants. They also noted that parking should be located close to the station entrance and nearby roadway, and that facilities that secure both the bike wheels and frame are preferred.

Other reviews of best practices for designing intermodal transportation stations have drawn on examples across Europe (Magginas et al., 2018) and worldwide (Bernal, 2016). Magginas et al. focused on facilitating active travel specifically, whereas Bernal considered all modes. Bernal provided a useful framework that articulates three types of station design elements: transfer and operational (features to make the transfer more efficient, e.g., bike facilities and integration around the station), placemaking (features to create a sense of place, e.g., amenities, lighting, signage); and implementation (management of space, including staffing and security arrangements). Magginas et al. focused on policies but highlighted environmental design affordances such as provision of bike rental and sharing services; streets bike infrastructure (direct cycle paths/connectivity of paths, bicycle friendly escalators and extended lanes); bike parking; information provision; motor vehicle traffic control (e.g., traffic calming and reduced speeds); and friendly spaces. Another important guide in the grey literature (Monigl et al.) focused specifically on innovative cycling facilities for transportation interchanges. It references successful examples, such as the Swedish Rail station in Lund, which implemented a bicycle bridge and authorized cyclists to use elevators to reduce their travel distances and effort to traverse the station.

Another vein of research on transit station/hub design investigates station quality by surveying users. Such studies also generally cover broader topics than micromobility access—on aspects of stations that affect all users. They also tend to focus within the bounds of the station (not the surrounds) and on pedestrian crossings and activity within the station (not how users with bikes navigate to and within the station). Such studies often highlight that bike parking at stations is an important factor (e.g., Chauhan et al., 2021; Dell'Asin et al., 2014). They also provide general insights that apply to the experience of connecting micromobility users. For example, one survey of California transit users found that they valued safety and ease of access most, over information (e.g., signage) amenities (e.g., seating, restrooms), and connection speed and reliability (Iseki & Smart, 2012).

Another approach to assessing transit station quality for users is through environmental audits. In an environmental audit, a researcher directly observes and records the presence or absence of specific features at a given site. They may come up with an index or scoring system to summarize the quality of the facility. For example, Moodley and Venter (2022) developed a tool for measuring the service quality of multimodal public transportation facilities through observational data collected on site and established convergent validity with satisfaction ratings from user surveys. The present research also combines user surveys and environmental audits.

Background

The present research builds upon a previous project in which the research team conducted environmental audits of 18 BART stations and mapped micromobility providers and bike lanes surrounding the stations (Ferguson & Sanguinetti, 2021). That project occurred during the height of the COVID-19 pandemic in 2020 when ridership had dropped dramatically, therefore it focused on inventorying physical environmental features and did not capture micromobility and BART station user behavior. Specifically, inventories were conducted of design features in and around the stations that might facilitate or hinder the use of personal, rented, or leased bikes, e-bikes, or e-scooters for first-and-last-mile connections. This seed grant supported additional environmental audits focusing on micromobility user behavior (documenting arrivals and departures and parking). BART ridership has increased to 60% of pre-pandemic levels so data on user behavior will be more meaningful. The seed grant also supported updates to the micromobility map and city, community, and industry stakeholder interviews.

The Bay Area and BART

BART was selected as a case study because it serves a region with both relatively high public transit and shared micromobility use as well as high rates of using micromobility for trips to and from transit (Said, 2019). As such, it is a potential testbed for innovative and adaptive transit station design features to support micromobility. BART started operation in 1972 as a heavy rail elevated and subway system designed to connect suburbs with urban centers, such as San Francisco and Silicon Valley. BART has 50 stations that cover 131 miles across 5 counties and in 2019 averaged 118 million annual passengers.

BART Station Observations

We conducted environmental audits at a subset of 18 BART stations, including stations in San Francisco and the East Bay cities of Berkeley, Oakland, and Emeryville. Eight stations in San Francisco were included: Embarcadero, Montgomery St, Powell St, Civic Center/UN Plaza, 16th St Mission, 24th St Mission, Glen Park, and Balboa Park; and ten in the East Bay: North

Berkeley, Downtown Berkeley, Ashby, MacArthur, Rockridge, 19th St/Oakland, 12th St/Oakland City Center, West Oakland, Lake Merritt, and Fruitvale. The goal was to collect data on micromobility use to complement our past observational research that described environmental design at and around the stations.

The subset was selected to focus on stations with relatively greater opportunities for use of shared micromobility. Each of the 18 stations has a co-located Lyft Bay Wheels docking station within one block on either BART and city land for classic bikes in the East Bay and both classic bikes and pedal assist electric bikes in San Francisco. Each of the four cities also have agreements with multiple shared micromobility service providers (Table 1). Available shared micromobility services vary throughout the region, as companies must apply for fleet use permits from each city and regulators manage permit agreements, rules, fees, fines, and operator exclusivity differently with each provider.

Table 1. Shared micromobility services by city as of October 2022

Shared Micromobility Operator	**City**			
	San Francisco (BART station, Embarcadero, Montgomery, Powell, Civic Center, 16th, 24th, Glen Park, Balboa Park)	**Berkeley** (BART station, N. Berkeley, D. Berkeley, Ashby)	**Emeryville**	**Oakland** (BART stations, Rockridge, MacArthur, W. Oakland, 19th, 12th, Lake Merritt, Fruitvale)
Lyft Bay Wheels (classic bike)	Yes	Yes	Yes	Yes
Lyft (e-bike)	Yes	No	No	No
Spin (e-scooter)	Yes	Yes	Yes	No
Spin (e-bike)	No	Yes	Yes	No
Link (e-scooter, seat-scooter)	No	Yes	Yes	Yes
Veo Ride (e-scooter, seat-scooter)	No	Yes	Yes	Yes
Lime (e-scooter)	Yes	No	Yes	Yes
Bird (e-scooter)	Yes	No	No	No
Total Permitted Operators	4	4	5	4
Source	www.sfmta.com	www.cityofberkeley.info	www.ci.emeryville.ca.us/	www.oaklandca.gov

Method

The lead researcher conducted all of the 18 BART station observations. Each station was observed on a single weekday (Monday through Friday) during a two-week period in October 2022 between 4:30 and 6:00 pm (for a total of 1-1.5 hours). Some data were collected remotely from shared micromobility service apps (described below). Appendix B and Appendix C provide all the data collected for East Bay and San Francisco BART stations, respectively.

There were two sets of observations at each station, conducted on the same visit and each recorded on a separate data sheet. One set of observations (and corresponding data sheet) focused on recording data about micromobility users–specifically, arrivals to and departures from the stations on personal or shared micromobility vehicles. The user observation was conducted for 45 minutes and required that the researcher find the best location to see the main entrance / exit to the BART station. At most stations, it was easy to find a location to clearly see the entrance / exit points. However, at seven stations, it was difficult to find a location where multiple entrance doors could be clearly seen, so the researcher divided the time spent across multiple entrances and remotely watched the shared micromobility apps for any arrivals or departures not in clear view.

Lyft Bay Wheels bikes, e-bikes and shared e-scooter vehicle arrivals and departures were recorded during the 45 min observation period at each of the 18 BART stations. The researcher started each station session by first documenting all the shared micromobility vehicles present. This was first done by physically looking for the vehicles and double-checking on each shared micromobility app. Throughout the observation period, the researcher kept an eye out for shared micromobility station arrival and departures and counted any vehicle changes on the apps. The researcher made a second station sweep at the end of the observation period to check for any shared vehicles that might have arrived or departed.

The second set of observations focused on the parking facilities at the stations, recording the number of different vehicle types, separately by operator for shared micromobility, parked at each kind of facility (e.g., indoor bike racks, outdoor bike racks or other outdoor furniture). The parking observation took 15-30 minutes depending on the size of the BART station. Inside the BART station, the researcher looked for bike racks or bikeep racks (these are personal bike racks that lock both the bike frame and wheel and are activated by using an app or contactless card). Outside the BART station, the researcher observed bike racks, bike stations, bike lockers and Lyft Bay Wheels dock stations to see how many parking spots were in use and how many available. The East Bay has three staffed BART Bike Stations with valet parking that are open weekdays from 7am-7pm; these are located about one block from each: the Downtown Berkeley BART station, 19th/Uptown BART station, and Fruitvale BART station. For this observation the researcher collected the total number of bikes and e-bikes parked that day from a station staff member between 6:30-7:00 pm.

User Observations

There were 90 total arrivals and departures of shared micromobility vehicles across all station observations; see Figure 1 and Figure 2. Arrivals ranged from 0 to 29 per station, [*Mean*(*SD*) = 1.6(2.4)]; and departures ranged from 0 to 11; [*Mean*(*SD*) = 3.4(3.5)]. The most used shared mode was e-scooter (36% of all arrivals and departures), followed by classic bike (32%), e-bike (29%), and least used were mopeds (seated scooters) (3%); see Figure 5.

Figure 1. Bay Wheels classic bike, Glen Park BART, San Francisco, CA, 2022

Figure 2. Link and Veo Ride scooters, MacArthur BART bike rack, Oakland, CA, 2022

There were 836 total arrivals and departures of personal micromobility vehicles across all station observations; see Figure 3 to Figure 4. Arrivals ranged from 8 to 56 per station [*Mean*(*SD*) = 25.3(15.3)]; and total departures ranged from 6 to 55; *Mean*(*SD*) = 21.1(14.5). The most used personal mode was classic bike (59% of all arrivals and departures), followed by e-scooter (23%), e-bike (8%), skateboard (6%), kick scooter (2%), and one-wheel (1%); see Figure 6.

Figure 3. Personal bike and roller skates at Fruitvale BART, Oakland, CA, 2022

Figure 4. Personal scooter leaving Ashby BART, Berkeley, CA, 2022

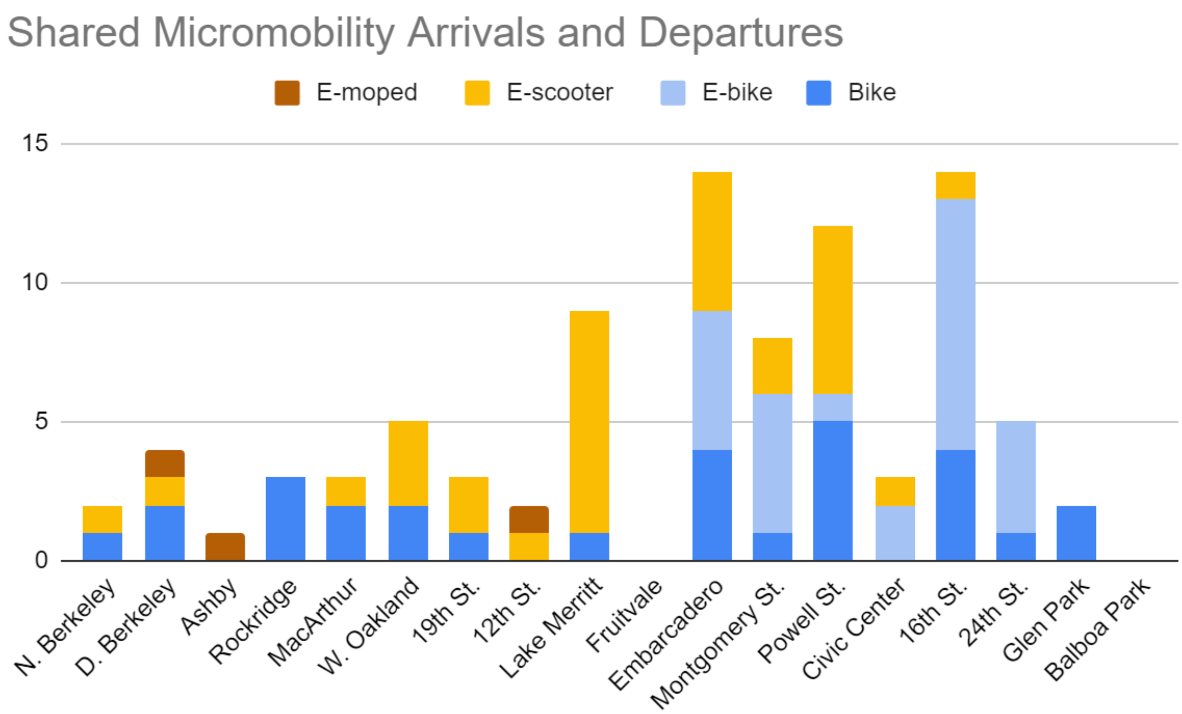

Figure 5. Shared Micromobility Arrivals and Departures

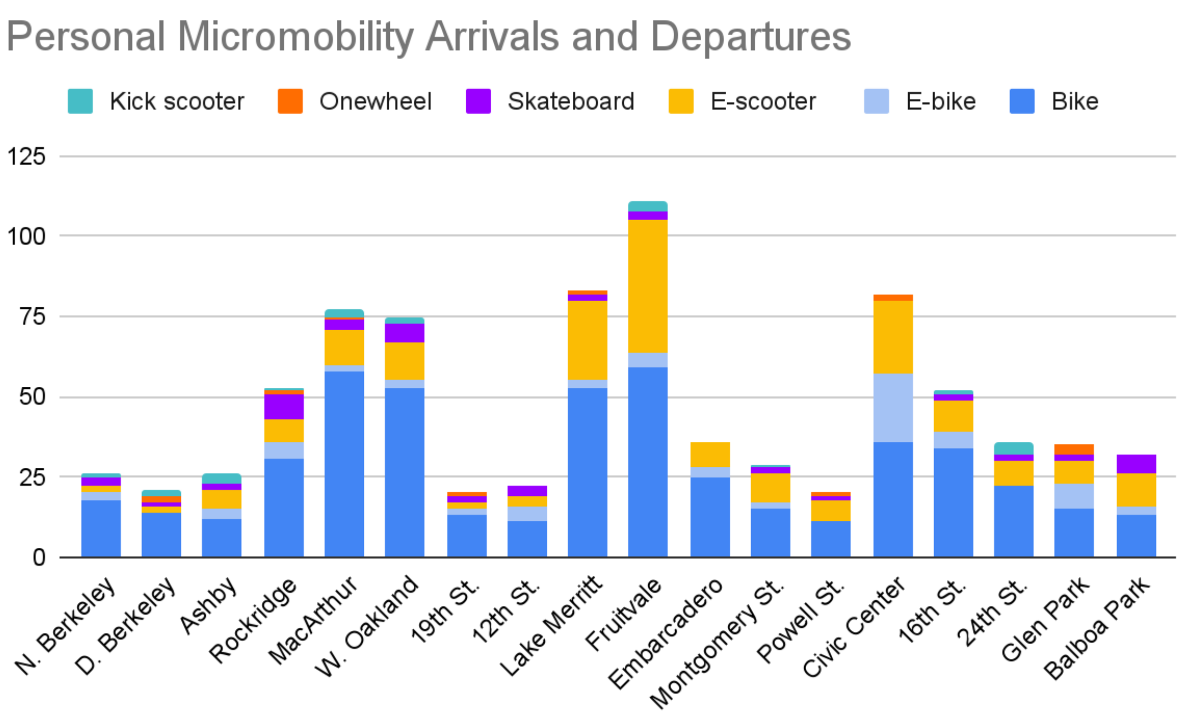

Figure 6. Personal Micromobility Arrivals and Departures

Parking Observations

Up to six different types of micromobility parking facilities were located at the observed stations. For shared dockless micromobility vehicles, locked and unlocked vehicles were counted separately. For Bay Wheels docked shared bikes and e-bikes, the data also specify whether the vehicles were active (i.e., available to ride) or inactive (i.e., at a station that was currently out of order).

Shared micromobility vehicle availability, use, and security

Across the 18 BART stations, 129 shared micromobility vehicles were counted parked at outdoor bike racks or other outdoor/street furniture such as a pole or fence near the station; see Figure 7, Figure 8, and Figure 9. Per station, total shared micromobility vehicles parked outside the station ranged from 0 to 19 [*Mean*(*SD*) = 7.2(5.5)]. See Figure 13. Across all stations, 85% of dockless shared vehicles parked around the station were appropriately locked.

Figure 7. Veo Ride e-scooters at Ashby BART, Berkeley, CA, 2022

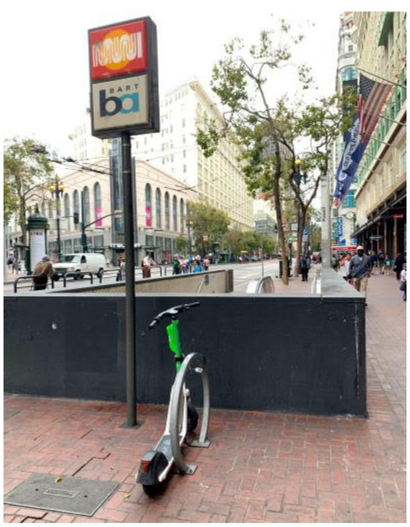

Figure 8. Lime e-scooter on bike rack at Powell BART, San Francisco, CA, 2022

Figure 9. Spin e-scooter locked to 16th/Mission BART entrance, San Francisco, CA, 2022

Across the 18 BART stations, 244 Bay Wheels classic bikes and 65 e-bikes (available only at San Francisco stations) were counted at the on-site or nearby Bay Wheels stations; see Figure 10, Figure 11, and Figure 12. Per BART station, classic bikes at Bay Wheels Stations ranged from 3 to 29 [*Mean*(*SD*) = 13.6(7.4)]. Bay Wheels e-bikes parked at Bay Wheels Stations at/near SF BART stations ranged from 1 to 19 per station [*Mean*(*SD*) = 8.1(6.2)]. One of the Bay Wheels Stations was out-of-order at the time of the observation. To give an estimate of the fullness of Lyft Bay Wheels Stations, the proportion of vehicles parked in docking spots or adjacent to the station (allowable for e-bikes) to the total capacity of the station (i.e., number of docks) ranged from 19% to 119% [*Mean*(*SD*) = 62%(29%)].

Parking capacity

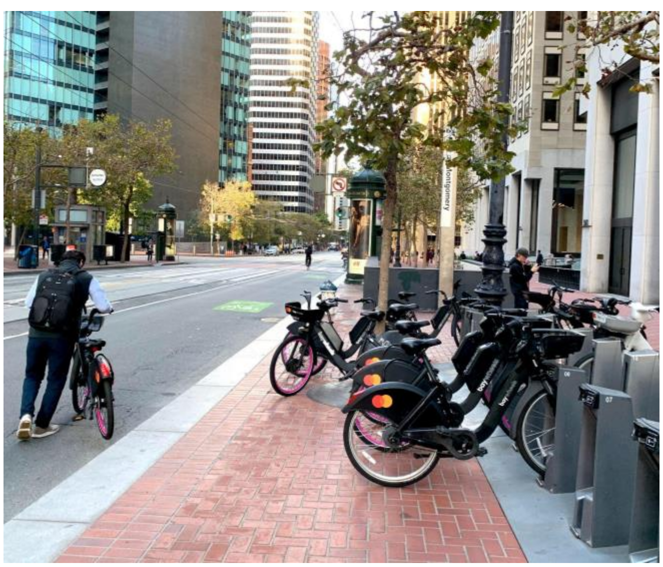

Figure 10. Lyft Bay Wheels dock (bike, e-bike) Montgomery BART, San Francisco, CA, 2022

Figure 11. Bay Wheels dock (bike, e-bike) Embarcadero BART, San Francisco, CA, 2022

Figure 12. Bay Wheels dock (classic bike only) Rockridge BART, Oakland, CA, 2022

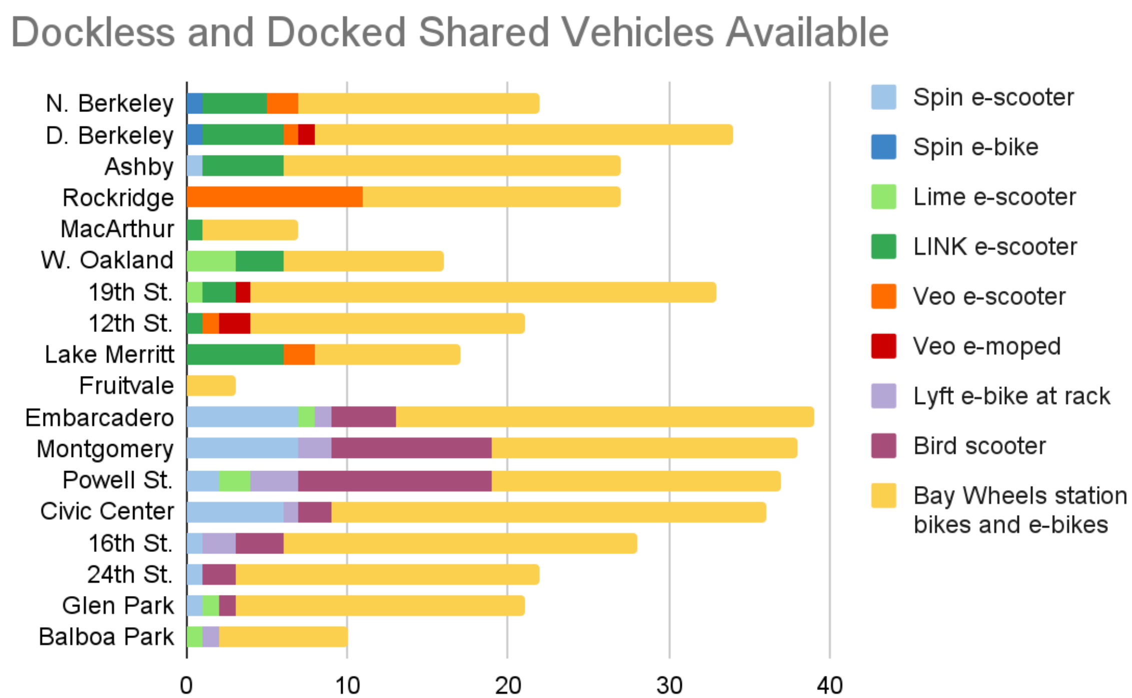

Figure 13. Dockless and Docked Shared Vehicles Available

Personal micromobility storage and capacity

Across the 18 BART stations, 388 personal micromobility vehicles were counted across all parking facility types; see Figure 14, Figure 15, and Figure 16. Per station, total counts across facility types ranged from 0 to 112 per station [*Mean*(*SD*) = 22.6(28.7)]. See Figure 17. Valet parking daily levels summed across the three facilities included 129 classic bikes and 36 e-bikes. Of the facilities assessed directly during observation, bike lockers accounted for the highest proportion of total stored personal micromobility despite only being available at a subset of stations (n = 11). The majority of personal micromobility vehicles stored at indoor and outdoor racks were classic bikes (one e-bike and one e-scooter were observed at outdoor racks).

Figure 14. Lake Merritt BART BIKELINK lockers, Oakland, CA, 2022

Figure 15. Bike racks outside Downtown Berkeley BART, Berkeley, CA, 2022

Figure 16. Civic Center BART Bike Station (bike rack room), San Francisco, CA, 2022

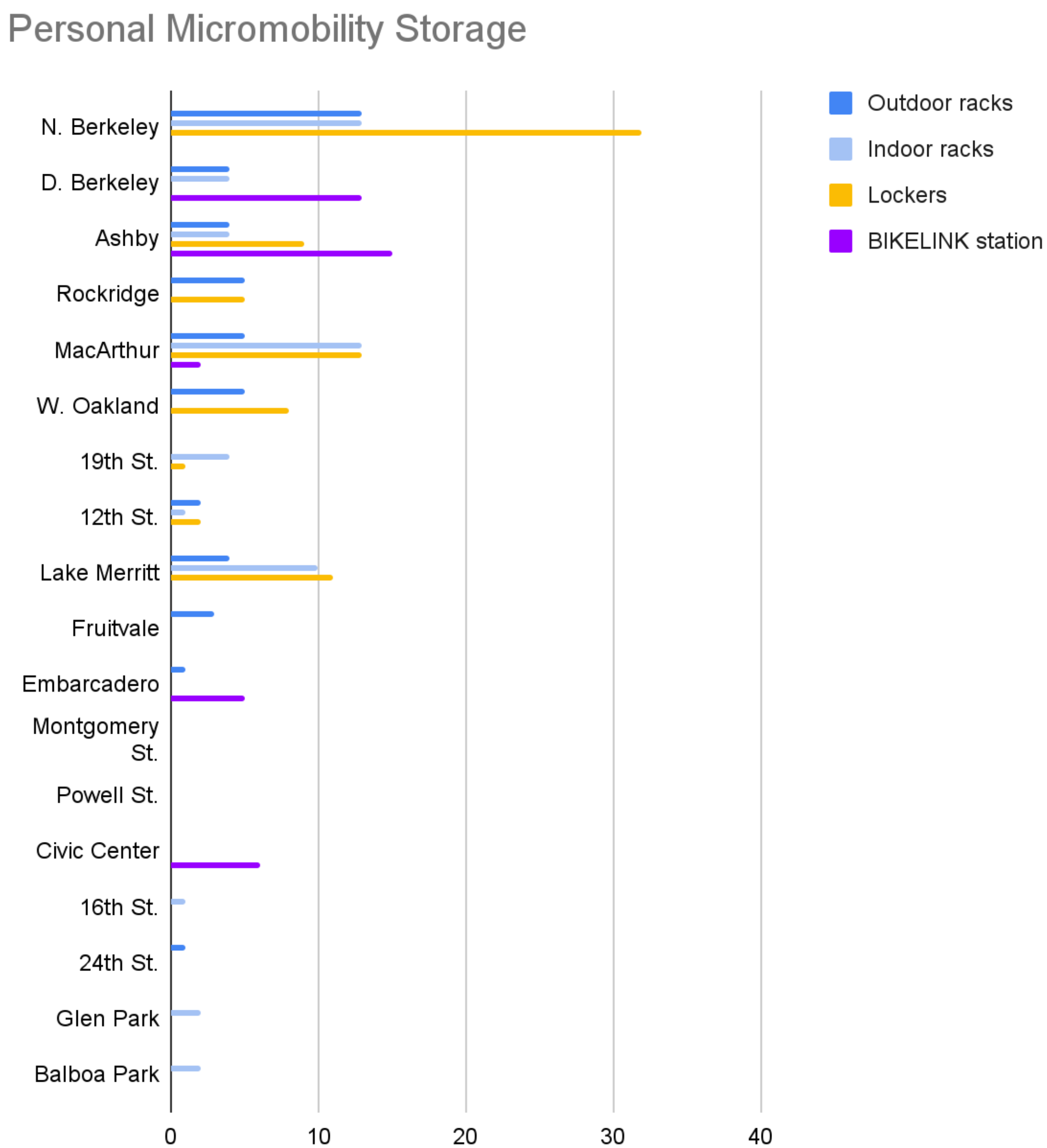

Figure 17. Personal Micromobility Storage

Types of parking facilities available exclusively for personal micromobility ranged from 0-36% utilization of parking spaces across stations: Indoor racks ranged from 0-33% (less in practice since 2 bikes or 2-4 scooters can be locked to a single rack and this calculation assumes one vehicle per rack); bikeLink lockers ranged from 0-36%; and BART Bike Stations (bikehub.com) ranged from less than 1% to 30% utilization. See Figure 18, Figure 19, and Figure 20. To give an estimate of the utilization of outdoor parking, the proportion of all vehicles (including shared and personal micromobility) parked at the outdoor racks or street furniture (e.g., poles or gates) adjacent to the station (allowable for shared and personal micromobility) to the total number of outdoor racks ranged from 11% to 233% [*Mean*(*SD*) = 58%(53%)]. Note that multiple vehicles can be locked to a single rack, e.g., two bikes or three or four scooters, so these estimates are inflated.

Figure 18. MacArthur BART BIKELINK lockers, Oakland, CA, 2022

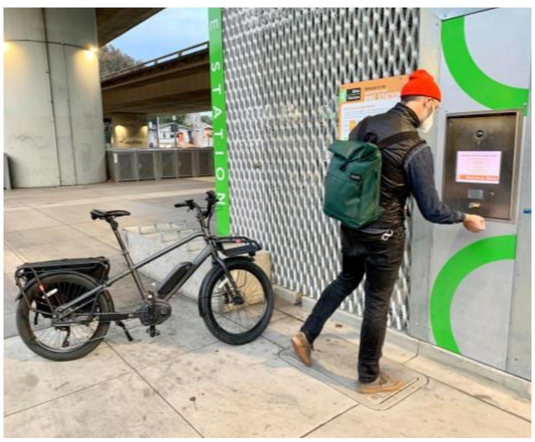

Figure 19. MacArthur BART Bike Station (bike rack room), Oakland, CA, 2022

Figure 20. MacArthur BART indoor bike racks, Oakland, CA, 2022

BART and Micromobility User Survey

An online survey was conducted to gain a better understanding of the influence of environmental design on travelers who use micromobility to connect with BART.

Method

The survey was conducted in September and November 2022. The survey questionnaire was programmed in Qualtrics software. Five hundred postcard size laminated flyers were printed with an anonymous link and QR code to access the survey. See Appendix A. The flyers were distributed at two BART stations and the surrounding streets. The two stations were MacArthur BART in Oakland and the Embarcadero BART in San Francisco because of their central locations. Flyers were attached to shared e-scooters and Lyft e-bikes and classic bikes parked on street bike racks and at the Lyft Bay Wheels Stations. In November 2022, BART and the San Francisco Bicycle Coalition pushed out the survey poster and QR code link on their Twitter. BART also shared it on their Facebook and Instagram social media accounts. See Figure 21.

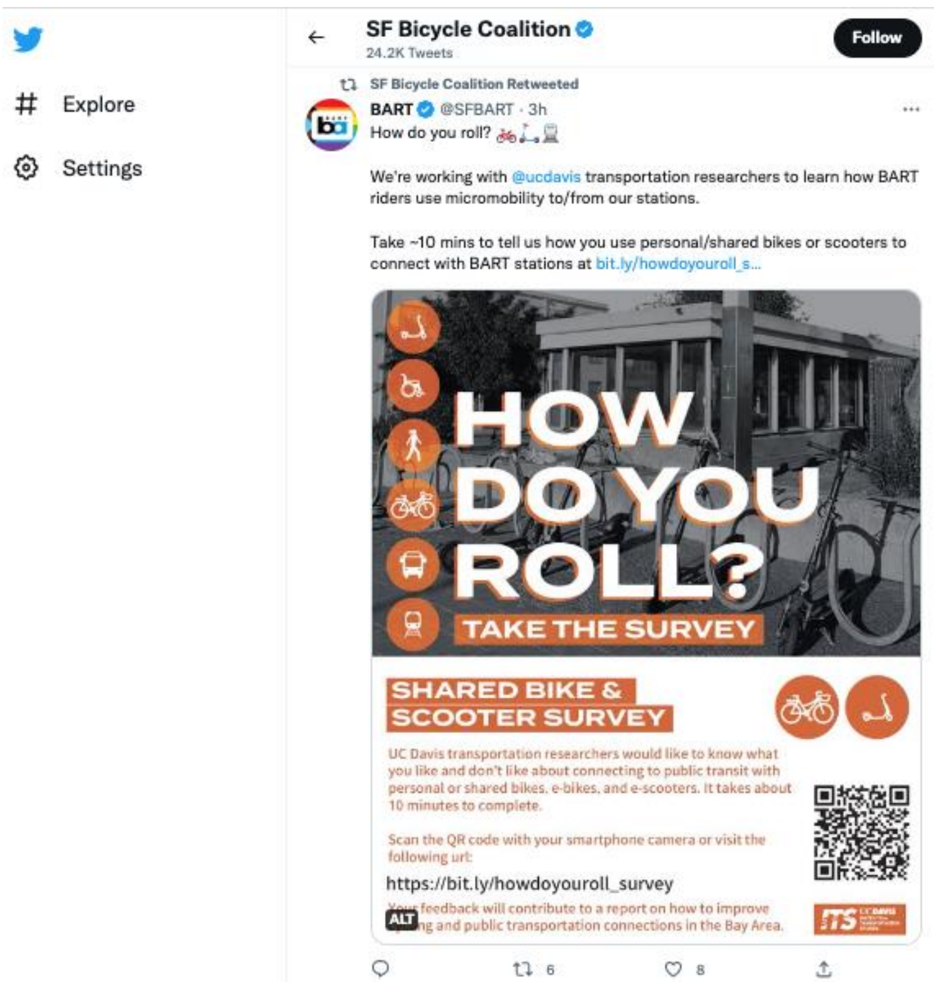

Figure 21. Survey social media push by BART and SF Bicycle Coalition on Twitter, Nov. 2022

Upon following the link or QR code, participants were asked whether they used any type of personal or shared micromobility to connect with BART stations. If they affirmed and declared they were at least 18 years old, they were allowed to continue with the survey.

The survey included questions about micromobility modes used to access BART stations and environmental design features of the stations and their surrounding neighborhoods that facilitate or inhibit those first and last mile connections. More specifically, features considered included micromobility accessibility, bike parking and storage, bike lanes, and other environmental design affordances impacting rider safety, comfort, and enjoyment. Given the recent increase in fuel prices and in shared mobility services prices, we also included a few additional questions about cost factors related to micromobility and public transit.

Participants

There were 115 participants, of which 70–74 answered the demographic questions at the end of the survey (age, gender, ethnicity and race). Age ranged from 18 to 84 years old [*n* =21; *Mean(SD)* = 37(14)]. Participants were 56% men, 37% women, and 5.5% other/non-binary (1.5% declined to state; *n* = 21). Sixty-two percent identified as White, 26% Asian, 7% multiracial, 3% Black, 3% declined to state. Fifteen percent identified as Hispanic, Latino, or Spanish ethnicity. Median household income was $75,000-99,999 (Figure 22), and the median number of automobiles per household was one [35%; 46% had no car].

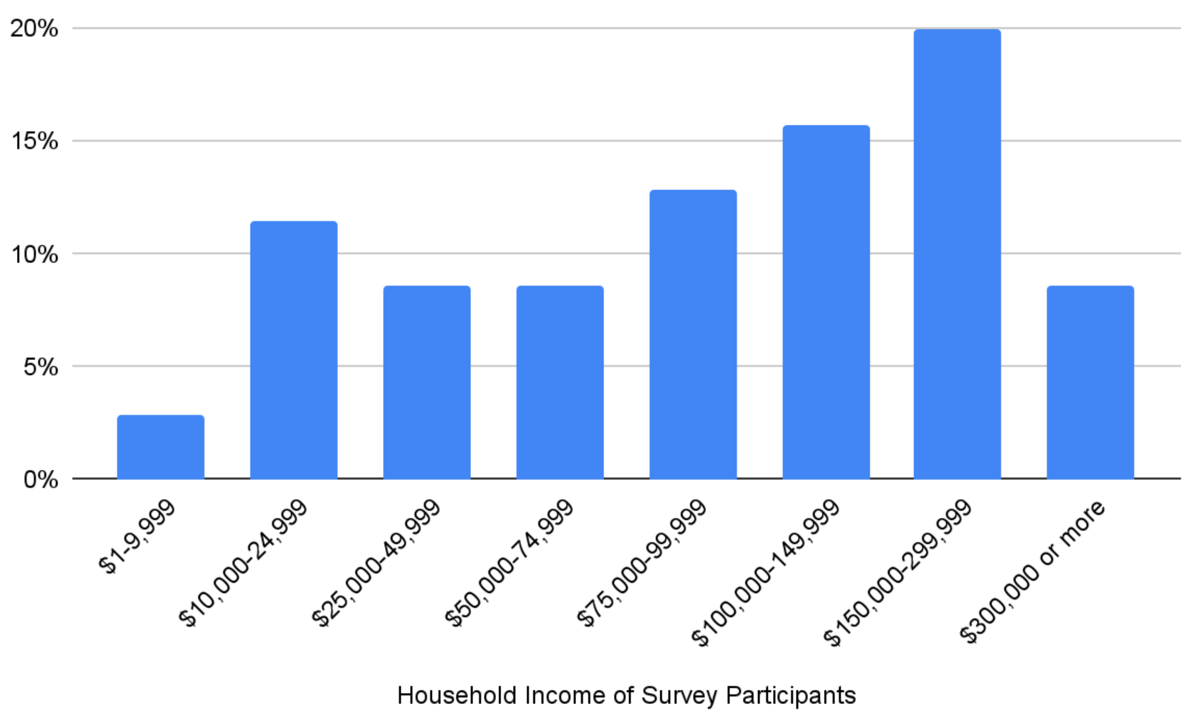

Figure 22. Household Income of Survey Participants

Results

Forty-five of the fifty BART stations are represented in the survey. These are stations our participants specified were their "home" stations (from which they typically started their BART trips; 34 represented) or others they regularly used to access destinations (43 represented). See Table 2. For the majority of participants (91%), their "home" station was less than 3 miles from their home (*n* = 113; Figure 23) and the mode of travel time to home station was 10-20 minutes (*n* = 108; Figure 23).

Table 2. Number of participants representing each BART station (near home or destination)

Station	Home Count	Destination Count
12th St. Oakland City Center	5	10
16th St. Mission (SF)	12	17
19th St. Oakland	0	13
24th St. Mission (SF)	5	12
Antioch	1	2
Ashby (Berkeley)	1	6
Balboa Park (SF)	3	2
Bay Fair (San Leandro)	0	1
Berryessa / North San José	0	7
Castro Valley	0	2
Civic Center / UN Plaza	11	22
Coliseum	0	5
Colma	1	0
Concord	0	1
Daly City	1	2
Downtown Berkeley	3	11
Dublin / Pleasanton	1	0
El Cerrito del Norte	1	1
El Cerrito Plaza	2	4
Embarcadero (SF)	8	22
Fremont	1	1
Fruitvale (Oakland)	5	2
Glen Park (SF)	2	2
Hayward	0	1
Lafayette	1	1
Lake Merritt (Oakland)	2	9
MacArthur (Oakland)	15	5
Millbrae	1	4
Milpitas	2	1
Montgomery St. (SF)	5	14
North Berkeley	1	5
North Concord / Martinez	0	0

Station	Home Count	Destination Count
Oakland International Airport	0	3
Orinda	0	3
Pittsburg / Bay Point	0	0
Pittsburg Center	0	0
Pleasant Hill / Contra Costa Centre	1	1
Powell St. (SF)	11	16
Richmond	2	4
Rockridge (Oakland)	2	6
San Bruno	1	2
San Francisco International Airport	0	7
San Leandro	1	3
South Hayward	0	0
South San Francisco	1	2
Union City	0	1
Walnut Creek	1	5
Warm Springs / South Fremont	0	0
West Dublin / Pleasanton	1	1
West Oakland	2	10

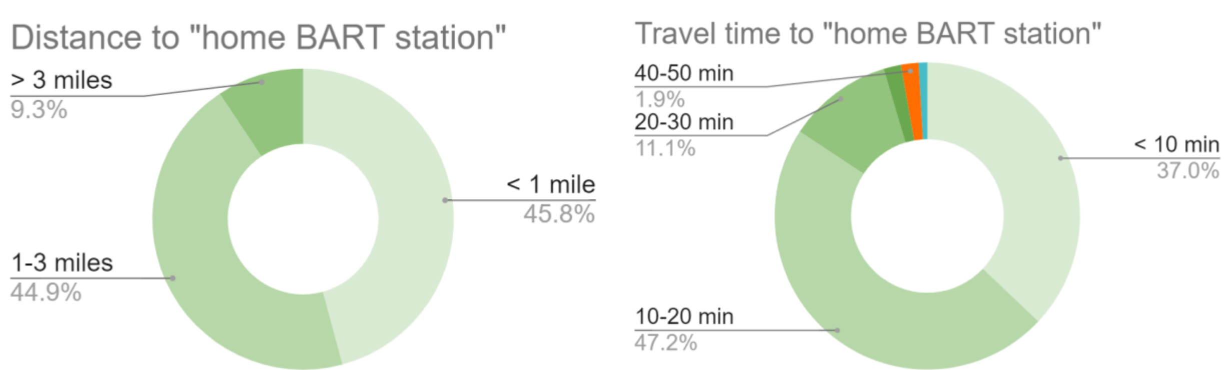

Figure 23. Distance to “home BART station” and Travel time to “home BART station”

Figure 24 presents the modes participants reported frequently using to connect with their home station and destination stations; note that they could select more than one. Survey respondents most commonly reported connecting between BART and home by walking, biking, and/or using shared micromobility. Among those who indicated frequent use of shared micromobility, the most commonly used were the Lyft/Bay Wheels classic and e-bikes, followed by the Lime, Spin, and Link e-scooters (Figure 25).

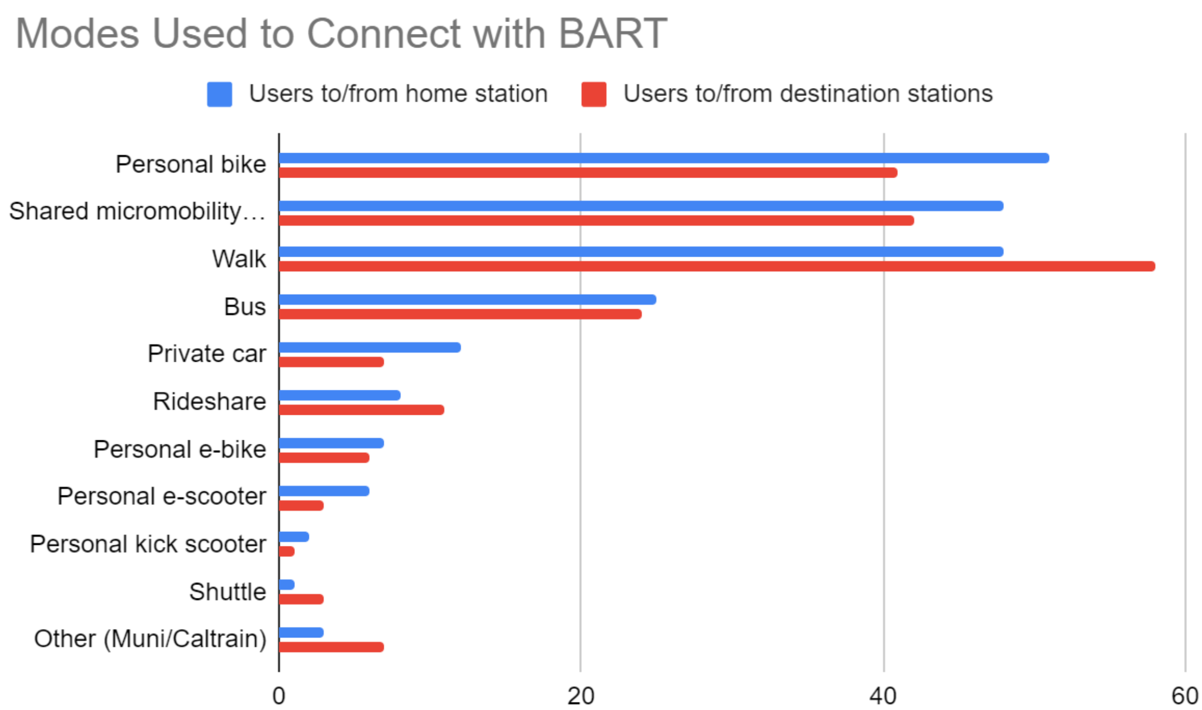

Figure 24. Micromobility Modes Used to Connect with BART

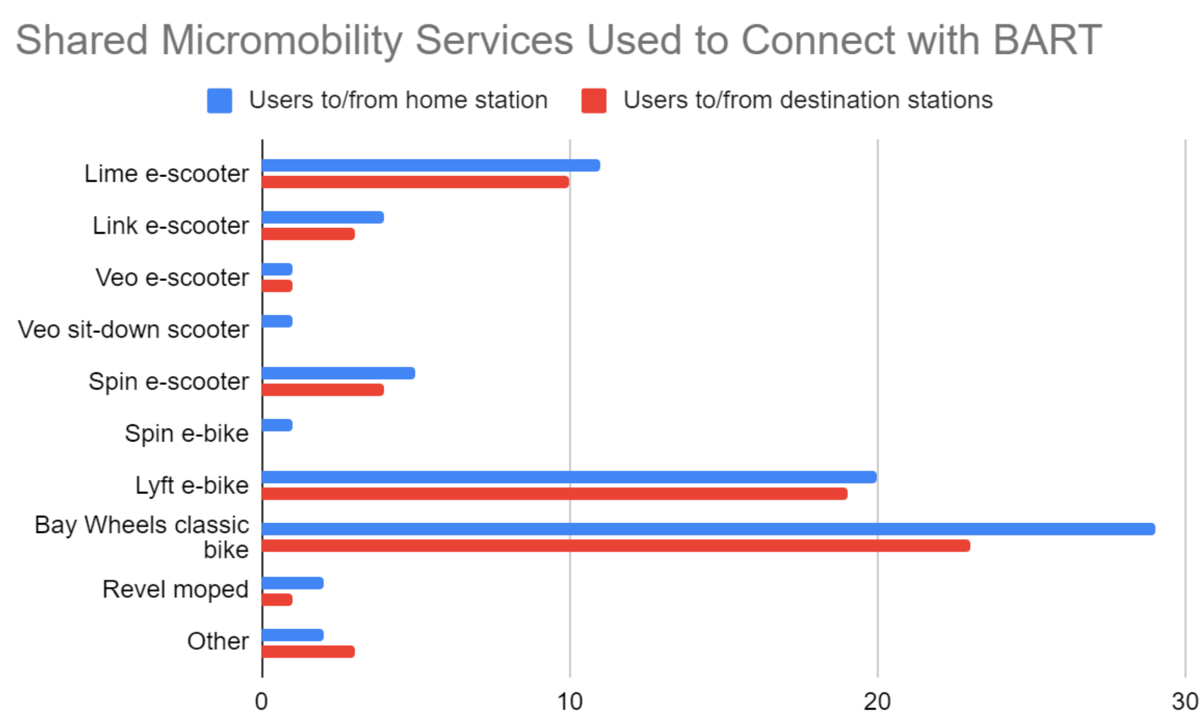

Figure 25. Shared Micromobility Services Used to Connect with BART

Micromobility access and parking

Of those who said they used personal micromobility (i.e., their own bikes or scooters) to connect between home and their home station, a slight majority (52%) said there was not enough parking for personal micromobility at the station, and 49% said they bring their vehicle onboard BART with them. We note that the question about parking sufficiency should be split into questions about quantity and quality in future studies.

Figure 26 shows the accessibility ratings (i.e., ease of finding vehicles) for those who used specific shared micromobility services to connect between home and their home BART station. Most micromobility users said they have on occasion been unable to find a shared vehicle to get from home to the BART station or the station back home (25% and 60%, respectively), and one-third said there was not enough parking for shared bikes and scooters at their home station. Of those who used Bay Wheels classic bikes (which can only be parked at the docking station) to connect with their home BART station, 42% said they had on occasion had trouble dropping off a bike because of lack of space at the Bay Wheels station nearest their home BART station.

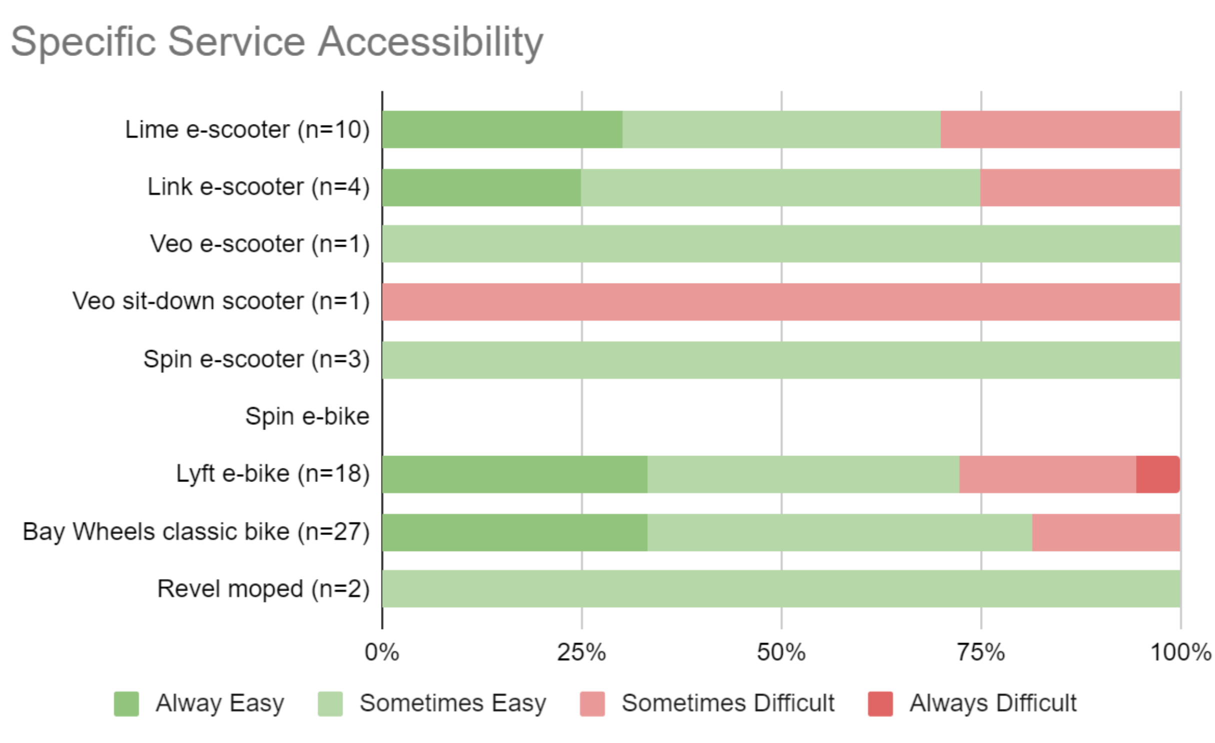

Figure 26. Specific Service Accessibility

Averaging across destination stations (rather than across all responses which varied in number for the different stations), 38% of respondents said shared micromobility vehicles were always difficult to find around their destination stations (Figure 27), 67% said they had on occasion been unable to find a shared vehicle, and 51% said there was insufficient parking for shared micromobility (Table 3).

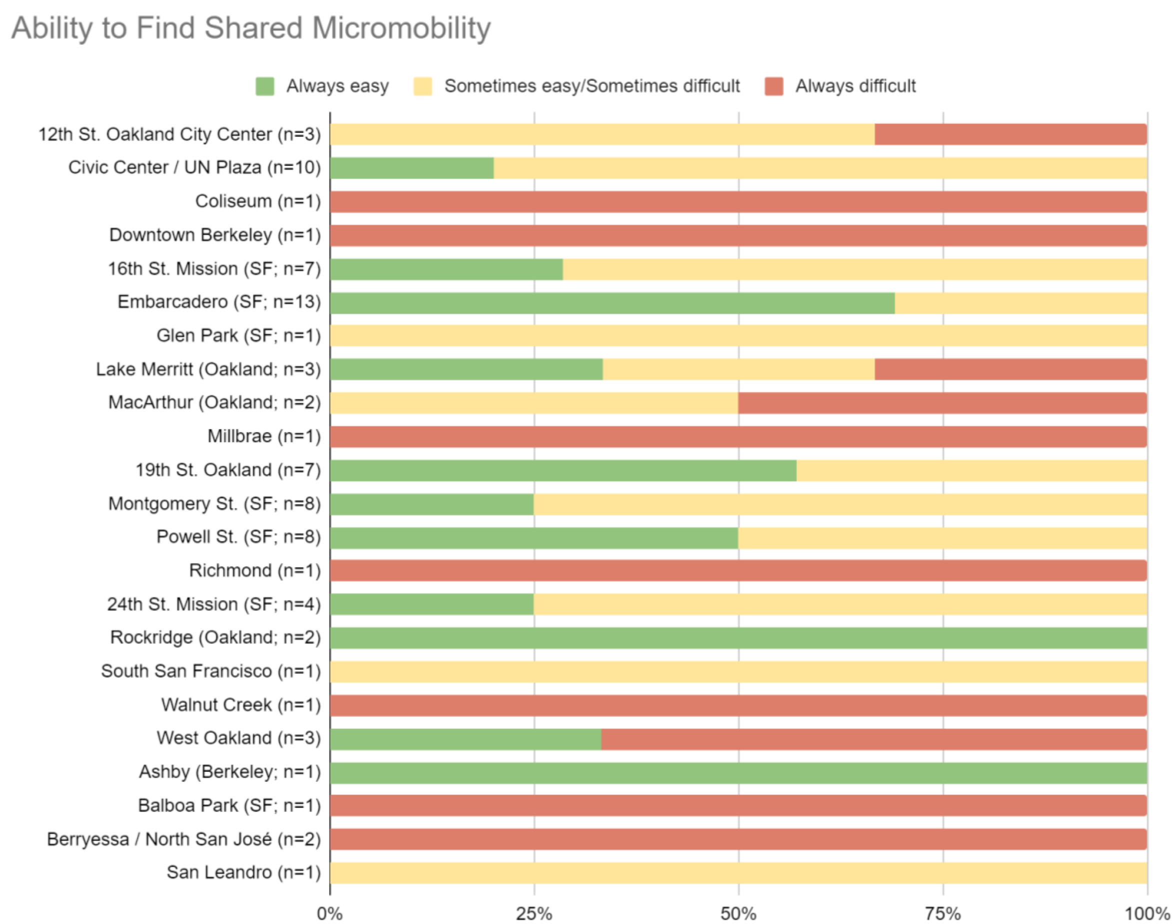

Figure 27. Ability to Find Shared Micromobility

Table 3 summarizes data on shared micromobility access, station safety, and bike lanes across responses for home destination stations and presents an index of those variables (unweighted average of percentages, with reverse-scoring of negative items) to reflect shared micromobility supportive design at each station. This index is only given for stations represented by at least 10 survey respondents (i.e., the sample size for each question comprising the index is 10 or more). This is provided as an example of an aggregate metric for micromobility-supportive station design that could be more useful if more data were available. A similar index could be created for personal micromobility, or for both personal and shared micromobility combined.

Table 3. Index comprised of shared micromobility access, station safety, and bike lane adequacy ($n \geq 10$)

	Always difficult to find a shared vehicle	Have been unable to find a shared vehicle	Sufficient shared vehicle parking	Station safety rated good or excellent	Bike lanes rated good or excellent	Micromobility supportive station score (grade)
16th St Mission (SF)	0%	50%	85%	12%	24%	54%
Civic Center/UN Plaza	0%	67%	71%	19%	62%	57%
MacAurthur (Oakland)	20%	70%	60%	28%	28%	45%
Montgomery St. (SF)	0%	25%	83%	33%	50%	68%
Powell St. (SF)	0%	46%	71%	48%	43%	63%

Safety, bike lanes, and other environmental design features

Participants rated their home station and other frequently used stations in terms of their overall safety for bikers and scooter users and the quality of bike lanes in the surrounding neighborhood. In terms of overall safety, they most commonly rated their home and destination stations as “average” (“average” was the mode and median; Figure 28 and Table 3). In terms of quality of bike lanes in the surrounding neighborhoods, they most commonly rated their home station as “average” (mode and median) and other stations as “good” (“good” was the mode, the median was “average”; Figure 28 and Table 3).

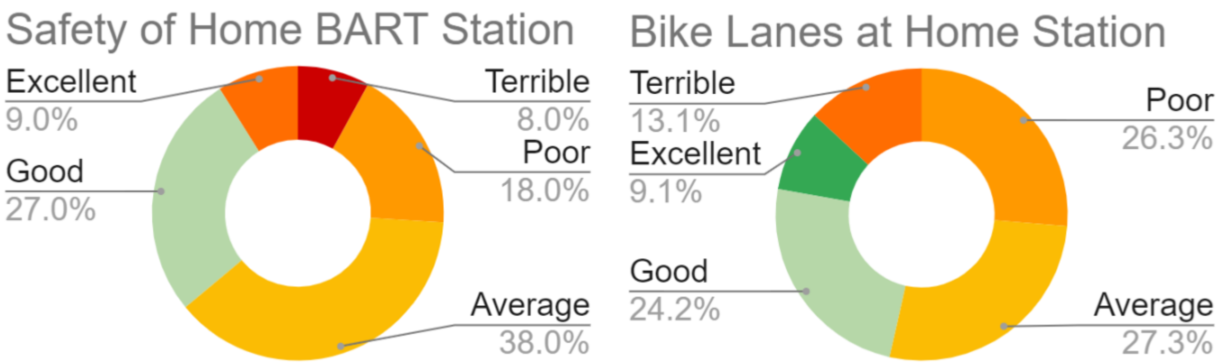

Figure 28. Station Safety and Bike Lane Quality around Home Station

Figure 29 presents the frequency with which participants indicated each of four proposed strategies would enhance safety for bikers and scooter users coming and going at their home station. Figure 30 presents the frequency with which participants indicated each of a wider range of (primarily environmental design) features, including those related to safety, could improve their experiences biking or scooting to and from BART stations. In both cases participants could select as many options as they wished, and enter comments in an “other” field. Protected bike lanes topped both lists. Open-ended responses for “other” included car-free streets, secure bike boxes/parking, more police, more elevators/escalators in stations, and less on-street car parking.

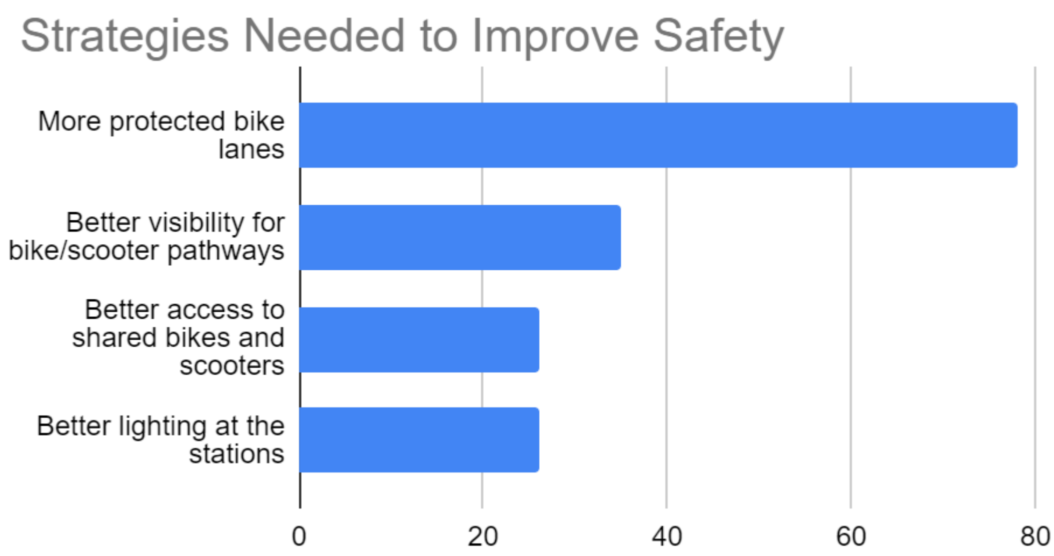

Figure 29. Strategies to Improve Safety

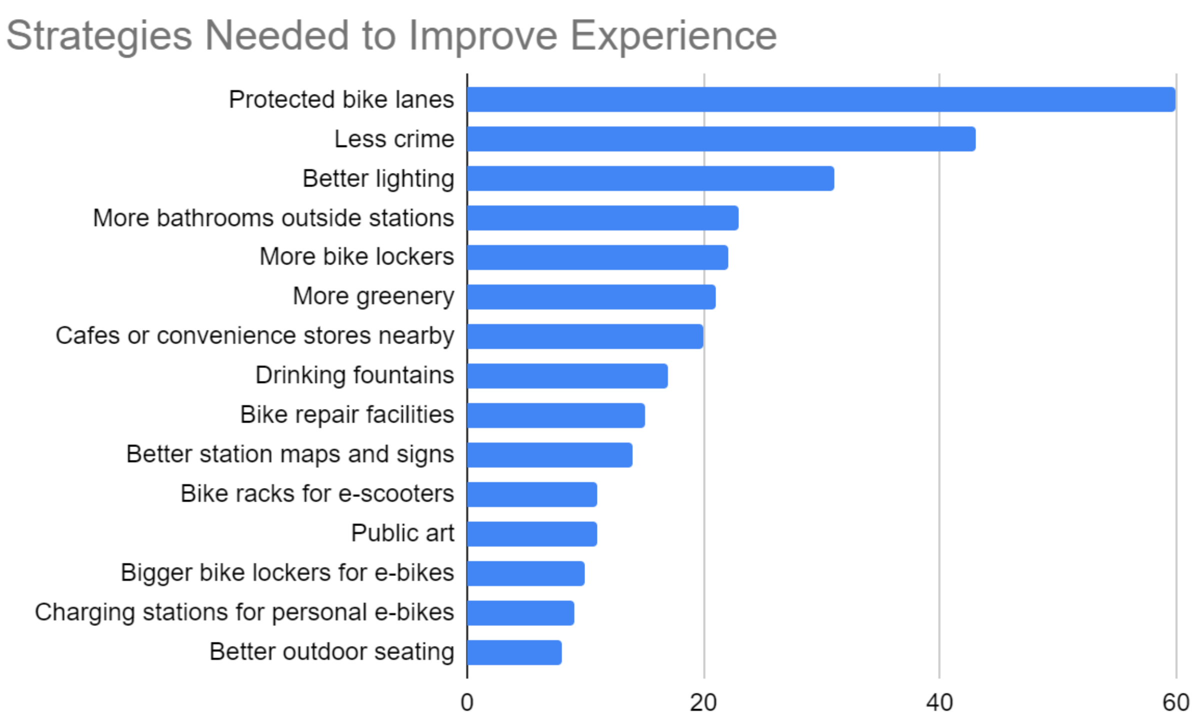

Figure 30. Strategies to Improve Micromobility Experience

Cost factors

A majority of participants (78%) reported that they had increased their use of public transit and/or micromobility since the recent rise in fuel prices (84 respondents answered this question; Figure 31). Also, 60% said they would use shared bike, e-bike, and/or scooter services (more) if they were cheaper (*n* = 84). Those who use shared micromobility most commonly reported that they spend less than $5 **in** a typical day of use (52%; *n* = 54). Among those who used Bay Wheels, 100% said their membership with Bay Wheels made shared bikes more affordable (*n* = 30).

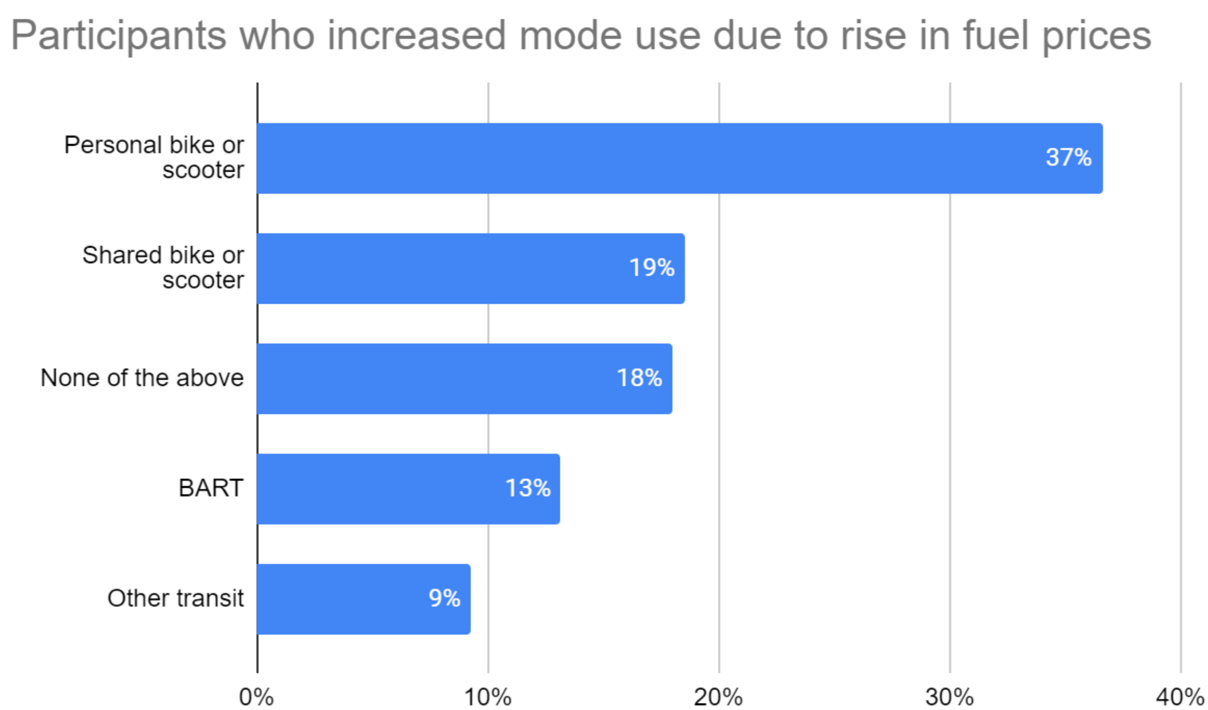

Figure 31. Participants who increased mode use due to rise in fuel prices

Stakeholder Interviews

We interviewed government, industry, and community stakeholders to gather more context for understanding our station observation and user survey data and to gain insights from their perspectives on environmental design problems and solutions related to the integration of micromobility with public transportation in the San Francisco Bay Area.

Method

Semi-structured interviews were conducted via video conference and lasted 30-60 minutes. Interviews were recorded and transcribed. Government stakeholder interviewees (4) included representatives of city and regional government in Oakland, San Francisco and Emeryville and BART. Industry stakeholder interviewees (6) included representatives of current and former shared micromobility and mobility software companies. Community stakeholder interviewees (6) included representatives of bicycle and community advocacy groups in San Francisco and the East Bay.

Interviewees were asked to describe their professional or volunteer role at the organization they represented, and the relevance of integrating micromobility and public transit for their work. They were asked to share success stories and challenges, and the interviewer provided prompts about the relevance of specific environmental design factors, including shared vehicle availability, bike lanes surrounding BART stations, and personal and shared micromobility parking at stations.

Results

The interview transcripts were coded according to both pre-determined themes (i.e., topics the interviewer prompted: shared micromobility vehicle availability at stations, quality of bike lanes around stations, micromobility parking at/near stations) and emergent themes. The following sections present the thematic analysis.

Limited shared micromobility access

Government and industry stakeholders both reported that they have data showing that accessing public transit is one of the main uses of shared micromobility, yet one theme that emerged was limited access to shared micromobility at BART stations. The local government perspective seemed to be openness, or even eagerness, to facilitate access to shared micromobility at BART stations (and throughout the region), recognizing the value for first-and-last mile. BART reported attentiveness to managing property use agreements with shared micromobility service operators to ensure they could locate vehicles at the stations, including co-located Bay Wheels docks. The BART interviewee noted that their “access hierarchy puts micromobility at the top above other transit and cars [because] it’s clean and we don’t have to provide more [car] parking”. Cities reported low barriers to entry for shared micromobility service operators, e.g., one interviewee said, “generally every application is approved that meets a minimum threshold”. Emeryville does not limit operators or their fleet sizes numbers (the interviewee referenced Populus, the city’s shared fleet management software, during the interview and reported 57 devices in their square-mile city and mentioned Spin was soon to launch e-bikes and e-scooters).

The community perspective was that most “core stations'' don't have a lot of shared micromobility vehicles available. One interviewee described that if you’re relying on shared micromobility, “Once you get to the city, SF or Oakland, you’re really out of luck”, so “people would rather just lug their own vehicle onto BART.” This interviewee also described other types of barriers to accessing shared micromobility for low-income communities, such as being “unbanked” when the services require a credit card to use or having language challenges.

The barriers to physical presence/access to shared vehicles at stations seem to mainly center on market challenges for the shared micromobility industry. Despite city stakeholders reporting open arms, industry stakeholders remarked on extremely high fees and fines charged by cities to operate. Additionally, policies to locate vehicles in certain areas, e.g., for equitable access, often means sacrificing vehicles to be stationed where they will not be used due to a lack of adequate street facilities for riding and parking or adequate community outreach.

Not surprisingly then, there continues to be high turnover and volatility in the industry, and one interviewee described, “It's definitely a free market… It's competitive… It's not as rich of a market as it once was.” Multiple interviewees referred to a situation in one Bay Area city where an electric bikeshare company had folded and abandoned their vehicles on the streets. There are also fluctuations of the same companies coming and going with changing agreements; one city interviewee described how one company has “had two stints” in their city and now are looking to have a third. The BART interviewee described how keeping property use agreements current is challenging “because it is a revolving cast of characters”.

Related to the competitiveness of the market, Lyft has an exclusivity agreement with San Francisco that they are the only providers of shared e-bikes. However, they reportedly do not have plans to expand to the East Bay. One city interviewee described (and industry stakeholders confirmed), “Their position has basically been that they would need financial support in order to [expand]... From a business standpoint it doesn't make sense for them because of the large extra costs. The e-bikes do see greater usage in those markets than the classic bikes and overall, they do increase ridership on the system, but they also come with significantly higher costs as well–for the batteries and the operation cost of charging and redistributing the charged batteries to the system.” This helps explain why cities in the East Bay have not had any vendors wanting to provide shared e-bikes (interviewees mentioned that people are buying their own) and why the City of Oakland and a non-profit organization plan to pilot e-bike lending libraries in 2023. It was mentioned that e-bike insurance was much less cost prohibitive then e-scooter insurance for a community lending library.

Adding to the expense of operators is the problem of rebalancing vehicles to ensure adequate numbers are at/near BART stations. One city interviewee described, “To properly rebalance these things is very costly, and [companies] want to focus on the tourists… The tourist areas are most lucrative…”[i.e., not BART stations]... They continued, “We’re at a point where the system is diverging between profit value for the operator and the social/behavior change we want to see for everyone–making bikeshare a real option, which means outreach, safety classes, showing people it’s an affordable option for what their needs are.”

Also, despite property use agreements for Lyft to locate docks at BART stations, there are physical limits to making that happen at many stations. Specifically, BART owns very little above-ground land at San Francisco stations. Regarding a Bay Wheels station that is a block away from a BART station, one government stakeholder bemoaned, “You’re talking about last mile, and we haven’t even connected the bikeshare… We’ve gotten the extension cord almost [connected, then we ask] ‘Why don’t people ride this? [Because] it’s not connected.”

Solutions for shared micromobility parking

Multiple interviewees had a similar narrative about the evolution of shared micromobility whereby early, unregulated launches of e-scooters led to chaotic and dangerous conditions at BART stations (and elsewhere) with vehicles being parked where they were blocking pathways and station entrances. One interviewee described the problem as “a nightmare at station entrances” during the first year after shared e-scooters arrived around 2018. Cities and operators later worked together to establish parking corrals and rules for shared vehicles to park in them, which were "only half successful" according to one interviewee, in that the companies used them for drop-offs but the consumers didn't use them well. One interviewee speculated that this was partly due to low visibility, since the corrals were painted on the ground. Companies also did not aggressively enforce the policy, perhaps due to not wanting to lose customers and also their geofencing technology reportedly may not have been sufficiently precise.

The latest solution involves repurposing old technologies—namely, bike racks and a policy requiring the vehicles be locked to them (or gates, lampposts, etc.). BART brought "old wave style" bike racks out of storage (which had been removed since they weren't very efficient for bikes) and installed them outside stations. These are easy and quick to install (few "ground parts"). One interviewee credited BART for installing lots of racks and locating them as close to the fare gates as possible. One interviewee mentioned that BART also put down ground stickers at the racks to show people where to park but those are less successful because they are less visible and fade.

There was consensus among interviewees that these solutions have dramatically reduced tripping hazards and complaints, as well as vandalism. Before the vehicles had to be locked, many scooters were being thrown into a lake (a geofencing strategy was also implemented to prevent parking lakeside). A related policy Oakland has implemented is a ten-cent fee for parking a shared micromobility vehicle in an area that has a parking meter; and that "goes straight into an infrastructure fund scooter supportive infrastructure. We've used it to install 100 bike racks… and we've got a bunch more in the hopper."

Another benefit of the racks as well as locks (lock-tos), according to one interviewee, is their familiarity, and the bike rack will benefit personal micromobility users and be useful into the future even if shared services no longer exist. This has been borne out to an extent. Multiple interviewees noted the irony in the timeline whereby the infrastructure "finally caught up with the demand", then the "demand disappeared" with the pandemic and lots of the extra parking installed for shared micromobility remains "underutilized" as residents continue to work from home or carry their own bike or scooter on BART.

A limitation of the bike racks solution is the lack of above-ground space BART owns as some of the stations, particularly in San Francisco. While the bike rack solution seems to be working remarkably well in the East Bay (Cities reported few complaints and confidence in being able to easily install more racks as needed), San Francisco stakeholders reported a lack of racks near their BART stations. There is one station in particular that has very heavy scooter use and insufficient parking, so the company frequently comes in to clear out the vehicles until the City finds a solution to install more sidewalk racks.

Other stakeholders advocated the value of secure, dedicated docking stations. Although their planning and installation is much more resource intensive, one city stakeholder said, "there's a fundamental function with the docks, which is to keep the streets organized." One industry stakeholder described how, without dedicated corrals or stations, they still receive complaints and see issues with users locking vehicles to things they should not be and causing hazards or inconveniences for others.

Unsafe personal micromobility parking and poor train car affordances

As successful as outdoor racks have been for shared micromobility, they are not working well for personal micromobility storage due to lack of security and high crime at many BART stations. One biking advocate explained how they strongly advise people (they were specifically talking about a program with homeless youth) against locking their bike at a station, "It's just going to immediately get stolen… People are not willing to take that risk, particularly folks who are not that secure."

The advocate went on to explain that because parking is "limited, expensive, and dangerous", you see "tons of bikes on BART [trains]." People are bringing their vehicles aboard with them rather than storing them. However, affordances within the train cars are also lacking. The racks in the train cars were described as cheap and mostly broken, such that you need to hold onto your bike to keep it securely stowed during travel. There is also a BART rule that bikes are not allowed on the first train car or on the escalator; folding scooters are allowed on any car, and standing scooters are prohibited entirely because of the temptation to ride them inside the station (but they are very common).

Station edge-to-gate features: Signage, pathways, and prohibitions

Moving to issues more strictly within station boundaries, the community perspective represented in the interviews was that BART is not particularly bike-friendly. One interviewee's interpretation was that BART has "begrudgingly put in systems that are moderately safe". For example, he explained that parking was available but much of it is not secure and the more secure parking is not well-marked, e.g., "If you don't happen to know that [indoor racks] those [indoor bikeep racks) exist/aren't comfortable getting in an elevator with crack addicts/can't carry your bike down 60 stairs, that's not really a resource, right? That could be much better."

Lack of signage was also mentioned with regard to pathways within station boundaries to help personal micromobility users navigate the station with their vehicles. The BART interviewee mentioned that there are some fifty-year old stations that are particularly unfriendly with regard to navigating within the station with a bike or scooter. He described these as "parking lots with a station in the middle… Maybe one of them have good bike lanes, but then you get [there and] you're dumped in the parking lot. Nobody thought, 'How do you bring your bike on the trains? How would you bring your bike to where all the bike parking is?" Another interview pointed to Holland and Switzerland as examples of stations with seamless and equitable integration of micromobility in terms of pathways coming into the station, bike escalators, stairway bike wheel groove, parking, and supportive signage.

The signage at BART stations directed toward micromobility users was described as negatively-framed, declaring policies about where riding and carrying your vehicle is *not* allowed, rather than specifying what to do and pointing to affordances. The policy to not bring a vehicle on the escalator is a good example. Users (if they follow this policy) must use the stairs or elevators which are often unpleasant and inconveniently located at best, but sometimes also dangerous. One interviewee observed that luggage, which is allowed on escalators (included wheeled luggage), sometimes rolls down if the owner is not careful, implying the logic for disallowing bikes and scooters may be flawed. Another interviewee pointed out that personal e-bikes are heavy and carrying them up BART stairs is a challenge for riders.

Insufficient safe and coherent street infrastructure

The need for better bike lanes around BART stations and throughout the region more generally was universally acknowledged by interviewees, with some describing it as "the main challenge" for supportive environmental design, e.g., "Safe places to bike and safe places to scooter are what we need." In particular, interviewees emphasized the need for protected bike lanes, separate from motor vehicle traffic. They discussed the insufficiency of bike boulevards, where cars and bikes share space, e.g., "Cars don't respect bike boulevards." They also discussed the inconsistency in bike lane design across the region, with different colors denoting the lanes and lack of a cohesive network/connectivity.

Stakeholders had some conflicting reports about e-scooters and street facilities, in terms of where users tend to ride. Some suggested they mainly use sidewalks. One noted that with regard to scooters, "social norms aren't there" for others to realize scooters should not be on the sidewalk and informally enforce that. The Emeryville stakeholder was concerned that there would be problems with scooters parking on their narrow sidewalks but said it has not been a problem (yet). Other stakeholders mentioned they had no complaints of scooters on the sidewalk and attributed this to the implementation of rules to restrict rider age to 18 and over and the driver's license requirement. Another said that if it's "even reasonably safe" users will ride in the street.

Cities discussed how infrastructure plans are made. Some are using Populus or other platforms to track shared micromobility vehicles to "make a case for where infrastructure is most necessary/potentially useful". Challenges include a long list of infrastructure projects "already in line" and competing with AC transit buses that would oppose road diets to remove car lanes in order to add protected bike lanes because it might slow down their bus fleet.

Although better street facilities was deemed a high priority and a very real safety issue, with frequent accidents involving motorists and micromobility users, interviewees also qualified the importance of bike lanes. For example, one interviewee observed that cultural barriers might be the bigger hurdle to encourage some communities to bike. Two others implied that confident bikers were not deterred by current infrastructure inadequacies, but "protected bike lanes encourage the hesitant", and one of these felt that San Francisco is getting to the point of having adequate safe infrastructure where more people feel comfortable. Two other interviewees mentioned that women in particular feel safer in protected bike lanes.

On-site charging for e-bikes and e-scooters

Multiple stakeholder groups felt charging infrastructure at BART for e-bike and e-scooters would be beneficial for shared micromobility operators and for the efficiency and environmental impact of the services, some naming some stations that would have the room and/or the demand (i.e., MacArthur, Fruitvale, UN Plaza, and Lake Merritt). One observed, “These sort of brand agnostic charging stations can be really beneficial… just in terms of keeping the fleet up like the uptime of the vehicles. And then, of course, just the efficiency of the overall system is improved”; and contrasted this approach with battery swapping, “One of the issues with battery swapping is that you’ve got to maintain basically double demand batteries, and batteries are the most resource-intensive aspect of the vehicle generally… It's a lot of extra cost and environmental impact to have all these extra batteries that you're swapping out. And the more that you can have vehicles charging in the right of way without having to be collected with a trip in a van is beneficial, because the vehicles come to you. Operators conveyed interest in having on-site charging at stations and one city said they would look into it “if [they] were hearing that it’d be really beneficial for the operator”, but those conversations do not seem to be happening yet with e-scooters, but Lyft is looking into ways of electrifying their docks to charge their e-bike fleet.

Challenges to providing on-site charging for shared, as well as personal, electric micromobility vehicle charging include the space at stations. One interviewee mentioned a company that provides shipping containers set up as charging stations, and that something like that could be located near a station. Another concern was security of the charging equipment. The Oakland interviewee explained, “We experience incredibly high levels of theft and vandalism in Oakland, of all infrastructure, so that includes some wires, batteries–especially batteries… At some point someone will attack the system and try to steal anything of value. [So] whatever you can do to install steel doors and things like that, that can deter them, I highly recommend that you invest in that upfront.”

Other environmental design considerations

Other environmental design issues, within and beyond the BART stations, were occasionally mentioned by interviewees. For example, several indicated the importance of land use in determining how people access BART stations. For example, one speculated that many people probably walk to MacArthur BART station because it is in a “dense neighborhood”. One city stakeholder discussed how they were requiring secure long-term bike parking in all new commercial development, and a community stakeholder mentioned how important it was to have secure parking at commercial spaces. The latter interviewee also mentioned that small, basic changing rooms could make a huge difference in supporting cyclists: “It’s [expletive] disgusting to have to go into a bathroom stall to change. Just a changing room would be sweet. Surprising how few office buildings have them.”

Vehicle design

Several interviewees talked about the importance of shared micromobility vehicle design. They highlighted improvements where cities and industry worked together to address issues. In particular, earlier scooter designs had small (6-8 inch) wheels, which caught in the many potholes in the streets, so a new requirement of 10-inch wheel requirement was implemented by cities and industry was moving in that direction at the same time. Injuries on scooters, many of which did not involve anybody else, e.g., potholes) have decreased since. Recent and more radical innovations mentioned included folding e-bikes, cargo e-scooters with integrated shopping carts, family e-bikes with seats for children, and a short-framed e-bike with no pedals (only throttle) and fold-up foot rests.

Clear dilemmas with regard to vehicle design include the tension between designing lightweight vehicles that are efficient or heavy vehicles that are more difficult to steal (and ride). BART's intolerance for scooters that do not fold (e.g., "The only way we can have scooters on our system is if they're folded") is because they reportedly provide "too much of a temptation to ride" and they "can't have that", presumably for safety reasons. Shared scooter operators do not offer folding scooters at this time. Another suggested solution was to potentially use geofencing to limit speeds (e.g., to 2 MPH) inside BART stations, if the technology could be reliable inside stations.

Beyond physical design: Moving from biking as subculture to integrated public transit

Several other issues emerged outside the current focus on design. One point made by many interviewees that was related to insufficient environmental design affordances was that micromobility users in the Bay Area, including with respect to connecting with BART, "have to be in the know". Micromobility users' habits regarding where and how to travel the streets, navigate stations, sign-up for a service, and park (or not park) are built from experience. One summarized, "There's a big subculture to it, it is not accessible." Another noted that biking is a "culture of resistance" and as such its members are used to being left on their own; he said, the "bike community needs to open their arms" to educate others and advocate support.

Finally, virtually all interviewees either implicitly or explicitly suggested the need to make micromobility part of the public transit system. For example, one said, "The challenge for micromobility is that it is basically replacing the local transit system." Interviewees called for government subsidies to support private operators and/or questioned whether the government should take on the operator role. They also called for integration of payment methods for more seamless connections. One interviewee summarized:

> *Is micromobility, and especially this use case of getting people to transit worthy of government subsidy and funding? I would say, "Yes." We subsidize car drivers to transit heavily. [For example], take the parking garage that's at the MacArthur Station–I'm sure it was in the tens of millions if not one hundred million dollars. Divide that by the number of cars and you're looking at a very, very, very hefty subsidy over time. Then for the scooter riders, it's zero dollars, essentially the cost of the rack–a few hundred bucks, and hundreds of riders a day. So why as government are we subsidizing this mode that we say we don't want, and that pollutes, and has massive negative externalities versus this one that has zero pollution, and very, very low, if any, negative externalities… These services are just hovering at the threshold of viability… There's no guarantee that they're going to be around for much longer. So we may have to confront this question as a government: Do we want this thing?... If so, are we willing to pay for it? And I think that it is worthy of subsidy because of its efficiency.*

A community stakeholder made a connection to the fragile state of public transit in the wake of the pandemic. He observed that BART's profit model is focused on having a large core group of users who are commuting, but now that many people have continued to work from home, travel is more about personal and pleasure trips, so the focus needs to shift to "serving neighborhoods". He stated, "They need to understand that [micromobility is] part of their revenue model. It's part of the population that they serve. The approach needs to shift from 'it's ok' to 'of course you can'. How does [micromobility] become part of the process of taking BART not, 'Oh you might bike there if you're weird.'"

Shared Micromobility, Transit Station and Bike Lane Maps

The purpose of the Micromobility Map tool is to visualize many of the same variables in our BART station survey and user observation study across San Francisco and the East Bay. This tool was designed to be used with project stakeholders from BART, city transportation agencies, micromobility providers, community organizations and mobility researchers.

Method

The ArcGIS map tool was developed to highlight shared micromobility service availability across four Bay Area cities. Data was gathered and triangulated from a variety of sources, including site visits to each of the 18 stations, Google Maps, BART and Bay Area Department of Transportation websites, city websites, ArcGIS shape files and shared micromobility service apps. The ArcGIS map layers help us explore which cities have permitted the various micromobility services providers, their operation zones, and how they overlap with BART stations for last mile commuting. They also show the location of the neighborhood Bay Wheels docking stations. The map layers show the different bike paths, bike lanes, and bike boulevards that connect or disconnect with 18 BART transit stations studied. We have included demographics and bicycle collisions in this online tool to see if there was a correlation between areas with fewer bike lanes and higher numbers of bicycle collisions.

Results

As of November 2022, six operators have permitted shared micromobility fleets operating in at least 1 of the 18 BART stations we surveyed across San Francisco, Berkeley, Emeryville, and Oakland (Table 1). Bay Wheels has over 7,000 bicycles (51% e-bike in San Francisco), and 550 docking stations across the Bay Area. The other five operators we documented have dockless shared micromobility services that include e-scooters, e-bikes, and sit-down e-scooters that operate in one or more of the cities covered. Figure 32 and Figure 33 demonstrate the service boundaries of each operator along with the BART station and bike lane type across the cities.

Figure 32 shows that Oakland has an area (shaded pink) served by Bay Wheels bike stations and e-scooter operators (Link, Veo, Lime). The number (or density) of bike stations as shown by the pink icons on the map, is relatively high in Oakland's central urban areas but much lower in East Oakland. Since users must return the Bay Wheels bikes to these stations, the lower density of dock stations in East Oakland makes the shared bikes system unfeasible for residents as a last mile mode choice from BART. Figure 32 shows Berkeley (shaded orange) and Emeryville (shaded yellow) to have Bay Wheels classic bikes, Veo Ride, and Link e-scooters and sit down e-scooters as well as Spin e-bikes and e-scooters. Spin has chosen not to operate in Oakland at this time making its vehicle operation zone limited to Emeryville and Berkeley city boundaries.

Figure 33 shows the operation zone for four operators in San Francisco including Bay Wheels (classic bikes and e-bikes) as well as e-scooters operated by Spin, Lime, and Bird. The distribution of Bay Wheels stations is concentrated in the denser urban neighborhoods. The map shows lower numbers of Bay Wheels stations in outlying neighborhoods like the Sunset District, Potrero District, Diamond Heights, Chinatown, and the Bayview District. These neighborhood residents can use the free-floating Lyft e-bikes if there is one available at a BART station if they lock it to a bike rack or post next to their final destination. Figure 33 highlights the 1.5-mile JFK Drive in Golden Gate Park that was a slow street pilot during the COVID 19 pandemic and was recently voted to be made a permanent car-free promenade November 2022.

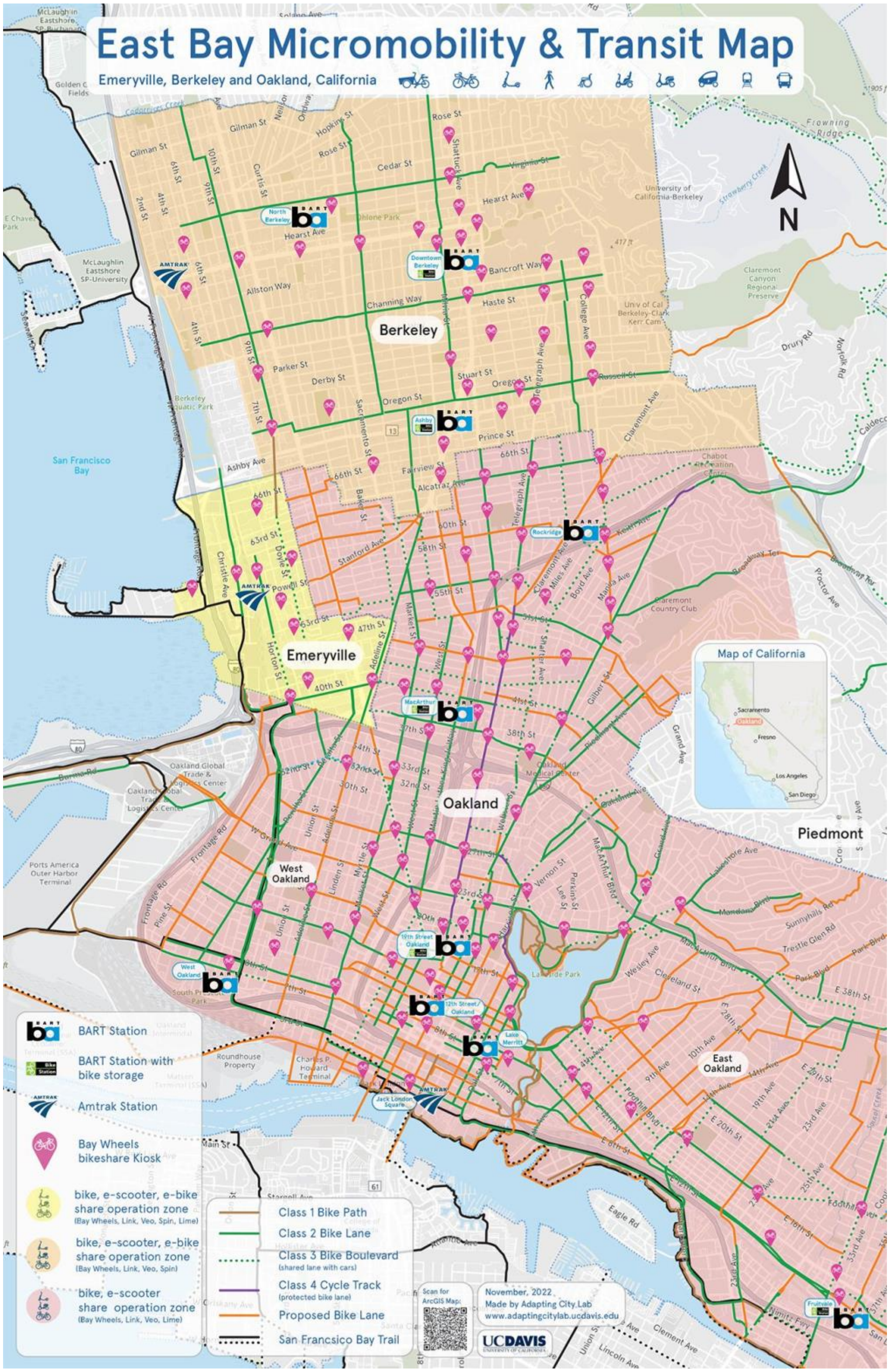

Figure 32. East Bay micromobility and transit map, B. Ferguson, J. Wattimena, 2022

Figure 33. San Francisco micromobility and transit map, B. Ferguson, J. Wattimena, 2022

Discussion

Limitations of this research include the small survey sample size of 115 people given the attempt to represent all 50 BART stations. The survey participants also may not accurately represent the distribution of personal and shared micromobility users. In particular, since some of the recruitment methods targeted shared micromobility users and communications materials emphasized share micromobility use, shared micromobility users may be overrepresented relative to personal micromobility users. However, oversampling shared micromobility users was deemed necessary in order to adequately capture their experiences.

Limitations of the station audits include validity issues as COVID-19 continues to affect public transportation. Interviewees reported that Bay Area residents continue to work from home at much greater rates than before the pandemic. If these patterns continue to change, e.g., if more residents return to workplaces, the data collected in the station audits will not be representative. Additionally, as mentioned in the station audit methods, some BART stations have multiple entrances and exits which created a challenge to complete the user observations. In such cases, it would be better to have multiple researchers present to conduct the audit together, to ensure arrivals and departures are all accounted for.

Perhaps the most striking finding from the user observations was the prevalence of personal micromobility. The rate was nearly tenfold that of shared micromobility. Looking just at electric e-bikes and e-scooters, there were nearly triple the number of arrivals and departures of personal electric vehicles than there were of shared electric vehicles.

Looking across the multiple research efforts reported here provides additional insights. One relates to the data being collected on micromobility. Interviews revealed that city managers are using (and paying high prices for) micromobility dashboards that show where shared vehicles are dropped off by operated and parked by users, as well as characteristics of users and their trips. These are informing their plans for infrastructure improvements. But these dashboards do not show personal scooters, e-bikes, and bikes being used. As more people choose personal micromobility, cities should increase the use of bicycle and pedestrian counters so that these numbers can be considered to support decisions about infrastructure investment planning.

Similarly, BART collects data on bike station and bike locker use but not on the number of people taking their bike or scooter on the train, and on the number of bikes and scooters parked inside stations. Data from the interviews and environmental audits showed that many riders are bringing their vehicle onboard and interviews further suggested that train car affordances are lacking. Despite a policy against bringing non-folding e-scooters into stations, many instances were observed during the environmental audits (although we did not document these numbers; future research should). Having data to quantify these practices could help justify further investment in better racks in the trains, clear signage and perhaps further policy changes.

Consistent with prior research, the findings establish the importance of protected bike lanes and bike parking in supporting the integration of public transit and micromobility. In addition to separating bike lanes from car traffic, they need to be coherently and consistently marked across the region to enable easier interpretation and navigation by users, and ultimately safety, as well as car drivers interacting with them.

Regarding parking, adequate capacity is not sufficient. Security is a major concern. There needs to be ample affordable and secure parking. Currently, secure parking facilities are not easy to find or access and they are not affordable for many users. More bike lockers and racks are needed at stations in both San Francisco and the East Bay.

There are conflicting ideas regarding the best solution for shared micromobility parking. Service operators appreciate corrals for dropping off vehicles and many stakeholders noted the benefit of orderly streets and reliable access. On the other hand, bike rack installations have largely solved the problem of complaints about inappropriate and hazardous vehicle parking according to government stakeholders. Limited above-ground space for BART to install racks or to locate bike stations or corrals leaves San Francisco stations still wanting for more shared vehicle parking.

Signage was not a focus of the station observations in this project, but the prior study upon which these builds found signage lacking and users represented in the survey and interviews agreed. BART station maps show riders where shuttles and bus routes leave from, but do not orient travelers to micromobility facilities. BART should include bike lanes, BART bike stations, bike lockers, shared micromobility bike rack drop off areas in their station wayfinding signs and maps.

City managers and community leaders observed that rebalancing to provide vehicles at transit stations was not happening enough. Micromobility operators explained that the rebalancing and battery charging was very expensive and models for public personal partnerships should be explored. Cities need to work with shared micromobility operators to plan how the rebalancing of vehicles should be done to target public transit stations at rush hour and support edge communities that are not able to enforce that their community gets coverage.

All of the 16 community, industry, and city stakeholders interviewed agreed that shared micromobility should be considered public transportation and that it is a low carbon last mile solution across the Bay Area. They showed interest in an incentive payment system across shared micromobility and public transit. Cities and community advocacy groups need to work together to provide bicycle, e-bike, and e-scooter training programs to help people learn how to sign up for the shared micromobility apps, e-bike library programs, and e-bike rebate programs.

Conclusion

The micromobility landscape continues to evolve as business models and private-public partnerships gain experience and travel behaviors find a new normal in the wake of the pandemic. Regardless of the shape it takes (personal or shared vehicles; scooters, bikes, or other), micromobility holds tremendous promise for facilitating first and last mile connections with public transit. Taking the California Bay Area Rapid Transit system as a case study, this research documented current micromobility use patterns at stations, examined transit station environmental design features, and explored stakeholder experiences with respect to the integration of micromobility and public transit. Successes and challenges were highlighted, and recommendations made for station design, including greater availability of shared micromobility vehicles, more affordable secure parking for personal micromobility vehicles, better signage and wayfinding. Beyond the station proper, there is a need for protected bike lanes and consistent design standards for bike facilities throughout the region. Further research and design solutions focused on facilitating micromobility connections with BART such as integrated payment systems will help California continue to demonstrate leadership in supporting low carbon transportation options and integrating micromobility as public transportation.

References

American Public Transit Association. Guidelines for design of rapid transit facilities. 1977

Bachand-Marleau, J., Lee, B.H. and El-Geneidy, A.M. (2012), "Better understanding of factors influencing likelihood of using shared bicycle systems and frequency of use", Transportation Research Record, Vol. 2314(1), pp. 66-71. https://doi.org/10.3141/2314-09

Bernal, L. M. M. D. Basic Parameters for the Design of Intermodal Public Transport Infrastructures. Transportation Research Procedia, Vol. 14, 2016, pp. 499–508.

De Bortoli A. Environmental performance of shared micromobility and personal alternatives using integrated modal LCA. Transportation Research Part D: Transport and Environment. 2021 Apr 1;93:102743.

Dell'Asin, G., A. Monzon, and M. E. Lopez-Lambas. Key Quality Factors at Urban Interchanges. Proceedings of the Institution of Civil Engineers - Transport, Vol. 168, No. TR4, 2014, pp. 326–335…. Chauhan V, Gupta A, Parida M. Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction with public transport. Transport Policy. 2021 Mar 1;102:47-60.

Edward A. Beimborn, Harvey Rabinowitz, Peter Lindquist, And Donna Opper. Market-Based Approach to Transit Facility Design. TRANSPORTATION RESEARCH RECORD.;1266:163.

Ferguson B, Sanguinetti A. Facilitating micromobility for first and last mile connection with public transit through environmental design: a case study of California bay area rapid transit stations. Proceedings of the Design Society. 2021 Aug;1:1577-86.

Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A.L., Badland, H., Foster, S., Lowe, M., Sallis, J.F., Stevenson, M. and Owen, N. (2016), "City planning and population health: a global challenge", The Lancet, Vol. 338(10062), pp. 2912-2924. https://doi.org/10.1016/S0140-6736(16)30066-6

Griffin KW. Building type basics for transit facilities. 2004

Iseki H, Smart MJ. How do people perceive service attributes at transit facilities? Examination of perceptions of transit service by transit user demographics and trip characteristics. Transportation research record. 2012 Jan;2274(1):164-74.

Kumar P, Jain SS, Kulkarni SY, Parida M. Accessibility to transit station in multi modal transport framework for Delhi. International Conference on Sustainable Built Environment (ICSBE-2010) Kandy, 13-14 December 2010

Magginas V, Nathanail E, Adamos G, Tsami M. Environmental friendly transport interchanges: Active travel accessibility and policy. In International Conference on Reliability and Statistics in Transportation and Communication 2018 Oct 17 (pp. 572-581). Springer, Cham….

Mallett, W.J. (2018), Trends in Public Transportation Ridership: Implications for Federal Policy, Congressional Research Service (No. R45144). Available at: https://fas.org/sgp/crs/misc/R45144.pdf (April 23, 2021)

Moffat D. The Art of Modern Transit Station Design. Places. 2004 Oct 1;16(3).

Monigl, J., Berki, Z., Szekely, A.: Guidelines for implementers of innovative cycling facilities for interchanges. NICHES+ (2010) chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.rupprecht-consult.eu/fileadmin/migratedRupprechtAssets/Documents/NICHES_WG2.2.pdf

Moodley S, Venter C. Measuring the Service Quality at Multimodal Public Transport Interchanges: A Needs-Driven Approach. Transportation Research Record. 2022 May 6:03611981221088782.

Moreau H, de Jamblinne de Meux L, Zeller V, D'Ans P, Ruwet C, Achten WM. Dockless e-scooter: A green solution for mobility? Comparative case study between dockless e-scooters, displaced transport, and personal e-scooters. Sustainability. 2020 Feb 28;12(5):1803.

Portland Bureau of Transportation (2018), 2018 E-Scooter Findings Report. Portland Bureau of Transportation, Portland. Available at: https://www.portland.gov/sites/default/files/2020-09/pbot_escooter_report_final.pdf (April 23, 2021)

Price, J., Blackshear, D., Blount, W., and Sandt, L. (2021), "Micromobility: A Travel Mode Innovation", U.S. Department of Transportation Available at: https://highways.dot.gov/public-roads/spring-2021/02

Shaheen, S. and Chan, N. (2016), "Mobility and the sharing economy: Potential to facilitate the first-and last-mile public transit connections", Built Environment, Vol. 42(4), pp. 573-588. https://doi.org/10.2148/benv.42.4.573

Shaheen, S. and Cohen, A. (2018), "Is it time for a public transit renaissance?: navigating travel behavior, technology, and business model shifts in a brave new world", Journal of Public Transportation, Vol. 21(1), p. 8. https://doi.org/10.5038/2375-0901.21.1.8

Shaheen, S.A., Zhang, H., Martin, E. and Guzman, S. (2011), "China's Hangzhou public bicycle: understanding early adoption and behavioral response to bikesharing", Transportation Research Record, Vol. 2247(1), pp. 33-41. https://doi.org/10.3141/2247-05

Zhao, P. (2014), "The impact of the built environment on bicycle commuting: Evidence from Beijing", Urban Studies, Vol. 51(5), pp.1019-1037. https://doi.org/10.1177/0042098013494423

Data Summary

Products of Research

Data were collected via station audits, BART and micromobility user survey, and stakeholder interviews.

Data Format and Content

Station audit data are compiled in a spreadsheet containing counts of variables observed and other contextual information. The survey is ongoing and will be archived in Dryad after a larger sample size is obtained. Interviews were recorded and transcribed on Zoom but will not be made available to protect the privacy of interviewees.

Data Access and Sharing

Appendix B and Appendix C contain the complete station audit data. For a copy of the survey data reported herein, contact asanguinetti@ucdavis.edu for a spreadsheet with the data (identifying information redacted) and copy of the survey.

Reuse and Redistribution

Data from the station audits available in Appendix B and Appendix C can be reused and this report cited.

Appendix A

Figure 34. 'How Do You Roll?' Survey Advertisement

Appendix B

Table 4. East Bay Observations

		N. Berkeley	D. Berkeley	Ashby	Rockridge	MacArthur	W. Oakland	19th St.	12th St.	Lake Merritt	Fruitvale
User Observation											
Shared Micromobility	Bike Arrivals	0	2	0	1	2	1	1	0	0	0
(Parked outside BART)	Bike Departures	1	0	0	2	0	1	0	0	1	0
	E-Bike Arrivals	0	0	0	0	0	0	0	0	0	0
	E- Bike Departures	0	0	0	0	0	0	0	0	0	0
	E-scooter Arrivals	0	1	0	0	0	0	0	0	0	0
	E-scooter Departures	1	0	0	0	1	3	2	1	8	0
	E-mopeds Arrivals	0	1	0	0	0	0	0	1	0	0
	E-mopeds Departures	0	0	1	0	0	0	0	0	0	0
	Total	**2**	**4**	**1**	**3**	**3**	**5**	**3**	**2**	**9**	**0**

Private Micromobility	E-Bike Arrivals	0	0	1	2	2	1	1	3	2	3
(Carried train)	E- Bike Departures	2	0	2	3	0	1	1	2	0	2
	Bike Arrivals	5	8	7	8	36	25	11	7	26	28
	Bike Departures	13	6	5	23	22	28	2	4	27	31
	E-scooter Arrivals	2	2	4	4	5	7	1	1	11	21
	E-scooter Departures	0	0	2	3	6	5	1	2	14	20
	Skateboard Arrivals	1	1	0	4	2	3	1	1	1	2
	Skateboard Departures	2	0	2	4	1	3	1	2	1	1
	Onewheel Arrivals	0	2	0	0	1	0	0	0	0	0
	Onewheel Departure	0	0	0	1	0	0	1	0	1	0
	Kick Scooter Arrivals	0	1	1	0	2	1	0	0	0	2
	Kick Scooter Departure	1	1	2	1	0	1	0	0	0	1
	Total	**26**	**21**	**26**	**53**	**77**	**75**	**20**	**22**	**83**	**111**

		N. Berkeley	D. Berkeley	Ashby	Rockridge	MacArthur	W. Oakland	19th St.	12th St.	Lake Merritt	Fruitvale
Parking Observation											
Bay Wheels Station	Empty Dock Spots	12	3	2	8	25	13	2	18	18	12
	Locked Classic Bikes	15	26	21	16	6	10	29	17	9	3
	Locked E-Bikes										
	Unlocked E-Bikes										
	Total Bikes Available	15	26	21	0	6	10	29	17	9	3
	Total Inactive (station down)	0	0	0	16	0	0	0	0	0	0
	Total Dock Spots	27	29	23	24	31	23	31	35	27	15

Outside Station (bike racks and poles)											
Shared Micromobility	Locked Spin Scooter	0	0	1							
	Unlocked Spin Scooter	0	0	0							
	Locked Spin ebike	1	1	0							
	Unlocked Spin ebike	0	0	0							
	Locked Lime Scooter	0	0	0	0	0	3	0	0	0	0
	Unlocked Lime Scooter	0	0	0	0	0	0	1	0	0	0
	Locked LINK Scooter	4	5	5	0	1	1	2	1	6	0
	Unlocked LINK Scooter	0	0	0	0	0	2	0	0	0	0
	Locked Veo Scooter	2	1	0	11	0	0	0	1	2	0
	Unlocked Veo Scooter	0	0	0	0	0	0	0	0	0	0
	Locked Veo e-moped	0	1	0	0	0	0	0	1	0	0
	Unlocked Veo e-moped	0	0	0	0	0	0	1	1	0	0
	Locked Lyft E-Bike										
	Unlocked Lyft E-bike										
	Locked Bird										

		N. Berkeley	D. Berkeley	Ashby	Rockridge	MacArthur	W. Oakland	19th St.	12th St.	Lake Merritt	Fruitvale
	Total Locked	**7**	**8**	**6**	**11**	**1**	**6**	**4**	**4**	**8**	**0**
	Total Unlocked	0	0	0	0	0	3	2	0	0	0
	Total Parking Capacity	**143**	**42**	**25**	**74**	**32**	**46**	**24**	**9**	**49**	**27**

Private Micromobility		N. Berkeley	D. Berkeley	Ashby	Rockridge	MacArthur	W. Oakland	19th St.	12th St.	Lake Merritt	Fruitvale
	E-bike	0	1	0	0	0	0	0	0	0	0
	Bike	13	3	4	5	5	5	0	2	4	3
	E-scooter	0	0	0	0	0	0	0	0	0	0
	Total	**13**	**4**	**4**	**5**	**5**	**5**	**0**	**2**	**4**	**3**
Bike Racks (Inside Station)											
	Total Used	13	4	4		13		4	1	10	
	Total Parking Capacity	0	70	14		66		79	30	40	
Private Bike Lockers	Total Used	32		9	5	13	8	1	2	11	0
	Total Parking Capacity	96		40	60	36	176	8	12	84	28
Bike Station	Total Used		13	15		2					
	Total Parking Capacity		44	128		208					
Bike Station Valet	Bike		64					30			35
	E-bike		27					6			3
	Total		**91**					**36**			**38**
	Capacity		326					130			200

Appendix C

Table 5. San Francisco Observations

		Embarcadero	Montgomery St.	Powell St.	Civic Center	16th St.	24th St.	Glen Park	Balboa Park
User Observation									
Shared Micromobility	Bike Arrivals	1	0	2	0	4	0	1	0
(Parked outside BART)	Bike Departures	3	1	3	0	0	1	1	0
	E-Bike Arrivals	0	1	0	1	6	1	0	0
	E- Bike Departures	5	4	1	1	3	3	0	0
	E-scooter Arrivals	2	0	0	0	0	0	0	0
	E-scooter Departures	3	2	6	1	1	0	0	0
	E-mopeds Arrivals	0	0	0	0	0	0	0	0
	E-mopeds Departures	0	0	0	0	0	0	0	0
	Total	**14**	**8**	**12**	**3**	**14**	**5**	**2**	**0**

Private Micromobility	E-Bike Arrivals	3	2	0	13	4	0	4	0
(Carried onto BART train)	E- Bike Departures	0	0	0	8	1	0	4	3
	Bike Arrivals	20	9	6	23	22	15	7	6
	Bike Departures	5	6	5	13	12	7	8	7
	E-scooter Arrivals	7	5	6	13	6	6	3	3
	E-scooter Departures	1	4	1	10	4	2	4	7
	Skateboard Arrivals	0	1	1	0	2	1	0	2
	Skateboard Departures	0	1	0	0	0	1	2	4
	Onewheel Arrivals	0	0	0	1	0	0	0	0
	Onewheel Departure	0	0	1	1	0	0	3	0
	Kick Scooter Arrivals	0	1	0	0	0	4	0	0
	Kick Scooter Departure	0	0	0	0	1	0	0	0
	Total	**36**	**29**	**20**	**82**	**52**	**36**	**35**	**32**

		Embarcadero	Montgomery St.	Powell St.	Civic Center	16th St.	24th St.	Glen Park	Balboa Park
Parking Observation									
Bay Wheels Station	Empty Dock Spots	7	14	17	2	16	0	21	17
	Locked Classic Bikes	7	6	12	16	10	9	17	5
	Locked E-Bikes	14	7	6	11	2	8	1	3
	Unlocked E-Bikes	5	6	0	0	0	2	0	0
	Total Bikes Available	**26**	**19**	**18**	**27**	**12**	**19**	**18**	**8**
	Total Inactive (station down)	0	0	0	0	0	0	0	0
	Total Dock Spots	28	27	35	29	28	16	39	25

Outside Station (bike racks / poles)									
Shared Micromobility	Locked Lyft E-Bike	1	2	0	0	1	0	0	0
	Unlocked Lyft E-Bike	0	0	3	1	1	0	0	1
	Locked bird scooter	4	10	12	2	3	2	1	0
	Unlocked bird scooter	0	0	0	0	0	0	0	0
	Locked Spin Scooter	7	7	1	2	1	0	0	0
	Unlocked Spin Scooter	0	0	1	4	0	1	1	0
	Locked Lime Scooter	1	0	2	0	0	0	1	0
	Unlocked Lime Scooter	0	0	0	0	0	0	0	1
	Active Locked Spin bike								
	Active Unlocked Spin bike								
	Active Locked LINK Scooter								
	Active Unlocked LINK Scooter								
	Active Locked Veo Scooter								

		Embarcadero	Montgomery St.	Powell St.	Civic Center	16th St.	24th St.	Glen Park	Balboa Park
	Active Unlocked Veo Scooter								
	Total Locked	**13**	**19**	**19**	**9**	**6**	**3**	**3**	**2**
	Total Unlocked	0	0	5	2	0	0	1	0
	Total Parking Capacity	**6**	**25**	**27**	**14**	**6**	**7**	**4**	**7**
Private Micromobility									
	E-bike	0	0	0	0	0	0	0	0
	Bike	1	0	0	0	0	0	0	0
	E-scooter	0	0	0	0	0	1	0	0
	Total Personal	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Bike Racks (Inside Station)									
	Total Used	0			0	1	0	2	2
	Total Parking Capacity	10			8	53	49	18	30
Private Bike Lockers	Total Used							0	0
	Total Parking Capacity							12	12
Bike Station (BIKELINK Room)	Total Used	5			6				
	Total Parking Capacity	114			142				