

California Air Resources Board

Quantification Methodology

California Air Resources Board
Clean Mobility Options

California Climate Investments



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Table of Contents

Section A. Introduction	1
Methodology Development	4
Tools.....	5
Updates.....	5
Section B. Methods.....	6
Project Types	6
General Approach.....	8
A. Emission Reductions from New or Expanded Service, Improvements to Increase Ridership, or Subsidies (for all Service Types except Public Transit)	9
B. Emission Reductions from Subsidies (for Public Transit only).....	13
C. Emission Reductions from Vehicle Replacement.....	15
D. Emission Reductions from Bike Infrastructure (for Bikeshare and Scooter-share only).....	17
Section C. References	20
Appendix A. Suggested Value Lookup Tables for Public Transit	21
Table 1. Service Types	6
Table 2. Project Types	7
Table 3. Service Types and Corresponding Project Types	8
Table 4. Active Transportation Adjustment Factors	17
Table 5. Key Destination Credits	18
Table 6: Length of Average Trip and Average Fare Cost by Transit Agency	21

List of Acronyms and Abbreviations

Acronym	Term
CARB	California Air Resources Board
CMO	Clean Mobility Options
Diesel PM	diesel particulate matter
GGE	gasoline gallon equivalent
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
lbs	pounds
MTCO _{2e}	metric tons of carbon dioxide equivalent
NO _x	nitrous oxide
PM _{2.5}	particulate matter with a diameter less than 2.5 micrometers
ROG	reactive organic gas
VMT	vehicle miles traveled

List of Definitions

Term	Definition
Baseline vehicle	The vehicle that is currently owned/in operation that will be replaced by a new zero- or near zero-emission vehicle purchase, or the vehicle that would have been purchased if not for this project (e.g., 2020 diesel bus).
Co-benefit	A social, economic, or environmental benefit as a result of the proposed project in addition to the GHG reduction benefit.
Community engagement level	Evaluation of the quantity, quality, and equity of the community engagement conducted. Options are Low, Medium, and High.
Energy and fuel cost savings	Changes in energy and fuel costs to the operator because of a change in the quantity of energy or fuel used due to conversion to an alternative energy or fuel source as a result of the project. This is only calculated for the Vehicle Replacement project type.
Key variable	Project characteristics that contribute to a project’s GHG emission reductions and signal an additional benefit (e.g., passenger VMT reductions, renewable energy generated).
Net fossil fuel use reductions	Net changes in the quantity of fossil fuels used in terms of gasoline gallon equivalent due to conversion to an alternative energy or fuel source as a result of the project. This is only calculated for the Vehicle Replacement project type.
Net passenger auto VMT reduction	Passenger auto vehicle miles traveled displaced by new mobility service due to mode shift as a result of the project minus vehicle miles traveled in passenger autos (sedans and SUVs) from the new mobility service. This is calculated for all project types except Vehicle Replacement.

Term	Definition
Project type	For the purposes of the CMO Quantification Methodology, eligible projects fall into four project types that are eligible for CMO funding and for which there are methods to quantify GHG emission reductions. Each project type may be funded for specific service types.
Quantification period	Number of years that the project component will provide GHG emission reductions. Sometimes also referred to as "Useful Life" or "Project Implementation Time Frame."
Service type	For the purposes of the CMO Quantification Methodology, eligible projects fall into eight service types that are eligible for CMO funding and for which there are methods to quantify GHG emission reductions. Each service type may be funded through specific project types.
Travel cost savings	Changes in travel costs to the user due to mode shift as a result of the project. This is calculated for all project types except Vehicle Replacement.

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as “priority populations.” Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

For the CARB Clean Mobility Options (CMO) Voucher Pilot Program, CARB staff developed this CMO Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type.

The CMO Benefits Calculator automates methods described in this document, provides a link to a step-by-step user guide with a project example, and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the CMO Benefits Calculator as well as the total project GHG emission reductions per dollar of GGRF funds requested. The CMO Benefits Calculator is available for download at: <http://www.arb.ca.gov/cci-resources>.

Using many of the same inputs required to estimate GHG emission reductions, the CMO Benefits Calculator estimates the following co-benefits and key variables for CMO projects:

- GHG emission reductions (MTCO₂e)
- Diesel PM emission reductions (lbs)
- NO_x emission reductions (lbs)
- PM_{2.5} emission reductions (lbs)
- ROG emission reductions (lbs)
- Net passenger auto VMT reductions (miles)
- Travel cost savings (\$)
- Net fossil fuel use reductions (GGE)
- Energy and fuel cost savings (\$)
- Community engagement level

- Total full-time equivalent jobs supported
- Full-time equivalent jobs directly supported
- Full-time equivalent jobs indirectly supported
- Full-time equivalent induced jobs supported

Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., vehicle miles traveled). Additional co-benefits for which CARB assessment methodologies were not incorporated into the CMO Benefits Calculator may also be applicable to the project. Applicants should consult the CMO Program Implementation Manual, voucher agreement terms and conditions, and other program materials to ensure they are meeting CMO requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.¹ CARB developed this CMO Quantification Methodology to be used to estimate the outcomes of proposed projects, confirm that projects meet minimum program requirements, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants and users;
- Use existing and proven methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the CMO project types. CARB also consulted with program staff to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

¹ California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

The CMO Benefits Calculator relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB's benefits calculators, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: <http://www.arb.ca.gov/cci-resources>. The Database Documentation explains how emission factors used in CARB benefits calculators are developed and updated.

The Program Administrator must use the CMO Benefits Calculator to estimate the GHG emission reductions and co-benefits of the proposed project. The CMO Benefits Calculator can be downloaded from: <http://www.arb.ca.gov/cci-resources>.

Updates

CARB staff periodically review each quantification methodology and benefits calculator to evaluate their effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB updated the CMO Quantification Methodology from the previous version to enhance the analysis and provide additional clarity. The changes include:

- Quantification of VMT displacement and associated emission reductions for the project components that result in new or expanded service or increased ridership on existing services;
- Addition of new service types and project types that will be funded by the CMO voucher pilot program;
- Inclusion of other co-benefits such as travel cost savings, energy and fuel cost savings, community engagement level, and jobs supported;
- Emission factor updates to account for new service types and updated emission factor data;
- Creation of a benefits calculator to help quantify benefits; and
- Creation of a step-by-step User Guide with a project example.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the CMO Benefits Calculator.

Project Types

For quantification purposes, CARB identified eight **Service Types** that are eligible for funding within CMO, defined in the table below.

Table 1. Service Types

Service Type	Definition
Carshare	Carshare services provide members with access to an automobile through short-term rentals.
Bikeshare	Bikeshare systems make bicycles or electric bicycles (e-bikes) available to members on a short-term rental basis.
Scooter-share	Scooter-share systems make electric scooters available to members on a short-term rental basis.
Carpool	Carpooling is the grouping of drivers and passengers with common origins and/or destinations into a shared vehicle. Carpooling is “self-serve” system, meaning the driver is a traveler in the pool just like other passengers, as opposed to a hired driver in shared taxi rides or ridehail services.
Vanpool	Vanpooling is the grouping of drivers and passengers with common origins and/or destinations into a shared van. Vanpooling is “self-serve” system, meaning the driver is a traveler in the pool just like other passengers, as opposed to a hired driver in shared taxi rides or ridehail services.
Innovative Transit	Innovative Transit is a broad category that includes on-demand shuttles and circulators, paratransit services, and private sector transit solutions commonly referred to as “microtransit”. The innovative transit service must be demand-responsive (routes and/or frequency of service are determined dynamically based on customer demand) and capable of serving multiple riders simultaneously (not only a single rider service).
Ride On-Demand	Service types in this category include on-demand rides provided by taxi companies and transportation network companies.
Public Transit	Traditional fixed-route transit services (e.g. bus service).

CARB identified five corresponding **Project Types** that are eligible for funding within CMO and for which there are methods to quantify GHG emission reductions,² defined in the table below.

Table 2. Project Types

Project Type	Definition
New or Expanded Service	Project that results in a new transportation service or expands an existing service. Examples include establishing a new car sharing program or adding new vehicles to an existing car sharing service.
Improvements to Increase Ridership	Project that improves or enhances an existing service (without expanding the service) that results in an increase in use of the service. Examples include network/fare integration or development of a mobile app for the service.
Subsidies	Free or reduced fare vouchers that increase the use of an existing service.
Vehicle Replacement	Projects that replace baseline fossil fuel vehicles with zero- or near zero-emission vehicles for an existing service (without expanding the service).
Bike Infrastructure	For the purposes of the CMO Quantification Methodology, this project type includes quick build projects that result in new class I bike paths, class II bike lanes, or class IV cycle tracks.

Not all service and project type combinations are eligible as standalone projects. See the CMO Program Implementation Manual for more information on project eligibility for different combinations of service and project types.

Other project features/components may be eligible for funding under CMO even if no quantification methodology is provided here. However, each project requesting GGRF funding must include at least one of the service type and project type combinations shown in the table below.

² <https://ww2.arb.ca.gov/our-work/programs/low-carbon-transportation-investments-and-air-quality-improvement-program/low>

Table 3. Service Types and Corresponding Project Types

	New or Expanded Service	Improvements to Increase Ridership	Subsidies	Vehicle Replacement	Bike Infrastructure
Carshare	X	X	X	X	
Bikeshare	X	X	X		X
Scooter-share	X	X	X		X
Carpool	X	X	X	X	
Vanpool	X	X	X	X	
Innovative Transit	X	X	X	X	
Ride-on-Demand	X	X	X		
Public Transit			X		

General Approach

Methods used in the CMO Benefits Calculator for estimating the GHG emission reductions and air pollutant emission co-benefits by project type are provided in this section. The Database Documentation explains how emission factors used in CARB benefits calculators are developed and updated.

These methods account for emission reductions from displaced vehicle miles traveled and vehicle replacement. In general, the GHG emission reductions are estimated in the CMO Benefits Calculator using the approaches below. The CMO Benefits Calculator also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate GHG emission reductions.

- **New or Expanded Service, Improvements to Increase Ridership, and Subsidies:** Emission Reductions from Displaced Autos – Emissions from New Service
 - If the project is a public transit subsidy, only emission reductions from displaced autos are quantified.
- **Vehicle Replacement:** Emission Reductions from Displaced (Baseline) Vehicle – Emissions from New Vehicle
- **Bike Infrastructure:** Emission Reductions from Displaced Autos

A. Emission Reductions from New or Expanded Service, Improvements to Increase Ridership, or Subsidies (for all Service Types except Public Transit)

Equation 1 calculates the annual auto VMT displaced by the new service. See references in Section C for more information on default values used.

Equation 1: Annual Auto VMT Displaced

$$AutoVMT_{Displaced_Yr} = R_{Yr} \times V_{Yr} \times T_{Yr} \times A \times L$$

Where,

		<u>Units</u>
$AutoVMT_{Displaced_Yr}$	= Annual auto VMT displaced in the first or final year	miles/year
R_{Yr}	= Average occupancy per vehicle in the first or final year. Defaults are 1 for bikeshare and scooter-share.	rider(s)/vehicle
V_{Yr}	= Number of vehicles directly associated with the project in the first or final year	vehicles
T_{Yr}	= Average number of vehicle trips per vehicle expected directly associated with the project in the first or final year	trips/vehicle
A	= Adjustment factor to account for transit dependency and induced trips. Defaults are 0.5 for local passenger trips and 0.83 for long-distance passenger trips. An additional adjustment of 0.6 is applied for ride-on-demand services to account for deadhead miles.	unitless
L	= Estimated length of average vehicle trip directly associated with the project (should include deadhead miles for ride-on-demand service)	mile(s)/trip

Equation 2 calculates the annual emission reductions associated with auto VMT displaced by the new service.

Equation 2: Annual Emission Reductions from Displaced Auto VMT

$E_{Reduced_Yr} = \frac{AutoVMT_{Displaced_Yr} \times EF_{Yr}}{CF}$		
<i>Where,</i>		
$E_{Reduced_Yr}$	= Annual emission reductions from displaced auto VMT	<u>Units</u> MTCO ₂ e/year or lbs/year
$AutoVMT_{Displaced_Yr}$	= Estimated VMT displaced in the first or final year attributed to the operation of the new service	miles/year
EF_{Yr}	= Emission factor in the first or final year (based on weighted fleet average)	grams/mile
CF	= Conversion factor	grams/MT or grams/lb

Equation 3 calculates the total emission reductions associated with auto VMT displaced by the new service.

Equation 3: Emission Reductions from Displaced Auto VMT

$E_{Reduced} = \frac{E_{Reduced_Yr1} + E_{Reduced_YrF}}{2} \times QP$		
<i>Where,</i>		
$E_{Reduced}$	= Total emission reductions from displaced auto VMT	<u>Units</u> MTCO ₂ e or lbs
$E_{Reduced_Yr1}$	= Emission reductions from displaced auto VMT in first year	MTCO ₂ e/year or lbs/year
$E_{Reduced_YrF}$	= Emission reductions from displaced auto VMT in final year	MTCO ₂ e/year or lbs/year
QP	= Quantification period	years

Equation 4 calculates the annual VMT from the new service.

Equation 4: Annual VMT of New Service

$$NSVMT = \frac{(V_1 \times T_1 \times L_{V_1}) + (V_F \times T_F \times L_{V_F})}{2}$$

<i>Where,</i>		<u>Units</u>
<i>NSVMT</i>	= Estimated average annual VMT directly associated with the project	miles/year
<i>V_{Yr}</i>	= Number of vehicles directly associated with the project in first or final year	vehicles
<i>T_{Yr}</i>	= Number of annual trips per vehicle expected in first or final year directly associated with the project	trips/vehicle
<i>L_{V_Yr}</i>	= Estimated length of average vehicle trip directly associated with the project	mile(s)/trip

Equation 5 calculates the annual emissions associated with operation of the new service.

Equation 5: Annual Emissions from New Service

$$AE_{New} = \frac{NSVMT \times NSEF \times \%RE}{CF}$$

<i>Where,</i>		<u>Units</u>
<i>AE_{New}</i>	= Average annual emissions from new service	MTCO ₂ e/year or lbs/year
<i>NSVMT</i>	= Estimated average annual VMT attributed to the operation of the new service	miles
<i>NSEF_{Yr}</i>	= Mid-year emission factor based on service type	grams/mile
<i>%RE</i>	= Sum of percent installed and purchased renewable electricity used for new vehicle charging, if applicable	unitless
<i>CF</i>	= Conversion factor	grams/MT or grams/lb

Equation 6 calculates the total emissions associated with operation of the new service.

Equation 6: Emissions from New Service

$$E_{New} = AE_{New} \times QP$$

Where,

Units

E_{New}	=	Total emissions from new service	MTCO _{2e} or lbs
AE_{New}	=	Average annual emissions from new service	MTCO _{2e} /year or lbs/year
QP	=	Quantification period	years

Equation 7 estimates the GHG and air pollutant emission reductions from New or Expanded Service, Improvements to Increase Ridership, or Subsidies (for all Service Types except Public Transit), calculated as the difference between the emission reductions from displaced autos and emissions associated with operation of the new service.

Equation 7: Net Emission Reductions from New Service

$$E = E_{Reduced} - E_{New}$$

Where,

Units

E	=	Net emission reductions	MTCO _{2e} or lbs
$E_{Reduced}$	=	Total emission reductions from displaced auto VMT	MTCO _{2e} or lbs
E_{New}	=	Total emissions from new service	MTCO _{2e} or lbs

B. Emission Reductions from Subsidies (for Public Transit only)

Equation 8 calculates the annual auto VMT displaced by the project. See references in Section C for more information on default values used.

Equation 81: Annual Auto VMT Displaced in Miles per Year

$$AutoVMT_{Displaced_Yr} = R_{Yr} \times A \times L_P$$

Where,

		<u>Units</u>
$AutoVMT_{Displaced_Yr}$	= Annual auto VMT displaced in the first or final year	miles/year
R_{Yr}	= Ridership in the first or final year as a result of the project	rider(s)/vehicle
A	= Adjustment factor to account for transit dependency. Defaults are 0.5 for local passenger trips and 0.83 for long-distance passenger trips.	unitless
L_P	= Estimated length of average passenger trip directly associated with the project (see Appendix A for suggested values).	mile(s)/trip

Equation 9 calculates the annual emission reductions associated with auto VMT displaced by the project.

Equation 9: Annual Emission Reductions from Displaced Auto VMT

$$E_{Reduced_Yr} = \frac{AutoVMT_{Displaced_Yr} \times EF_{Yr}}{CF}$$

Where,

		<u>Units</u>
$E_{Reduced_Yr}$	= Annual emission reductions from displaced auto VMT	MTCO ₂ e/year or lbs/year
$AutoVMT_{Displaced_Yr}$	= Estimated VMT displaced in the first or final year attributed to the operation of the new service	miles/year
EF_{Yr}	= Emission factor in the first or final year (based on weighted fleet average)	grams/mile
CF	= Conversion factor	grams/MT or grams/lb

Equation 10 estimates both the GHG and air pollutant emission reductions from Subsidies for Public Transit as the emission reductions from displaced auto VMT.

Equation 10: Emission Reductions from Displaced Auto VMT

$$E_{Reduced} = \frac{E_{Reduced_Yr1} + E_{Reduced_YrF}}{2} \times QP$$

Where,

		<u>Units</u>
$E_{Reduced}$	= Total emission reductions from displaced auto VMT	MTCO ₂ e or lbs
$E_{Reduced_Yr1}$	= Emission reductions from displaced auto VMT in first year	MTCO ₂ e/year or lbs/year
$E_{Reduced_YrF}$	= Emission reductions from displaced auto VMT in final year	MTCO ₂ e/year or lbs/year
QP	= Quantification period	years

C. Emission Reductions from Vehicle Replacement

Equation 11 calculates the annual emissions associated with the baseline and new vehicles.

Equation 11: Annual Emissions from Baseline or New Vehicle

$AnnualE_{Vehicle} = \frac{AnnualVMT \times VehicleEF_{Yr} \times HDR \times \%RE}{CF}$		
<i>Where,</i>		
	<u>Units</u>	
$AnnualE_{Vehicle}$	= Annual emissions per vehicle from baseline or new vehicle	MTCO ₂ e/year or lbs/year
$AnnualVMT$	= Estimated annual VMT of the new vehicle	miles/year
$VehicleEF_{Yr}$	= Emission factor, based on project-specific inputs, in the mid-year	grams/mile
HDR	= Hybrid discount rate, if applicable (0.8)	unitless
$\%RE$	= Sum of percent installed and purchased renewable electricity used for new vehicle charging, if applicable	unitless
CF	= Conversion factor	grams/MT or grams/lb

NOTE: For the acquisition of a new zero- or near zero-emission vehicle where there is a current vehicle to be replaced, the Program Administrator should enter current vehicle information as the baseline vehicle. For the acquisition of a new zero- or near zero-emission vehicle as an alternative to the acquisition of a fossil fuel vehicle, the Program Administrator should enter vehicle information of the newest available fossil fuel-equivalent vehicle as the baseline vehicle. For example, if the project is to purchase a zero-emission vehicle that would be operational in 2021, the Program Administrator should input a 2021 model year fossil fuel vehicle as the baseline vehicle.

Equation 12 calculates the emissions associated with the baseline and new vehicles.

Equation 12: Emissions from Baseline or New Vehicle

$E_{Vehicle} = AnnualE_{Vehicle} \times QP \times V$		
<i>Where,</i>		<u>Units</u>
$E_{Vehicle}$	= Total emissions from baseline or new vehicle(s)	MTCO ₂ e or lbs
$AnnualE_{Vehicle}$	= Annual emissions per vehicle from baseline or new vehicle	MTCO ₂ e/year or lbs/year
QP	= Quantification period	years
V	= Number of vehicles directly associated with the project	vehicles

Equation 13 estimates both the GHG and air pollutant emission reductions from Vehicle Replacement as the difference between the emissions associated with the baseline vehicle and emissions associated with the new vehicle.

Equation 13: Net Emission Reduction from Vehicle Replacement

$E = E_{Vehicle_Baseline} - E_{Vehicle_New}$		
<i>Where,</i>		<u>Units</u>
E	= Net emission reductions	MTCO ₂ e or lbs
$E_{Vehicle_Baseline}$	= Total emissions from baseline vehicle	MTCO ₂ e or lbs
$E_{Vehicle_New}$	= Total emissions from new vehicle	MTCO ₂ e or lbs

D. Emission Reductions from Bike Infrastructure (for Bikeshare and Scooter-share only)

Equation 14 calculates the annual auto VMT displaced by the project. Projects that maintain the same bikeway class that already exists are not quantifiable. See references in Section C for more information on default values used.

Equation 142: Annual Auto VMT Reduced in Miles per Year

$AutoVMT_{Displaced_Yr} = D \times ADT \times (A + C) \times GFA \times L$		
<i>Where,</i>		<u>Units</u>
$AutoVMT_{Displaced_Yr}$	= Annual auto VMT displaced in the first or final year	miles/year
D	= Annual days of use of new facility. Default is 200 days.	days/year
ADT	= Average two-way daily traffic on road parallel to facility.	vehicle trips/day
A	= Adjustment factor for active transportation (see Table 5).	mile(s)/trip
C	= Credit for key destinations near facility (see Table 6).	unitless
GFA	= Growth factor adjustment. Default is 1 for new Class II bike lanes, 1.54 for new Class I bike paths or Class IV cycle tracks, and 0.54 for conversion from Class II bike lanes to Class IV cycle tracks.	unitless
L	= Average length of auto trip replaced. Default is 1.5 miles.	miles

Table 4. Active Transportation Adjustment Factors

Average Daily Traffic (vehicle trips per day)	One-way Facility Length ³ (miles)	Adjustment Factor for Population > 250,000 or Non-university Town with Population < 250,000	Adjustment Factor for University Town with Population < 250,000
1 to 12,000	≤ 1	0.0019	0.0104
1 to 12,000	1.01 to 2	0.0029	0.0155
1 to 12,000	> 2	0.0038	0.0207
12,001 to 24,000	≤ 1	0.0014	0.0073
12,001 to 24,000	1.01 to 2	0.0020	0.0109
12,001 to 24,000	> 2	0.0027	0.0145

³ The length of bicycle facilities should be measured in one direction because the adjustment factor, based on length and ADT, accounts for two-way trips.

Average Daily Traffic (vehicle trips per day)	One-way Facility Length ³ (miles)	Adjustment Factor for Population > 250,000 or Non-university Town with Population < 250,000	Adjustment Factor for University Town with Population < 250,000
24,001 to 30,000	≤ 1	0.0010	0.0052
24,001 to 30,000	1.01 to 2	0.0014	0.0078
24,001 to 30,000	> 2	0.0019	0.0104

Table 5. Key Destination Credits

Number of Key Destinations	Credit Within ½ Mile of Facility	Credit Within ¼ Mile of Facility
0 to 2	0	0
3	0.0005	0.001
4 to 6	0.0010	0.002
≥ 7	0.0015	0.003

Equation 15 calculates the annual emission reductions associated with auto VMT displaced by the project.

Equation 15: Annual Emission Reductions from Displaced Auto VMT

$$E_{Reduced_Yr} = \frac{AutoVMT_{Displaced_Yr} \times EF_{Yr}}{CF}$$

Where,

		<u>Units</u>
$E_{Reduced_Yr}$	= Annual emission reductions from displaced auto VMT	MTCO ₂ e/year or lbs/year
$AutoVMT_{Displaced_Yr}$	= Estimated VMT displaced in the first or final year attributed to the project	miles/year
EF_{Yr}	= Emission factor in the first or final year (based on weighted fleet average)	grams/mile
CF	= Conversion factor	grams/MT or grams/lb

Equation 16 estimates both the GHG and air pollutant emission reductions from Bike Infrastructure as the emission reductions from displaced auto VMT. See references in Section C for more information on default values used.

Equation 16: Emission Reductions from Displaced Auto VMT

$$E_{Reduced} = \frac{E_{Reduced_Yr1} + E_{Reduced_YrF}}{2} \times QP$$

Where,

		<u>Units</u>
$E_{Reduced}$	= Total emission reductions from displaced auto VMT	MTCO ₂ e or lbs
$E_{Reduced_Yr1}$	= Emission reductions from displaced auto VMT in first year	MTCO ₂ e/year or lbs/year
$E_{Reduced_YrF}$	= Emission reductions from displaced auto VMT in final year	MTCO ₂ e/year or lbs/year
QP	= Quantification period. Default is 20 years for Class I bike paths and 15 years for Class II bike lanes or Class IV cycle tracks.	years

Section C. References

The following references were used in the development of this Quantification Methodology and the CMO Benefits Calculator.

California Air Resources Board. (2019). Clean Miles Standard 2018 Base-year Emissions Inventory Report. <http://www.arb.ca.gov/our-work/programs/clean-miles-standard/resources>

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Appendix A. Suggested Value Lookup Tables for Public Transit

List of Acronyms and Abbreviations

Acronym	Term
CB	commuter bus
CC	cable car
CR	commuter rail
DO	directly operated
DR	demand response
DT	demand response taxi
FB	ferryboat
HR	heavy rail
LR	light rail
MB	bus
MG	monorail/automated guideway
PT	purchased transportation
RB	bus rapid transit
SR	streetcar rail
TB	trolley bus
VP	vanpool
YR	hybrid rail

CARB staff developed these suggested values to use for the length of the average unlinked passenger trip and baseline average fare cost by agency, by mode, and by type of service using 2017 Annual data from the National Transit Database.⁴ These values were calculated by dividing passenger miles traveled by unlinked passenger trips.

Table 6: Length of Average Trip and Average Fare Cost by Transit Agency

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Access Services	DR	PT	11.47	\$2.22
Access Services	DT	PT	14.69	\$2.39
Alameda-Contra Costa Transit District	CB	DO	14.19	\$2.49
Alameda-Contra Costa Transit District	DR	PT	10.47	\$3.81
Alameda-Contra Costa Transit District	MB	DO	3.28	\$1.36
Alameda-Contra Costa Transit District	MB	PT	13.03	\$2.48

⁴ Federal Transit Administration. National Transit Database. Available at <https://www.transit.dot.gov/ntd>.

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Altamont Corridor Express	CR	PT	42.86	\$6.85
Anaheim Transportation Network	MB	PT	1.98	\$0.55
Antelope Valley Transit Authority	CB	PT	42.05	\$8.53
Antelope Valley Transit Authority	DR	PT	9.18	\$2.21
Antelope Valley Transit Authority	MB	PT	7.15	\$1.13
Butte County Association of Governments	DR	PT	4.33	\$2.09
Butte County Association of Governments	MB	PT	4.92	\$1.11
California Vanpool Authority	VP	DO	42.28	\$3.27
Central Contra Costa Transit Authority	DR	PT	9.89	\$3.55
Central Contra Costa Transit Authority	MB	DO	4.54	\$1.12
City of Commerce Municipal Buslines	DR	DO	9.36	\$0.00
City of Commerce Municipal Buslines	MB	DO	4.03	\$0.00
City of Elk Grove	CB	PT	13.46	\$1.80
City of Elk Grove	DR	PT	6.27	\$5.17
City of Elk Grove	MB	PT	4.00	\$1.34
City of Fairfield - Fairfield and Suisun Transit	CB	PT	20.40	\$3.88
City of Fairfield - Fairfield and Suisun Transit	DR	PT	9.63	\$4.94
City of Fairfield - Fairfield and Suisun Transit	MB	PT	3.17	\$1.03
City of Gardena Transportation Department	DR	DO	3.17	\$0.50
City of Gardena Transportation Department	MB	DO	3.20	\$0.77
City of Glendale	DR	PT	5.26	\$1.09
City of Glendale	MB	PT	2.20	\$0.62
City of La Mirada Transit	DR	PT	2.86	\$0.77
City of Los Angeles Department of Transportation	CB	PT	17.00	\$3.03
City of Los Angeles Department of Transportation	DR	PT	4.69	\$0.92
City of Los Angeles Department of Transportation	DT	PT	2.18	\$2.77
City of Los Angeles Department of Transportation	MB	PT	1.55	\$0.37
City of Petaluma	DR	PT	3.90	\$2.23
City of Petaluma	MB	PT	2.76	\$0.64
City of Redondo Beach - Beach Cities Transit	DR	PT	4.43	\$0.85

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
City of Redondo Beach - Beach Cities Transit	MB	PT	4.10	\$0.84
City of Riverside Special Transportation	DR	DO	7.79	\$2.11
City of San Luis Obispo	MB	PT	3.10	\$0.62
City of Santa Rosa	DR	PT	5.46	\$3.13
City of Santa Rosa	MB	DO	3.94	\$0.77
City of Santa Rosa	MB	PT	3.00	\$10.28
City of Tulare	DR	PT	5.38	\$2.27
City of Tulare	MB	PT	4.36	\$0.84
City of Turlock	DR	PT	7.42	\$3.01
City of Turlock	MB	PT	3.33	\$0.56
City of Visalia - Visalia City Coach	CB	PT	45.01	\$7.69
City of Visalia - Visalia City Coach	DR	PT	7.69	\$3.93
City of Visalia - Visalia City Coach	MB	PT	6.26	\$0.90
Culver City Municipal Bus Lines	DR	DO	2.03	\$0.45
Culver City Municipal Bus Lines	MB	DO	3.33	\$0.63
El Dorado County Transit Authority	CB	DO	31.03	\$5.37
El Dorado County Transit Authority	DR	DO	11.22	\$10.25
El Dorado County Transit Authority	MB	DO	8.97	\$1.47
Foothill Transit	MB	PT	7.62	\$1.19
Fresno Area Express	DR	PT	7.30	\$1.30
Fresno Area Express	MB	DO	2.60	\$0.79
Gold Coast Transit	DR	PT	7.45	\$2.62
Gold Coast Transit	MB	DO	4.25	\$0.81
Golden Empire Transit District	DR	DO	6.48	\$2.69
Golden Empire Transit District	MB	DO	3.59	\$0.84
Golden Gate Bridge, Highway and Transportation District	DR	PT	11.82	\$4.09
Golden Gate Bridge, Highway and Transportation District	FB	DO	10.85	\$8.05
Golden Gate Bridge, Highway and Transportation District	MB	DO	18.65	\$4.79
Imperial County Transportation Commission	DR	PT	18.47	\$2.09
Imperial County Transportation Commission	MB	PT	9.91	\$0.83
Kings County Area Public Transit Agency	DR	PT	3.75	\$1.92
Kings County Area Public Transit Agency	MB	PT	6.46	\$0.73
Laguna Beach Municipal Transit	MB	DO	2.22	\$0.04

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Livermore / Amador Valley Transit Authority	DR	PT	6.02	\$4.14
Livermore / Amador Valley Transit Authority	MB	PT	4.62	\$1.22
Long Beach Transit	DR	PT	4.76	\$1.66
Long Beach Transit	MB	DO	3.23	\$0.61
Los Angeles County Metropolitan Transportation Authority dba: Metro	HR	DO	5.00	\$0.78
Los Angeles County Metropolitan Transportation Authority dba: Metro	LR	DO	7.31	\$0.78
Los Angeles County Metropolitan Transportation Authority dba: Metro	MB	DO	4.03	\$0.82
Los Angeles County Metropolitan Transportation Authority dba: Metro	MB	PT	4.72	\$0.43
Los Angeles County Metropolitan Transportation Authority dba: Metro	RB	DO	6.56	\$0.78
Los Angeles County Metropolitan Transportation Authority dba: Metro	VP	PT	44.79	\$3.93
Marin County Transit District	DR	PT	8.10	\$3.33
Marin County Transit District	MB	PT	4.09	\$1.08
Modesto Area Express	DR	PT	6.84	\$2.87
Modesto Area Express	DT	PT	4.90	\$1.69
Modesto Area Express	MB	PT	4.26	\$0.89
Montebello Bus Lines	DT	PT	2.16	\$0.29
Montebello Bus Lines	MB	DO	3.25	\$0.76
Montebello Bus Lines	MB	PT	2.90	\$1.20
Monterey-Salinas Transit	CB	DO	40.49	\$16.91
Monterey-Salinas Transit	DR	PT	8.58	\$2.59
Monterey-Salinas Transit	MB	DO	6.21	\$2.14
Monterey-Salinas Transit	MB	PT	3.71	\$1.92
Napa Valley Transportation Authority	CB	PT	30.84	\$2.33
Napa Valley Transportation Authority	DR	PT	7.19	\$2.43
Napa Valley Transportation Authority	MB	PT	7.42	\$0.69
North County Transit District	CR	PT	26.44	\$4.04
North County Transit District	DR	PT	12.97	\$3.83
North County Transit District	MB	PT	4.32	\$0.95
North County Transit District	YR	PT	8.58	\$1.06
Norwalk Transit System	DR	PT	3.41	\$1.14
Norwalk Transit System	MB	DO	4.19	\$0.88
Omnitrans	DR	PT	14.01	\$3.78

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Omnitrans	MB	DO	5.14	\$1.01
Omnitrans	MB	PT	3.12	\$1.08
Orange County Transportation Authority	CB	DO	21.11	\$1.68
Orange County Transportation Authority	CB	PT	19.28	\$1.44
Orange County Transportation Authority	DR	PT	11.29	\$4.42
Orange County Transportation Authority	DT	PT	3.02	\$3.44
Orange County Transportation Authority	MB	DO	3.35	\$0.99
Orange County Transportation Authority	MB	PT	3.88	\$0.97
Orange County Transportation Authority	VP	PT	34.51	\$3.95
Paratransit, Inc.	DR	DO	9.74	\$4.20
Paratransit, Inc.	DR	PT	10.46	\$7.07
Paratransit, Inc.	DT	PT	8.37	\$4.47
Peninsula Corridor Joint Powers Board dba: Caltrain	CR	PT	21.77	\$4.96
Peninsula Corridor Joint Powers Board dba: Caltrain	MB	PT	3.47	\$0.00
Placer County Department of Public Works and Facilities	CB	PT	20.11	\$5.37
Placer County Department of Public Works and Facilities	DR	DO	11.84	\$3.53
Placer County Department of Public Works and Facilities	DR	PT	3.41	\$0.73
Placer County Department of Public Works and Facilities	DT	PT	15.71	\$3.54
Placer County Department of Public Works and Facilities	MB	DO	7.64	\$1.05
Placer County Department of Public Works and Facilities	MB	PT	3.09	\$0.67
Placer County Department of Public Works and Facilities	VP	PT	33.94	\$2.79
Pomona Valley Transportation Authority	DR	PT	5.50	\$0.81
Pomona Valley Transportation Authority	DT	PT	4.81	\$1.94
Redding Area Bus Authority	DR	PT	8.86	\$3.26
Redding Area Bus Authority	MB	PT	6.99	\$1.02
Riverside Transit Agency	CB	DO	19.49	\$3.83
Riverside Transit Agency	CB	PT	23.22	\$2.08
Riverside Transit Agency	DR	PT	11.28	\$3.68
Riverside Transit Agency	DT	PT	17.51	\$4.05
Riverside Transit Agency	MB	DO	6.27	\$0.90
Riverside Transit Agency	MB	PT	6.64	\$1.33

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Sacramento Regional Transit District	DR	DO	2.59	\$1.38
Sacramento Regional Transit District	LR	DO	6.01	\$1.29
Sacramento Regional Transit District	MB	DO	3.46	\$1.53
San Diego Association of Governments	VP	PT	48.70	\$3.11
San Diego Metropolitan Transit System	CB	PT	24.51	\$4.17
San Diego Metropolitan Transit System	DR	PT	10.38	\$4.52
San Diego Metropolitan Transit System	LR	DO	5.61	\$1.04
San Diego Metropolitan Transit System	MB	DO	4.51	\$1.02
San Diego Metropolitan Transit System	MB	PT	3.25	\$1.00
San Francisco Bay Area Rapid Transit District	HR	DO	13.72	\$3.64
San Francisco Bay Area Rapid Transit District	MG	PT	3.18	\$5.58
San Francisco Bay Area Water Emergency Transportation Authority	FB	PT	15.01	\$7.07
San Francisco Municipal Railway	CC	DO	1.26	\$4.34
San Francisco Municipal Railway	DR	PT	6.17	\$2.29
San Francisco Municipal Railway	LR	DO	2.73	\$0.77
San Francisco Municipal Railway	MB	DO	2.15	\$0.77
San Francisco Municipal Railway	SR	DO	1.43	\$0.77
San Francisco Municipal Railway	TB	DO	1.48	\$0.77
San Joaquin Regional Transit District	CB	PT	44.30	\$4.45
San Joaquin Regional Transit District	DT	PT	5.83	\$3.73
San Joaquin Regional Transit District	MB	DO	3.53	\$0.82
San Joaquin Regional Transit District	MB	PT	4.56	\$0.82
San Luis Obispo Regional Transit Authority	DR	DO	7.85	\$3.05
San Luis Obispo Regional Transit Authority	MB	DO	11.05	\$1.31
San Mateo County Transit District	DR	PT	8.10	\$2.51
San Mateo County Transit District	DT	PT	11.89	\$2.38
San Mateo County Transit District	MB	DO	3.61	\$1.32
San Mateo County Transit District	MB	PT	6.19	\$1.34
Santa Barbara Metropolitan Transit District	MB	DO	4.09	\$1.12
Santa Clara Valley Transportation Authority	DR	PT	10.24	\$3.45
Santa Clara Valley Transportation Authority	DT	PT	10.68	\$2.86
Santa Clara Valley Transportation Authority	LR	DO	5.25	\$0.88
Santa Clara Valley Transportation Authority	MB	DO	5.18	\$0.88

Quantification Methodology for the CARB CMO Voucher Pilot Program

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Santa Clara Valley Transportation Authority	MB	PT	3.68	\$0.00
Santa Clarita Transit	CB	PT	24.78	\$3.03
Santa Clarita Transit	DR	PT	6.11	\$1.14
Santa Clarita Transit	MB	PT	4.23	\$0.84
Santa Cruz Metropolitan Transit District	CB	DO	31.21	\$5.42
Santa Cruz Metropolitan Transit District	DR	DO	7.24	\$4.08
Santa Cruz Metropolitan Transit District	DT	PT	7.23	\$2.09
Santa Cruz Metropolitan Transit District	MB	DO	4.27	\$1.52
Santa Maria Area Transit	DR	PT	7.40	\$0.44
Santa Maria Area Transit	MB	PT	3.73	\$1.02
Santa Monica's Big Blue Bus	DR	PT	2.27	\$0.41
Santa Monica's Big Blue Bus	MB	DO	3.81	\$0.89
Solano County Transit	CB	PT	13.78	\$2.50
Solano County Transit	DR	PT	5.36	\$2.21
Solano County Transit	MB	PT	2.64	\$2.43
Sonoma County Transit	DR	PT	12.17	\$3.77
Sonoma County Transit	MB	PT	8.33	\$1.49
Southern California Regional Rail Authority dba: Metrolink	CR	PT	29.15	\$5.79
SunLine Transit Agency	DR	DO	12.02	\$2.05
SunLine Transit Agency	MB	DO	6.86	\$0.65
The Eastern Contra Costa Transit Authority	DR	PT	6.00	\$3.08
The Eastern Contra Costa Transit Authority	MB	PT	7.23	\$1.11
Torrance Transit System	DT	PT	5.20	\$1.74
Torrance Transit System	MB	DO	4.95	\$0.66
Transit Joint Powers Authority for Merced County	DR	PT	6.36	\$3.69
Transit Joint Powers Authority for Merced County	MB	PT	6.22	\$1.57
Unitrans - City of Davis/ASUCD	MB	DO	2.15	\$0.79
Ventura Intercity Service Transit Authority	CB	PT	20.34	\$1.60
Ventura Intercity Service Transit Authority	DR	PT	3.18	\$1.75
Ventura Intercity Service Transit Authority	MB	PT	4.37	\$0.85
Victor Valley Transit Authority	CB	PT	52.89	\$10.12
Victor Valley Transit Authority	DR	PT	13.17	\$2.96
Victor Valley Transit Authority	MB	PT	6.74	\$1.08
Victor Valley Transit Authority	VP	PT	48.72	\$4.17

Agency	Mode	Type of Service	Length of Average Trip	Average Fare Cost per Trip
Western Contra Costa Transit Authority	CB	PT	23.95	\$4.12
Western Contra Costa Transit Authority	DR	PT	8.15	\$1.35
Western Contra Costa Transit Authority	MB	PT	7.29	\$1.10
Yolo County Transportation District	DR	PT	12.25	\$4.88
Yolo County Transportation District	MB	PT	10.63	\$1.67
Yuba-Sutter Transit Authority	CB	PT	39.33	\$4.48
Yuba-Sutter Transit Authority	DR	PT	5.87	\$1.83
Yuba-Sutter Transit Authority	MB	PT	3.05	\$0.65