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Environmental Design for Micromobility and Public Transit

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16. Abstract

Micromobility has the potential to reduce greenhouse gas emissions, traffic congestion, and air pollution, particularly when replacing private vehicle use and working in conjunction with public transit for first- and last-mile travel. The design of the built environment in and around public transit stations plays a key role in the integration of public transit and micromobility. This research presents a case study of rail stations in the San Francisco Bay Area, which are in the operation zone of seven shared micromobility operators. Nineteen stations and their surroundings were surveyed to inventory design features that could enable or constrain use of micromobility for first- and last-mile access. Shared mobility service characteristics, crime records, and connections to underserved communities were also documented. An interactive Bay Area Micromobility Transit ArcGIS map tool was created to aid analysis and provide a useful resource to stakeholders. The map shows layers such as train stations, bike lanes, bike share kiosks, and micromobility operation zones that vary between Oakland, Emeryville, Berkeley, San Francisco, and San Jose. Key design solutions were identified based on the findings, including protected bike lanes, increased shared bike and scooter fleet size and service area, and clear signage indicating bike rack parking corral and docking points.

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Micromobility, shared mobility, public transit, rail transit stations, accessibility, urban design, digital mapping, case studies

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Disclaimer

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Executive Summary

Micromobility has the potential to reduce greenhouse gas emissions, traffic congestion, and air pollution, particularly when replacing private vehicle use and working in conjunction with public transit for first- and last-mile travel. The design of the built environment in and around public transit stations plays a key role in the integration of public transit and micromobility. This research presents a case study of Bay Area Rapid Transit (BART) heavy rail stations in the San Francisco Bay Area, which are in the operation zone of seven shared micromobility operators. The stations were surveyed to inventory design features that might facilitate or hinder the use of personal, rented, or leased bikes, e-bikes, and e-scooters for first- and last-mile connections. The purpose of the study was to highlight best practices and opportunities for improvement that can be applied to other types of transit stations and locations.

The San Francisco Bay Area was selected as the focus of this case study due to both its relatively high public transit and shared micromobility usage, as well as high micromobility usage rates for trips to and from transit. As such, it is a potential testbed for innovative and adaptive transit station design features that support micromobility. Four cities with BART stations in the Bay Area currently have agreements with shared micromobility providers: Berkeley, Oakland, San Francisco, and San Jose. The 19 BART stations in these cities were the focus of this study in order to focus on stations with relatively abundant opportunities for shared micromobility usage.

Data were collected between July 2020 and April 2021 to describe the stations as well as surrounding areas within a one-mile radius, which can be considered the catchment area for first- and last-mile travel origins and destinations. Data were gathered and cross referenced from a variety of sources, including site visits to each of the 19 stations, Google Maps, shared micromobility service apps, BART, Bay Area Department of Transportation, and city websites. Features inventoried at each station included: level of protection and connectivity of bike lanes surrounding the station; service vehicle density; micromobility parking facilities; station safety (crime rates); features contributing to the attractiveness of the station and surrounding area (plants and outdoor seating at the stations, and nearby cafes); micromobility parking affordances; and signage.

The Micromobility Map tool was created with ArcGIS to aid analysis. The map tool includes interactive layers to show train stations, bike lanes, bike share kiosks, and micromobility operation zones that vary between Oakland, Emeryville, Berkeley, San Francisco, and San Jose. Data sources used to create the map included: the UC Berkeley Transportation Injury Mapping System SafeTREC tool, City of Oakland DOT, City of San Francisco DOT, the BART website, and micromobility operator app maps (Bay Wheels, Lime, Link, Revel, Scoot, Spin, and VeoRide).

While many innovative features were documented, the findings also highlighted areas for improvement. Specifically, results indicated a lack of safe street facilities for bikes and scooters around transit stations; insufficient micromobility parking (particularly for dockless vehicles requiring a locking bike rack) and associated signage at stations; and gaps in micromobility service provision throughout the region. Key design solutions were identified based on these findings, including protected bike lanes, clear signage indicating parking corral and docking points, and increased shared bike and scooter fleet size and service area.

For optimal facilitation of micromobility and transit connectivity, cities and public transit agencies should work together to implement networks of protected bike lanes within a two-to-five-mile radius of transit stations. Bike lane investments, street lighting, and marked wayfinding around stations will improve safety and popularity for shared micromobility and cycling in general. Stations need to prioritize corrals with racks to increase reliability and ease of use of shared micromobility services; it also helps to maintain order and protect pedestrian safety from trip hazards. Transit stations should update their printed maps and websites to highlight shared micromobility docking stations in and around the station, dockless vehicle parking zones, and recommended safe routes for bikes and e-scooters. Finally, each operating micromobility service should be consistently available throughout a highly connected urban region so users do not have to learn to navigate multiple service apps, use different vehicle types, and remember different rules.

Many of the design principles discussed here will be beneficial to global cities managing public transit and micromobility. Micromobility stands to become an important part of public transportation, addressing the problem of first- and last-mile connectivity and providing an alternative or complementary option for public transit users in the wake of the COVID-19 pandemic. Future research should solicit feedback from shared micromobility and transit users on their preferred station design features and attempt to quantify the influence of station design features on shared micromobility use for first- and last-mile travel.

Contents

Introduction

Revolutionizing urban transportation on a massive scale within the next ten years is necessary to meet the climate goals set by the Paris Agreement and mitigate global warming (Santos, 2017). Industry stakeholders, policy-makers, and academicians are imagining a more sustainable transportation system where mobility-as-a-service (MaaS), including shared micromobility, ride-hailing, and public transit, supplants private vehicle ownership as the dominant model (Shaheen & Cohen, 2018; Sheller & Urry, 2016; Sperling, 2018). This research focuses on the integration of shared micromobility and public transit.

Shared micromobility services are rapidly proliferating. More established ride-hailing operators like Uber and Lyft have also been investing in dockless shared e-bike systems, recognizing that shorter trips (2–5 miles) can be made faster and cheaper on two wheels. A study of e-scooter potential in Chicago found that e-scooters would be a cost-effective alternative to private cars for 1/2 to 2-mile trips, particularly in parking-constrained environments, and fill a gap in mobility for underserved communities (Smith & Schwieterman, 2018). There are limited studies on the actual impacts of shared micromobility, since many of these services are still relatively new, but early evidence suggests they contribute to increased mobility, reduced greenhouse gas emissions, decreased automobile use, economic development, and health benefits (Portland Bureau of Transportation, 2018; Shaheen & Cohen, 2019, 2021).

In contrast, public transit use has decreased in recent years (Mallett, 2018) and now faces further challenges due to the COVID-19 pandemic (Zheng et al., 2020). New shared mobility options, including ride-hailing and shared micromobility (i.e., on-demand docked and dockless bikes, e-bikes, and e-scooters), present both a challenge and an opportunity for increasing public transit use since some user segments adopt these modes to replace public transit whereas others use them in conjunction with public transit (Circella et al., 2018; Shaheen et al., 2011). Shared mobility is particularly 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 (ideally also more easily and safely) 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).

Shared micromobility in particular holds promise as a first- and last-mile solution. These modes are less likely to compete with public transit. For example, the study of e-scooter potential in Chicago found they would be cost-prohibitive and therefore non-competitive for trips over three miles, but, when used in conjunction with transit in the business district, they would make 16% more jobs reachable within 30 minutes compared to current opportunities accessible by transit and walking (Smith & Schwieterman, 2018). Recognizing this potential, shared micromobility companies and public transit agencies have begun to form partnerships (e.g., Bizjak, 2018).

The potential for shared micromobility as a solution for first- and last-mile connectivity with public transit depends on a variety of factors related to service accessibility, ease of use, and safety. These factors include 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 factors are influenced by the design of the built environment, which is the focus of this research.

A good deal of attention has been given to built environment interventions that promote traditional active modes (e.g., walking and non-motorized bicycling) connected to public transit, for healthy and sustainable cities (Giles-Corti et al., 2016). These include managing parking demand by parking availability and increasing cost, 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.). For bikes in particular, protected bicycle lanes, mixed-use neighborhoods, and connectivity between local streets have been found to promote use (Zhao, 2014).

Less is known regarding built environment supports for shared micromobility, particularly dockless light electric vehicles. The literature on (docked, non-motorized) bikesharing finds that 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: technologies that communicate real-time bike and parking availability, improved bike maintenance and locking mechanisms, extended operational hours, and dense vehicle availability in multiple locations nearby each other to create a network effect (Cohen & Shaheen, 2016; Shaheen et al., 2011).

Shared dockless e-bikes and e-scooters have a particular need for built environment supports that indicate where users can and cannot ride and park, including the infrastructure itself, operator apps, and signage that communicates the rules. Mainstream street designs are not conducive to optimal and safe travel on these bikes and e-scooters; thus, these modes present challenges for cities tasked with regulating them. For example, e-bikes and traditional bikes travel at different speeds in shared lanes, and e-scooters sharing sidewalks with pedestrians are potentially dangerous for pedestrians or riding in the street are potentially dangerous for scooter rides. Policies and infrastructure vary widely across (and even within) cities.

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 the actual impacts of built environment factors (and policies). Exceptions include an evaluation of an e-scooter pilot in Portland (Portland Bureau of Transportation, 2018), 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).

The present research focuses on infrastructure and other built environment supports for shared micromobility in and around transit stations through a case study of heavy rail stations in the California Bay Area, operated by Bay Area Rapid Transit (BART). BART began operation in 1972 as a heavy rail elevated and subway system designed to connect suburbs with urban centers, such as San Francisco, Oakland, and Peninsula. BART has 50 stations that cover 131 miles across 5 counties and in 2019 averaged 118 million annual passengers.

The Bay Area was selected as a case study for this research because it is 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 that support micromobility. This research aimed to identify best practices and opportunities for improvements to increase ridership across both modes, particularly to support shared micromobility as a first- and last-mile solution in conjunction with transit.

Methodology

A subset of 19 BART stations were selected to focus on those with relatively greater opportunities for shared micromobility use. 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, and operator exclusivity differently with each provider. Four cities with BART stations in the Bay Area currently have agreements with shared micromobility providers: Berkeley, Oakland, San Francisco, and San Jose. The 19 BART stations in these cities were the focus of this study. The City of Emeryville has started to increase its permitted micromobility operators (Link, Spin) but does not have a BART station, though it does have an Amtrak station with a Bay Wheels bikeshare station.

Data were collected between July 2020 and April 2021 to describe the stations and surrounding areas within a 1-mile radius, which can be considered the catchment area for first- and last-mile travel origins and destinations. Features that facilitate micromobility, according to past research, were inventoried at each station, including level of protection and connectivity of bike lanes surrounding the station; service vehicle density; micromobility parking facilities; station safety (crime rates); and features contributing to the attractiveness of the station and surrounding area (plants and outdoor seating at the stations, and nearby cafés). Data were gathered on other relevant features, including micromobility parking affordances and signage, since signage to support wayfinding is a critical aspect of user experience at transit hubs (Farr et al., 2012). Data was gathered and triangulated from a variety of sources, including site visits to each of the 19 stations, Google Maps, BART and Bay Area Department of Transportation websites, city websites, and shared micromobility service apps. Table 1 provides the codebook for data collection, which includes definitions and levels of the variables assessed and data sources.

Table 1. BART Station Survey CODEBOOK

Feature	Definition	Codes	Data Sources
Shared Micromobility Service Availability			
Shared micromobility service provider	Station is in the service provider operating area	Lyft Bay Wheels Spin Link VeoRide Lime Scoot Revel	baywheels.com/map spin.app link.city veoride.com li.me scoot.co gorevel.com

Feature	Definition	Codes	Data Sources
Bay Wheels dock density	Total number of bike spots (open or filled) at the Bay Wheels docking station at the BART station	Count	baywheels.com/map
Nearby Bay Wheels docking stations	Number of other nearby Bay Wheels docking stations for picking up/dropping off shared bikes and e-bikes within 1-mile radius of BART station	Count	baywheels.com/map
Micromobility Parking and Storage			
E-scooter corral	Demarcated areas for dropping off shared dockless e-scooters and e-bikes adjacent to BART station	Count	Site observation
Outdoor bike racks	Number of outdoor bike racks for parking private and shared dockless bikes and scooters	Count	Site observation Bart.gov/guide/bikes
Indoor bike racks	Number of indoor bike racks for parking private bikes and shared scooters	Count of each: BIKEEP, indoor racks	Site observation Bart.gov/guide/bikes
24-hour bike station	Number of parking spots in BikeLink 24-hour card-secure parking rooms within 1 block of station	Count	Site observation bikehub.com/bart/
Bike lockers	Digital bike lockers for bike and gear managed by Bikelink card	Count	Site observation bikelink.org
Valet bike parking	Number of parking spots for 7 AM–7 PM BikeHub valet parking service	Count	Site observation Bikehub.com/bart/
Other Supportive Station Design			
Signage	Content of maps and signs around station	Shared micromobility signage [pictures and descriptions of other content]	Site observation

Feature	**Definition**	**Codes**	**Data Sources**
Charging facilities	Presence of charging stations for personal e-bikes and e-scooters	Yes or No	Site Observation
Bike repair facilities	Self-service stand with tools for DIY repairs or BikeHub shop with repair service staff	BikeHub shop Self-service	Site Observation bikehub.com/bart/
Multilevel access	Accommodations for multilevel station access for bikes and scooters	Escalator Elevator Stairs with bike channel Stairs without bike channel	Site Observation bart.gov/guide/bikes
Accessible fare gates	Wider fare gates to accommodate personal vehicles (bikes, e-scooters, wheelchairs, stroller)	Count	Site Observation
Station Attractiveness			
Outdoor Seating	Presence of any seating outside the station	Yes or No	Site Observation
Cafés	Presence of café at station or within 1-2 blocks	Yes or No	Site Observation yelp.com
Plants	Presence and type of plant	Trees Shrubs Flowers Empty Planter Nothing	Site Observation google.com/earth
Crime incidents in 2019	Police reported crimes at BART stations during 2019 (time period selected to describe stations prior to the COVID-19 pandemic)	Count	bartcrimes.com
Supportive Street Facilities			
Car lane (only)	Least supportive of micromobility	Yes or No	Site Observation google.com/maps with bicycle filter

Feature	Definition	Codes	Data Sources
Bike boulevard (Class 3)	Street lane shared by bikes, buses, and cars (25 mph limit); better than car-only but can be dangerous	Yes or No	Site Observation google.com/maps with bicycle filter
Bike lane (Class 4)	Portion of road designated by striping for bike	Yes or No	Site Observation google.com/maps with bicycle filter
Protected cycle track (Class 2)	Bikeway at street level with physical protection	Yes or No	Site Observation google.com/maps with bicycle filter
Greenway bike path (Class 1)	Bike path with no cars	Yes or No	Site Observation google.com/maps with bicycle filter
Slow street	Streets closed to through traffic during COVID-19	Count	google.com/maps
Other Multimodal Affordances			
TNC zone	Presence of a designated zone (signage) for TNC drop-off/pick-up	Yes or No	Site Observation
Bus connection	Bus stop adjacent to BART station	Yes or No	Site Observation
Car parking	Number of parking spots at BART station lots	Count	Site Observation
Car share	Parking spots marked for Zipcar or GIG Car at East Bay BART stations or within 3-4 blocks of SF BART stations	Count	Site Observation
Motorcycle parking	Number of parking spots at BART station lots	Count	Site Observation

The purpose of the Micromobility Map tool is to visualize many of the same variables in our BART station survey. This tool was designed to be used with project stakeholders from BART, city transportation agencies, and micromobility providers. The ArcGIS map layers help us explore which cities have permitted the various micromobility companies, 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 necessary to return rented classic bikes after picking one up at a BART station. The map layers show the different bike paths, bike lanes, and bike boulevards that connect with transit stations. We 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. Table 2 provides the Micromobility Map Tool data layers, description and data sources used.

Table 2. Micromobility Map Tool Data Sources

Data Layer	Description	Source
Public Transit		
Micromobility	Identifies shared mobility services in four of the Bay Area cities: Berkeley, San Jose, San Francisco, and Oakland. Services include Bay Wheels, Lime, Link, Revel, Scoot, Spin, and VeoRide.	Bay Wheels, Lime, Link, Revel, Scoot, Spin, and VeoRide Apps, June, 2021
Lyft Bay Wheel locations	Locations of Lyft Bay Wheels stations in the Bay Area, including capacity (number of bikes or scooters).	Lyft Bay Wheels data, downloaded May 21, 2021
BART Stations	Bay Area Rapid Transit (BART) system station locations.	BART, downloaded May 2021
Amtrak and Caltrain Stations	Existing Amtrak and Caltrain stations and stops for the San Francisco Bay Region.	Metropolitan Transportation Commission Open Data (MTC), last updated in 2019.
Passenger Rail Stations	All passenger, commuter, and light rail stations and stops for the San Francisco Bay Region, including MUNI.	Metropolitan Transportation Commission Open Data (MTC), last updated in 2019.
Bikeways		
Berkeley Bicycle Boulevards	Location of bicycle priority streets in the City of Berkeley	City of Berkeley Open Data, downloaded May 2021
Oakland Existing and Proposed Bikeways	Existing and proposed bikeways in the City of Oakland.	City of Oakland Open Data, downloaded May 2021. More data can be found on Oakland Maps.
San Francisco Bay Trail	The San Francisco Bay Trail is a planned 500-mile walking and cycling path around the entire San Francisco Bay.	Metropolitan Transportation Commission Open Data (MTC), April 2021

Data Layer	**Description**	**Source**
San Francisco Bikeway Network	Bikeway network in the City of San Francisco.	Municipal Transportation Agency (MTA), downloaded May 2021.
Other Data		
Bike Collisions, 2015-2020	TIMS query for 2015-2020 collisions identified as a "Bicycle Collision" for Alameda and San Francisco counties (approx. 6,400 entries). Data displays as a cluster when zoomed out, and as point locations when zoomed in. There might be more than one incident in the same location (click on the point, then look for a right arrow to click through the different incidents).	Transportation Injury Mapping System (TIMS), UC Berkeley, 2021
City Boundaries	Boundaries for incorporated cities in the Bay Area.	Census 2010
Race & Ethnicity	Identifies percent People of Color by census tract (all race/ethnicities except for White) for Alameda and San Francisco counties.	ACS 2019 5-year, Table DP05

Results and Discussion

Results of the station inventory and Micromobility Mapping tool are organized into the categories developed for the station feature design codebook and presented along with interpretations regarding implications for micromobility and transit connectivity.

Shared micromobility service availability

There is a high turnover rate of permitted micromobility companies: several operators came and went during the period over which this research was conducted. As of April 2021, seven operators have permitted fleets operating in at least 1 of the 19 BART stations (Table 3). Bay Wheels is a docked classic bike and e-bike service operated by Motivate in partnership with Lyft, the Metropolitan Transportation Commission, and the Bay Area Air Quality Management District. Bay Wheels has over 2,600 bicycles and 262 stations, including share bike stations (for example, Figure 1) at all the BART stations we surveyed. The other six operators have dockless vehicle services (primarily e-scooters). Figure 2 and Figure 3 map the service boundaries of each operator along with BART stations and bike lanes. Figure 2 shows that Oakland has an area (shaded orange) served by e-scooter operators (Spin, Link, Veoride) and Bay Wheels bike share stations. The number (or density) of Bay Wheels bikeshare stations, shown by the pink icons on the map, is relatively high in Oakland's central urban areas but lower in East Oakland. Since users must return the Bay Wheels bikes to these stations, this lower density in East Oakland makes using the bikes for first- and last-mile in the area unfeasible for many residents. Berkeley currently does not allow e-scooter operators, but they allow Bay Wheels classic bikeshare.

Table 3. Shared micromobility services by city as of April 2021

		City			
		San Francisco (BART station, Embarcadero, Montgomery, Powell, Civic Center, 16th, 24th, Glen Park, Balboa Park)	**Berkeley** (BART station, N. Berkeley, Downtown Berkeley, Ashby)	**Oakland** (BART stations, Rockridge, MacArthur, W. Oakland, 19th, 12th, Lake Merritt, Fruitvale)	**San Jose** (BART stations, Berryessa/North)
Shared Micromobility Operator	**Bay Wheels** (bike, e-bike, e-scooter)	Yes	Yes	Yes	Yes
	Spin (e-scooter)	Yes	No	Yes	No
	Link (e-scooter)	No	No	Yes	Yes
	VeoRide (e-scooter)	No	No	Yes	No
	Lime (e-scooter, e-bike)	Yes	No	No	Yes
	Scoot (e-scooter, e-moped)	Yes	No	No	No
	Revel (e-moped)	Yes	Yes	Yes	No
	Total Permitted Operators	5	2	5	3
	Source	www.sfmta.com	www.cityofberkeley.info	www.oaklandca.gov	www.sanjoseca.gov

Figure 1. North Berkeley BART Bay Wheels bikeshare station

Consistency of operators across cities, as with Bay Wheels, may create a seamless experience. For example, a user could take a Bay Wheels bike from a dock near their home to a Berkeley BART station, ride the train to an Oakland BART station, pick up another shared bike there, and ride it to work. In contrast, the multiple dockless micromobility fleets are not consistently available across Bay Area cities. This creates complexity that could inhibit adoption because each service has its own app, vehicle types, and rules with which users must become familiar. The high turnover of operators and changing service agreements from year-to-year is also problematic; users must adapt when their preferred operators reduce or remove their fleets. Bay Wheels stations at these BART stations have an average of 27 docks (*SD* = 6). The number of Bay Wheels docking stations in the surrounding neighborhood (1-mile radius) vary considerably (*Mdn* = 15; min-max: 2-57). As Shaheen et al. (2011) noted, a high density of vehicles at multiple locations is needed to create a network effect. BART stations with fewer nearby Bay Wheels stations are thus less conducive to last-mile access for users who live or work further from the BART station and other Bay Wheels docking stations. “Rebalance vans” or trailers are used to move the Bay Wheels bikes when fleet numbers are low or outnumber the docking spots. Vans are also used to transport e-scooters and e-bikes to warehouses to recharge their batteries or do repair work.

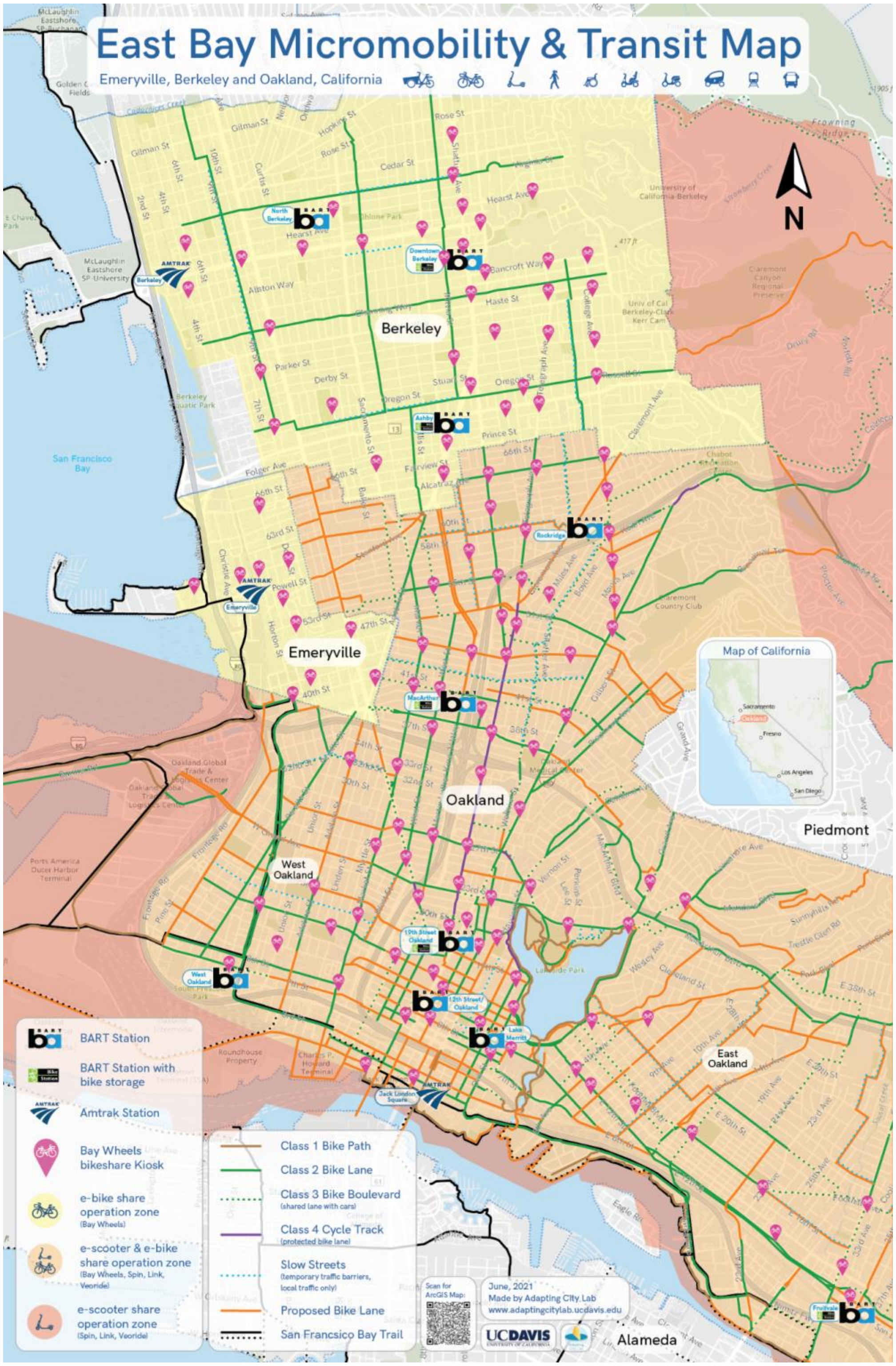


Figure 2. East Bay micromobility and transit map tool example, B. Ferguson, J. Wattimena, 2021

Figure 3. San Francisco micromobility and transit map tool example, B. Ferguson, J. Wattimena, 2021

Micromobility parking and storage

Parking corrals are an analogous facility to docking stations but for shared dockless e-scooters and e-bikes, providing designated parking, lockable bike racks, and reliable access. Corrals were present at only two stations (Figure 4 and Figure 5). In the absence of corrals, shared dockless vehicle users are left without direction as to where to drop off a vehicle (Figure 7). San Francisco and Oakland recently began requiring all e-bikes and e-scooters to be locked to a bike rack or street sign when parked (Figure 5). While this prevents vehicles from blocking a sidewalk, it also creates the need for additional designated bike racks to accommodate both private and shared bikes and scooters. Cities and mobility providers must work together to create clear user parking information both digitally and physically to reduce confusion. Figure 6 shows Lime e-scooters blocking bike racks at the W. Oakland BART before the e-scooter locking rule was implemented.

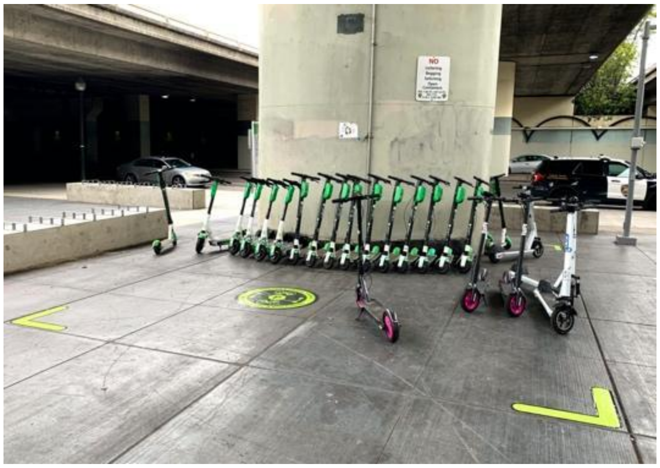


Figure 4. MacArthur BART station e-scooter corral for locked parking

Figure 5. MacArthur BART station e-scooter lockable bike rack corral

The presence and capacity of indoor and outdoor bike racks and secure private bike storage ranged widely across stations (Table 4). They were particularly limited in underground San Francisco stations with minimal above-ground space in this high-density urban area. Outdoor racks are especially important for facilitating shared micromobility to increase visibility to available e-scooter or e-bike fleets beyond the various apps. (Figure 6). Vehicles left in undesignated spaces can become a trip hazard (Figure 7).

Table 4. Micromobility Parking and Storage Facilities at BART Stations

	East Bay & San Jose	San Francisco	All Stations
E-scooter corral	Present at 2 stations	Present at 0 stations	Present at 2 stations
Outdoor racks	Mdn = 28; min-max: 2-169	Mdn = 3; min-max: 0-12	Mdn = 12; min-max: 0-169
Indoor racks	Mdn = 14; min-max: 0-60	Mdn = 0; min-max: 0-45	Mdn = 0; min-max: 0-60
Secure storage	Mdn = 154; min-max: 12-383	Mdn = 6; min-max: 100	Mdn = 96; min-max: 0-383

Figure 6. W. Oakland BART station with e-scooter blocking bike racks in the absence of marked corral

Figure 7. Bay Wheels e-bike parked at the top of the Civic Center BART station stairs

Other micromobility supportive station design features

Other micromobility supportive station features include signage, e-bike and e-scooter charging stations, bike repair services, and multilevel access and fare gate affordances for riders traveling with private bikes or scooters. Shared micromobility signage was only observed at the two stations with corrals (Figure 8), indicating where users should drop off their scooters and bikes. Signage for bus schedules and maps of stations and surroundings were prevalent, but none included place markers for Bay Wheels docking stations or corrals (e.g., Figure 9).

Figure 8. BART dockless parking sticker marking corral

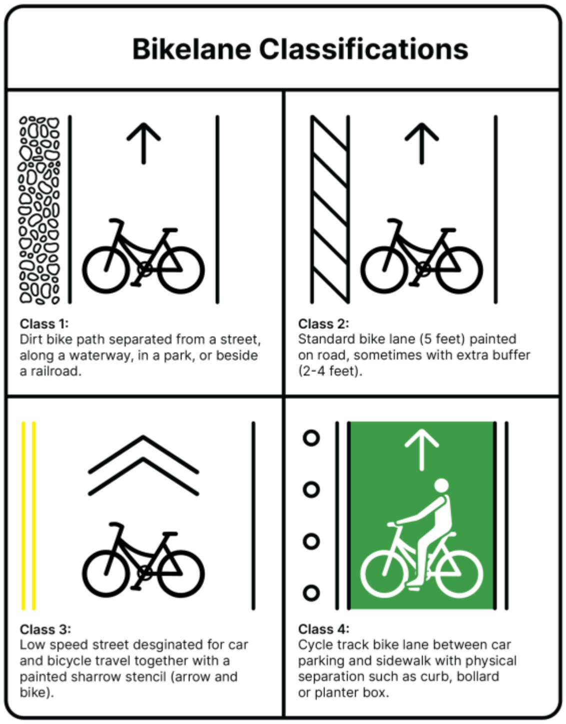
Figure 9. Map of bus transit stops around the MacArthur BART station that does not show the Bay Wheel bikeshare station or the parking corral for shared dockless e-scooters

Three East Bay BART stations include bike repair shops. Five East Bay BART stations include attended and self-park bike stations (storage rooms). There are plans for personal e-bike charging to be included at the Downtown Berkeley station's new valet bike parking service. San Francisco BART stations do not provide bike repair services but they have two bike stations for secure locking. (Forty of BART's stations include on-demand BikeLink lockers that work with a card on a first-come, first-served basis.)

BART riders traveling with a bike or stand-up scooter are instructed (via signage) to use the elevator or stairs to reach the train platforms at underground or multilevel stations. All stations have an elevator and stairs; however, these facilities are not always convenient, easy to locate, or safe. Although escalators are also present in every station and are generally more convenient and easy to locate, bikes and scooters are not allowed on them. Despite policy, however, riders were observed with bikes and scooters on escalators. BART has installed a bike wheel channel alongside the stairs at the 16th Street Mission BART station, so riders do not have to carry their vehicle up or down the stairs. All BART stations also have at least one accessible fare gate for bikes, wheelchairs, bags, and baby strollers. BART's website says “BART does not permit scooters or mopeds on trains,” meaning large gas scooters, but this could be misleading for people wanting to carry stand-up kick or e-scooters with them and should be updated.

Micromobility supportive street facilities

In the station inventory, data were collected on the presence of varying types of street facilities (i.e., bike lanes) that serve bikes, e-bikes, and e-scooters within a four-block radius of each BART station (i.e., the most station-adjacent part of a travelers’ first- and last-mile journey). Figure 10 depicts the main types of bike lanes defined by the US National Association of City Transportation Officials (NACTO). The Micromobility Map tool (e.g., Figure 2 and Figure 3) illustrates the distribution of these different types of street facilities throughout the study region.



Class 1:
Dirt bike path separated from a street, along a waterway, in a park, or beside a railroad.

Class 2:
Standard bike lane (5 feet) painted on road, sometimes with extra buffer (2-4 feet).

Class 3:
Low speed street desginated for car and bicycle travel together with a painted sharrow stencil (arrow and bike).

Class 4:
Cycle track bike lane between car parking and sidewalk with physical separation such as curb, bollard or planter box.

Figure 10. Bike lane classification. B. Ferguson, J. Wattimena, 2021 (data source: NACTO)

All stations had at least some nearby street segment without any type of bike lane. Most stations (84% of all stations) had nearby Class 2 classic bike lanes and/or Class 3 bike boulevards (shared with cars). Class 1 separated bike paths and Class 4 protected cycle tracks, which are safer and more comfortable facilities, were found near 37% and 16% of stations, respectively (Figure 11). There was a lack of consistency in the bike lane networks noted, including intermittent Class 2 bike lanes and Class 3 bike boulevards on the same route, bike lanes that stop altogether from block-to-block, and the absence of bike lanes in streets directly adjacent to stations. The San Francisco map (Figure 3) shows that some neighborhoods, such as the Bayview District, have mostly bike boulevards rather than protected bike lanes, forcing micromobility riders to share a car lane, which is often dangerous and discourages use. Notably, there were Slow Streets near 58% of stations. Slow Streets—where a segment of street is closed to through traffic to support walking and biking for all ages—have been implemented in many cities in response to the COVID-19 pandemic (including in San Francisco, Oakland, and Berkeley).

Figure 11. Short segment of protected Class 4 cycle track on Telegraph Ave. Oakland, CA

Station attractiveness

Safe and attractive neighborhoods surrounding public transit stations are important to support active transportation and micromobility (Giles-Corti et al., 2016). Features that may contribute to attractiveness include outdoor seating, shade trees at stations, and nearby cafés. All East Bay stations (and the new San Jose station) had outdoor seating, whereas almost no San Francisco BART stations did; again, this is likely due to limited above-ground space near the stations in dense urban areas managed by the SFMTA and not BART. Cafés were found within 1-2 blocks of all but four stations.

Greenery (specifically, trees) were observed at 63% of stations; there were empty planter boxes at two stations. Over the years, BART has struggled to maintain landscaping and many station planter boxes were empty or had plants in poor health due to California's extreme droughts, lack of maintenance budgets, and lack of working irrigation systems. (H. Maddox, personal communication, 2021). Crime incidents at the stations in 2019 ranged from 7 to 108 (Mdn = 30; n = 18); Berryessa BART station was excluded from this analysis since it just opened in June 2020. The high crime rate at some stations could certainly be a deterrent to use of the station and BART in general, as well as use of micromobility for first- and last-mile connections.

Other multimodal affordances

Designated ride-hailing loading zones have implications for micromobility safety because, in their absence, ride-hailing drivers may be interfering with bike and e-scooter riders at the curbs surrounding the station. Only 37% of the BART stations surveyed had marked ride-hailing zones, although ride-hailing companies are not allowed along Market Street in San Francisco. All stations had bus connections, but many of the bus stops forced the bus to cross bike lanes and increased the level of danger for micromobility users. 47% of stations had car-share parking (i.e., Zipcar, GIG Car Share), 42% had car parking, and 21% had motorcycle parking. Similar to micromobility parking, car parking was much less prevalent at denser urban stations in San Francisco.

Conclusion

This research inventoried transit station design features with implications for micromobility at a subset of California Bay Area Rapid Transit (BART) heavy rail stations. This case study should reveal exemplary practices in designing for the integration of shared micromobility and public transit since it is a region where both services are heavily used relative to most other parts of the US. While many innovative features were documented, the findings also highlight areas for improvement.

Due to inconsistent availability of micromobility operators throughout the region, users may have to learn to navigate multiple service apps, use different vehicle types, and remember different rules for riding and parking across city boundaries. Stations lacked adequate parking facilities, particularly for dockless vehicles requiring a locking bike rack, and associated signage. Users must actively look for micromobility at transit stations or nearby streets with the assistance of multiple apps. Stations need to prioritize corrals with racks to increase reliability and ease of use of shared micromobility services. Corrals also helps to maintain order and protect pedestrian safety from trip hazards. Transit stations should update their printed maps and websites to highlight shared micromobility docking options in and around the station, dockless vehicle parking zones, and recommended safe routes for bikes, e-bikes and e-scooters.

Results indicated a lack of safe street facilities for bikes and e-scooters around transit stations. For optimal facilitation of micromobility and transit connectivity, cities and public transit agencies should work together to implement networks of protected bike lanes within a two-to-five-mile radius of transit stations. Bike lane investments, street lighting, and marked wayfinding around stations will improve safety and popularity for shared micromobility and cycling in general.

Many of the design principles discussed here will be beneficial to cities around the world managing public transit and micromobility. Micromobility stands to become an important part of public transportation, solving for the problem of first- and last-mile connectivity and providing an alternative or complementary option for public transit users in the wake of the COVID-19 pandemic. Future research should solicit feedback from shared micromobility and transit users on their preferred station design features and attempt to quantify the influence of station design features on shared micromobility use for first- and last-mile travel.

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