Title

Revisiting Average Trip Length Defaults and Adjustment Factors for Quantifying VMT Reductions from Car Share, Bike Share, and Scooter Share Services

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Publication Date

2020-05-01

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May 2020

A Technical Report from the National Center for Sustainable Transportation

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NCST-UCD-RR-20-28	N/A	N/A

4. Title and Subtitle	**5. Report Date**
Revisiting Average Trip Length Defaults and Adjustment Factors for Quantifying VMT Reductions from Car Share, Bike Share, and Scooter Share Services	May 2020
	6. Performing Organization Code N/A
7. Author(s) Jamey Volker, Ph.D., https://orcid.org/0000-0002-4559-6165 Susan Handy, Ph.D., https://orcid.org/0000-0002-4141-1290 Alissa Kendall, Ph.D., https://orcid.org/0000-0003-1964-9080 Elisa Barbour, Ph.D., https://orcid.org/0000-0002-4685-4517	**8. Performing Organization Report No.** UCD-ITS-RP-20-110
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. USDOT Grant 69A3551747114 CARB Agreement 16TTD004
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 Air Resources Board California Climate Investments Program 1001 I Street, Sacramento, CA 95814	**13. Type of Report and Period Covered** Technical Report (July 2017 – June 2020)
	14. Sponsoring Agency Code USDOT OST-R

15. Supplementary Notes
Originally published at https://ww2.arb.ca.gov/resources/documents/california-climate-investments-ghg-quantification-research

16. Abstract
Under California's Cap-and-Trade program, the State's portion of the proceeds from Cap-and-Trade auctions is deposited in the Greenhouse Gas Reduction Fund (GGRF). The Legislature and Governor enact budget appropriations from the GGRF for State agencies to invest in projects that help achieve the State's climate goals. These investments are collectively called California Climate Investments. Senate Bill (SB) 862 requires the California Air Resources Board (CARB) to develop guidance on reporting and quantification methods for all State agencies that receive appropriations from the GGRF. CARB may review and update quantification methodologies, as needed. CARB developed quantification methodologies to provide project-level GHG estimates for administering agencies to use when selecting projects for funding. CARB's quantification methods use a similar formula to measure GHG emissions reductions from both new bike share programs and new car share programs. That formula includes as inputs both average trip length per bike or car share trip, and an adjustment factor to account for trips that either would not have been previously made (induced new vehicle trips) or would substitute for non-private automobile trips (like transit or walking trips). This report summarizes outcomes from a literature review and analysis of shared mobility program data to (1) identify average trip length defaults for car share, bike share, and scooter share projects, and (2) determine whether and how the current adjustment factors used for car share and bike share projects could be modified to better reflect emerging data and methods for estimating VMT and greenhouse gas (GHG) emissions reductions from shared mobility programs.

17. Key Words	**18. Distribution Statement**
Shared mobility, greenhouse gas emission reductions, vehicle miles traveled (VMT), car share, bike share, quantification methodologies	No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	31	N/A

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

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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) through the University Transportation Centers program, and by the California Air Resources Board (CARB). The authors would like to thank the NCST, the USDOT, and CARB for their support of university-based research in transportation, and especially for the funding provided in support of this project.

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NCST

Revisiting Average Trip Length Defaults and Adjustment Factors for Quantifying VMT Reductions from Car Share, Bike Share, and Scooter Share Services

Technical Report

California Climate Investments Quantification Methods Assessment
California Air Resources Board
Agreement #16TTD004

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May 29, 2020

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Section A. Introduction

Under California's Cap-and-Trade program, the State's portion of the proceeds from Cap-and-Trade auctions is deposited in the Greenhouse Gas Reduction Fund (GGRF). The Legislature and Governor enact budget appropriations from the GGRF for State agencies to invest in projects that help achieve the State's climate goals. These investments are collectively called California Climate Investments. Senate Bill (SB) 862 requires the California Air Resources Board (CARB) to develop guidance on reporting and quantification methods for all State agencies that receive appropriations from the GGRF. CARB may review and update quantification methodologies, as needed.

To date, multiple California Climate Investments programs have offered funding for new bike share or car share programs, including CARB's Low Carbon Transportation program, the Strategic Growth Council's Affordable Housing and Sustainable Communities (AHSC) and Transformative Climate Communities programs, and the Department of Transportation's (Caltrans) Active Transportation Program (California Air Resources Board, 2016, 2017, 2019a, 2019b, 2019c). CARB developed quantification methodologies to provide project-level GHG estimates for administering agencies to use when selecting projects for funding. CARB's quantification methods use a similar formula to measure GHG emissions reductions from both new bike share programs and new car share programs (California Air Resources Board, 2019a). That formula includes as inputs both average trip length per bike or car share trip, and an adjustment factor to account for trips that either would not have been previously made (induced new vehicle trips) or would substitute for non-private automobile trips (like transit or walking trips) (California Air Resources Board, 2019a, 2019b, 2019c).

This report summarizes outcomes from a literature review and analysis of shared mobility program data to (1) identify average trip length defaults for car share, bike share, and scooter share projects, and (2) determine whether and how the current adjustment factors used for car share and bike share projects could be modified to better reflect emerging data and methods for estimating VMT and greenhouse gas (GHG) emissions reductions from shared mobility programs. Scooter share programs are very new and there is limited research on how they impact private auto use. Therefore, their adjustment factors are not studied in this report.

Section B. Summary of Current Quantification Methods

CARB's current methods for estimating VMT reductions from auto trips displaced by new car share and bike share projects are summarized below.

Equation (1) is used for car share projects:

Equation 1: Annual Auto VMT Reduced

$$Auto\ VMT = (R) * (V) * (T) * (A) * (L)$$

Where,

			Units
R	=	Number of riders per car share vehicle	Riders
V	=	Number of vehicles directly associated with the project	Vehicles
T	=	Number of annual trips per vehicle expected directly associated with the project	Trips
A	=	Adjustment factor to account for transit dependency and induced trips (default is 0.27)	Unitless
L	=	Estimated length of average vehicle trip directly associated with the car share project (no current default)	Miles

(California Air Resources Board, 2019a [Appendix D, 7], 2019c [18]).

Equation (2) is used for new bike share projects:

Equation 2: Annual Auto VMT Reduced

$$Auto\ VMT = (T) * (A) * (L)$$

Where,

			Units
T	=	Number of annual trips expected in the first year	Trips
A	=	Adjustment factor to account for induced trips and recreational bike share use (default is 0.5)	Unitless
L	=	Average length of bike share trip (default is 1.5 miles, and is the same for both pedal (non-electric) and electric bicycles)	Miles

(California Air Resources Board, 2019b [20], 2019c [Appendix D, 7]).

CARB's VMT reduction equations for both car share and bike share programs include as inputs average trip length and an adjustment factor to account for trips that either substitute for non-private automobile trips or otherwise fail to reduce VMT in private automobiles (California Air Resources Board, 2019a, 2019b, 2019c). For car share projects, CARB's equation (Equation 1) uses a default adjustment factor of 0.27, primarily to account for transit dependency and induced trips (new trips that would not have otherwise been made). It does not suggest a default car share trip length. For bike share projects, CARB's equation (Equation 2) uses a default adjustment factor of 0.5, primarily to account for induced trips and recreational bike share use. It uses a default bike share trip length of 1.5 miles.

The CARB methods then use the estimates of displaced auto VMT and the corresponding estimates of new car share VMT or bike share miles traveled (BMT) to estimate net GHG emissions reductions. For car share projects, the CARB method computes the GHG emissions from the displaced VMT calculated in Equation 1 (based on county-specific vehicle emission factors) and subtract the emissions from estimated new car share VMT (California Air Resources Board, 2019a). For pedal (non-electric) bike share projects, the CARB method simply apply county-specific vehicle emission factors to the displaced auto VMT output from Equation 2 to estimate reductions in GHG emissions (California Air Resources Board, 2019b). For electric bike share projects, CARB's method subtracts from that GHG emissions reduction estimate the GHG emissions calculated for the new electric bike share program (based on the energy consumption per mile for electric bikes and an emission factor for California grid electricity) (California Air Resources Board, 2019b).

Section C. Average Trip Length Findings

This section reviews the academic literature as well as government and industry reports on average trip lengths for car share, bike share, and scooter share programs, focusing on shared mobility programs in the United States and, where available, California specifically. It also reviews trip data for three car share programs operating in California: BlueLA, Green Commuter, and Envoy.[1]

The literature and data reviewed (1) provide a range of options for CARB to choose a default trip length for the four primary types of car share programs in urban areas, (2) indicate that a default average trip length may not be suitable for car share programs in rural areas, (3) indicate that the default 1.5-mile average trip length in CARB's current method is appropriate, albeit potentially conservative, for both docked pedal and dockless electric bike share programs, and (4) indicate that a default trip length around 1.0 miles could be appropriate for electric scooter share programs.

Car Share Trip Lengths

Car sharing programs can take multiple forms, including roundtrip, A-B (or "one-way"), free-floating, and peer-to-peer car share (Amatuni, 2019; Martin & Shaheen, 2016; Movmi, 2018). Roundtrip programs are probably the most common, where the vehicle must be returned to the same location or "station" where the user picked it up. Zipcar, Green Commuter, Our Community Carshare, and Miocar are all examples of roundtrip programs in California. Envoy is also a type of roundtrip program – it is a "community-based" roundtrip program. Envoy vehicles are stationed at apartment complexes, hotels, and workplaces, and their use is restricted to residents, employees, or guests of those establishments.

A-B programs allow one-way trips between stations (in addition to roundtrips ending at the originating hub). BlueLA is one example of an A-B program in California.
Free-floating programs allow users to pick up and drop off cars at any station or designated parking space within the cars' "home zone," which could be a city, a region, or even multiple regions. Program users can make either one-way trip or roundtrips. Gig and Waive are examples of free-floating programs in California.

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[1] Representatives for Zipcar, Gig, Getaround, Waive, Maven, Our Community Carshare, and MioCar were also contacted. MioCar does not currently have trip length data (only trip time data). The other car share programs either are still determining internally whether they can provide trip length data or have not responded to the data requests. The bike and scooter share program that was contacted (Lime) likewise is still determining whether they can provide trip length data.

Peer-to-peer programs allow users to rent vehicles owned by private people, with the vehicle owners receiving part of the rental revenue. These programs generally require users to return the vehicles the same place (e.g. city block or designated parking lot) they started their trip. Getaround and Maven are two examples of peer-to-peer programs in California.

The type of car share program, the program geography, and the types of vehicles offered for rent can all affect average trip length. For example, trips taken with roundtrip programs and peer-to-peer programs will generally be roundtrips. By contrast, trips taken with A-B or free-floating programs could be either roundtrips or one-way trips, and thus might have a lower average trip distance. With respect to geography, programs operating in suburban or rural areas might have a higher share of intermediate- or long-distance trips than programs in urban areas. And regardless of geography, programs offering vehicles with longer range and an option for full-day or multi-day reservations enable longer trips (e.g. for an interregional business trip or a weekend getaway).

With these sources of variability in mind, Table 1 reports average car share trip lengths with as much disaggregated detail as possible, including program type, trip type (roundtrip or one way), geography, time period, and source. For reference, Table 1 also reports the average trip length in the United States across all trip purposes and days of the week, as estimated by the Federal Highway Administration from the 2017 National Household Travel Survey (NHTS).

TABLE 1. Summary of Reported Average Car Share Trip Distance

Source	Program Type	Location	Time Period	Data Type	Trip Type	Number of Trips	Average Trip Distance
BlueLA (2020)	A-B (station-based)	Los Angeles, CA	August 2019 – October 2019	Program reported	Roundtrip	18,790	All trips: 21.1 mi. Converted to one-way:[1] 13.6 mi.
					One-way	15,201	
Green Commuter (2020)	Roundtrip (station-based)	Los Angeles, Fresno, Kern, Merced, and San Bernardino counties, CA	2019 (all months)	Program reported	Roundtrip	519[2]	111.3 mi.
Envoy (2020)	Roundtrip (community-based)	Northern California	2019 (all months)	Program reported	Roundtrip	12,153	15.6 mi.
		Southern California	2019 (all months)	Program reported	Roundtrip	7,799	31.0 mi.
Electrify America (2019)	Free-floating (Gig Car Share)	Sacramento, California	August 2019 – October 2019	Program reported	One-way and roundtrip	>33,000	~9 mi.
Feigon & Murphy (2016)	Roundtrip (Zipcar, City CarShare, Enterprise, Scoot), Free-floating (Car2Go), and Peer-to-peer (Getaround)	San Francisco, Los Angeles, Seattle, Chicago, Boston, Austin, and Washington, D.C. metro regions	2015 (survey year)	User reported (via survey)	One-way[3]	N/A (>3,500 survey resp.)	8.5 mi.
FHWA (2018)	N/A (includes all trips across all modes and purposes)	United States	2017 (survey year)	2017 NHTS	Mostly one-way	N/A	12 mi.

1 Converted to effective one-way trips by dividing the total trip mileage for all trips by double the total number of roundtrips plus the total number of actual one-way trips..

2 This excludes (1) trips made using Green Commuter's vanpool service, (2) trips with recorded distances of less than 0.5 miles or 1,000 miles or greater, and (3) trips longer than 7 days.

3 Respondents were asked about the length of their most-frequent one-way car sharing trip.

Defaults for A-B and Free-Floating Programs

The available data (Table 1) show a range in average trip distances of 9 to 21.1 miles for programs allowing both one-way trips and roundtrips (A-B and free-floating programs). Combining the Q3 2019 trip distance data for Gig (free-floating) in Sacramento and BlueLA (A-B) in Los Angeles yields a collective average trip distance of approximately 15 miles.

That compares to an average one-way trip distance of 8.5 miles reported in response to a 2015 survey by more than 4,500 users of a mix of car share programs (including roundtrip, free-floating, and peer-to-peer) in the San Francisco, Los Angeles, Seattle, Austin, Chicago, Boston, and Washington, D.C. metropolitan areas. Respondents to that survey by the Shared Use Mobility Center were asked for the one-way (not roundtrip) distance of their most frequent car sharing trip (Feigon & Murphy, 2016). However, it is likely that some respondents actually reported the roundtrip distance for their most frequent car sharing trip, since, for example, many trips involve chaining together two or more stops – they are not simple one-way trips or "there and back" trips whose distance can be neatly divided in two. If the 8.5-mile average does in fact include some roundtrips, it would be more comparable to the average trip distance for A-B and free-floating car share programs than a strictly one-way trip distance average would be. That is because those types of programs allow both one-way trips and roundtrips, as discussed above and as illustrated by the breakdown of the BlueLA data in Table 1 by number of one-way and roundtrips.

The available data thus yield a blended average trip distance range of 8.5 to 21.1 miles (for one-way trips and roundtrips combined) that CARB could use in its quantification method to bracket default trip distances for urban car share projects that allow both one-way trips and roundtrips (like A-B and free-floating programs). To be conservative, CARB could use the lowest end of that range – 8.5 miles – as a default in its quantification method. An 8.5-mile default would be conservative based on the available trip distance averages for at least three reasons. First, it is the lowest of the available averages. Second, while the 8.5-mile average likely incorporates some roundtrip distances as just discussed, the proportion of respondents who reported true one-way trip distances is still likely greater than the actual proportion of one-way trips in A-B and free-floating programs – for example, less than half of the BlueLA trips reported in Table 1 were one-way trips. Third, the 8.5-mile average might be lower than a true blended (or even just one-way) trip average because it is based on reported distances for respondents' "most frequent" one-way trips – longer, less-frequent trips (e.g. for a weekend getaway or longer business trip) might be underreported.

Another option would be to hone the default based on an estimate of average distances for the trips that carsharing replaces. Studies indicate that car sharing trips substitute for trips made by multiple different modes for a wide range of purposes (Cervero, Golub, & Nee, 2007; Lane, 2005; Martin & Shaheen, 2016; Millard-Ball, Murray, ter Schure, Fox, & Burkhardt, 2005; Namazu & Dowlatabadi, 2018). A reliable source for composite trip length averages across modes and purposes is the National Household Travel Survey. The 2017 NHTS shows a 12-mile average one-way (mostly) trip length in the United States across all trip purposes, modes, and days of the week (Federal Highway Administration, 2018). It is true that the 12-mile average includes rural trips, which tend to be longer in distance. But the average also includes bike and walking trips, the two modes with the shortest average trip distance. And carsharing trips are much less likely to replace those shorter active travel trips than to substitute for modes used for longer trips and which more closely resemble driving (e.g. private auto use, taxis and ridesharing, commuter trains, etc.) (Ceccato & Diana, 2018; Lane, 2005; Martin & Shaheen, 2016). So, on balance, 12 miles could be a reasonable ballpark estimate for a blended (one-way and roundtrip) average car share trip distance. Indeed,12 miles falls within – and on the lower end – of the 8.5-to-21.1-mile range from the available carsharing data.

Defaults for Roundtrip and Peer-to-Peer Programs

Average trip distances for programs requiring roundtrips (roundtrip and peer-to-peer programs, generally) would logically be greater than for A-B and free-floating programs that allow one-way trips. One way to derive a default trip distance for these programs would be to simply double the 8.5-mile average of one-way trip lengths reported from the Shared Use Mobility Center's 2015 survey of car share users across the United States, though as discussed above that average likely includes some roundtrips as well. Another way would be to double the 12-mile average trip distance estimated from the 2017 NHTS. Using those approaches would yield a default roundtrip length of 17 miles or 24 miles.

Those values are in the same ballpark as the average 2019 trip lengths for Envoy's community-based roundtrip programs in both Northern California (15.6 miles) and Southern California (31.0 miles) (Table 1). The combined average for Envoy's programs in both geographies (21.6 miles) just about splits the difference between the 17-mile and 24-mile values.

However, neither of those values comes close to the average roundtrip distance calculated from Green Commuter's 2019 car share trip data – 111.3 miles (Table 1). But some of the Green Commuter program's features might help explain this high-mileage result.[1] For one, Green Commuter operates not only in urban areas (e.g. Los Angeles) like most car share programs, but also in rural areas (e.g. Merced, Kern, and Fresno counties) where average trip distances are longer (McGuzkin & Fucci, 2018). Green Commuter also is a relatively new program with a relatively small fleet size (e.g. 12 vehicles in the Central Valley), which could make it difficult to attract regular daily-use members, particularly in areas like Los Angeles with multiple car share providers and also longer-established car share programs with more vehicles (like Zipcar and Getaround). Early users could instead view Green Commuter as more of an option for longer, less-frequent trips (like weekend getaways or interregional business trips). That could be especially so given that many of Green Commuter's vehicles are Tesla Model Xs, which are better equipped for comfortable, longer-distance trips than the more compact

[1] See Green Commuter's website for more details about the program: https://greencommuter.org

vehicles that predominate in many urban car share fleets. Indeed, nearly 53% of the Green Commuter trips for which duration data was reported spanned two or more days.

The upshot is that context matters. And certain types of car share projects, particularly projects in rural areas or programs with pricing structures that incentivize longer or multi-day trips, might not follow default trip distance or other values derived from data from primarily urban car share programs.

Bike Share Trip Lengths

There are four primary types of bike share programs, docked (station-based) electric, docked pedal (non-electric), dockless (free-floating) electric, and dockless pedal (National Association of City Transportation Officials, 2019). JUMP and Lime are examples of dockless electric programs, which operate in numerous cities across California and the United States. Bay Wheels in the San Francisco Bay Area operates a hybrid system that includes both docked pedal bikes and dockless electric bikes. Metro Bike Share in Los Angeles offers both docked pedal and docked electric bikes, as well as dockless pedal bikes.

Docked bike share programs (both electric and pedal) still predominate across the United States, with 36.5 million trips in 2018, compared to 9 million trips on dockless bikes (National Association of City Transportation Officials, 2019). But the traditional pedal bikes are increasingly being replaced by e-bikes, potentially increasing the effective range and average distance of bike share trips. In 2018, 6.5 million e-bike trips were made across both docked and dockless programs (National Association of City Transportation Officials, 2019). In terms of geography, almost all bike share programs are in urban areas (Farrah, 2019), and the data and studies discussed below are from urban bike share programs.

Tables 2 through 4 report average bike share trip lengths by program type and type of rider (casual or member)[1] from the available literature. For reference, Table 4 also reports the average bicycle trip length (1.5 miles) estimated from the most recent California Household Travel Survey, which is the same as the default trip distance as in CARB's VMT reduction equation for bike share projects (California Department of Transportation, 2013 [119]).

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[1] Reported where available and applicable. This generally only applies to docked bike share programs. Dockless programs generally require the user to have an app installed on their mobile phone with pre-loaded personal and payment information (just like might be required for a "membership" to a docked bike share program).

TABLE 2. Summary of Reported Average Trip Distance for Docked Pedal Programs

Source	Program Type	Location	Time Period	Data Type	Type of Rider	Average Trip Distance
NACTO (2019)	Docked pedal	San Francisco Bay Area (California) Chicago (Illinois), Boston (Massachusetts), New York City (New York), and Washington, D.C.	2018 (all months)	Program and city reported	Casual	2.5 mi.
					Member	1.2 mi.
Shaheen & Cohen (2019)	Docked pedal (Bluebikes)	Boston (Massachusetts)	2018 (all months)	Program reported	All	1.2 mi.
	Docked pedal	Fort Worth (Texas)	2017 (all months)	Program reported	All	4.5 mi.
Babagoli et al. (2019)	Docked pedal (Citi Bike)	New York City (New York)	August, 2015 – July 2016	Program reported	Member	1.75 mi.
Motivate (2017)	Docked pedal (Citi Bike, Divvy, and Capital Bikeshare)	Chicago (Illinois), New York City (New York), and Washington, D.C.	2016 (all months)	User reported	All	~2 mi.
Fishman et al. (2014)	Docked pedal (Capital Bikeshare)	Washington, D.C.	2012 (all months)	Program reported	All	1.9 mi.
	Docked pedal (Nice Ride Minnesota)	Minneapolis/St. Paul (Minnesota)	April 8, 2012 – November 7, 2012	Program reported	All	2.2 mi.
Shaheen et al. (2013)	Docked pedal (B-Cycle)	Denver (Colorado)	2011 (all months)	Program reported	All	3.4 mi.

The available data for docked pedal bike share programs in the United States (Table 2) show a range of average trip distances from 1.2 miles to 4.5 miles. The median of the nine averages is 2 miles. Even when including the data from Los Angeles' Metro Bike Share's hybrid program (including docked pedal, docked electric, and dockless electric bikes; Table 4), the median of the averages is still around 2 miles (2.1 miles). The 1.5-mile default trip length in CARB's current quantification method is within the 1.2-to-4.5-mile range of averages, albeit lower than the 2-mile (or 2.1-mile) median (and thus possibly conservative).

TABLE 3. Summary of Reported Average Trip Distance for Dockless Electric Programs

Source	Program Type	Location	Time Period	Data Type	Type of Rider	Average Trip Distance
NACTO (2019)	Dockless electric	United States	2018 (all months)		All	1.5 mi.
Rzepecki (2019)	Dockless electric (JUMP)	San Francisco, California	2018 (all months)	Program reported	All	2.6 mi.

For dockless electric bike programs in the United States, NACTO (2019) indicates a 2018 national average trip length of 1.5 miles. The only other available data, from the JUMP bike program in San Francisco, California, show a 2.6-mile average for all 2018 trips (Rzepecki, 2019). The 1.5-mile default trip length in CARB's current method accords with the national average from NACTO (2019), though it is less than the 2018 average for the JUMP program in San Francisco. Again, as with docked pedal programs, the data indicate default trip length in CARB's current method is appropriate, albeit potentially conservative.

TABLE 4. Summary of Reported Average Trip Distance for Hybrid Programs or from Combined Data

Source	Program Type	Location	Time Period	Data Type	Type of Rider	Average Trip Distance
Metro Bike Share (2020)	Docked pedal, docked electric, and dockless electric	Los Angeles, California	Q3 2016 – Q4 2019	Program reported	All	3.2 mi.
Lime (2019)	Dockless electric bikes and dockless electric scooters (Lime; combined numbers)	Global	2018 (all months)	Program reported	All	1.1 mi. (combined average for Lime bike and scooter share trips)
Caltrans (2013)	N/A (includes all trips across all modes and purposes)	United States	2017 (survey year)	2017 NHTS	N/A	1.5 mi.

In sum, the 1.5-mile default trip length in CARB's current quantification method for bike share projects accords with the data on average trip lengths from both docked pedal and dockless electric programs, though it might be conservative. It also matches the average bike trip length estimated from the most recent California Household Travel Survey (Table 4). An important caveat is that the bike share trip length data presented in Tables 2-4 is primarily, if not entirely, from bike share programs in urban areas. It is unclear from the available data whether the 1.5-mile default trip length would be appropriate for a bike share program in a rural area.

Scooter Share Trip Lengths

The scooter share programs considered in this report are of a single type – dockless standing scooters in urban areas, equipped with a handlebar, standing deck, and electric motor (Shaheen & Cohen, 2019). Examples of dockless electric scooter programs include JUMP, Lime, Lyft, Bird, Spin, and others. Table 5 reports the average scooter share trip lengths in the United States by source and geography from the available literature.

TABLE 5. Summary of Reported Average Trip Distance for Scooter Share Programs

Source	Program Type	Location	Time Period	Data Type	Average Trip Distance
Austin Public Health (2019)	Dockless (and standing) electric scooter share	Austin (Texas)	September 5, 2018 – November, 30, 2018	Program reported	0.95 mi.
Lime (2019)	Dockless electric bikes and dockless electric scooters (Lime; combined numbers)	Global	2018 (all months)	Program reported	1.1 mi. (combined average for Lime bike and scooter share trips)
NACTO (2019)	Dockless (and standing) electric scooter share	United States	2018 (all months)	Program reported	~1.2 mi.
Portland Bureau of Transportation (2019)	Dockless (and standing) electric scooter share	Portland (Oregon)	July 23, 2018 – November 20, 2018	Program reported	1.15 mi.
Noland (2019)	Dockless (and standing) electric scooter share	Louisville (Kentucky)	August 9, 2018 – February 28, 2019	Program reported	1.3 mi.

The available literature (Table 5) indicates that average scooter share trip lengths hover around 1 mile (in urban areas), with a range from 0.95 miles to 1.3 miles and median (of the averages) of 1.15 miles. CARB could use a default trip length around 1 mile if it decides to develop a method for estimating VMT or GHG emissions reductions from new scooter share programs.

Section D. Adjustment Factors

This section reviews the academic as well as government and industry literature on car share and bike share programs to determine whether and how the adjustment factors used in CARB's current VMT reduction equations for car share and bike share projects could be modified to better reflect emerging data and methods.

The literature reviewed indicates that (1) CARB's current method might underestimate the VMT and GHG emissions reductions from auto trips displaced by new car share projects, at least in urban areas, (2) that an adjustment factor of at least 1.0 might be appropriate for CARB's VMT reduction equation for car share projects, (3) that CARB could incorporate a carpool factor (like 1.15) into its VMT reduction equation to account for the fact that not all auto trips that car sharing replaces would have been made by the driver alone, and (4) that the current 0.5 default adjustment factor for bike share projects is at least appropriate for dockless electric programs.

Car Share Adjustment Factor

CARB's current VMT reduction equation for car share projects uses a default adjustment factor of 0.27 to account for transit dependency and induced trips (new trips that would not have otherwise been made without car sharing) (California Air Resources Board, 2019a). The idea is that not every new car share trip will replace a trip that would otherwise be made in a private vehicle (e.g. a personally owned vehicle, taxi, carpool, or ride hail). And the studies bear out this phenomenon (Cervero, Golub, & Nee, 2006; Lane, 2005; Martin & Shaheen, 2011b; Namazu & Dowlatabadi, 2018; Nijland & van Meerkerk, 2017).

For example, Cervero et al. (2006) surveyed users of the City CarShare program (taken over by Getaround in 2016) in San Francisco and Oakland, California, and asked them what modes they would otherwise have taken for the trips being surveyed if car share had not been available. They found that 27.3% of trips would have been made by users driving themselves, taking a taxi, renting a car, or getting a ride from someone. Another 28.6% of trips would have been made on transit, 6.9% by walking, and 3.9% on a bicycle. And 30.1% of trips would not have been made at all (Cervero et al., 2006).

Nijland and van Meerkerk (2017) asked a similar question of car share users in the Netherlands. They found that 35% of the kilometers from respondents' last car share trips would have been traveled by car (as a driver or passenger), while 45% would have been traveled by transit, and 15% would not have been traveled at all (Nijland & van Meerkerk, 2017).

These findings regarding the hypothetical substitution rate of private auto trips for car share trips would appear to support default adjustment factor (0.27) in CARB's current method. But they actually obscure car sharing's full effect on total auto VMT (private auto VMT plus car share VMT), as Amatuni (2019 [36]) discusses. The reason is that they do not reveal how car share users' travel modes and distances changed because of car share participation.

Looking just at the substitution factors, it would appear that both total miles traveled (by any mode) and total auto VMT (car share plus private auto use) increase for car share users. For example, using the findings from Cervero et al. (2006), a new car share user who took 100 car share trips last year would appear to have increased their total auto use by 72.7 trips (subtracting the 27.3 trips that would have otherwise been made via auto) and increased their overall number of trips by 30.1 (the 30.1% of car share trips that would not have otherwise been made). But these calculations ignore the other travel changes that the car user might have made in addition to using car share. For example – and most importantly for auto VMT purposes – some car share users are able to shed (or avoid acquiring) a privately owned vehicle and substantially reduce their private auto VMT (Cervero et al., 2007; Cooper, Howe, & Mye, 2000; Lane, 2005; Martin & Shaheen, 2016; Martin & Shaheen, 2010, 2011a; Millard-Ball et al., 2005; Nijland & van Meerkerk, 2017; Zipcar, 2018). Instead, they pair car share with increased use of transit, walking, biking, and other modes to meet their transportation needs (Lane, 2005; Martin & Shaheen, 2016).

Numerous studies across different types of car sharing programs (including roundtrip, A-B, and free-floating) in (primarily urban) locations across California, the United States, and the world find that the large reduction in auto VMT by auto-shedding car share users more than offsets the additional driving by other car share users (e.g. users who were previously carless or those who maintain their private auto use and instead substitute cars sharing for transit or non-motorized modes) (Cervero et al., 2007; Cooper et al., 2000; Lane, 2005; Martin & Shaheen, 2016; Martin & Shaheen, 2010, 2011a; Millard-Ball et al., 2005; Nijland & van Meerkerk, 2017; Zipcar, 2018). Martin and Shaheen (2016) described the result thusly from their study of car2go (free-floating car share) users in five North American cities (including San Diego, California):

> The results of this study suggest that access to ubiquitous shared automobiles allows some residents to get rid of a car or avoid acquiring one altogether. These actions taken by a minority of members have VMT-reducing effects that are estimated to exceed the additional driving that does take place within car2go vehicles.
> (Martin & Shaheen, 2016 [3]).

The upshot is that CARB's current method might underestimate the VMT and GHG emissions reductions from auto trips displaced by new car share projects, at least in urban areas (much less is known about the effects of car sharing programs in rural areas). Because car share programs cause a net reduction in auto VMT amongst their users, it means that on average each car share trip replaces at least one private auto trip (either in a user-owned vehicle, a taxi, a ride-hail vehicle, or a carpool). That would equate to an adjustment factor of at least 1.0 in CARB's equation for calculating displaced auto VMT (Equation 1).

By contrast, the ridership factor in CARB's current method (R in Equation 1) might overestimate the VMT and GHG emissions reductions from auto trips displaced by new car share projects. It is possible that car share users are more likely to carpool in a shared vehicle than a private auto. But not all auto trips that car sharing replaces would have been made by the driver alone. To account for that, CARB could consider dividing the ridership factor by a carpool factor. One option for the carpool factor is the average vehicle occupancy rate used by Caltrans (1.15) (California Department of Transportation, 2016).

Bike Share Adjustment Factor

CARB's current VMT reduction equation for bike share projects uses a default adjustment factor of 0.5 to account for induced trips, recreational bike share use, and substitution from non-auto modes (California Air Resources Board, 2019a). The idea is that not every new bike share trip will replace a trip that would otherwise be made in a private vehicle (e.g. a personally owned vehicle, taxi, carpool, or ride hail). Unlike with car sharing, however, the literature does not indicate that bike share users shed their private autos or otherwise drastically change their auto use. As a result, the substitution rate is an appropriate method for estimating auto VMT reduced from bike share trips.

The literature on auto-to-bike share substitution rates is sparse. Fishman et al. (2014) analyzed survey data from 2010-2012 for five docked pedal bike share programs in Minneapolis and St. Paul (Minnesota), Washington, D.C., Melbourne (Australia), Brisbane (Australia), and London (England). Surveys were conducted separately in the five cities, but they all asked how the bike share user respondents would have made their last bike share trip if bike share did not exist. Between 2% (London) and 21% (Brisbane) of respondents reported that they would have made the trip by car, including 7% in Minnesota and 19% in Washington, D.C. (Fishman et al., 2014). By contrast, in a survey of dockless electric bike and scooter share users in the City of Santa Monica (California), 50.2% reported that they would have made their last bike or scooter share trip by car (City of Santa Monica, 2019).

The results from the Santa Monica support using the 0.5 adjustment factor in CARB's current method with dockless electric bike share programs. The results from Minnesota and Washington, D.C., indicate that 0.5 might be too high for docked pedal bike share programs. However, the surveys for those two programs were administered when both programs were in their infancy (both programs started in 2010, and the surveys were administered in 2010 and 2011 for Minnesota and Washington, D.C., respectively) (Fishman et al., 2014). It thus is possible that the substitution rate increased in those areas as the programs grew and worked out operational kinks, and as people became more familiar with bike sharing in general.

Scooter Share Adjustment Factor

CARB uses the default adjustment factor of 0.5 for local services like scooter share. These programs are very new and there is limited research on how they impact private auto use. Therefore, their adjustment factors are not studied in this report.

Section E. Summary and Recommendations

This report discusses outcomes from a literature review and analysis of shared mobility program data to (1) identify average trip length defaults for car share, bike share, and scooter share projects, and (2) determine whether and how the current adjustment factors used for car share and bike share projects could be modified to better reflect emerging data and methods for estimating VMT and greenhouse gas (GHG) emissions reductions from shared mobility programs. This report's findings and recommendations regarding default trip distances and adjustment factors are summarized below.

Default Trip Distances – Car Share Programs

A-B and free-floating car share programs allow both one-way trips and roundtrips. A blended average trip distance could thus make a useful default. The available data indicate a range of blended average trip lengths from 8.5 miles to 21.1 miles. To be conservative, CARB could use an 8.5-mile default.

If CARB instead decides to supply separate defaults for one-way trips and roundtrips, 8.5 miles would be also be a reasonable default for one-way trips length. The 8.5-mile average comes from car share user responses to a survey question about the one-way distance of their most frequent car sharing trip. While those responses likely include at least some roundtrip distances, the 8.5-mile average is the closest to a true one-way trip length average reported in the literature reviewed for this report. It also appears reasonable (and reasonably conservative) when compared to the 12-mile average one-way (mostly) trip length in the United States across all trip purposes, modes, and days of the week, based on 2017 NHTS data (Federal Highway Administration, 2018).

The data also indicate that a simple doubling of the default one-way trip length could be appropriate as a default roundtrip length (for roundtrip and peer-to-peer programs, as well as roundtrips in A-B and free-floating programs), e.g. 17 miles using the potential 8.5-mile default for one-way trip length. The average trip distance across all of Envoy's roundtrip programs in California in 2019 – 21.6 miles – is right in the same ballpark. However, it is also clear that context matters. Certain types of car share projects, particularly projects in rural areas or programs with pricing structures that incentivize longer or multi-day trips, might not follow default trip distance or other values derived from data from primarily urban car share programs.

Default Trip Distances – Bike Share Programs

The literature reviewed indicates that the default 1.5-mile average trip length in CARB's current method is appropriate, albeit potentially conservative, for both docked pedal and dockless electric bike share programs.

Default Trip Distances – Scooter Share Programs

The literature reviewed indicates that a default trip length around 1.0 miles could be appropriate for electric scooter share programs.

Adjustment Factors – Car Share Programs

The literature reviewed indicates that CARB's current method, which uses an adjustment factor of 0.27, might underestimate the VMT and GHG emissions reductions from auto trips displaced by new car share projects, at least in urban areas. An adjustment factor of at least 1.0 would more appropriately account for the increasing evidence that car share programs cause a net reduction in auto VMT amongst their users.

By contrast, the ridership factor in CARB's current method (R in Equation 1) might overestimate the VMT and GHG emissions reductions from auto trips displaced by new car share projects because not all auto trips that car sharing replaces would have been made by the driver alone. CARB could rectify this by incorporating a carpool factor (like 1.15) into its VMT reduction equation.

Adjustment Factors – Bike Share Programs

The literature reviewed indicates that the current 0.5 default adjustment factor for bike share projects is at least appropriate for dockless electric programs, though it might be too high for docked pedal bike share programs. However, the literature on auto-to-bike share substitution rates is sparse for all types of bike share programs.

Adjustment Factors – Scooter Share Programs

CARB uses the default adjustment factor of 0.5 for local services like scooter share. These programs are very new and there is limited research on how they impact private auto use. Therefore, their adjustment factors are not studied in this report.

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