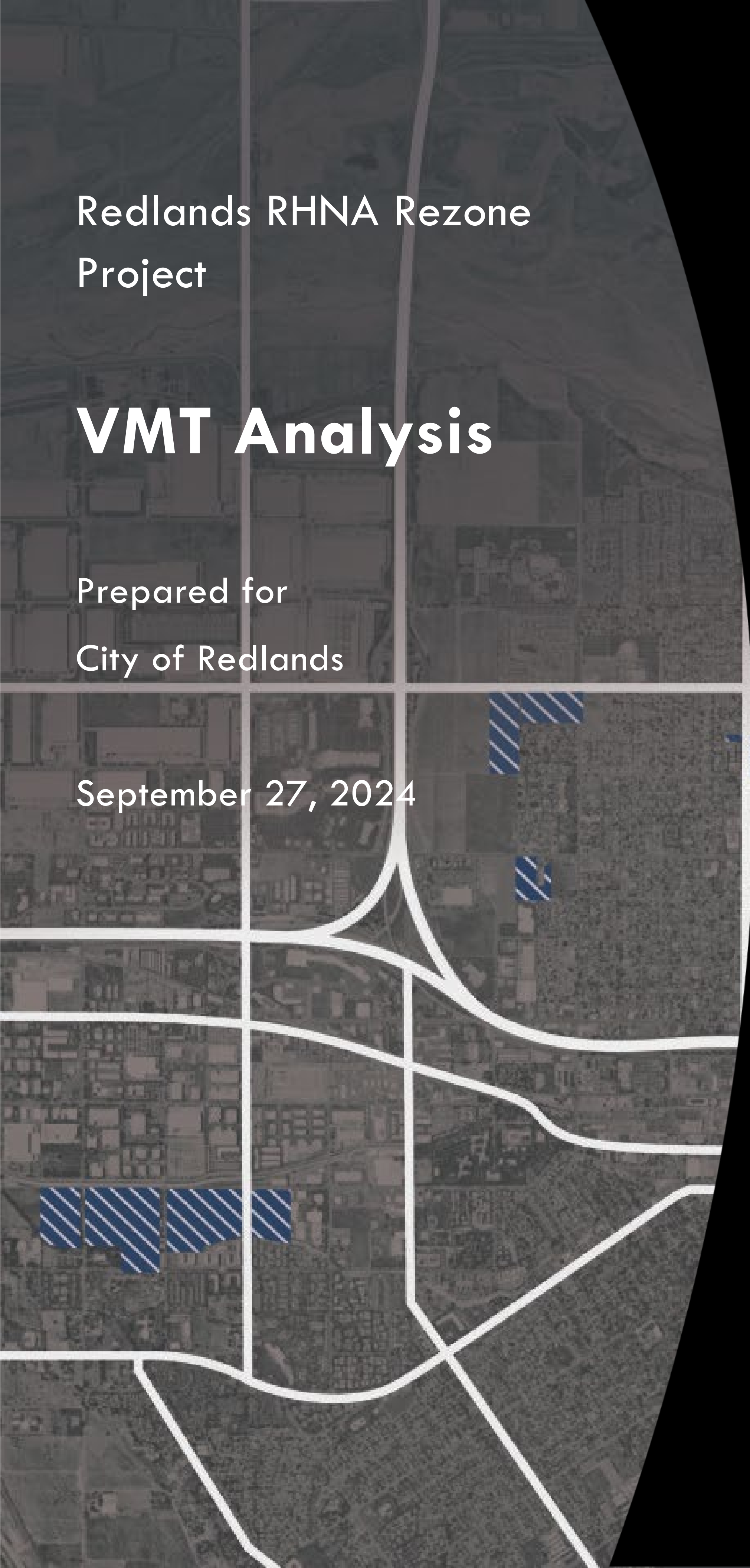

Redlands RHNA Rezone Project

VMT Analysis

Prepared for

City of Redlands

September 27, 2024

Prepared by

Alex J. Garber

Simon Lin, EIT

Maryam Javanmardi

Contact:
techservices@EPDsolutions.com

EPD SOLUTIONS, INC

949.794.1180
3333 Michelson Drive, Suite 500
Irvine, CA 92612

EPDSolutions.com

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1 EXECUTIVE SUMMARY

This vehicle miles traveled (VMT) analysis has been prepared by EPD Solutions, Inc. (EPD) to analyze the potential traffic related impacts of the proposed Redlands RHNA Rezone Project under the California Environmental Quality Act (CEQA).

The Housing Element identifies the Project sites as having a capacity of up to 2,436 housing units and assumes that implementation of residential development within the 24 Project sites would occur through the year 2035 and beyond. The Project could allow the development of up to 2,436 housing units and 151,048[1] square feet (SF) of Public/Institutional floor area compared to buildout potential under the current general plan (GP) land use designations that could allow up to a total of 1,656,670 SF of Commercial/Industrial uses, 552,341 SF of Commercial/Administrative Professional uses, and 111 housing units. Therefore, buildout pursuant to the Redlands RHNA Rezone Project would result in an increase of 2,325 residential units and decrease of 2,057,992 SF of non-residential uses.

Project VMT Screening Analysis

The following screening thresholds were utilized to identify if the Project would be considered to have a less than significant impact on VMT and therefore could be screened out from further VMT analysis:

1. The project is located within a Transit Priority Area (TPA).
    - None of the 24 Project sites are located within a TPA; therefore, none of the Project sites would meet Screening Criterion 1.

[1] Grove High School, the existing use, would remain onsite and no redevelopment of the site is proposed. For the purpose of this programmatic analysis, site 24 is analyzed based on the buildout SF of 151,048 SF instead of the existing SF based upon the request by the City of Redlands.

2. The project is consistent with the existing GP and is in a low VMT-generating area.
   - Sites 1-7, 9-19 and 24 are not consistent with the existing GP; therefore, these sites would not meet Screening Criterion 2.
   - Sites 8, 20, 21, and 23 are consistent with the existing GP, but are not located in a low VMT generating area; therefore, these sites would not meet Screening Criterion 2.
   - Site 22 is consistent with the existing GP and is located in a low VMT generating area; therefore, Site 22 would meet Screening Criterion 2 and buildout of site 22 would be presumed to have a less than significant VMT impact.
   - The Project cumulatively would not meet the requirements of Screening Criterion 2
3. The project type has been identified as a local-serving project type, or the Projects generate less than 3,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) per year.
   - Sites 1-23 do not propose any local serving uses, while site 24 currently is developed with a land use that constitutes a local-serving use (an educational facility, Grove High School) and is presumed to have a less than significant VMT impact.
   - Sites 1-23 could propose an individual development generating less than 3,000 $MTCO_2e$ (299 Multifamily Housing (Mid-Rise) units), propose affordable housing, or propose senior housing, and therefore could be presumed to have a less than significant VMT impact dependent on future buildout of the sites.
   - The Project cumulatively would not meet the requirements of Screening Criterion 3.

The Project cumulatively would not meet any of the City's screening criteria; therefore, a full analysis of VMT was prepared.

Project VMT Evaluation

The Project VMT per service population (VMT/SP) (Service population = population + employment) is shown below for each Project site:

- Sites 1-2 (TAZ 53827208) would be 39.6% below the threshold under Project Baseline 2024 conditions and 36.2% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of sites 1-2 would have a less than significant VMT impact.
- Sites 3-7, 9-15 and 24 (TAZ 53827403) would be 23.4% below the threshold under Project Baseline 2024 conditions and 27.9% below the threshold under Cumulative Year 2050 condition. Therefore, buildout of sites 3-7, 9-15 and 24 would have a less than significant VMT impact.
- Site 8 (TAZ 53827403) would be 23.4% below the threshold under Project Baseline 2024 conditions. Therefore, buildout of site 8 would have a less than significant VMT impact.
- Site 16 (TAZ 53827501) would be 34.7% below the threshold under Project Baseline 2024 conditions and 44.5% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of site 16 would have a less than significant VMT impact.
- Sites 17-19 (TAZ 53836401) would be 17.6% below the threshold under Project Baseline 2024 conditions and 9.6% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of sites 17-19 would have a less than significant VMT impact.
- Sites 20-21 (TAZ 53835402) would be 85.1% above the threshold under Project Baseline 2024 conditions. Therefore, buildout of sites 20-21 would have a potentially significant VMT impact, and mitigation would be required.

- Site 23 (TAZ 53835101) would be 8.1% above the threshold under Project Baseline 2024 conditions. Therefore, buildout of site 23 would have a potentially than significant VMT impact, and mitigation would be required.

The Redlands Citywide Boundary VMT/SP is 3.1% lower with the project added under cumulative conditions with buildout pursuant to the Redlands RHNA Rezone Project; therefore, the Project would have a less than significant cumulative impact on VMT, and mitigation would not be required for the cumulative impact.

Project VMT Mitigation

The rezoning of sites 20, 21, and 23 would have a potentially significant impact on VMT. As this is a programmatic analysis, and project level specifics about future development are not known at this time, the feasibility and applicability of mitigation measures are not able to be determined. However, the following mitigation measures identified in the California Air Pollution Control Officers Association (CAPCOA) handbook are applicable to residential developments and may be appropriate to analyze and implement to reduce VMT when project level specifics are identified in future analyses:

Mitigation Measure T-1:

Prior to approval of any site plan, any applicant for an implementing project fully within or partially within sites 20, 21, or 23 shall prepare a VMT Screening Analysis pursuant to the City of Redlands CEQA Assessment VMT Analysis Guidelines and provide this analysis to the City of Redlands Planning Division and Engineering Division. The VMT Screening Analysis shall demonstrate that the implementing project meets the screening criteria set forth in in the City of Redlands CEQA Assessment VMT Analysis Guidelines.

If the implementing project does not meet applicable screening criteria, the implementing project applicant shall prepare a VMT analysis pursuant to the City of Redlands CEQA Assessment VMT Analysis Guidelines. For projects with VMT per Service Population exceeding the City's significance thresholds, a mitigation plan shall be developed and implemented. Mitigation should consist of Transportation Demand Management (TDM) measures analyzed under a VMT-reduction methodology consistent with the California Air Pollution Control Officers Association's (CAPCOA) Final Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity (2021) and approved by the City of Redlands. Examples of measures include but are not limited to:

- **CAPCOA Measure T-1 Increase Residential Density:** Higher residential density encourages mixed-use development and reduces sprawl. Placing more people closer to amenities, workplaces, and public transit decreases the distance people need to travel for daily activities, thereby reducing overall VMT.
- **CAPCOA Measure T-4 Integrate Affordable and Below Market Rate (BMR) Housing:** BMR housing provides greater opportunity for lower income families to live closer to job centers and achieve a jobs/housing match near transit and can decrease the VMT generated by the project.
- **CAPCOA Measure T-7 Implement Commute Trip Reduction Marketing:** Information sharing and marketing promote and educate workers about their travel choices to the employment location beyond driving such as carpooling, taking transit, walking, and biking, thereby reducing VMT. This could be implemented through an HOA.

- **CAPCOA Measure T-8 Provide Ridesharing Program:** Ridesharing encourages carpooled vehicle trips in place of single-occupied vehicle trips, thereby reducing the number of trips, VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-9 Implement Subsidized or Discounted Transit Program:** Reducing the out-of-pocket cost for choosing transit improves the competitiveness of transit against driving, increasing the total number of transit trips and decreasing vehicle trips. This decrease in vehicle trips results in reduced VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-15 Limit Residential Parking Supply:** The reduction in VMT that can be achieved by limiting the total parking supply available at a residential project. When parking is limited, scarcity is created, and additional time and inconvenience is added to trips made by private auto. The reduction in the convenience of driving results in a shift to other modes and can decrease the VMT generated by the project.
- **CAPCOA Measure T-16 Unbundle Residential Parking Costs from Property Cost:** Parking costs are passed through to the vehicle owners/drivers utilizing the parking spaces, this measure results in decreased vehicle ownership and, therefore, a reduction in VMT.
- **CAPCOA Measure T-18 Provide Pedestrian Network Improvement:** Providing sidewalks and an enhanced pedestrian network encourages people to walk instead of drive. This mode shift results in a reduction in VMT.
- **CAPCOA Measure T-19-A Construct or Improve Bike Facility:** Building or enhancing bike facilities such as dedicated bike lanes, secure parking, and bike-sharing programs promotes cycling as a convenient and safe transportation option. This reduces the number of short-distance car trips, contributing to lower VMT.
- **CAPCOA Measure T-19-B Construct or Improve Bike Boulevard:** Bike boulevards are designed to prioritize cyclists by providing dedicated lanes and traffic calming measures. By creating safer and more attractive cycling routes, bike boulevards encourage residents to use bicycles for commuting and local trips, thereby reducing VMT.
- **CAPCOA Measure T-20 Expand Bikeway Network:** Expanding the bikeway network connects different parts of the community with safe and accessible bike routes. This infrastructure improvement makes cycling a more practical choice for daily transportation needs, reducing reliance on motor vehicles and lowering VMT.
- **CAPCOA Measure T-21-A Implement Conventional Carshare Program:** Conventional carshare programs provide access to vehicles on a short-term basis. By promoting shared vehicle usage, particularly for occasional trips, they reduce the need for individual car ownership and decrease VMT.
- **CAPCOA Measure T-21-B Implement Electric Carshare Program:** Electric carshare programs offer access to EVs for shared use. Providing convenient access to environmentally friendly transportation options encourages residents and employees to choose EVs over traditional vehicles, thus lowering VMT and emissions.
- **CAPCOA Measure T-22-A Implement Pedal (Non-Electric) Bikeshare Program:** Pedal bikeshare programs make bicycles readily available for short trips. Offering an alternative to driving for local transportation needs reduces congestion and lowers VMT.
- **CAPCOA Measure T-22-B Implement Electric Bikeshare Program:** Electric bikeshare programs provide access to electric-assisted bicycles. These bikes make cycling more accessible to a broader range of users and encourage more trips to be taken by bike instead of by car, contributing to reduced VMT.

- **CAPCOA Measure T-22-C Implement Scooter Share Program:** Scooter share programs offer electric scooters for short-distance trips. By providing a convenient alternative to driving for short trips within the community, scooter share programs reduce the number of car trips and help decrease VMT.
- **CAPCOA Measure T-23 Provide Community-Based Travel Planning (CBTP):** CBTP is a residential-based approach to outreach that provides households with customized information, incentives, and support to encourage the use of transportation alternatives in place of single occupancy vehicles, thereby reducing household VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-24 Implement Market Price Public Parking (On-Street):** Increasing the cost of parking increases the total cost of driving to a location, incentivizing shifts to other modes and thus decreasing total VMT to and from the priced areas.
- **CAPCOA Measure T-27 Implement Transit-Supportive Roadway Treatments:** Transit-supportive treatments incorporate a mix of roadway infrastructure improvements and/or traffic signal modifications to improve transit travel times and reliability. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT.

Conclusion

Since there is not enough information available to appropriately analyze the actual reduction in VMT at this time, no credit was taken for the identified mitigation measures, and the Project would have a significant and unavoidable VMT impact.

2 INTRODUCTION

The scope of work for this VMT analysis was reviewed and approved by the City of Redlands and is provided in Appendix A. The Project description and proposed scope of work for the Redlands RHNA Rezone Project (Project) is discussed in detail below. This VMT analysis is based on the requirements of the *City of Redlands CEQA Assessment VMT Analysis Guidelines* (City's Guidelines) adopted by the City of Redlands City Council on July 21, 2020.

2.1 Project Description

The Project consists of 24 sites. Under the current General Plan (GP) land use designations, the 24 sites could possibly be developed or redeveloped with the following maximum development potentials based on their current GP land use designation:

- Sites 1-7, 9-16, 24:
  - 828,350 SF of warehouse
  - 828,350 SF of retail
- Sites 17-19:
  - 276,170.5 SF of office
  - 276,170.5 SF of retail
- Sites 8, 20, 21, 22, 23:
  - 111 multi-family housing units

The Housing Element identifies the Project sites as having a capacity of up to 2,436 housing units and assumes that implementation of residential development would occur through the year 2035. The Project would allow the development of 2,436 housing units and 151,048 square feet (SF) of Public/Institutional development compared to the buildout under the current general plan (GP) land use of 1,656,6970 SF of Commercial/Industrial uses, 552,341 SF of Commercial/Administrative Professional uses, and 111 housing units. Therefore, buildout pursuant to the Redlands RHNA Rezone Project would result in an increase of 2,325 residential units and decrease of 2,057,992 SF of non-residential uses.

Table 1 lists the existing and proposed GP land use designation of the 24 Project sites. As shown in Table 1, 18 of the 24 sites propose a change to the General Plan land use designation. The 23 sites designated for residential development would have an allowed density from 15 to 30 dwelling units per acre (DU/acre). Site 24 proposes Public/Institutional development up to a 0.5 Floor to Area Ratio (FAR). While this analysis assumes that Site 24 could be developed to its maximum FAR of 0.5 for approximately 151,048 SF of public/institutional uses. Grove High School, the existing use on site 24, would remain onsite and no redevelopment of the site is proposed or anticipated.

The Project site locations are depicted in Figure 1. Aerial views of the individual Project sites are shown in Figures 2 and 3.

Table 1: Current and Proposed GP Land Use Designation of the Project

Site Number	Acreage	Current GP Land Use Designation	Current GP Density[1]	Current Maximum Buildout	Proposed GP Land Use Designation	Proposed GP Density[1]	Proposed Maximum Buildout
1	8.91	Commercial/ Industrial	0.5 FAR	194,060 SF	MDR	15 DU/acre	133 DU
2	4.26	Commercial/ Industrial	0.5 FAR	92,783 SF	MDR	15 DU/acre	63 DU
3	5.84	Commercial/ Industrial	0.5 FAR	127,195 SF	HDR	30 DU/acre	175 DU
4	3.15	Commercial/ Industrial	0.5 FAR	68,607 SF	HDR	30 DU/acre	94 DU
5	1.07	Commercial/ Industrial	0.5 FAR	23,305 SF	HDR	30 DU/acre	32 DU
6	1.9	Commercial/ Industrial	0.5 FAR	41,382 SF	HDR	30 DU/acre	57 DU
7	1.9	Commercial/ Industrial	0.5 FAR	41382 SF	HDR	30 DU/acre	57 DU
8	4.07	MDR	10 DU/acre	40 DU	MDR	15 DU/acre	61 DU
9	2.5	Commercial/ Industrial	0.5 FAR	54,450 SF	HDR	30 DU/acre	75 DU
10	4.03	Commercial/ Industrial	0.5 FAR	87,773 SF	HDR	30 DU/acre	120 DU
10A	0.08	Commercial/ Industrial	0.5 FAR	1,742 SF	MDR	30 DU/acre	2 DU
11	4.7	Commercial/ Industrial	0.5 FAR	102,366 SF	MDR	15 DU/acre	70 DU
12	2.31	Commercial/ Industrial	0.5 FAR	50,312 SF	MDR	15 DU/acre	34 DU
13	4.73	Commercial/ Industrial	0.5 FAR	103,019 SF	HDR	30 DU/acre	141 DU
14	4.21	Commercial/ Industrial	0.5 FAR	91,694 SF	HDR	30 DU/acre	126 DU
15	8.86	Commercial/ Industrial	0.5 FAR	192,971 SF	HDR	30 DU/acre	265 DU
15A	0.02	Commercial/ Industrial	0.5 FAR	436 SF	HDR	30 DU/acre	1 DU
16	10.65	Commercial/ Industrial	0.5 FAR	231,957 SF	MDR	15 DU/acre	159 DU
16A	0.01	Commercial/ Industrial	0.5 FAR	218 SF	MDR	15 DU/acre	0 DU
17	14.05	Commercial/Admin . Professional	0.5 FAR	306,009 SF	MDR	15 DU/acre	210 DU
18	5	Commercial/Admin . Professional	0.5 FAR	108,900 SF	HDR	30 DU/acre	150 DU
19	6.31	Commercial/Admin . Professional	0.5 FAR	137,432 SF	HDR	30 DU/acre	189 DU
20	4.76	MDR	1DU/2.5 acre	1.83 DU	MDR	15 DU/acre	71 DU
21	1.64	MDR	7,200 SF/DU	9.93 DU	MDR	15 DU/acre	24 DU

22	0.33	HDR	3,000 SF/DU	4.76 DU	HDR	27 DU/acre	9 DU
23	3.96	HDR	3,000 SF/DU	57.47 DU	HDR	27 DU/acre	118 DU
	Total Residential			**111 DU**			**2436 DU**
24	10.91	Commercial/ Industrial	0.5 FAR	151,048 SF	Public/ Institutional	0.5 FAR	151,048 SF
	Total Non-Residential			**2,209,041 SF**			**151,048 SF**

Notes: FAR = Floor Area Ratio, MDR = Medium Density Residential, HDR = High Density Residential, DU = dwelling units
1 Densities include FAR, measured by square footage (SF) and DU measured by maximum number of units per acre.
2 Grove High School, the existing use, would remain onsite and no redevelopment of the site is proposed. For the purpose of this programmatic analysis, site 24 is analyzed based on the buildout SF of 151,048 SF instead of the existing SF based upon the request by the City of Redlands.

Figure 1: Project Location

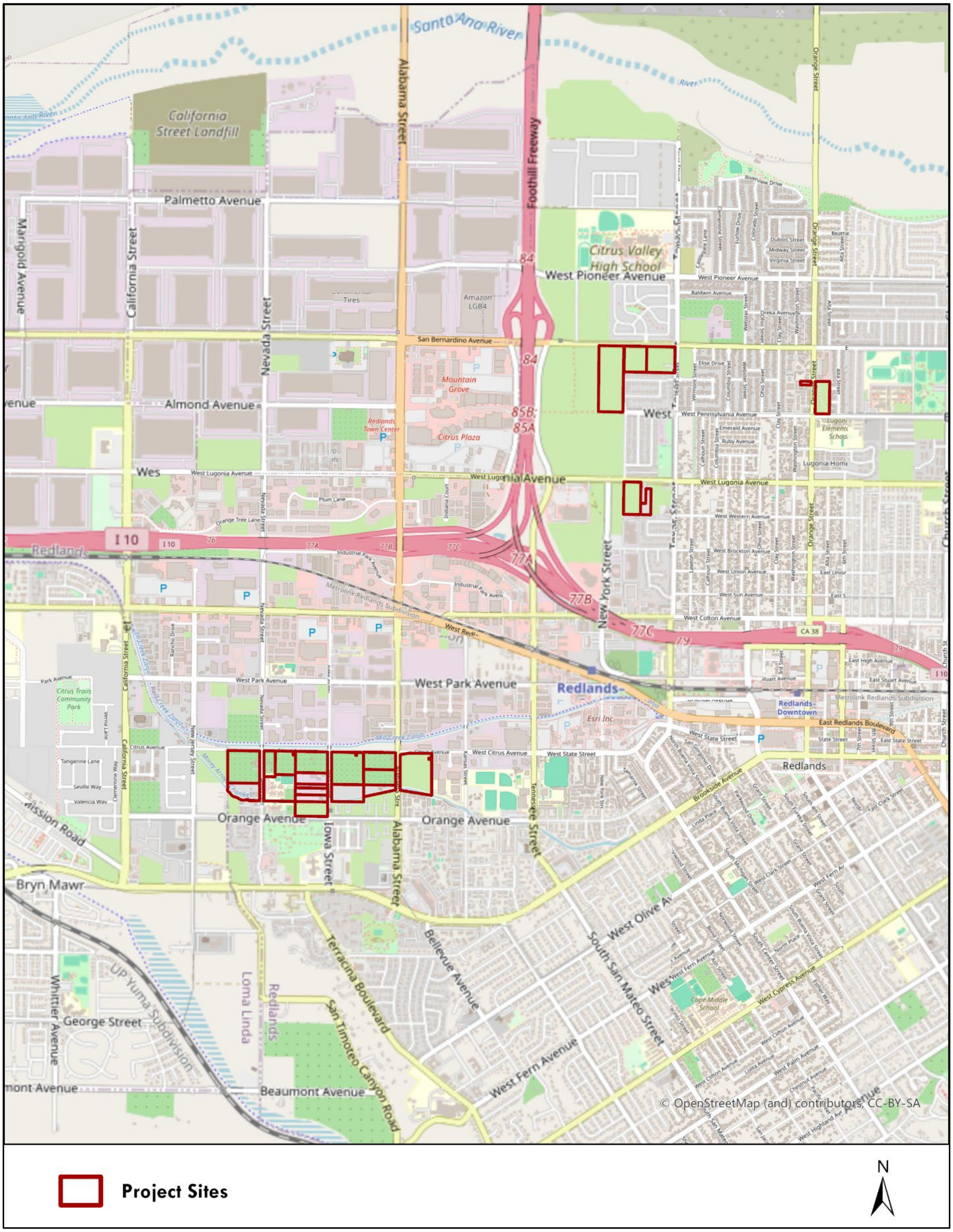
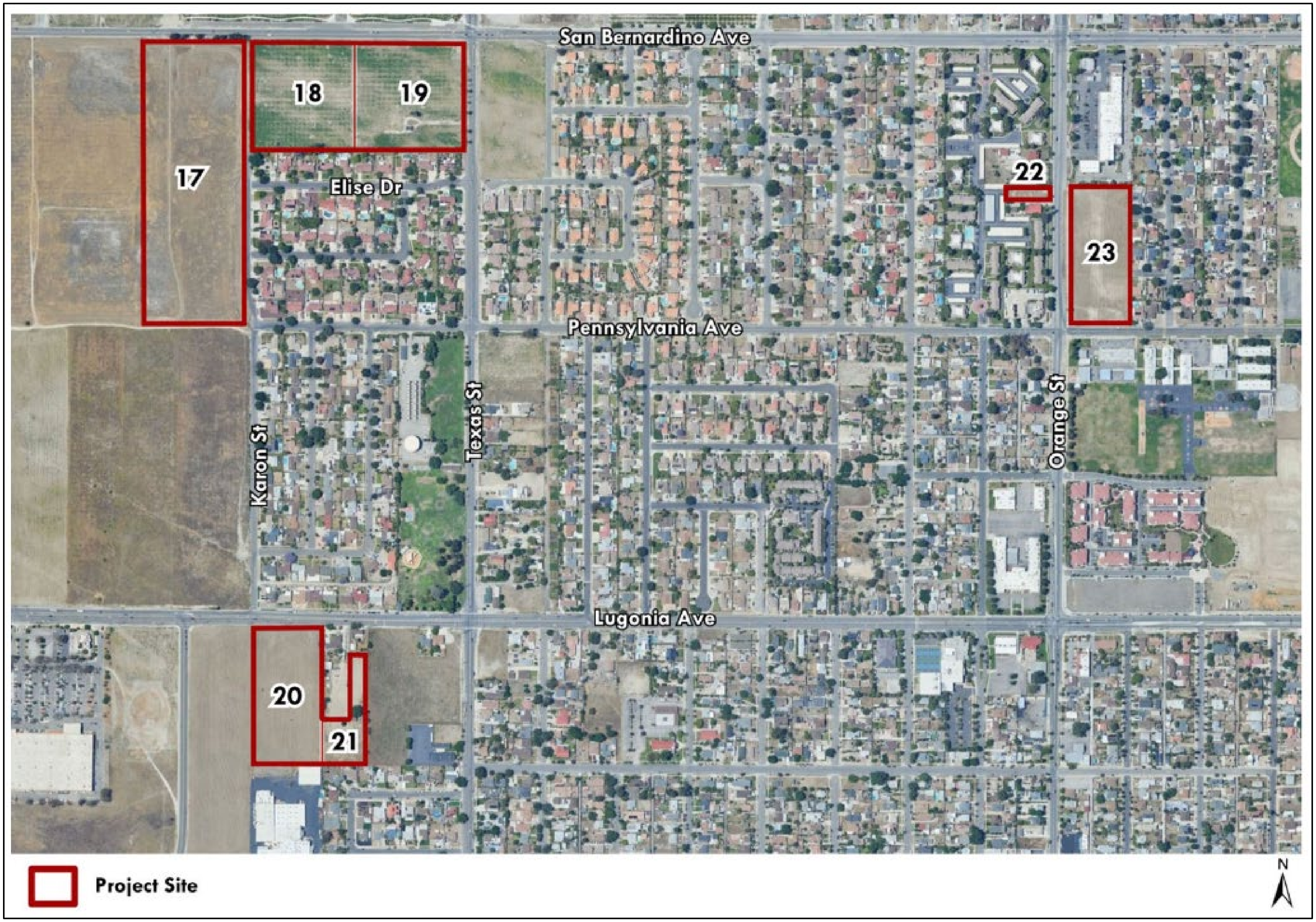


Figure 2: Project Aerial View #1 – Sites 1-16 & 24

Figure 3: Project Aerial View #2 – Sites 17-23



2.2 Project Trip Generation

The Project trip generation shown in Table 2 was calculated using trip rates from the Institute of Transportation Engineers (ITE), *Trip Generation 11th Edition*, 2021. The ITE land use rates for Warehouse (ITE Land Use Code (LUC) 150), Multifamily Housing (Mid-Rise) (ITE LUC 221), Daycare Center (ITE LUC 565), General Office Building (ITE LUC 710), and Shopping Center (>150k) (ITE LUC 820) were utilized because of the following reasoning:

- Sites 1-7, 9-16, 24 (existing Commercial/Industrial):
  - ITE LUC 820 Shopping Center (>150k) was used for the commercial portion due to the size of the planned commercial development under current GP, LUC 820 also has the lowest trip rate among commercial uses for the purpose of a conservative analysis.
  - ITE LUC 150 Warehouse, which has the lowest trip rate among industrial uses was used for the Industrial portion for the purpose of a conservative analysis.
- Sites 17-19 (existing Commercial/Admin. Professional):
  - ITE LUC 820 Shopping Center (>150k) was used for the commercial portion due to the size of the planned commercial development under current GP, LUC 820 also has the lowest trip rate among commercial uses for the purpose of a conservative analysis.
  - ITE LUC 710 General Office Building was used for the admin professional portion because it is the most appropriate LUC for this type of development.
- Site 1-23 (existing and proposed MDR and HDR):
  - ITE LUC 221 Multifamily Housing (Mid-Rise) was used, due the number of stories (four stories) for the planned housing units under current and proposed GP.
- Site 24 (proposed Public/Institutional):
  - Grove High School, the existing use, would remain onsite and no redevelopment of the site is proposed. For the purpose of this programmatic analysis, site 24 is analyzed based on the buildout SF instead of the existing SF based upon the request by the City of Redlands. ITE LUC 565 Day Care is the most accurate LUC to use instead of ITE LUC 525 High School, because the majority of the site is owned and operated as a Montessori daycare.

As indicated in Table 2, the Project is estimated to generate approximately 27,540 net fewer daily trips, including 1,034 net new trips during the AM peak hour and 1,716 net fewer trips during the PM peak hour.

Table 2A: Project Trip Generation under Current GP Land Use Designation

	Land Use[1]	Project Size	ITE Code[2]	Unit	ITE Daily Trip Rate/Unit	Project ADTs	ITE AM Trip Rate/Unit	Project AM Trips	ITE PM Trip Rate/Unit	Project PM Trips
Current GP Land Use (Baseline)	Warehouse (Site 1-7, 9-16, 24)	-828.349	150	KSF	1.71	-1,416	0.17	-141	0.18	-149
	Passenger Vehicles (64.9%)					-919		-91		-97
	2-Axle truck (7.7%)					-109		-11		-11
	3-Axle truck (6.2%)					-88		-9		-9
	4+-Axle Trucks (21.2%)					-300		-30		-32
	Retail (Site 1-7, 9-16, 24)	-828.349	820	KSF	37.01	-30,657	0.84	-696	3.40	-2,816
	Multi-Family Housing (Sites 8, 20, 21, 22,23)	-111	221	DU	4.54	-504	0.37	-41	0.39	-43
	Office (Site 17-19)	-276.170	710	KSF	10.84	-2,994	1.52	-420	1.44	-398
	Retail (Site 17-19)	-276.170	820	KSF	37.01	-10,221	0.84	-232	3.40	-939
Current GP Land Use(Baseline) TOTAL TRIPS						**-45,792**		**-1,529**		**-4,345**

Table 3B: Project Trip Generation under Proposed GP Land Use Designation

	Land Use[1]	Project Size	ITE Code[2]	Unit	ITE Daily Trip Rate/Unit	Project ADTs	ITE AM Trip Rate/Unit	Project AM Trips	ITE PM Trip Rate/Unit	Project PM Trips
Proposed GP Land Use (Project)	Multi-Family Housing(Site 1-23)	2,436	221	DU	4.54	11,059	0.37	901	0.39	950
	Daycare Center(Site 24)	151.048	565	KSF	47.62	7,193	11.00	1,662	11.12	1,680
Proposed GP Land Use TOTAL TRIPS						**18,252**		**2,563**		**2,630**

Table 4C: Project Net Trip Generation from Current to Proposed GP Land Use Designation

	Land Use[1]	Project Size	ITE Code[2]	Unit	ITE Daily Trip Rate/Unit	Project ADTs	ITE AM Trip Rate/Unit	Project AM Trips	ITE PM Trip Rate/Unit	Project PM Trips
Current GP Land Use + Proposed GP Land Use (Total) TOTAL TRIPS						**-27,540**		**1,034**		**-1,716**

Notes: KSF=Thousand Square Feet, DU= Dwelling Units
1Truck % from the Institute of Transportation Engineers (ITE), Trip Generation Manual,11th Edition, 2021. Truck axle split from the SCAQMD Warehouse (Composite) Truck Trip Study Data Results and Usage, July 17, 2014.
2Trip rates from the Institute of Transportation Engineers (ITE), Trip Generation Manual,11th Edition, 2021of this programmatic analysis, site 24 is analyzed based on the buildout SF of 151,048 SF instead of the existing SF based upon the request by the City of Redlands.

3 VEHICLE MILES TRAVELED BACKGROUND AND SIGNIFICANCE THRESHOLDS

Senate Bill (SB) 743 was signed by Governor Brown in 2013 and required the Governor's Office of Planning and Research (OPR) to amend the California Environmental Quality Act (CEQA) Guidelines to replace level of service (LOS) as the appropriate method for evaluating transportation impacts under CEQA. SB 743 specified that the new criteria should promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses. The bill also specified that delay-based LOS could no longer be considered an indicator of a significant impact on the environment under CEQA. In response, the Natural Resources Agency amended the CEQA Guidelines to include Section 15064.3, *Determining the Significance of Transportation Impacts*. This section states that vehicle miles traveled (VMT) is the most appropriate measure of a project's transportation impacts and provides lead agencies with the discretion to choose the most appropriate methodology and thresholds for evaluating VMT. Section 15064.3(c) states that the provisions of the section shall apply statewide beginning on July 1, 2020.

3.1 City of Redlands VMT Screening Criteria

The City's Guidelines provide the following screening thresholds to identify if a project would be considered to have a less than significant impact on VMT and therefore could be screened out from further VMT analysis:

1. The project is located within a Transit Priority Area (TPA).
2. The project is in a low VMT-generating area.
3. The project type has been identified as a local-serving project type, or the Projects generate less than 3,000 metric tons of CO_2e per year.

If a project meets one of the criteria above, then the VMT impact of the project would be considered less than significant and no further analysis of VMT would be required.

3.2 VMT Significance Thresholds

Projects not screened through the steps above should complete VMT analysis and forecasting through the San Bernardino Transportation Analysis Model (SBTAM) to determine if they have a significant VMT impact. A project would result in a significant VMT impact if either of the following conditions are satisfied:

1. The baseline project-generated VMT per service population (VMT/SP) exceeds a level 15 percent below the San Bernardino County regional average VMT per service population or,
2. For projects that are inconsistent with the City's GP, the cumulative project-generated VMT/SP exceed a level 15 percent below the San Bernardino County regional average VMT per service population.

A project would result in a cumulatively significant VMT impact if the following condition is satisfied:

For projects that are inconsistent with the City's GP, the project causes total daily VMT per service population within the City to be higher than the no Project alternative under cumulative conditions.

4 VEHICLE MILES TRAVELED ANALYSIS

4.1 VMT Screening Analysis

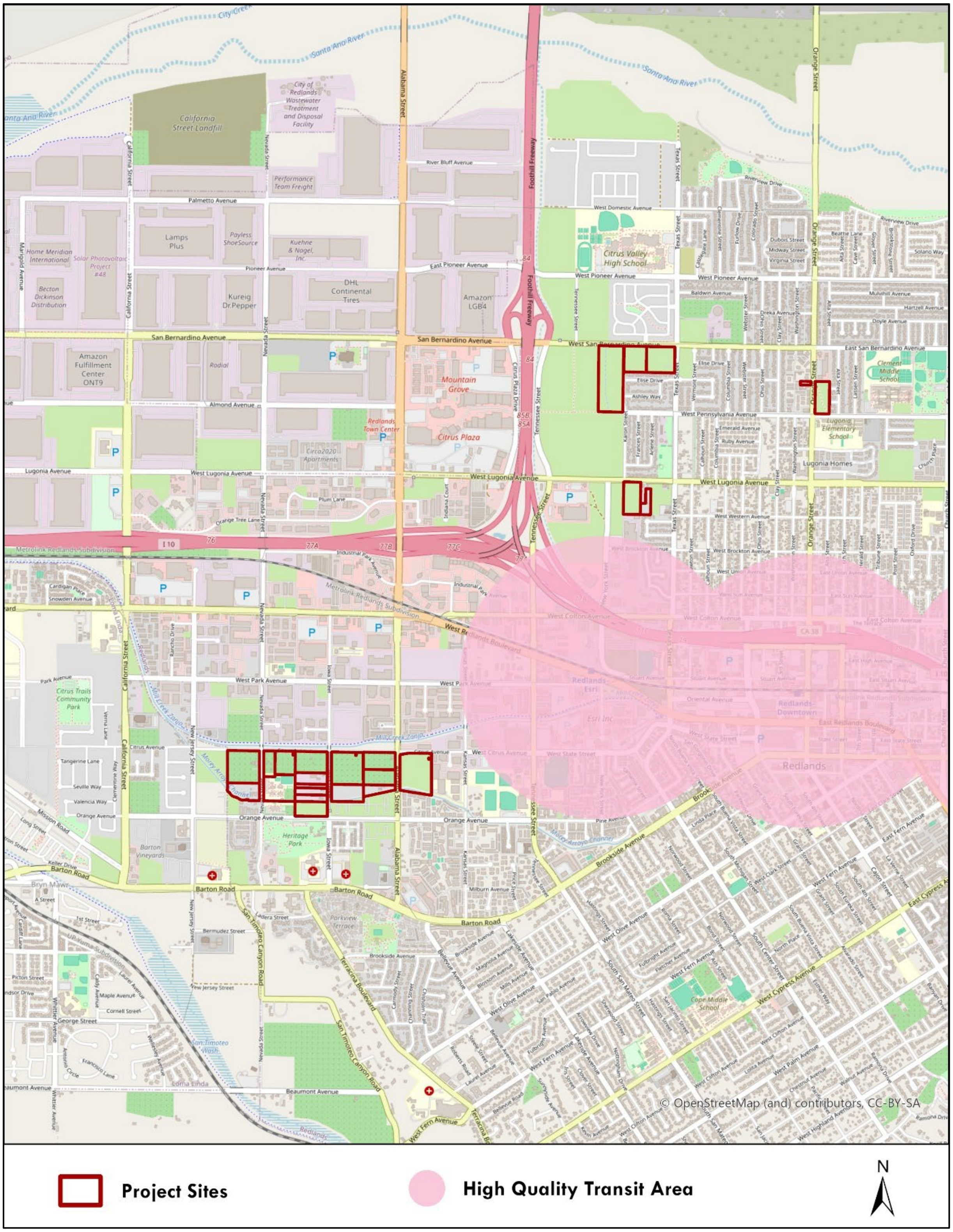
The applicability of each screening criterion to the Project is discussed below.

Screening Criterion 1 – Transit Priority Area (TPA) Screening

Per the City's Guidelines, projects located in a Transportation Priority Area (TPA) may be presumed to have a less than significant VMT impact. The guidelines further suggest that projects within one-half mile of major transit stops may also be presumed to have a less than significant impact.

The TPA map from the San Bernardino County Transportation Authority (SBCTA) VMT screening tool output is shown in Figure 4. As shown, none of the proposed Project sites are located within a TPA. Therefore, the Project does not meet the requirements of Screening Criterion 1.

Figure 4: TPA Map from SBCTA VMT Screening Tool



Note: Transit Priority Area (TPA) designated in the figure as High Quality Transit Area.

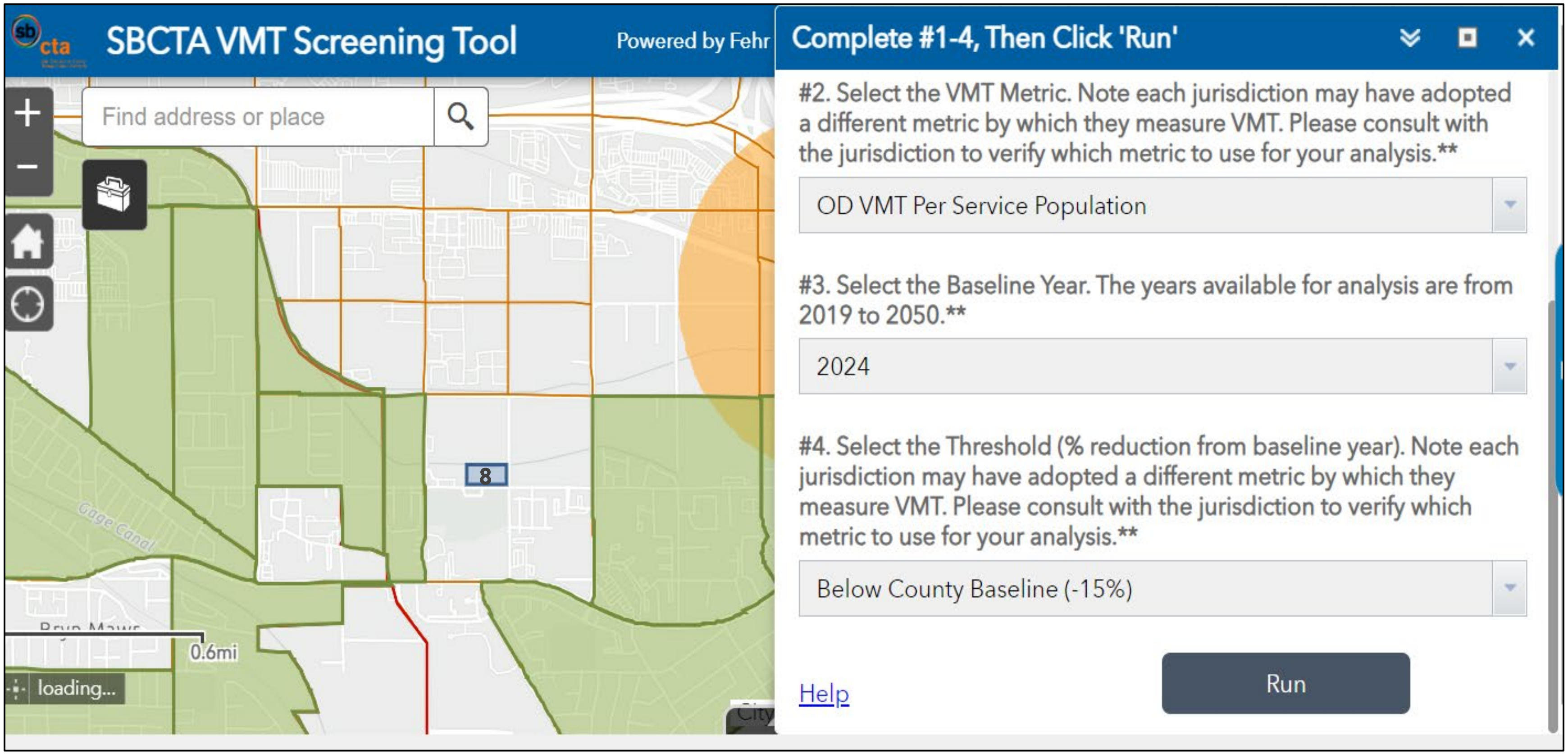
Screening Criterion 2 – Low VMT Area Screening

The City's guidelines include a screening threshold for projects located in a low-VMT generating area, which is defined as traffic analysis zones (TAZs) with a total daily VMT/SP that is 15 percent less than the baseline level for the county. For projects that are inconsistent with the land use assumptions coded into the projects' TAZ, this screening criterion would not be appropriate, and the project would not satisfy the requirements of Screening Criterion 2.

As shown in Table 1, the proposed land use designations for 19 of the 24 Project sites are inconsistent with the existing general plan designations and would therefore not satisfy Screening Criterion 2. Buildout of sites 8 and 20-23 would be consistent with the existing GP land use designation and would meet Screening Criterion 2 if their respective TAZs are 15 percent below the County's Origin-Destination (OD) VMT/SP baseline. The SBCTA VMT screening tool output for low-VMT generating areas is shown in Figures 5, 6, and 7.

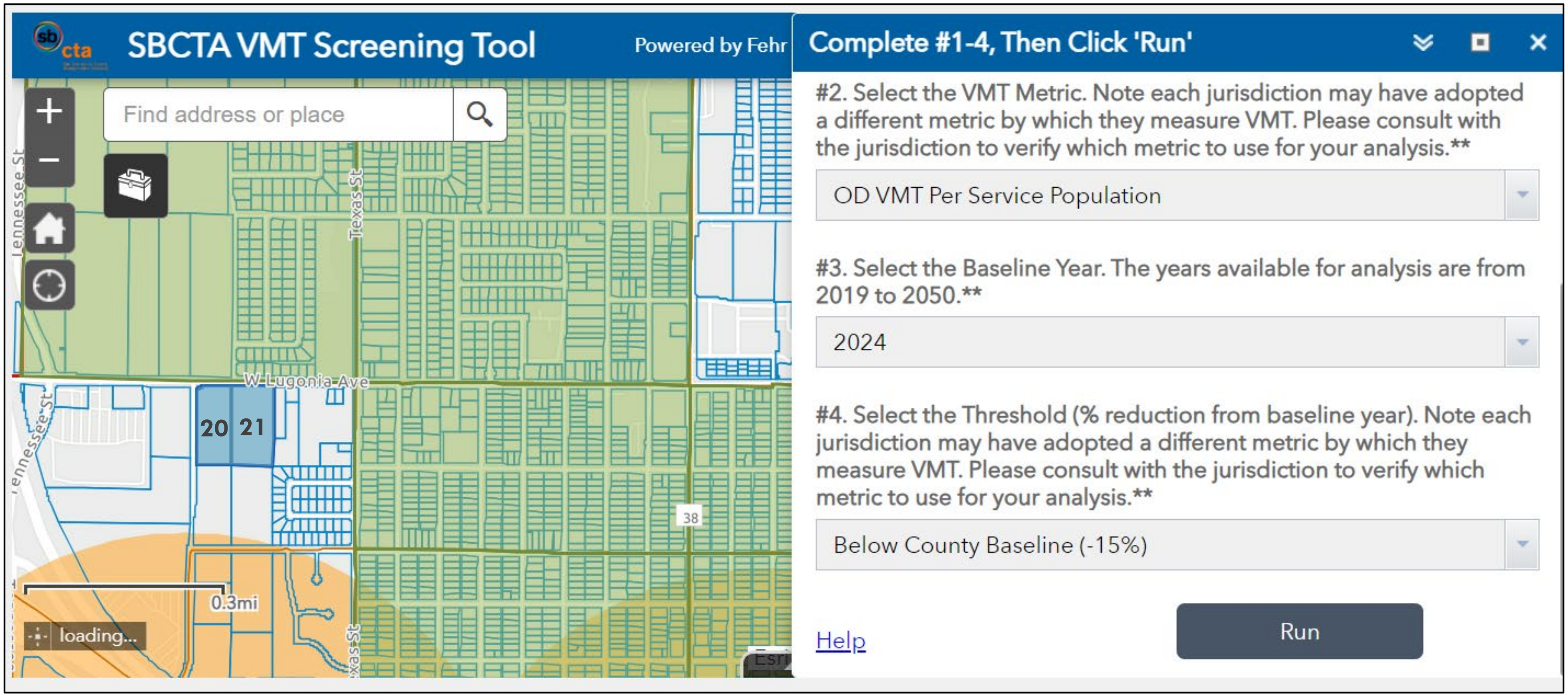
As shown in Figures 5, 6, and 7, site 22 is located in a Low VMT area, and would satisfy Screening Criterion 2, resulting in a less than significant impact to VMT. Sites 8, 20, 21, and 23 are not located in a low VMT generating area. Therefore, all Project sites with the exception of site 22 would not satisfy the requirements of Screening Criterion 2.

Figure 5: Low VMT Generating Area Output from SBCTA VMT Screening Tool – Site 8



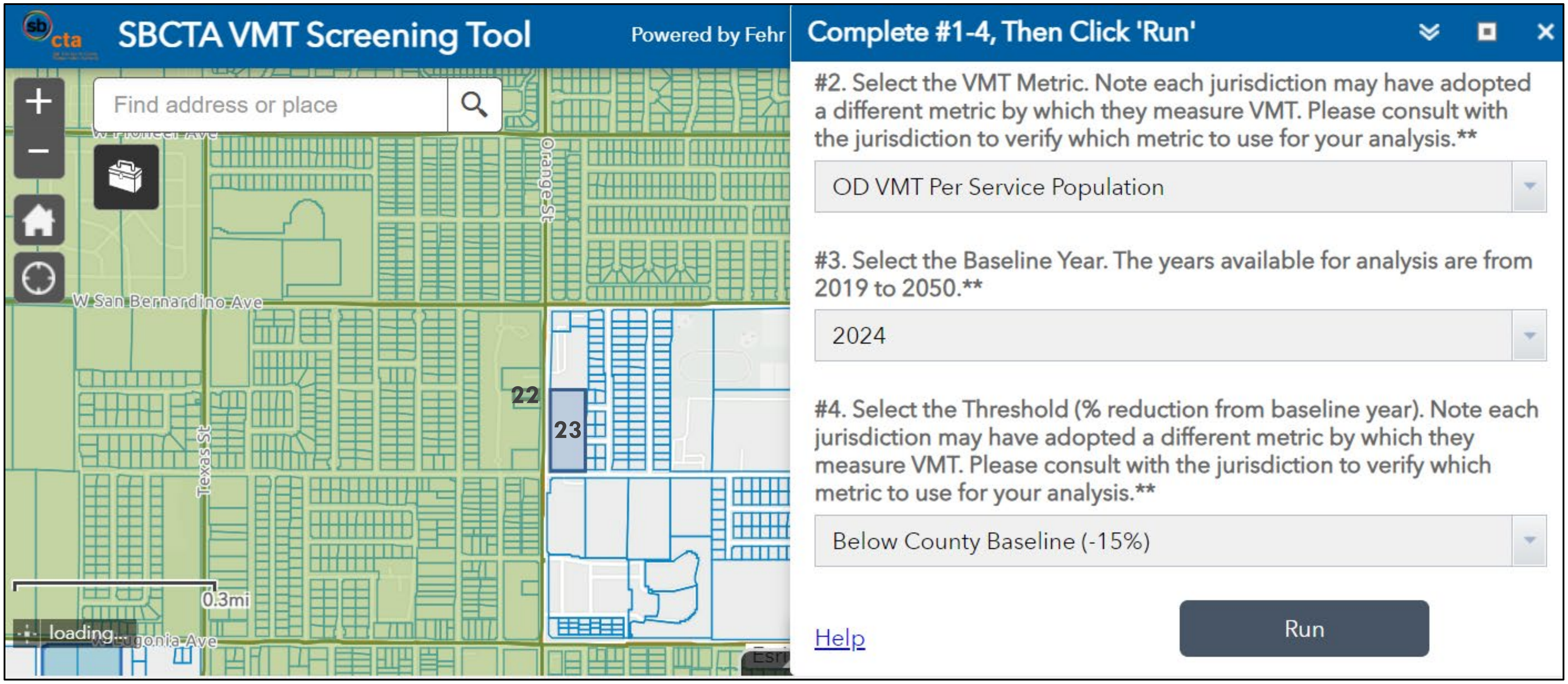
Source: SBCTA VMT Screening Tool

Figure 6: Low VMT Generating Area Output from SBCTA VMT Screening Tool – Sites 20-21



Source: SBCTA VMT Screening Tool

Figure 7: Low VMT Generating Area Output from SBCTA VMT Screening Tool – Sites 22-23



Source: SBCTA VMT Screening Tool

Screening Criterion 3 - Project Type Screening

Based on the guidelines referenced, the following projects would satisfy Screening Criterion 3 and can be presumed to have a less than significant impact on VMT:

- Local-serving retail (retail projects less than 50,000 square feet)
- Local-serving K-12 schools
- Local parks
- Day care centers
- Local-serving gas stations
- Local-serving banks
- Non-destination hotels,
- Student housing projects,
- Local-serving assembly uses (places of worship, community organizations)
- Community institutions (Public libraries, fire stations, local government)
- Local serving community colleges thot ore consistent with the assumptions
- Affordable or supportive housing
- Assisted living facilities
- Senior housing (as defined by HUD)
- Projects that generate less than 3,000 metric tons of CO_2e per year

Based on the City's Guidelines, Multifamily Housing (Mid-Rise) projects consisting of 299 dwelling units or fewer would generate less than 3,000 metric tons of CO_2e per year and may be presumed to have a less than significant impact.

The following is a summary of the Project as it relates to the above criteria:

- Sites 1-23 do not propose any local serving uses, while buildout of site 24 would include a land use that constitutes a local serving use, such as an educational facility or government office, and would be presumed to have a less than significant VMT impact.
- Sites 1-23 could propose an individual development that generates less than 3,000 $MTCO_2e$ (299 Multifamily Housing (Mid-Rise) units), propose affordable housing, or propose Senior housing, and could therefore be presumed to have a less than significant VMT impact. However, given that the size of residential development resulting from buildout within sites 1-23 is unknown, it cannot be determined that VMT impacts would be less than significant.
- The Project cumulatively would not meet the requirements of Screening Criterion 3.

Overall, since the totality of the Project does not meet the requirements of Screening Criterion 3, and project specifics are not known at this time to determine if the land uses meet the requirements for Screening Criterion 3, it is determined that Screening Criterion 3 has not been met.

Because the totality of the Project would not meet any of the City's screening criteria, a full analysis of VMT has been prepared for the project.

4.2 VMT Analysis Methodology

The City's Guidelines require use of SBTAM for preparation of VMT analysis. The latest version of SBTAM, SBTAM Plus Version 3.2 (SBTAM+) was utilized for the analysis. SBTAM+ includes validated scenarios for Base Year (2019) and Cumulative Year (2050).

The Project is located within TAZs 53827208 (sites 1 and 2), 53827403 (sites 3-15, 24), 53827501 (site 16), 53836401 (sites 17-19), 53835402 (sites 20-21), 53836402 (site 22) and 53835101(site 23). The SBTAM+ roadway network near the Project sites was reviewed, and no changes were necessary for the roadway network.

SBTAM+ was run for the Base Year 2019 and Cumulative Year 2050 without and with project conditions (i.e., four full Model runs).

The total OD VMT of each TAZ was evaluated using the SBTAM+ VMT post-processor from the SBTAM Base Year (2019) and Cumulative Year (2050) with-Project Model runs. To determine VMT/SP, the total OD VMT of the TAZs is divided by the with-Project SP of the TAZs. The 2024 VMT/SP was interpolated using linear interpolation between the 2019 and 2050 Model outputs.

The San Bernardino County VMT/SP for Project Baseline Year 2024 was calculated from the SBCTA VMT web map results for base year (2019) and Cumulative Year (2050) using linear interpolation.

The VMT/SP within the City of Redlands under with Project condition for Cumulative Year (2050) was obtained using the with-Project Model run. The VMT/SP within the City of Redlands under no Project conditions for Cumulative Year (2050) was obtained using the without-Project model run. To determine VMT/SP, the total boundary VMT of the City is divided by the SP of the City.

According to the City's Guidelines, if a project results in a significant impact under either of the impact criteria, feasible mitigation measures would be required to reduce the project impact to a less than significant level.

4.3 Project Generated VMT Evaluation

The VMT analysis results per the City's Guidelines for Project generated VMT evaluation for TAZs 53827208, 53827403, 53827501, 53836401, 53835402, and 53835101 are shown in Tables 3 through 9. Based on the San Bernardino County average, the VMT/SP baseline for Project Base Year 2024 is 35.63 VMT/SP. Therefore, the City's threshold of significance for Baseline 2024 is 30.29 VMT/SP, 15% below the 35.63 VMT/SP baseline. The City's threshold of significance for Cumulative Year 2050 is 33.18 VMT/SP, 15% below the 39.03 VMT/SP baseline.

As shown in Table 3, the Project VMT/SP for sites 1-2 (TAZ 53827208) would be 39.6% below the threshold under Project Baseline 2024 conditions and 33.0% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of sites 1 and 2 under the proposed Project would result in a less than significant VMT impact, and no mitigation would be required.

Table 5: VMT Analysis of Project Sites 1-2 (TAZ 53827208)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	13,913	793	17.5	N/A	N/A	N/A
Project Baseline (2024)	14,513	793	18.3	30.29	-39.6%	No
Model Cumulative Year (2050)	17,639	794	22.2	33.18	-33.0%	No

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 4, the Project VMT/SP for sites 3-7, 9-15 and 24 (TAZ 53827403) would be 23.4% below the threshold under Project Baseline 2024 conditions and 25.5% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of sites 3-7, 9-15 and 24 under the proposed Project would result in a less than significant VMT impact, and no mitigation would be required.

Table 6: VMT Analysis of Project Sites 3-7, 9-15 and 24 (TAZ 53827403)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	96,137	4,198	22.9	N/A	N/A	N/A
Project Baseline (2024)	97,984	4,223	23.2	30.29	-23.4%	No
Model Cumulative Year (2050)	107,586	4,353	24.7	33.18	-25.5%	No

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 5, the Project VMT/SP for site 8 (TAZ 53827403) would be 23.4% below the threshold under Project Baseline 2024 conditions. Since the project is consistent with the GP land use designation, the project would not require a cumulative year analysis. Therefore, buildout of site 8 under the proposed Project would result in a less than significant VMT impact, and no mitigation would be required.

Table 7: VMT Analysis of Project Site 8 (TAZ 53827403)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	96,137	4,198	22.9	N/A	N/A	N/A
Project Baseline (2024)	97,984	4,223	23.2	30.29	-23.4%	No
Model Cumulative Year (2050)	107,586	4,353	24.7	N/A	N/A	N/A

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 6, the Project VMT/SP for site 16 (TAZ 53827501) would be 34.7% below the threshold under Project Baseline 2024 conditions and 44.5% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of site 16 pursuant to the proposed Project would result in a less than significant VMT impact, and no mitigation would be required.

Table 8: VMT Analysis of Project Site 16 (TAZ 53827501)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	91,664	4,571	20.1	N/A	N/A	N/A
Project Baseline (2024)	90,786	4,589	19.8	30.29	-34.7%	No
Model Cumulative Year (2050)	86,221	4,682	18.4	33.18	-44.5%	No

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 7, the Project VMT/SP for sites 17-19 (TAZ 53836401) would be 17.6% below the threshold under Project Baseline 2024 conditions and 9.6% below the threshold under Cumulative Year 2050 conditions. Therefore, buildout of sites 17-19 under the proposed Project would result in a less than significant VMT impact, and no mitigation would be required.

Table 9: VMT Analysis of Project Sites 17-19 (TAZ 53836401)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	42,151	1,762	23.9	N/A	N/A	N/A
Project Baseline (2024)	44,527	1,784	25.0	30.29	-17.6%	No
Model Cumulative Year (2050)	56,879	1,896	30.0	33.18	-9.6%	No

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 8, the Project VMT/SP for sites 20-21 (TAZ 53835402) would be 85.1% above the threshold under Project Baseline 2024 conditions. Since the Project is consistent with the GP land use designation, the project would not require a cumulative year analysis. Therefore, buildout of sites 20 and 21 under the proposed Project would result in a significant VMT impact. Mitigation is discussed in Section 5.

Table 10: VMT Analysis of Project Sites 20-21 (TAZ 53835402)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	53,628	945	56.7	N/A	N/A	N/A
Project Baseline (2024)	55,702	993	56.1	30.29	85.1%	Yes
Model Cumulative Year (2050)	66,487	1,245	53.4	N/A	N/A	N/A

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

As shown in Table 9, the Project VMT/SP for site 23 (TAZ 53835101) would be 8.1% above the threshold under Project Baseline 2024 conditions. Since the project is consistent with the GP land use designation, the project would not require a cumulative year analysis. Therefore, buildout of site 23 under the Project could result in a significant VMT impact. Therefore, future development projects within sites 20, 21, and 23 would be required to conduct a Project-specific VMT screening analysis to determine whether the development would screen out of a further VMT analysis pursuant to Mitigation Measure T-1. Should the development not screen out of a VMT analysis, the project would be required to conduct a full VMT analysis and implement further VMT-reduction measures as feasible. Potential VMT-reduction measures and Mitigation Measures T-1 are discussed in Section 5.

Table 11: VMT Analysis of Project Site 23 (TAZ 53835101)

Scenario	Project VMT	Project service population	Project VMT per service population	Threshold[1]	% above the threshold	Impact?
Model Base Year (2019)	43,164	1,337	32.3	N/A	N/A	N/A
Project Baseline (2024)	43,760	1,337	32.7	30.29	8.1%	Yes
Model Cumulative Year (2050)	46,859	1,337	35.0	N/A	N/A	N/A

[1] Source: SBTAM+, the threshold is calculated based on San Bernardino County's 34.98 VMT/SP for Base Year 2019 and 39.03 VMT/SP for Cumulative Year 2050.

4.4 Project's Effect on Citywide VMT

According to the City's Guidelines, for projects that are inconsistent with the City's General Plan, if the project causes total daily VMT/SP within the City to be higher than the no project scenario under cumulative conditions, the project's effect on VMT would be considered cumulatively significant.

As shown in Table 10, the Redlands Citywide Boundary VMT/SP is 3.1% lower with the project added under cumulative conditions; therefore, the Project's effect on citywide VMT would be considered less than significant.

Table 12: Project's Effect on VMT Results per City's Guidelines

	Cumulative 2050
Citywide Boundary VMT With Project	3,268,701
Citywide Service Population With Project	147,175
With Project Citywide Boundary VMT/SP	**22.21**
Citywide Boundary VMT No Project	3,238,348
Citywide Service Population No Project	141,337
No Project Citywide Boundary VMT/SP	**22.91**
% Above/Below Threshold	-3.1%
Impact?	**No**

5 VMT MITIGATION

5.1 VMT Mitigation Overview

As shown in Tables 8 and 9, sites 20, 21, and 23 located in TAZs 53835402 and 53835101 would result in a significant VMT impact, requiring mitigation. The City's Guidelines state that individual project mitigation measures are recommended to reduce the project specific VMT impacts by implementing Transportation Demand Management (TDM) strategies. The effectiveness of identified TDM strategies is based primarily on research documented in California Air Pollution Control Officers Association (CAPCOA) *Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity* (CAPCOA Guidance).

5.2 VMT Mitigation Measures

This analysis is programmatic in nature, as there is no specific development proposed, and the Project only includes a General Plan amendment, zone change, and specific plan amendments. Therefore, the applicability of specific VMT mitigation measures, and measuring the reduction from VMT mitigation measures, cannot be feasibly determined at this time for site specific VMT impacts. Therefore, the following measures discussed in this section are recommendations for future projects located at sites 20, 21, and 23 to consider.

The applicability of every CAPCOA VMT reduction measure to the Project is shown in Table 11. The supporting documentation for each applicable measure is included in Appendix B.

Table 13: CAPCOA VMT Reduction Measures

Mitigation		Applicable to Project?	Justification
Land Use Measures			
T-1	Increase Residential Density	Yes	Feasible
T-2	Increase Job Density	No	Address Employee Commute Trips
T-3	Provide Transit Oriented Development	No	Not in a TPA.
T-4	Integrate Affordable and Below Market Rate Housing	Yes	Feasible
T-17	Improve Street Connectivity	No	Ineffective at Project Scale
Trip Reduction Programs			
T-5	Implement Commute Trip Reduction Program (Voluntary)	No	Address Employee Commute Trips
T-6	Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)	No	Address Employee Commute Trips
T-7	Implement Commute Trip Reduction Marketing	Yes	Feasible through an HOA
T-8	Provide Ridership Program	Yes	Feasible through an HOA

Mitigation		Applicable to Project?	Justification
T-9	Implement Subsidized or Discounted Transit Program	Yes	Feasible through an HOA
T-10	Provide End-of-Trip Bicycle Facilities	No	Address Employee Commute Trips
T-11	Provide Employer-Sponsored Vanpool	No	Address Employee Commute Trips
T-12	Price Workplace Parking	No	Address Employee Commute Trips
T-13	Implement Employee Parking Cash-Out	No	Address Employee Commute Trips
T-23	Provide Community-Based Travel Planning	Yes	Feasible through an HOA
Parking or Road Pricing/Management			
T-14	Provide Electric Vehicle Charging Infrastructure	No	Does not Reduce VMT
T-15	Limit Residential Parking Supply	Yes	Feasible
T-16	Unbundle Residential Parking Costs from Property Cost	Yes	Feasible
T-24	Implement Market Price Public Parking (On-Street)	Yes	Feasible
Neighborhood Design			
T-18	Provide Pedestrian Network Improvement	Yes	Feasible
T-19-A	Construct or Improve Bike Facility	Yes	Feasible
T-19-B	Construct or Improve Bike Boulevard	Yes	Feasible
T-20	Expand Bikeway Network	Yes	Feasible
T-21-A	Implement Conventional Carshare Program	Yes	Feasible
T-21-B	Implement Electric Carshare Program	Yes	Feasible
T-22-A	Implement Pedal (Non-Electric) Bikeshare Program	Yes	Feasible
T-22-B	Implement Electric Bikeshare Program	Yes	Feasible
T-22-C	Implement Scooter share Program	Yes	Feasible
Transit			
T-25	Extend Transit Network Coverage or Hours	No	Ineffective at Project Scale
T-26	Increase Transit Service Frequency	No	Ineffective at Project Scale
T-27	Implement Transit-Supportive Roadway Treatments	Yes	Feasible
T-28	Provide Bus Rapid Transit	No	Ineffective at Project Scale
T-29	Reduce Transit Fares	No	Ineffective at Project Scale
Clean Vehicles and Fuels			
T-30	Use Cleaner-Fuel Vehicles	No	Does not Reduce VMT

As shown in Table 11, out of 34 VMT reduction measures, 19 would apply to the project. The remaining 15 measures would not apply for the following reasons:

- **Not in a TPA:** One measure (T-3) is only applicable to projects that are within a 10-minute walk (0.5 mile) of a high frequency transit station. The site closest to a high frequency transit station is site 20, which is 1 mile away from the Redlands - Esri Metrolink Station, outside the 0.5-mile distance to qualify.
- **Not VMT Reducing:** Two measures (T-14 & T-30) could reduce greenhouse gas (GHG) emissions but would not result in a measurable reduction in VMT and therefore are not considered applicable to the Project.
- **Address Employee Commute Trips:** Seven measures (T-2, T-5, T-6, T-10, T-11, T-12 and T-13) are intended to reduce employee commute trips and would be implemented by employers. Sites 20-21 and 23 are residential and would not involve substantial employee commute trips to these sites; therefore, making these measures infeasible or ineffective.
- **Ineffective at Project Scale:** Five measures (T-17, T-25, T-26, T-28 and T-29) are appropriate to projects that are a plan scale (i.e., specific plan, corridor, or entire municipality). The Project proposes land use changes to provide more housing opportunities; however, it is not at a large enough scale to effectively implement Transit and Roadway network improvements that would reduce the project level impact identified for sites 20, 21 and 23. Therefore, these measures would not be effective in reducing VMT for a project size as proposed.

The remaining 19 mitigation measures have been identified to be potentially applicable to future development projects in the Project sites 20, 21, and 23.

Mitigation Measure T-1:

Prior to approval of any site plan, any applicant for an implementing project fully within or partially within sites 20, 21, or 23 shall prepare a VMT Screening Analysis pursuant to the City of Redlands CEQA Assessment VMT Analysis Guidelines and provide this analysis to the City of Redlands Planning Division and Engineering Division. The VMT Screening Analysis shall demonstrate that the implementing project meets the screening criteria set forth in in the City of Redlands CEQA Assessment VMT Analysis Guidelines.

If the implementing project does not meet the screening criteria set forth in Screening Criterion 1, 2, 3, or 4, the implementing project applicant shall prepare a VMT analysis pursuant to the City of Redlands CEQA Assessment VMT Analysis Guidelines. For projects with VMT per Service Population exceeding the City's significance thresholds, a mitigation plan shall be developed and implemented. Mitigation should consist of Transportation Demand Management (TDM) measures analyzed under a VMT-reduction methodology consistent with the California Air Pollution Control Officers Association's (CAPCOA) Final Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity (2021) and approved by the City of Redlands. Examples of measures include but are not limited to:

- **CAPCOA Measure T-1 Increase Residential Density:** Higher residential density encourages mixed-use development and reduces sprawl. Placing more people closer to amenities, workplaces, and public transit decreases the distance people need to travel for daily activities, thereby reducing overall VMT.

- **CAPCOA Measure T-4 Integrate Affordable and Below Market Rate (BMR) Housing:** BMR housing provides greater opportunity for lower income families to live closer to job centers and achieve a jobs/housing match near transit and can decrease the VMT generated by the project.
- **CAPCOA Measure T-7 Implement Commute Trip Reduction Marketing:** Information sharing and marketing promote and educate workers about their travel choices to the employment location beyond driving such as carpooling, taking transit, walking, and biking, thereby reducing VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-8 Provide Ridesharing Program:** Ridesharing encourages carpooled vehicle trips in place of single-occupied vehicle trips, thereby reducing the number of trips, VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-9 Implement Subsidized or Discounted Transit Program:** Reducing the out-of-pocket cost for choosing transit improves the competitiveness of transit against driving, increasing the total number of transit trips and decreasing vehicle trips. This decrease in vehicle trips results in reduced VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-15 Limit Residential Parking Supply:** The reduction in VMT that can be achieved by limiting the total parking supply available at a residential project. When parking is limited, scarcity is created, and additional time and inconvenience is added to trips made by private auto. The reduction in the convenience of driving results in a shift to other modes and can decrease the VMT generated by the project.
- **CAPCOA Measure T-16 Unbundle Residential Parking Costs from Property Cost:** Parking costs are passed through to the vehicle owners/drivers utilizing the parking spaces, this measure results in decreased vehicle ownership and, therefore, a reduction in VMT.
- **CAPCOA Measure T-18 Provide Pedestrian Network Improvement:** Providing sidewalks and an enhanced pedestrian network encourages people to walk instead of drive. This mode shift results in a reduction in VMT.
- **CAPCOA Measure T-19-A Construct or Improve Bike Facility:** Building or enhancing bike facilities such as dedicated bike lanes, secure parking, and bike-sharing programs promotes cycling as a convenient and safe transportation option. This reduces the number of short-distance car trips, contributing to lower VMT.
- **CAPCOA Measure T-19-B Construct or Improve Bike Boulevard:** Bike boulevards are designed to prioritize cyclists by providing dedicated lanes and traffic calming measures. By creating safer and more attractive cycling routes, bike boulevards encourage residents to use bicycles for commuting and local trips, thereby reducing VMT.
- **CAPCOA Measure T-20 Expand Bikeway Network:** Expanding the bikeway network connects different parts of the community with safe and accessible bike routes. This infrastructure improvement makes cycling a more practical choice for daily transportation needs, reducing reliance on motor vehicles and lowering VMT.
- **CAPCOA Measure T-21-A Implement Conventional Carshare Program:** Conventional carshare programs provide access to vehicles on a short-term basis. By promoting shared vehicle usage, particularly for occasional trips, they reduce the need for individual car ownership and decrease VMT.
- **CAPCOA Measure T-21-B Implement Electric Carshare Program:** Electric carshare programs offer access to EVs for shared use. Providing convenient access to environmentally friendly transportation

options encourages residents and employees to choose EVs over traditional vehicles, thus lowering VMT and emissions.

- **CAPCOA Measure T-22-A Implement Pedal (Non-Electric) Bikeshare Program:** Pedal bikeshare programs make bicycles readily available for short trips. Offering an alternative to driving for local transportation needs reduces congestion and lowers VMT.
- **CAPCOA Measure T-22-B Implement Electric Bikeshare Program:** Electric bikeshare programs provide access to electric-assisted bicycles. These bikes make cycling more accessible to a broader range of users and encourage more trips to be taken by bike instead of by car, contributing to reduced VMT.
- **CAPCOA Measure T-22-C Implement Scooter Share Program:** Scooter share programs offer electric scooters for short-distance trips. By providing a convenient alternative to driving for short trips within the community, scooter share programs reduce the number of car trips and help decrease VMT.
- **CAPCOA Measure T-23 Provide Community-Based Travel Planning (CBTP):** CBTP is a residential-based approach to outreach that provides households with customized information, incentives, and support to encourage the use of transportation alternatives in place of single occupancy vehicles, thereby reducing household VMT. This could be implemented through an HOA.
- **CAPCOA Measure T-24 Implement Market Price Public Parking (On-Street):** Increasing the cost of parking increases the total cost of driving to a location, incentivizing shifts to other modes and thus decreasing total VMT to and from the priced areas.
- **CAPCOA Measure T-27 Implement Transit-Supportive Roadway Treatments:** Transit-supportive treatments incorporate a mix of roadway infrastructure improvements and/or traffic signal modifications to improve transit travel times and reliability. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT.

Since there is not enough information available to appropriately analyze the reduction in VMT at this time, no credit was taken for the identified mitigation measure, and the Project would have a significant and unavoidable project level VMT impact.

APPENDIX A – SCOPE OF WORK

Date:	May 6, 2024
Prepared by:	Simon Lin, Alex J. Garber, EPD Solutions Inc
To:	City of Redlands-Community Development Department
Site:	Redlands RHNA Rezone
Subject:	**Vehicle Miles Traveled Scope of Work for Redlands RHNA Rezone Project**

This memo outlines the proposed scope of work for the Vehicle Miles Traveled (VMT) Analysis for the proposed Redlands RHNA Rezone Project (Project). The Project description and proposed scope of work is discussed in detail below. The City of Redlands City Council adopted *the City of Redlands CEQA Assessment VMT Analysis Guidelines* (City Guidelines) on July 21, 2020. Please note that this VMT analysis will be based on the requirements of the adopted City Guidelines.

Project Location

The proposed Project consists of 27 total Rezone Sites (Rezone Sites 1 through 24). Sites 1 through 16A and 24 are located south of Citrus Avenue and are within the EVCSP. Sites 17 through 24 are located 0.25 miles east of SR-210, just south of West San Bernardino Avenue. Figure 1 shows the location of the Project Site.

Project Description

The Housing Element identifies the Project Sites as having a capacity of up to 2,436 housing units and assumes that implementation of residential development within the Project Sites would occur through the year 2035. The Project proposes the development of 2,436 housing units and 151,048.46 square feet (SF) of Public/Institutional development, to replace the existing general plan land use of 1,743,270.9 SF of Commercial/Industrial use, 552,340.8 SF of Commercial/Admin Professional use, and 111 housing units.

Table 1 lists the existing and proposed General Plan land use designation, zoning, and buildout of the 24 sites. All sites, with the exception of Site 8, 20, 21, 22, 23 and 24, would require a GPA to change the land use designations from Commercial/Industrial or Commercial/Admin Professional to Medium Density Residential (MDR) or High-Density Residential (HDR) land uses. The site would have an allowed density of either 15 or 30 dwelling units per acre (DU/acre), respectively. Sites 8, 20, 21, 22 and 23 would maintain their existing Land Use designation and propose a higher housing density than what is proposed by the existing zoning. Site 24 would require a GPA to change the land use designation from Commercial/Industrial to Public/Institutional. The breakdown of each existing land use is listed as follows:

- Site 1-7, 9-16, 24 (existing)
  - 871,635.45 SF of warehouse
  - 871,635.45 SF of retail
- Site 17-19 (existing):
  - 276,170.4 SF of office
  - 276,170.4 SF of retail
- Sites 8, 20, 21, 22, 23 (existing):
  - 111 multi-Family housing units

Project Trip Generation

The project trip generation was calculated using trip rates from the Institute of Transportation Engineers, *Trip Generation 11th Edition*, 2021. The ITE Land Use rates for Warehouse (ITE Land Use Code 150), Multifamily Housing (Mid-Rise) (ITE Land Use Code 221), Daycare Center (ITE Land Use Code 565), General Office Building (ITE Land Use Code 710), Shopping Center(>150k) (ITE Land Use Code 820) were utilized due to the size of the commercial land use and the density of the housing units. As indicated in Table 2, the Project is estimated to generate approximately 29,216 fewer (negative 29,216) daily trips, including 990 new trips during the AM peak hour and 1,871 fewer (negative 1,871) trips during the PM peak hour.

Figure 1: Project Site

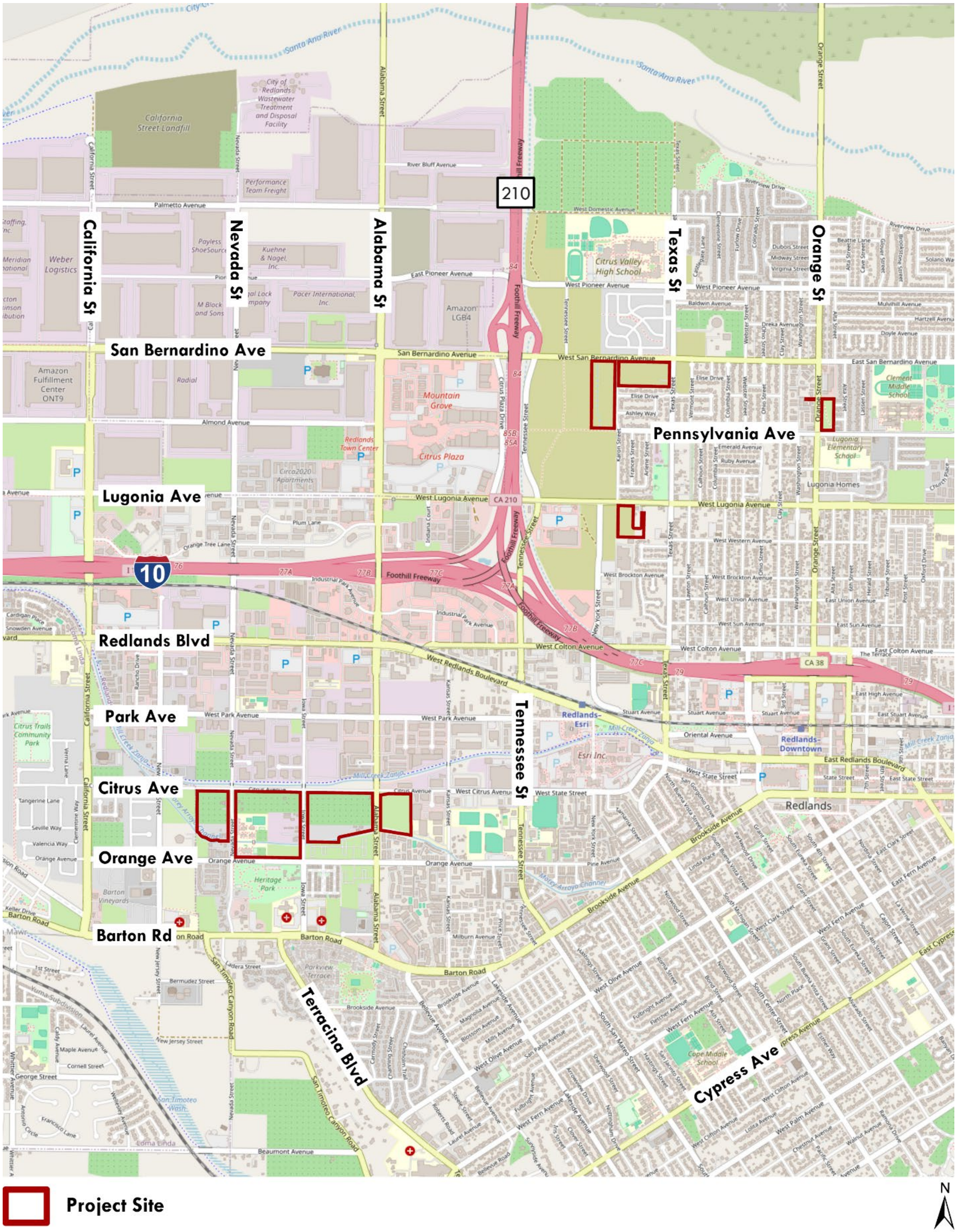


Table 1: Proposed General Plan Buildout

Site Number	Existing General Plan Land Use Designation	Existing General Plan Zoning	Proposed GP Land Use Designation	Proposed Zoning	Proposed Density (DU/acre)	Proposed Maximum Buildout (DU)
1	Commercial/Industrial	EV/IC	MDR	R-2	15	133
2	Commercial/Industrial	EV/IC	MDR	R-2	15	63
3	Commercial/Industrial	EV/IC	HDR	R-3	30	175
4	Commercial/Industrial	EV/IC	HDR	R-3	30	94
5	Commercial/Industrial	EV/IC	HDR	R-3	30	32
6	Commercial/Industrial	EV/IC	HDR	R-3	30	57
7	Commercial/Industrial	EV/IC	HDR	R-3	30	57
8	MDR	EV3000RM	MDR	EV2500RM	15	61
9	Commercial/Industrial	EV/IC	HDR	R-3	30	75
10	Commercial/Industrial	EV/IC	HDR	R-3	30	120
10A	Commercial/Industrial	EV/IC	MDR	R-3	30	2
11	Commercial/Industrial	EV/IC	MDR	R-2	30	70
12	Commercial/Industrial	EV/IC	MDR	R-2	30	34
13	Commercial/Industrial	EV/IC	HDR	R-3	30	141
14	Commercial/Industrial	EV/IC	HDR	R-3	30	126
15	Commercial/Industrial	EV/IC	HDR	R-3	30	265
15A	Commercial/Industrial	EV/IC	HDR	R-3	30	1
16	Commercial/Industrial	EV/IC	MDR	R-2	30	159
16A	Commercial/Industrial	EV/IC	MDR	R-2	15	0
17	Commercial/Admin. Professional	CP-4	MDR	R-2	15	210
18	Commercial/Admin. Professional	CP-4	HDR	R-3	30	150
19	Commercial/Admin. Professional	CP-4	HDR	R-3	30	189
20	MDR	A-1	MDR	R-2	15	71
21	MDR	R-1	MDR	R-2	15	24
22	HDR	R-2	HDR	R-3	27	9
23	HDR	R-2	HDR	R-3	27	118
24	Commercial/Industrial	EV/IC	Public/Institutional (PI)	EV/IP	0.5 Floor Area Ratio (FAR)	151,048.46 SF
Total						**2,436**

Table 2: Project Trip Generation

	Land Use	ITE Code[1]	Unit[2]	ITE Daily Trip Rate/Unit	Project Size	Project ADTs	ITE AM Trip Rate/Unit	Project AM Trips	ITE PM Trip Rate/Unit	Project PM Trips
Existing Zoning (Baseline)	Warehouse (Site 1-7, 9-16, 24)	150	KSF	1.71	-871.63545	(1,490)	0.17	(148)	0.18	(157)
	Passenger Vehicles	64.9%				(967)		(96)		(102)
	2-Axle truck	7.7%				(115)		(11)		(12)
	3-Axle truck	6.2%				(93)		(9)		(10)
	4+-Axle Trucks	21.2%				(315)		(31)		(33)
	Retail (Site 1-7, 9-16, 24)	820	KSF	37.01	-871.63545	(32,259)	0.84	(732)	3.40	(2,964)
	Multi-Family Housing (Sites 8, 20, 21, 22,23)	221	DU	4.54	-111	(504)	0.37	(41)	0.39	(43)
	Office (Site 17-19)	710	KSF	10.84	-276.1704	(2,994)	1.52	(420)	1.44	(398)
	Retail (Site 17-19)	820	KSF	37.01	-276.1704	(10,221)	0.84	(232)	3.40	(939)
Existing Zoning (Baseline) TOTAL TRIPS						**(47,468)**		**(1,573)**		**(4,500)**
Proposed RHNA Zoning (Project)	Multi-Family Housing	221	DU	4.54	2436	11,059	0.37	901	0.39	950
	Daycare Center	565	KSF	47.62	151.04846	7,193	11.00	1662	11.12	1680
Proposed Project TOTAL TRIPS						**18,252**		**2,563**		**2,630**
Existing Zoning + Proposed RHNA Zoning (Total) TOTAL TRIPS						**(29,216)**		**990**		**(1,871)**

[1]Trip rates & truck % from the Institute of Transportation Engineers (ITE), Trip Generation Manual,11th Edition, 2021.
Truck axle split from the SCAQMD Warehouse (Composite) Truck Trip Study Data Results and Usage, July 17, 2014.

[2]KSF=Thousand Square Feet, DU= Dwelling Units

Vehicle Miles Traveled Screening

Based on City Guidelines, if a project meets any of the following criteria, then the VMT impact of the project would be considered less than significant, and no further VMT analysis would be required:

1. Transit Priority Areas (TPA) Screening
2. Low VMT Area Screening
3. Project Type Screening

EPD will review applicability of the criteria to the Project programmatically, as details of the actual development of the residential and public/institutional uses are not known at this time. The applicability of the three criteria to each individual site will be discussed, however, Project specific analysis will be done at the time physical development is proposed. A cumulative analysis for VMT will be done for the Project.

Modeling Methodology

The Project will conduct the VMT analysis and roadway volumes forecast using the San Bernardino Transportation Analysis Model (SBTAM). The following tasks will be required to prepare the VMT analysis:

1. EPD will modify the socio-economic data (SED) of the SBTAM to enter the Project's population and household data into the existing TAZs and remove employment from existing TAZs, based on the conversion factors shown in Table 3 below. The average household occupancy for the city of Redlands is also shown in Table 3. Two full model runs will be prepared to evaluate the base year 2016 and cumulative year 2040 VMT with the Project.

Table 3: Model Land Use Conversion Factors

Land Use Type	Average Square Feet per Employee
Regional Retail[1]	1,009
R & D/Flex Space[1]	834
Warehouse[1]	1,195
Low-Rise Office[1]	697
Household[2]	2.6 persons per household

[1]Source: Employment Density Study Summary Report by SCAG, October 31, 2001
[2]Source: SBTAM 2040

2. The SBTAM model roadway network was reviewed by EPD, and no adjustments are deemed necessary for the base year 2016 or the cumulative year 2040 network.

3. Based on the Guidelines, the Project-effect on VMT will be evaluated by calculating the Citywide link-level VMT/service population for without and with project conditions. The project is considered to have a significant impact if VMT/service population is increased under project conditions when compared to the no project condition.

4. If a significant VMT impact is identified, EPD will identify appropriate mitigation measures such as change in the Project description, transportation demand management (TDM) measures, or participation in an impact fee and/or exchange program (if any applicable to the Project) to reduce VMT to achieve acceptable levels.

We appreciate your review of this information. Upon completion of your review, please forward any comments or approval of this methodology to techservices@epdsolutions.com. If you have any questions, please do not hesitate to contact us by e-mail or at (949) 794-1180.

City Approval of Scope of Work:

Kevin Beery

Signature

Kevin Beery

Name

5/21/2024

Date

APPENDIX B – SUPPORTING DOCUMENTATION FOR VMT MITIGATION

T-1. Increase Residential Density

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased density can put people closer to resources they may need to access during an extreme weather event. Increased density can also shorten commutes, decreasing the amount of time people are on the road and exposed to hazards such as extreme heat or flooding.

Health and Equity Considerations

Neighborhoods should include different types of housing to support a variety of household sizes, age ranges, and incomes.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of dwelling units (du) compared to the average residential density in the U.S. Increased densities affect the distance people travel and provide greater options for the mode of travel they choose. Increasing residential density results in shorter and fewer trips by single-occupancy vehicles and thus a reduction in GHG emissions. This measure is best quantified when applied to larger developments and developments where the density is somewhat similar to the surrounding area due to the underlying research being founded in data from the neighborhood level.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is most accurately quantified when applied to larger developments and/or developments where the density is somewhat similar to the surrounding neighborhood.

Cost Considerations

Depending on the location, increasing residential density may increase housing and development costs. However, the costs of providing public services, such as health care, education, policing, and transit, are generally lower in more dense areas where things are closer together. Infrastructure that provides drinking water and electricity also operates more efficiently when the service and transmission area is reduced. Local governments may provide approval streamlining benefits or financial incentives for infill and high-density residential projects.

Expanded Mitigation Options

When paired with Measure T-2, *Increase Job Density*, the cumulative densification from these measures can result in a highly walkable and bikeable area, yielding increased co-benefits in VMT reductions, improved public health, and social equity.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–30.0	%	calculated
User Inputs				
B	Residential density of project development	[ ]	du/acre	user input
Constants, Assumptions, and Available Defaults				
C	Residential density of typical development	9.1	du/acre	Ewing et al. 2007
D	Elasticity of VMT with respect to residential density	-0.22	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The residential density of typical development is based on the blended average density of residential development in the U.S. forecasted for 2025. This estimate includes apartments, condominiums, and townhouses, as well as detached single-family housing on both small and large lots. An acre in this context is defined as an acre of developed land, not including streets, school sites, parks, and other undevelopable land. If reductions are being calculated from a specific baseline derived from a travel demand forecasting model, the residential density of the relevant transportation analysis zone should be used instead of the value for a typical development.
- (D) – A meta-regression analysis of five studies that controlled for self-selection found that a 0.22 percent decrease in VMT occurs for every 1 percent increase in residential density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose for the 30 percent cap is to limit the influence of any single built environmental factor (such as density). Projects that implement multiple land use strategies (e.g., density, design, diversity) will show more of a reduction than relying on improvements from a single built environment factor.

Subsector Maximum

($\sum A_{max_{T\text{-}1\ through\ T\text{-}4}} \leq 65\%$) This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by increasing the residential density of the project study area. In this example, the project's residential density would be 15 du per acre (B), which would reduce GHG emissions from project VMT by 14.2 percent.

$$A = \frac{15\ \frac{du}{ac} - 9.1\ \frac{du}{ac}}{9.1\ \frac{du}{ac}} \times -0.22 = -14.2\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Ewing, R., K. Bartholomew, S. Winkelman, J. Walters, and D. Chen. 2007. *Growing Cooler: The Evidence on Urban Development and Climate Change*. October. Available: https://www.nrdc.org/sites/default/files/cit_07092401a.pdf. Accessed: January 2021.
- Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Available: https://www.researchgate.net/publication/309890412_Does_Compact_Development_Make_People_Drive_Less. Accessed: January 2021.

T-2. Increase Job Density

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased density can put people closer to resources they may need to access during an extreme weather event. Increased density can also shorten commutes, decreasing the amount of time people are on the road and exposed to hazards such as extreme heat or flooding.

Health and Equity Considerations

Increased job density may increase nearby housing prices. Jurisdictions should consider the jobs-housing balance and consider measures to reduce displacement and increase affordable housing.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of jobs compared to the average job density in the U.S. Increased densities affect the distance people travel and provide greater options for the mode of travel they choose. Increasing job density results in shorter and fewer trips by single-occupancy vehicles and thus a reduction in GHG emissions.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is most accurately quantified when applied to larger developments and/or developments where the density is somewhat similar to the surrounding neighborhood.

Cost Considerations

Areas with increased job density generally have higher economic gross metropolitan product (GMP) and job growth. Prosperity, measured as GMP per job, also grows faster in areas with increased job density. Decreased commute times and car use may also generate funds for public transit and reduce the need for infrastructure spending on road maintenance.

Expanded Mitigation Options

When paired with Measure T-1, *Increase Residential Density*, the cumulative densification from these measures can result in a highly walkable and bikeable area, yielding increased co-benefits in VMT reductions, improved public health, and social equity.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–30.0	%	calculated
User Inputs				
B	Job density of project development	[ ]	jobs per acre	user input
Constants, Assumptions, and Available Defaults				
C	Job density of typical development	145	jobs per acre	ITE 2020
D	Elasticity of VMT with respect to job density	-0.07	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The jobs density is based on the calculated density of a development with a floor-area ratio of 1.0 and 300 square feet (sf) of building space per employee:

  $$\frac{43{,}560\ \frac{sf}{acre}}{300\ \frac{sf}{employee}} \times 1.0\frac{sf}{acre} = 145\frac{employees}{acre}$$

  If reductions are being calculated from a specific baseline derived from a travel demand forecasting model, the job density of the relevant transportation analysis zone should be used for this variable instead of the default value presented above.
- (D) – A meta-regression analysis of two studies that controlled for self-selection found that a 0.07 percent decrease in VMT occurs for every 1 percent increase in job density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose for the 30 percent cap is to limit the influence of any single built environmental factor (such as density). Projects that implement multiple land use strategies (e.g., density, design, diversity) will show more of a reduction than relying on improvements from a single built environment factor.

Subsector Maximum

$(\sum A_{max_{T\text{-}1\ \text{through}\ T\text{-}4}} \leq 65\%)$ This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by increasing the job density of the project study area. In this example, the project's job density would be 400 jobs per acre (B), which would reduce GHG emissions from project VMT by 12.3 percent.

$$A = \frac{400\ \frac{\text{job}}{\text{acre}} - 145\ \frac{\text{job}}{\text{acre}}}{145\ \frac{\text{job}}{\text{acre}}} \times \text{-}0.07 = \text{-}12.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Institute of Transportation Engineers (ITE). *Trip Generation Manual.* 10th Edition. Available: https://www.ite.org/technical-resources/topics/trip-and-parking-generation/trip-generation-10th-edition-formats/. Accessed: January 2021.
- Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Available: https://www.researchgate.net/publication/309890412_Does_Compact_Development_Make_People_Drive_Less. Accessed: January 2021.

T-3. Provide Transit-Oriented Development

GHG Mitigation Potential

31%

Up to 31.0% of GHG emissions from project VMT in study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing TOD puts a large number of people close to reliable public transportation, diversifying their transportation options during an extreme weather event.

Health and Equity Considerations

TOD may increase housing prices, leading to gentrification and displacement. Please refer to the *Accountability and Anti-Displacement and Housing* section in Chapter 5, *Measures for Advancing Health and Equity*, for potential strategies to minimize disruption to existing residents. TOD coupled with affordable housing options can help to support equity by helping to lower transportation costs for residents and increase active mobility.

Measure Description

This measure would reduce project VMT in the study area relative to the same project sited in a non-transit-oriented development (TOD) location. TOD refers to projects built in compact, walkable areas that have easy access to public transit, ideally in a location with a mix of uses, including housing, retail offices, and community facilities. Project site residents, employees, and visitors would have easy access to high-quality public transit, thereby encouraging transit ridership and reducing the number of single-occupancy vehicle trips and associated GHG emissions.

Subsector

Land Use

Locational Context

Urban and suburban. Rural only if adjacent to commuter rail station with convenient rail service to a major employment center.

Scale of Application

Project/Site

Implementation Requirements

To qualify as a TOD, the development must be a residential or office project that is within a 10-minute walk (0.5 mile) of a high frequency transit station (either rail, or bus rapid transit with headways less than 15 minutes). Ideally, the distance should be no more than 0.25 to 0.3 of a mile but could be up to 0.5 mile if the walking route to station can be accessed by pedestrian-friendly routes. Users should confirm “unmitigated” or “baseline” VMT does not already account for reductions from transit proximity.

Cost Considerations

TOD reduces car use and car ownership rates, providing cost savings to residents. It can also increase property values and public transit use rates, providing additional revenue to municipalities, as well as open new markets for business development. Increased transit use will likely necessitate increased spending on maintaining and improving public transit systems, the costs of which may be high.

Expanded Mitigation Options

When building TOD, a best practice is to incorporate bike and pedestrian access into the larger network to increase the likelihood of transit use.

GHG Reduction Formula

$$A = \frac{(B \times C)}{-D}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	6.9–31.0	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Transit mode share in surrounding city	Table T-3.1	%	FHWA 2017a
C	Ratio of transit mode share for TOD area with measure compared to existing transit mode share in surrounding city	4.9	unitless	Lund et al. 2004
D	Auto mode share in surrounding city	Table T-3.1	%	FHWA 2017b

Further explanation of key variables:

- (B and D) – Ideally, the user will calculate transit and auto mode share for a Project/Site at a scale no larger than a census tract. Ideally, variables B and D will reflect travel behavior in locations that are *not* already within 0.5 mile of a high-quality transit stop and may instead substitute data from nearby tracts further from transit if such locations exist. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode share for one of the six most populated core-based statistical areas (CBSAs) in California, as presented in Table T-3.1 in Appendix C, *Emission Factors and Data Tables*. Transit mode share is likely to be smaller for areas not covered by the listed CBSAs, which represent the most transit-accessible areas of the state. Conversely, auto mode share is likely to be larger.
- (C) – A study of people living in TODs in California found that, on average, transit shares for TOD residents exceed the surrounding city by a factor of 4.9 (Lund et al. 2004).

GHG Calculation Caps or Maximums

Measure Maximum

($(B \times C)_{max}$) The transit mode share in the project study area with the measure is capped at 27 percent. This is based on the weighted average transit commute mode share of five surveyed sites in California where residents lived within 3 miles of rail stations (Lund et al. 2004). As transit mode share is typically higher for commute trips compared to all trips, 27 percent represents a reasonable upper bound for expected transit mode share in a TOD area. Projects in the CBSAs of San Francisco-Oakland-Hayward and San Jose-Sunnyvale-Santa Clara would have their transit mode share capped at 27 percent in the formula.

(A_{max}) For projects that use default CBSA data from Table T-3.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 31.0 percent. This is based on a project in the CBSA of San Francisco-Oakland-Hayward with a transit mode share that reaches the cap $((B \times C)_{max})$. This maximum scenario is presented in the below example quantification.

Subsector Maximum

$(\sum A_{max_{T\text{-}1 \text{ through } T\text{-}4}} \leq 65\%)$ This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by locating their project in a TOD location. Project site residents, employees, and visitors would have easy access to high-quality public transit, thereby encouraging transit use and reducing single occupancy vehicle travel. In this example, the project is within the San Jose-Sunnyvale-Santa Clara CBSA with an existing transit mode share (B) of 6.69 percent. Applying a 4.9 ratio of transit mode share for TOD area with the measure compared to existing transit mode share in the surrounding city yields 33 percent, which exceeds the 27 percent cap $((B \times C)_{max})$. Therefore, 27 percent is used to define $(B \times C)$. The existing vehicle mode share is 86.96 percent (D). The user would reduce GHG emissions from project study area VMT (as compared to the same project in a non-TOD location) by 31 percent.

$$A = \frac{27\%}{-86.96\%} = -31\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration. 2017a. *National Household Travel Survey–2017 Table Designer. Travel Day PMT by TRPTRANS by HH_CBSA*. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration. 2017b. *National Household Travel Survey – 2017 Table Designer. Average Vehicle Occupancy by HHSTFIPS*. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Lund, H., R. Cervero, and R. Wilson. 2004. *Travel Characteristics of Transit-Oriented Development in California*. January. Available: https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-lund-cerv-wil.pdf. Accessed: January 2021.

T-4. Integrate Affordable and Below Market Rate Housing

GHG Mitigation Potential

28.6%

Up to 28.6% of GHG emissions from project/site multifamily residential VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing affordable housing creates the opportunity for a greater diversity of people to be closer to their desired destinations and the resources they may need to access during an extreme weather event. Close proximity to destinations allows for more opportunities to use active transportation and transit and to be less reliant on private vehicles. Alleviating the housing-cost burden also enables more people to remain housed, and increases people's capacity to respond to disruptions, including climate impacts.

Health and Equity Considerations

Neighborhoods should include different types of housing to support a variety of household sizes, age ranges, abilities, and incomes.

Measure Description

This measure requires below market rate (BMR) housing. BMR housing provides greater opportunity for lower income families to live closer to job centers and achieve a jobs/housing match near transit. It is also an important strategy to address the limited availability of affordable housing that might force residents to live far away from jobs or school, requiring longer commutes. The quantification method for this measure accounts for VMT reductions achieved for multifamily residential projects that are deed restricted or otherwise permanently dedicated as affordable housing.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Multifamily residential units must be permanently dedicated as affordable for lower income families. The California Department of Housing and Community Development (2021) defines lower-income as 80 percent of area median income or below, and affordable housing as costing 30 percent of gross household income or less.

Cost Considerations

Depending on the source of the affordable subsidy, BMR housing may have implications for development costs but would also have the benefit of reducing costs for public services, similar to Measure T-1, *Increase Residential Density*.

Expanded Mitigation Options

Pair with Measure T-1, *Increase Residential Density*, and Measure T-2, *Increase Job Density*, to achieve greater population and employment diversity.

GHG Reduction Formula

A = **B** × C

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from Project/Site VMT for multifamily residential developments	0–28.6	%	calculated
User Inputs				
B	Percent of multifamily units permanently dedicated as affordable	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in VMT for qualified units compared to market rate units	-28.6	%	ITE 2021

Further explanation of key variables:

- (B) – This refers to percent of multifamily units in the project that are deed restricted or otherwise permanently dedicated as affordable.
- (C) – The 11th Edition of the *ITE Trip Generation Manual* (ITE 2021) contains daily vehicle trip rates for market rate multifamily housing that is low-rise and not close to transit (ITE code 221) as well as affordable multifamily housing (ITE code 223). While these rates do not account for trip length, they serve as a proxy for the expected difference in vehicle trip generation and VMT generation presuming similar trip lengths for both types of land use. If the user has information about trip length differences between market rate and affordable housing, then adjusting the percent reduction accordingly is recommended.

  Users should note that the ITE trip rate estimates are based on a small sample of studies for the affordable housing rate and that no stratification of affordable housing by number of stories was available. This is an important distinction since the multifamily low-rise vehicle trip rate applies to four or fewer stories. Therefore, this measure may not apply to affordable housing projects with more than four stories.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 28.6 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}1\ through\ T\text{-}4}} \leq 65\%$) This measure is in the Land Use subsector. This subsector includes Measures T-1 through T-4. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces project VMT by requiring a portion of the multifamily residential units to be permanently dedicated as affordable. In this example, the percent of units (B) is 100 percent, which would reduce GHG emissions from VMT by 28.6 percent.

$$A = \mathbf{100\%} \times -28.6\% = -28.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

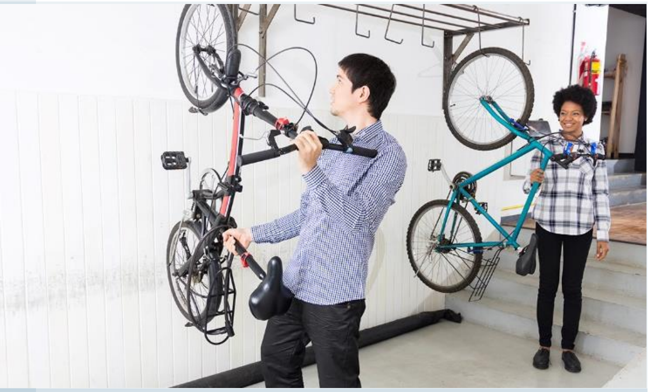
VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- California Department of Housing and Community Development. 2021. *Income Limits*. Available: https://www.hcd.ca.gov/grants-funding/income-limits/index.shtml#:~:text=%E2%80%9CAffordable%20housing%20cost%E2%80%9D%20for%20lower,of%20gross%20income%2C%20with%20variations. Accessed; November 2021.
- Institute of Transportation Engineers (ITE). 2021. *Trip Generation Manual*. 11th Edition. Available: https://www.ite.org/technical-resources/topics/trip-and-parking-generation/. Accessed; November 2021.

T-5. Implement Commute Trip Reduction Program (Voluntary)



GHG Mitigation Potential

4%

Up to 4.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

CTR programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs need to ensure equitable access and benefits to all employees are provided considering disparate existing mobility options in diverse communities.

Measure Description

This measure will implement a voluntary commute trip reduction (CTR) program with employers. CTR programs discourage single-occupancy vehicle trips and encourage alternative modes of transportation such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions. Voluntary implementation elements are described in this measure.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Voluntary CTR programs must include the following elements to apply the VMT reductions reported in literature.

- Employer-provided services, infrastructure, and incentives for alternative modes such as ridesharing (Measure T-8), discounted transit (Measure T-9), bicycling (Measure T-10), vanpool (Measure T-11), and guaranteed ride home.
- Information, coordination, and marketing for said services, infrastructure, and incentives (Measure T-7).

Cost Considerations

Employer costs may include recurring costs for transit subsidies, capital and maintenance costs for the alternative transportation infrastructure, and labor costs for staff to manage the program. Where the local municipality has a VMT reduction ordinance, costs may include the labor costs for government staff to track the efficacy of the program.

Expanded Mitigation Options

Other strategies may also be included as part of a voluntary CTR program, though they are not included in the VMT reductions reported by literature and thus are not incorporated in the VMT reductions for this measure.

This program typically serves as a complement to the more effective workplace CTR measures such as pricing workplace parking (Measure T-12) or implementing employee parking “cash-out” (Measure T-13).

GHG Reduction Formula

$A = B \times C$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–4.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in commute VMT from eligible employees	-4	%	Boarnet et al. 2014

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who participate in the program.
- (C) – A policy brief summarizing the results of employer-based trip reduction studies concluded that these programs reduce total commute VMT for employees at participating work sites by 4 to 6 percent (Boarnet et al. 2014). To be conservative, the low end of the range is cited.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-6, which represents the same implementation activities as Measure T-5, except that the CTR program would be mandatory. Users should select either Measure T-5 or T-6.

If this measure is selected, the user may not also take credit for Measures T-7 through T-11. Measure T-5 accounts for the combined GHG reductions achieved by each of these individual measures. To combine the GHG reductions from T-5 with any of these measures would be considered double counting. However, the user may take credit for Measures T-12 through T-13 within the larger CTR subcategory, so long as the combined VMT reduction does not exceed 45 percent, as noted above.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project offer a voluntary commute trip reduction program to their employees. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 4 percent.

$A = \mathbf{100\%} \times -4\% = -4\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Boarnet, M., H. Hsu, and S. Handy. 2014. *Impacts of Employer-Based Trip Reduction Programs and Vanpools on Passenger Vehicle Use and Greenhouse Gas Emissions*. September. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Employer-Based_Trip_Reduction_Programs_and_Vanpools_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-6. Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)

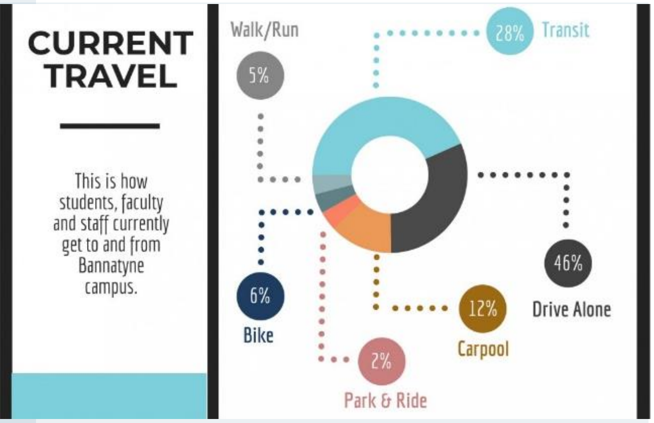


Photo Credit: University of Manitoba, 2018

GHG Mitigation Potential

26%

Up to 26.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Commute trip reduction programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs needs to consider existing mobility options in diverse communities and ensure equitable access and benefit to all employees.

Measure Description

This measure will implement a mandatory CTR program with employers. CTR programs discourage single-occupancy vehicle trips and encourage alternative modes of transportation such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The mandatory CTR program must include all other elements (i.e., Measures T-7 through T-11) described for the voluntary program (Measure T-5) plus include mandatory trip reduction requirements (including penalties for non-compliance) and regular monitoring and reporting to ensure the calculated VMT reduction matches the observed VMT reduction.

Cost Considerations

Employer costs may include recurring, direct costs for transit subsidies, capital and maintenance costs for alternative transportation infrastructure, and labor costs for staff to manage the program. If the local municipality has a mandatory VMT reduction ordinance, additional employer costs could include non-compliance penalties if the municipality fines CTR programs that do not meet a VMT goal. Municipal costs may include the labor costs for government staff to track the efficacy of the program, which may be outweighed by revenue generated from fines collected from non-compliant businesses.

Expanded Mitigation Options

This program typically serves as a complement to the more effective workplace CTR measures, such as pricing workplace parking (Measure T-12) or implementing employee parking "cash-out" (Measure T-13).

GHG Reduction Formula

$A = B \times C \times D$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–26.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in vehicle mode share of employee commute trips	-26	%	Nelson\Nygaard Consulting Associates 2015
D	Adjustment from vehicle mode share to commute VMT	1	unitless	assumed

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who participate in the program.
- (C) – A multiyear study of mode share on Genentech's South San Francisco campuses tracked the long-run change in employee commute mode share with implementation of mandatory CTR. Between 2006 and 2014, employee vehicle mode share (includes single-occupied vehicles and carpools) decreased from approximately 90 percent to 64 percent, which is a 26 percent reduction (Nelson\Nygaard Consulting Associates 2015).
- (D) – The adjustment factor from vehicle mode share to commute VMT is 1. This assumes that all vehicle trips will average out to typical trip length. Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 26 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-5, which represents the same implementation activities as Measure T-5, except that the CTR program would be mandatory. Users should select either Measure T-5 or T-6.

If this measure is selected, the user may not also take credit for Measures T-7 through T-11. Measure T-6 accounts for the combined GHG reductions achieved by each of these individual measures. To combine the GHG reductions from T-6 with any of these measures would be considered double counting. However, the user may take credit for Measure T-12 and T-13 within the larger CTR subcategory, so long as the combined VMT reduction does not exceed 45 percent, as noted above.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that the employer of the proposed project offer a mandatory CTR program to their employees. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 26 percent.

$A = \mathbf{100\%} \times -26\% \times 1 = -26\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

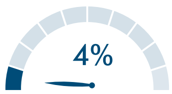
Sources

- Nelson/Nygaard Consulting Associates. 2015. *Genentech–South San Francisco Campus TDM and Parking Report.* June. Available: http://ci-ssf-ca.granicus.com/MetaViewer.php?view_id=2&clip_id=859&meta_id=62028. Accessed: January 2021.

T-7. Implement Commute Trip Reduction Marketing

Photo Credit: Sacramento Area Council of Governments, 2012

GHG Mitigation Potential



Up to 4.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Commute trip reduction programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs needs to consider existing mobility options in diverse communities and ensure equitable access and benefit to all employees. CTR programs may need to include multi-language materials.

Measure Description

This measure will implement a marketing strategy to promote the project site employer's CTR program. Information sharing and marketing promote and educate employees about their travel choices to the employment location beyond driving such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The following features (or similar alternatives) of the marketing strategy are essential for effectiveness.

- Onsite or online commuter information services.
- Employee transportation coordinators.
- Onsite or online transit pass sales.
- Guaranteed ride home service.

Cost Considerations

Employer costs include labor and materials for development and distribution of survey and marketing materials to promote the program and educate potential participants.

Expanded Mitigation Options

This measure could be packaged with other commute trip reduction measures (Measures T-8 through T-13) as a comprehensive CTR program (Measure T-5 or T-6).

GHG Reduction Formula

$A = B \times C \times D$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–4.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in employee commute vehicle trips	-4	%	TRB 2010
D	Adjustment from vehicle trips to VMT	1	unitless	assumed

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who actually participate in the program.
- (C) – A review of studies measuring the effect of transportation demand management measures on traveler behavior notes that the average empirically-based estimate of reductions in vehicle trips for full-scale, site-specific employer support programs is 4 to 5 percent. To be conservative, the low end of the range is cited (TRB 2010).
- (D) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-8 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project market to employees travel options for modes alternative to single-occupied vehicles. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 4 percent.

$$A = \mathbf{100\%} \times -4\% \times 1 = -4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

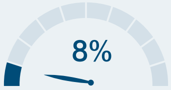
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Transportation Research Board (TRB). 2010. *Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 19, Employer and Institutional TDM Strategies*. June. Available: http://www.trb.org/Publications/Blurbs/163781.aspx. Accessed: January 2021.

T-8. Provide Ridesharing Program

GHG Mitigation Potential



Up to 8.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Ridesharing programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Program should include all onsite workers, such as contractors, interns, and service workers. Because ridesharing is vehicle-based, and some employees may not be in areas with feasible rideshare networks, design of programs need to ensure equitable benefits to those with and without access to rideshare opportunities.

Measure Description

This measure will implement a ridesharing program and establish a permanent transportation management association with funding requirements for employers. Ridesharing encourages carpooled vehicle trips in place of single-occupied vehicle trips, thereby reducing the number of trips, VMT, and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Ridesharing must be promoted through a multifaceted approach. Examples include the following.

- Designating a certain percentage of desirable parking spaces for ridesharing vehicles.
- Designating adequate passenger loading and unloading and waiting areas for ridesharing vehicles.
- Providing an app or website for coordinating rides.

Cost Considerations

Costs of developing, implementing, and maintaining a rideshare program in a way that encourages participation are generally borne by municipalities or employers. The beneficiaries include the program participants saving on commuting costs, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When providing a ridesharing program, a best practice is to establish funding by a non-revocable funding mechanism for employer-provided subsidies. In addition, encourage use of low-emission ridesharing vehicles (e.g., shared Uber Green).

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$A = B \times C$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–8.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in employee commute VMT	Table T-8.1	%	SANDAG 2019

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who actually participate in the program.
- (C) – The percent reduction in employee commute VMT by place type is provided in Table T-8.1 in Appendix C. The reduction differs by place type because the willingness and ability to participate in carpooling is higher in urban areas than in suburban areas. Note that this measure is not applicable for implementation in rural areas (SANDAG 2019).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 8 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7 and T-9 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project provide a ridesharing program to their employees. In this example, the percent of employees eligible (B) at a packaging and distribution center is 50 percent and the place type of the project is urban (C). GHG emissions from employee commute VMT would be reduced by 4 percent.

A = **50%** × -8% = -4%

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document.* June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-9. Implement Subsidized or Discounted Transit Program

GHG Mitigation Potential

5.5 %

Up to 5.5% of emissions from employee/resident vehicles accessing the site

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Climate Resilience

Subsidized and discounted transit programs increase the capacity of low-income populations to use transit to evacuate or access resources during an extreme weather event. They could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Lower overall out-of-pocket costs would also help increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Program should include all onsite workers, such as contractors, interns, and service workers.

Measure Description

This measure will provide subsidized or discounted, or free transit passes for employees and/or residents. Reducing the out-of-pocket cost for choosing transit improves the competitiveness of transit against driving, increasing the total number of transit trips and decreasing vehicle trips. This decrease in vehicle trips results in reduced VMT and thus a reduction in GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The project should be accessible either within 1 mile of high-quality transit service (rail or bus with headways of less than 15 minutes), 0.5 mile of local or less frequent transit service, or along a designated shuttle route providing last-mile connections to rail service. If a well-established bikeshare service (Measure T-22-A) is available, the site may be located up to 2 miles from a high-quality transit service.

If more than one transit agency serves the site, subsidies should be provided that can be applied to each of the services available. If subsidies are applied for only one service, all variable inputs below should also pertain only to the service that is subsidized.

Cost Considerations

The employer cost is the recurring, direct cost for transit subsidies. The subsidies will lower the per capita income of the transit service, decreasing the revenue of the local transit agency. This cost may be offset by increased revenue from increased ridership. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{C}{B} \times G \times D \times E \times F \times H \times I$$

GHG Calculation Variables

If subsidies or discounts target employees, the GHG reduction from this measure may be limited to work-related employee trips only (i.e., home-to- work) and work-to-other, where at least one trip end is work). If residents are targeted, the GHG reductions extend to all trips.

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee/resident vehicles accessing the site	0–5.5	%	calculated
User Inputs				
B	Average transit fare without subsidy	[ ]	$	user input
C	Subsidy amount	[ ]	$	user input
D	Percent of employees/residents eligible for subsidy	0–100	%	user input
E	Percent of project-generated VMT from employees/residents	0–100	%	user input
Constants, Assumptions, and Available Defaults				
F	Transit mode share of all trips or work trips	Table T-3.1 or Table T-9.1	%	FHWA 2017
G	Elasticity of transit boardings with respect to transit fare price	-0.43	unitless	Taylor et al. 2008
H	Percent of transit trips that would otherwise be made in a vehicle	50	%	Handy & Boarnet 2013
I	Conversion factor of vehicle trips to VMT	1.0	unitless	assumption

Further explanation of key variables:

- (B and C) – The average transit fare and subsidy amount can be presented as either a fare per ride, or the cost of a monthly pass for typical transit service near the site. Pricing should be based on the expected means of subsidy implementation; for instance, if a monthly pass is provided to all residents, prices should be input on a monthly basis.
- (D) – The percentage of employees/residents associated with the site who have access to the subsidy. If subsidy is provided as an employee benefit, care should be taken to account for any contract or temporary workers who do not receive such benefits.
- (E) – The percentage of project-generated VMT from employees/residents is used to adjust the percent reduction in GHG emissions from the scale of employee and/or resident-generated VMT to project-generated VMT. If subsidies or discounts target employees at an office development, this value would simply be 100 percent. If the project site is a multifamily development with no onsite workers, this value would also be

100 percent. If the project site is a retail development, this value would be less than 100 percent, as it does not account for retail shopper trips to the site. The share of total VMT generated by employees for visitor-intensive uses, such as retail or medical offices, can be roughly estimated by multiplying the total number of employees by two (to account for both arrival and departure), divided by the total number of daily trips.

- (F) – Ideally, the user will calculate transit mode share for work trips or all trips of a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. Care should be taken *not* to present the reported commute mode share as retrieved from the American Community Survey (ACS), unless the land use is office or employment based and the tables are based on work location (rather than home location). If the subsidies or discounts target employees and their commute trips, then the mode share should use the home-to-work trip purpose. If the user is not able to provide a project-specific value using one of the data sources described above, they have the option to input the transit mode share for one of the six most populated CBSAs in California. The transit mode share for work trips by CBSA is presented in Table T-9.1 in Appendix C (FHWA 2017). The transit mode share for all trips is provided in Table T-3.1 in Appendix C.
- (G) – A cross-sectional analysis of transit use in 265 urbanized areas in the U.S. found that a 0.43 percent decrease in transit boardings occurs for every 1 percent increase in transit fare price (Taylor et al. 2008). A policy brief summarizing the results of transit service strategies found this analysis to fall in the mid-point of observed, short-term values (Handy & Boarnet 2013). Price elasticities of transit demand vary based on both long-term and short-term demand, service type, and service location (Litman 2020 and Handy & Boarnet 2013).
- (H) – Not all new transit trips replace a vehicle trip. The share of transit trips that would otherwise be made by private vehicle ranges from less than 5 percent to 50 percent across studies. This assumption is based on observed values for high quality BRT service under the assumption that this measure is implemented alongside marketing measures and is targeted primarily at reducing vehicle commute trips. (Handy & Boarnet 2013). Note that this study looked at service improvements rather than fare changes and is used as a proxy variable. If project-specific or location-specific information is available, it should be substituted for this assumptive variable.
- (I) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT. Subsidies or discounts targeting commute trips may have a higher factor as they are generally longer than the trip lengths for other purposes.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction is capped at 5.5 percent, which is based on the following assumptions:

- (C=B) – The subsidy coverage is capped at 100 percent of the typical transit fare.
- (D) – All employees are eligible for the subsidy.

- (E) – All project-generated VMT is from employee-generated VMT.
- (F) – Employees at an office development in the San Francisco-Oakland-Hayward CBSA have a default transit mode share for work trips of 25.60 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5\ \text{through}\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7, T-8, T-10 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

In this example, the user reduces VMT by providing all employees (D) of a proposed office development in the San Francisco-Oakland-Hayward CBSA a 100 percent transit subsidy in the form of a \$100 monthly transit pass (C=B). The user would reduce GHG emissions from VMT by 5.5 percent.

$$A = \left(\frac{\$100}{\$100} \times -0.43\right) \times \mathbf{100\%} \times \mathbf{100\%} \times 25.60\% \times 50\% \times 1 = -5.5\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer.* Travel Day PMT by TRPTRANS by HH_CBSA, Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
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- Taylor, B., D. Miller, H. Iseki, and C. Fink. 2008. *Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across US Urbanized Areas.* Transportation Research Part A: Policy and Practice, 43(1), 60-77. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.367.5311&rep=rep1&type=pdf. Accessed: January 2021.

T-10. Provide End-of-Trip Bicycle Facilities

GHG Mitigation Potential

4.4%

Up to 4.4% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

End-of-trip bicycle facilities could take more cars off the road, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. They could also make it easier for bicycle users to access resources in an extreme weather event.

Health and Equity Considerations

Facilities should be inclusive of all gender identities and expressions. Consider including gender-neutral, single-occupancy options to allow for additional privacy for those who want it.

Measure Description

This measure will install and maintain end-of-trip facilities for employee use. End-of-trip facilities include bike parking, bike lockers, showers, and personal lockers. The provision and maintenance of secure bike parking and related facilities encourages commuting by bicycle, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

End-of-trip facilities should be installed at a size proportional to the number of commuting bicyclists and regularly maintained.

Cost Considerations

Employer costs include capital and maintenance costs for construction and maintenance of facilities and potentially labor and materials costs for staff to monitor facilities and provide marketing to encourage use of new facilities. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to include an onsite bicycle repair station and post signage on or near secure parking and personal lockers with information about how to reserve or obtain access to these amenities.

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{C \times (E - (B \times E))}{D \times F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee project/site commute VMT	0.1–4.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Bike mode adjustment factor	1.78 or 4.86	unitless	Buehler 2012
C	Existing bicycle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
D	Existing vehicle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
E	Existing bicycle mode share for work trips in region	Table T-10.2	%	FHWA 2017b
F	Existing vehicle mode share for work trips in region	Table T-10.2	%	FHWA 2017b

Further explanation of key variables:

- (B) – The bike mode adjustment factor should be provided by the user based on type of bike facility. A study found that commuters with showers, lockers, and bike parking at work are associated with 4.86 times greater likelihood to commute by bicycle when compared to individuals without any bicycle facilities at work. Individuals with bike parking, but no showers and lockers at the workplace, are associated with 1.78 times greater likelihood to cycle to work than those without trip-end facilities (Buehler 2012).
- (C and D) – Ideally, the user will calculate bicycle and auto trip length for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the trip lengths for bicycles and vehicles for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017a). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.
- (E and F) – Ideally, the user will calculate bicycle and auto mode share for work trips for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average mode shares for bicycle and vehicle

work trips for one of the six most populated CBSAs in California, as presented in Table T-10.2 in Appendix C (FHWA 2017b). If the project study area is not within the listed CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. For areas not covered by the listed CBSAs, which represent the denser areas of the state, bicycle mode share is likely to be lower and vehicle share higher than presented in Table T-10.2.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4.4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5\ through\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7, T-8, T-9, and T-11 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces VMT by providing end-of-trip facilities for the project's employees, which encourages bicycle trips in place of vehicle trips. In this example, the type of bike facility provided by the project is parking with showers, bike lockers, and personal lockers (B). The project is within San Jose-Sunnyvale-Santa Clara CBSA, and the user does not have project-specific values for trip lengths and mode shares and for bicycles and vehicles. Per Tables T-10.1 and T-10.2 in Appendix C, inputs for these variables are 2.8 miles, 11.5 miles, 4.1 percent, and 86.6 percent, respectively (C, D, E, and F). GHG emissions from employee commute VMT would be reduced by 4.4 percent.

$$A = \frac{2.8 \text{ miles} \times \left(4.1\% - (4.86 \times 4.1\%)\right)}{11.5 \text{ miles} \times 86.6\%} = \text{-}4.4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Buehler, R. 2012. *Determinants of bicycle commuting in the Washington, DC region: The role bicycle parking, cyclist showers, and free car parking at work.* Transportation Research Part D, 17, 525–531. Available: http://www.pedbikeinfo.org/cms/downloads/DeterminantsofBicycleCommuting.pdf. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer.* Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

T-11. Provide Employer-Sponsored Vanpool

Photo Credit: UCLA Transportation/Flickr, 2021

GHG Mitigation Potential

20.4%

Up to 20.4% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Employer-sponsored vanpools could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Consider using zero-emission or plug-in electric vehicles (PHEVs) for additional emission reduction benefits.

Measure Description

This measure will implement an employer-sponsored vanpool service. Vanpooling is a flexible form of public transportation that provides groups of 5 to 15 people with a cost-effective and convenient rideshare option for commuting. The mode shift from long-distance, single-occupied vehicles to shared vehicles reduces overall commute VMT, thereby reducing GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban, rural

Scale of Application

Project/Site

Implementation Requirements

Vanpool programs are more appropriate for the building occupant or tenant (i.e., employer) to implement and monitor than the building owner or developer.

Cost Considerations

Employer costs primarily include the capital costs of vehicle acquisition and the labor costs of drivers, either through incentives to current employees or the hiring of dedicated drivers. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When implementing a vanpool service, best practice is to subsidize the cost for employees that have a similar origin and destination and provide priority parking for employees that vanpool.

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{((1-B)\times C\times F) + \left(B\times \frac{D}{E}\times G\right)}{((1-B)\times C\times F) + (B\times D\times F)} - 1$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	3.4–20.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Percent of employees that participate in vanpool program	2.7	%	SANDAG 2019
C	Average length of one-way vehicle commute trip in region	Table T-11.1	miles per trip	FHWA 2017
D	Average length of one-way vanpool commute trip	42.0	miles per trip	SANDAG 2019
E	Average vanpool occupancy (including driver)	6.25	occupants	SANDAG 2019
F	Average emission factor of average employee vehicle	307.5	g CO_2e per mile	CARB 2020
G	Vanpool emission factor	763.4	g CO_2e per mile	CARB 2020

Further explanation of key variables:

- (B) – The percent of employees that would participate in a vanpool program is based on a survey of commuters in San Diego County (SANDAG 2019). If the project is not within San Diego County or the user is able to provide a project-specific value for within San Diego County, the user should replace the default employee participation rate in the GHG reduction formula.
- (C) – Ideally, the user will calculate auto commute trip lengths for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average one-way auto commute trip length for one of the six most populated CBSAs in California, as presented in Table T-11.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.
- (D and E) – The average one-way vanpool commute trip length and occupancy are based on data from the San Diego Association of Government's regional vanpool program (SANDAG 2019). If the project is not within San Diego County or the user is

able to provide a project-specific value for within San Diego County, the user should replace these defaults in the GHG reduction formula.

- (F and G) – The average GHG emission factors for employee commute and vanpool vehicles were calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average using diesel and gasoline fuel. The average of the light-duty automobile (LDA) and light duty truck (LDT1/LDT2) vehicle categories represents employee non-vanpool vehicles and the light-heavy duty truck (LHDT1) vehicle category conservatively represents a large cargo vanpool vehicle. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the defaults in the GHG reduction formula.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects in San Diego County that use default CBSA data from Table T-11.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 20.4 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent of employees that participate in the vanpool program is capped at 15 percent, which is based on the high end of vanpool participation survey data for several successful programs in the U.S. (SANDAG 2019).

Subsector Maximum

($\sum A_{max_{T\text{-}5\ through\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7 through T-10, T-12, and T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that the employer of the project to sponsor a vanpool program. In this example, the project is in the San Diego-Carlsbad CBSA and would have an average vehicle commute trip length of 14.52 miles (C). The percent of employees that participate in the vanpool program is 15 percent (B_{max}). GHG emissions from employee commute would be reduced by 20.4 percent.

A=

$$\frac{\left((1-15\%)\times 14.52\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)+\left(15\%\times\frac{42\ \frac{\text{miles}}{\text{trip}}}{6.25\ \text{occupants}}\times 763.4\ \frac{\text{g } CO_2e}{\text{miles}}\right)}{\left((1-15\%)\times 14.52\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)+\left(15\%\times 42\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)}$$

$$-1 = \text{-}20.4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption (H) can be calculated using the GHG reduction formula except that (F) and (G) should be replaced by (I) and (J), as follows.

Fuel Use Reduction Formula

$$H = \frac{\left((1-B)\times C\times I\right)+\left(B\times\frac{D}{E}\times J\right)}{\left((1-B)\times C\times I\right)+(B\times D\times I)}-1$$

Fuel Use Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
H	Percent reduction in fuel use from project/site employee commute VMT	4.7–21.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
I	Fuel efficiency of average employee vehicle	0.03639	gallon (gal) per mile	CARB 2020
J	Fuel efficiency of vanpool vehicle	0.08328	gal per mile	CARB 2020

Further explanation of key variables:

- (I and J) – The average fuel efficiencies for employee commute and vanpool vehicles were calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average using diesel and gasoline fuel. The average of the LDA, LDT1, and LDT2 vehicle categories represents employee non-vanpool vehicles, and the LHDT1 vehicle category conservatively represents a large cargo vanpool vehicle. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the defaults in the fuel use reduction formula.

- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

VMT Reductions

The percent reduction in VMT can be calculated using a modified version of the GHG reduction formula, as shown below.

$$\%\ \text{VMT Reduction} = \frac{\left((1 - B) \times C\right) + \left(B \times \frac{D}{E}\right)}{C} - 1$$

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day VT by HH_CBSA by TRPTRANS by TRIPPURP. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-12. Price Workplace Parking

GHG Mitigation Potential

20%

Up to 20.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Priced workplace parking could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Parking pricing should include hourly and daily options so part-time staff do not need a monthly pass. If the project includes low-waged employees that have fewer transportation choices or time and resource constraints, it is instead recommended to consider implementing Measure T-13, *Implement Employee Parking Cash-Out*, or other transportation subsidy.

Measure Description

This measure will price onsite parking at workplaces. Because free employee parking is a common benefit, charging employees to park onsite increases the cost of choosing to drive to work. This is expected to reduce single-occupancy vehicle commute trips, resulting in decreased VMT, thereby reducing associated GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Implementation may include the following.

- Explicitly charging for employee parking.
- Implementing above-market rate pricing.
- Validating parking only for invited guests (or not providing parking validation at all).
- Not providing employee parking and transportation allowances.

In addition, this measure should include marketing and education regarding available alternatives to driving.

Cost Considerations

Parking fees would be a direct, recurring cost for employees. Employer costs include labor costs for program management and monitoring, but this may be offset by revenue generated by the program.

Expanded Mitigation Options

Best practice is to ensure that other transportation options are available, convenient, and have competitive travel times (i.e., transit service near the project site, shuttle service, or a complete active transportation network serving the site and surrounding community), and that there is not alternative free parking available nearby (such as on-street). This measure is substantially less effective in environments that do not have other modes available or where unrestricted street parking or other offsite parking is available nearby and has adequate capacity to accommodate project-related vehicle parking demand.

GHG Reduction Formula

For calculating effectiveness of pricing residential parking, see Measure T-16, *Unbundle Residential Parking Costs from Property Cost*. For calculating effectiveness of pricing parking at visitor-intensive land uses, see Measure T-24, *Implement Market Price Public Parking (On-Street)*.

$$A = \frac{B - C}{C} \times E \times D \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee commute VMT	0–20.0	%	calculated
User Inputs				
B	Proposed parking price	[ ]	$	user input
C	Baseline parking price	[ ]	$	user input
D	Share of employees paying for parking	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
E	Elasticity of parking demand with respecting to parking price	-0.4	unitless	Lehner & Peer 2019
F	Ratio of vehicle trip reduction to VMT	1	unitless	assumption

Further explanation of key variables:

- (B) – Parking price can be provided on an hourly, daily, or monthly basis. Monthly pricing is less effective than requiring daily or hourly payment since the price signal is diluted to only once a month.
- (C) – If baseline parking price is $0 (that is, if parking is typically free), set C = ¼ B, allowing for the maximum 50 percent increase in price. Alternatively, for locations that are located within 0.5 mile of transit service, set C = average transit fare to/from the location.
- (D) – Many organizations allow some employees free parking benefits. VMT reductions should be adjusted based on the share of employees that would be paying for parking.
- (E) – A meta-analysis of parking price studies found that a 0.40 percent decrease in parking demand occurs for every 1 percent increase in parking price (Lehner & Peer 2019). Price elasticity of parking demand varies by location, day of the week, and time of day.
- (F) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT. Subsidies or discounts targeting commute trips may have a higher factor as they are generally longer than the trip lengths for other purposes.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from priced workplace parking is capped at 20 percent. This maximum scenario is presented in the below example quantification.

($\frac{B-C}{C}_{max}$) The percent increase in parking price is capped at 50 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5\ through\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-13, *Implement Employee Parking Cash-Out*. While both measures focus on providing a price signal for employees to consider other modes for their work commute, this measure actively charges all employees to park, while Measure T-13 reimburses employees who do not park. Users should select either Measure T-12 or T-13.

Example GHG Reduction Quantification

The user reduces VMT by increasing the price of a monthly parking permit. In this example, the permit fee is increased from $50 (C) to $75 (B). If 100 percent of employees are subject to parking pricing (D), the user would reduce GHG emissions from VMT by 20 percent.

$$A = \frac{\$75 - \$50}{\$50} \times -0.4 \times 100\% \times 1 = -20\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Lehner, S., Peer, S. 2019. *The Price Elasticity of Parking: A Meta-analysis*. Transportation Research Part A: Policy and Practice 121 2019. Available: http://sustainabletransportationsc.org/garage/pdf/parking_elasticity.pdf. Accessed: January 2021.

T-13. Implement Employee Parking Cash-Out

GHG Mitigation Potential

12%

Up to 12.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Employee parking cash-out could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Non-applicable

Measure Description

This measure will require project employers to offer employee parking cash-out. Cash-out is when employers provide employees with a choice of forgoing their current subsidized/free parking for a cash payment equivalent to or greater than the cost of the parking space. This encourages employees to use other modes of travel instead of single occupancy vehicles. This mode shift results in people driving less and thereby reduces VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

To prevent spill-over parking and continued use of single occupancy vehicles, residential parking in the surrounding area must be permitted, and public on-street parking must be market rate.

Cost Considerations

Employer costs include the recurring, direct cost for payment to program participants and labor costs for program management. Employees that participate in the program would achieve cost savings through the cash-out benefit and potentially through reduced vehicle ownership and usage.

Expanded Mitigation Options

This measure could be paired with many other commute trip reduction strategies (Measures T-7 through T-11) for increased reductions.

GHG Reduction Formula

$A = B \times C$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site commute VMT	0–12.0	%	calculated
User Inputs				
B	Percentage of employees eligible	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in commute VMT from implementation of measure	-12	%	Shoup 2005

Further explanation of key variables:

- (B) – The percentage of employees eligible refers to the employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This does not refer to the percentage of employees who end up participating in the program.
- (C) – A study of eight California firms that complied with California's 1992 parking cash-out law found employee commute VMT decreased by an average of 12 percent (Shoup 2005).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum percent reduction in GHG emissions (A) is 12.0 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-12, *Price Workplace Parking*. While both measures focus on providing a price signal for employees to consider other modes for their work commute, this measure reimburses employees who do not park, while Measure T-12 actively charges all employees to park. Users should select either Measure T-12 or T-13.

Example GHG Reduction Quantification

The user reduces project/site VMT by offering commuters the option to choose a cash payment equal to or greater than the current parking subsidy offered by their employer. In this example, all employees (i.e., 100 percent) are eligible to participate (B), which would reduce GHG emissions from employee commute VMT by 12 percent.

$A = \mathbf{100\%} \times -12\% = -12\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

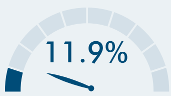
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Shoup, D. 2005. *Parking Cash Out.* Planners Advisory Service, American Planning Association. Available: http://shoup.bol.ucla.edu/ParkingCashOut.pdf. Accessed: January 2021.

T-14. Provide Electric Vehicle Charging Infrastructure

GHG Mitigation Potential



Up to 11.9% of GHG emissions from vehicles accessing the commercial or multifamily housing building

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing electric vehicle charging infrastructure increases fuel redundancy for electric vehicles even if an extreme weather event disrupts other fuel sources. Electric vehicles could also provide benefits to buildings and the grid, such as emergency backup, energy reserves, and demand response.

Health and Equity Considerations

Differential costs of PHEVs compared to conventional vehicles are decreasing over time, but at present are more expensive, which means this measure could disproportionately benefit those of greater economic means. As costs come into parity over time, this will be less of an issue. Employer, electricity provider, and state incentives for PHEV purchase could help address near-term disparities.

Measure Description

Install onsite electric vehicle chargers in an amount beyond what is required by the 2019 California Green Building Standards (CALGreen) at buildings with designated parking areas (e.g., commercial, educational, retail, multifamily). This will enable drivers of PHEVs to drive a larger share of miles in electric mode (eVMT), as opposed to gasoline-powered mode, thereby displacing GHG emissions from gasoline consumption with a lesser amount of indirect emissions from electricity. Most PHEVs owners charge their vehicles at home overnight. When making trips during the day, the vehicle will switch to gasoline mode if/when it reaches its maximum all-electric range.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban, rural

Scale of Application

Project/Site

Implementation Requirements

Parking at the chargers must be limited to electric vehicles.

Cost Considerations

The primary costs associated with electric vehicle charging infrastructure include the capital costs of purchasing and installing charging stations, electricity costs from use of stations, and maintenance costs of keeping the charging stations in working order. Costs initially fall to the station owners, either municipalities or private owners, but can be passed along to station users with usage fees. Depending on station placement and charging times required for PHEVs, businesses near charging stations can derive benefits from patronage of station users.

Expanded Mitigation Options

In addition to increasing the percentage of electric miles for PHEVs, the increased availability of chargers from implementation of this measure could mitigate consumer "range anxiety" concerns and increase the adoption and use of battery electric vehicles (BEVs), but this potential effect is not included in the calculations as a conservative assumption. Expanded mitigation could include quantification of the effect of this measure on BEV use.

GHG Reduction Formula

$$A = \frac{B \times D \times (F - E) \times (G - (H \times I \times K \times L))}{-C \times J}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicles accessing the office building or housing	0–11.9	%	calculated
User Inputs				
B	Number of chargers installed at site	[ ]	integer	user input
C	Total vehicles accessing the site per day	[ ]	integer	user input
Constants, Assumptions, and Available Defaults				
D	Average number of PHEVs served per day per charger installed	2	integer	CARB 2019
E	Percent of PHEV miles in electric mode without measure	46	%	CARB 2020a
F	Percent of PHEV miles in electric mode with measure	80	%	CARB 2017
G	Average emission factor of PHEV in gasoline mode	205.1	g CO_2e per mile	CARB 2020a; U.S. DOE 2021
H	Energy efficiency of PHEV in electric mode	0.327	kilowatt hours (kWh) per mile	CARB 2020b; U.S. DOE 2021
I	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per megawatt hour (MWh)	CA Utilities 2021
J	Average emission factor of non-electric vehicles accessing the site	307.5	g CO_2e per mile	CARB 2020a
K	conversion from lb to g	454	g per lb	conversion
L	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (D) – The average number of PHEVs served per day per charger installed is 2 vehicles (CARB 2019). If the user can provide a project-specific value, they should replace the default in the GHG reduction formula.
- (E) - Based on the EMFAC2017 model (v1.0.3), 46 percent of miles traveled by PHEVs in California are eVMT, and 54 percent are in gasoline mode (CARB 2020a).

- (F) – A review of EV user surveys and analytics included in the CARB's *Advanced Clean Cars Mid-Term Report* suggest that PHEV owners can reach 80 percent eVMT with access to adequate supportive charging infrastructure (CARB 2017).
- (G) – As described for (J), the average GHG emission factor for gasoline vehicles is 307.5 grams of CO_2e per mile.
- The fuel efficiency of a PHEV in gasoline mode is calculated as 66.7 percent of the fuel consumption rate of a gasoline vehicle, based on the assumption that a gasoline hybrid vehicle has 50 percent higher fuel economy (miles per gal [mpg]) than a comparable gasoline vehicle, based on a comparison of the gasoline and hybrid Toyota Camry and Corolla models (U.S. DOE 2021). This percentage is applied to the average GHG emission factor for gasoline vehicles to determine the average emission factor for PHEVs in gasoline mode as ($66.7\% \times 307.5$ g CO_2e per mile). If the user can provide a project-specific value by running EMFAC based on the future year of a project, they should replace the default in the GHG reduction formula.
- (H) – Scaled from a light-duty automobile gasoline equivalent fuel economy 30.3 mpg (CARB 2020a), an energy efficiency ratio (EER) of 2.5 (CARB 2020b), and an assumption of 33.7 kWh electricity per gallon of gasoline (U.S. DOE 2021).
- (I) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.
- (J) – The average GHG emission factor for non-electric vehicles accessing the site was calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of LDA, LDT1, and LDT2 vehicles using diesel and gasoline fuel. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020a) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the GHG reduction formula.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 11.9 percent, which is based on the following assumptions used to generate a maximum scenario:

- (B) – number of chargers installed = 20. CALGreen provides a non-residential voluntary Tier 2 measure that requires projects with 201 or more parking spaces to allocate 10 percent of total parking spaces for "EV Capable" parking spaces (or 20 parking spaces) (CBSC 2019). Note that EV Capable parking spaces do not actually have EV chargers installed, though they do have electrical panel capacity, a dedicated branch circuit, and a raceway to the EV parking spot to support future installation of charging stations. Therefore, using the number of EV Capable parking spaces as a proxy for EV chargers as a high-end estimate is conservative.

- (C) – total vehicles accessing the site = 200. Per the CALGreen voluntary measure, the number of total parking spaces that correspond with 20 "EV Capable" parking spaces is 201.
- (D) – PHEVs served per day per charger installed = 7. This value is the max (D_{max}). This assumes that all PHEV drivers would coordinate sharing of the limited number of chargers at the site. Value is based on data from the National Renewable Energy Laboratory (CARB 2019).
- (I) – carbon intensity of local electricity provider = 0 lb CO_2e per MWh. This assumes that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero.

Subsector Maximum

($\sum A_{max_{T\text{-}14\text{ through }T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user will install electric vehicle chargers at their proposed office or multifamily housing development, which will enable employees or residents with PHEVs to drive a larger share of miles in electric mode, as opposed to gasoline-powered mode, thereby displacing GHG emissions from gasoline consumption with a lesser amount of indirect emissions from indirect electricity. In this example, 20 chargers (B) will be installed at a workplace with 200 daily employee vehicles accessing the site (C). The electricity provider for the project area is the Sacramento Municipal Utility District (SMUD) and the analysis year is 2022. The carbon intensity of electricity is therefore 344 lb CO_2e per MWh (I). The GHG impact is calculated as a 3.4 percent reduction from the total emissions from vehicles accessing the site.

$$A = \frac{20 \times 2\,\frac{\text{PHEVs}}{\text{charger}\cdot\text{day}} \times (80\% - 46\%) \times (205.1\,\frac{\text{g CO}_2\text{e}}{\text{miles}} - (0.327\,\frac{\text{kWh}}{\text{mile}} \times 344\,\frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 454\,\frac{\text{g}}{\text{lb}} \times 0.001\,\frac{\text{MWh}}{\text{kWh}}))}{-200\text{ vehicles} \times 307.5\,\frac{\text{g CO}_2\text{e}}{\text{miles}}} = 3.4\%$$

Quantified Co-Benefits

While the measure will achieve fuel savings, it will also increase electricity consumption. This section defines the methods for quantifying Improved Local Air Quality and fuel savings, as well as increased electricity consumption.

Improved Local Air Quality

Local criteria pollutants will be reduced by the reduction in fossil fuel combustion. The percent reduction in criteria pollutants can be calculated using the GHG reduction formula. Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from vehicles charging will not generate localized criteria pollutant emissions. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed, or the electricity intensity (I) can be set to zero.

Fuel Savings (Increased Electricity)

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in criteria pollutant emissions. The percent increase in electricity use (M) from this measure can be calculated as follows.

Electricity Use Increase Formula

$$M = \frac{B \times D \times (F - E) \times J \times N \times O}{-C \times P}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
M	Increase in electricity from PHEVs	[ ]	%	calculated
User Inputs				
N	Existing electricity consumption of project/site	[ ]	kWh per year	user input
O	Days per year with vehicles accessing the site	260–365	days per year	user input
P	Average annual VMT of vehicles accessing the site	[ ]	miles per day per vehicle	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (N) – The user should take care to properly quantify building electricity using accepted methodologies (such as CalEEMod).
- (O) – If the proposed development is a workplace in which employees access the site an average of 5 days per week, the user should input 260 workdays. If the development is multifamily dwelling, the user should input 365 days.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2017. *Advanced Clean Cars Mid-Term Report, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis*. Available: https://ww2.arb.ca.gov/resources/documents/2017-midterm-review-report. Accessed: January 2021.
- California Air Resources Board (CARB). 2019. *Final Sustainable Communities Strategy Program and Evaluation Guidelines Appendices*. November. Available: https://ww2.arb.ca.gov/sites/default/files/2019-11/Final%20SCS%20Program%20and%20Evaluation%20Guidelines%20Appendices.pdf. Accessed: January 2021.

- California Air Resources Board (CARB). 2020a. *EMFAC2017 v1.0.3.* August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- California Air Resources Board (CARB). 2020b. *Unofficial electronic version of the Low Carbon Fuel Standard Regulation.* Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf
- California Air Resources Board (CARB). 2021. OFFROAD2017–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. March 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- California Building Standards Commission (CBSC). 2019. Green Building Standards Code, Title 24, Part 11. Appendix A5 – Nonresidential Voluntary Measures. Table A5.601 Nonresidential Buildings: Green Building Standards Code Proposed Performance Approach. July. Available: https://codes.iccsafe.org/content/CAGBSC2019/appendix-a5-nonresidential-voluntary-measures. Accessed: May 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Download Fuel Economy Data.* January. Available: https://www.fueleconomy.gov/feg/download.shtml. Accessed: January 2021.

T-15. Limit Residential Parking Supply

GHG Mitigation Potential

Up to 13.7% of GHG emissions from resident vehicles accessing the site

Co-Benefits (icon key on pg. 34)

Climate Resilience

Limiting residential parking supply could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Evacuation plans and plans for transport to cooling/heating/clean air centers during power outages or unhealthy air quality events, however, would need to consider needs of households without access to private vehicles.

Health and Equity Considerations

Limiting parking supply can reduce the cost of housing development and, potentially, increase housing supply and decrease housing expenses. However, this may negatively impact residents that do not have a viable alternative to personal vehicle travel.

Measure Description

This measure will reduce the total parking supply available at a residential project or site. Limiting the amount of parking available creates scarcity and adds additional time and inconvenience to trips made by private auto, thus disincentivizing driving as a mode of travel. Reducing the convenience of driving results in a shift to other modes and decreased VMT and thus a reduction in GHG emissions. Evidence of the effects of reduced parking supply is strongest for residential developments.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is ineffective in locations where unrestricted street parking or other offsite parking is available nearby and has adequate capacity to accommodate project-related vehicle parking demand.

Cost Considerations

Reducing residential parking supply, especially in high density residential areas, can have high-cost savings if it reduces the need for additional investment in parking infrastructure. Some of these savings may be offset by investments in alternative transport solutions, which will need to be robust to ensure that residents can effectively travel to work and all other destinations without a car.

Expanded Mitigation Options

When limiting parking supply, a best practice is to do so at sites that are located near high quality alternative modes of travel (such as a rail station, frequent bus line, or in a higher density area with multiple walkable locations nearby). Limiting parking supply may also allow for more active uses on any given lot, which may support Measures T-1 and T-2 by allowing for higher density construction.

GHG Reduction Formula

$$A = -\frac{B - C}{B} \times D \times E \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from resident vehicles accessing the site	0–13.7	%	calculated
User Inputs				
B	Residential parking demand	[ ]	parking spaces	user input
C	Project residential parking supply	[ ]	parking spaces	user input
D	Percentage of project VMT generated by residents	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
E	Percent of household VMT that is commute based	37	%	Caltrans 2012
F	Percent reduction in commute mode share by driving among households in areas with scarce parking	37	%	Chatman 2013

Further explanation of key variables:

- (B) – The user can calculate the parking demand in the *ITE Parking Generation Manual* based on the project building square footage or number of du. For residential projects, this demand varies based on the size of each unit, and ranges from 1.0 spaces/unit for one-bedroom apartments to 2.6 spaces/unit for single-family homes with 3+ bedrooms.
- (D) – Available research on changes in parking supply focuses on residential land uses. Therefore, reductions are applied only to the share of VMT generated by residents of a project. For most residential projects, this will be 100 percent; however, for mixed-use projects, the user will need to provide project-specific data.
- (E) – The percent of household VMT that is commute-based varies from location to location; the statewide average is 37 percent (Caltrans 2012). If the user can provide a project-specific value based on their project type and area, they should replace the default in the GHG reduction formula.
- (F) – A study found that among households with limited off-street parking (<1 space per adult), there was a 37 percent decrease in auto mode share for commute trips. The method above pro-rates this reduction based on how much the project's parking supply is reduced from demand rates calculated in the *ITE Parking Generation Manual* (ITE 2019). In addition, this reduction is applied to commute trips only due to the limitations of the research.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions is capped at 13.7 percent. This occurs for projects that have no onsite parking (C), 100 percent of VMT arising from residential land use (D), and 37 percent of all VMT arising from commute trips (E). This maximum scenario is presented in the below example quantification.

(C>B) Parking supply is considered to be limited when demand (C) exceeds supply (B). If demand is equal to or less than supply, then implementation of this measure would not result in a GHG reduction.

Subsector Maximum

($\sum A_{max_{T\text{-}14 \text{ through } T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user reduces VMT by reducing a project's parking supply. In this example, the parking demand per ITE is 100 parking spaces (B) and the project would not supply any parking spaces (C). The user would reduce GHG emissions from VMT by 13.7 percent.

$$A = -\frac{100 \text{ spaces} - 0 \text{ spaces}}{100 \text{ spaces}} \times 100\% \times 37\% \times 37\% = -13.7\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- California Department of Transportation (Caltrans). 2012. *California Household Travel Survey (CHTS)*. Available: https://www.nrel.gov/transportation/secure-transportation-data/tsdc-california-travel-survey.html. Accessed: January 2021.
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- Institute of Transportation Engineers (ITE). 2019. Parking Generation Manual. 5th Edition. February. Available: https://ecommerce.ite.org/IMIS/ItemDetail?iProductCode=PG5-ALL. Accessed: May 2021.

T-16. Unbundle Residential Parking Costs from Property Cost

GHG Mitigation Potential

15.7%

Up to 15.7% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Climate Resilience

Unbundling residential parking costs from property costs could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

The unbundling of parking costs would help decrease housing costs for individuals who do not own personal vehicles.

Measure Description

This measure will unbundle, or separate, a residential project's parking costs from property costs, requiring those who wish to purchase parking spaces to do so at an additional cost. On the assumption that parking costs are passed through to the vehicle owners/drivers utilizing the parking spaces, this measure results in decreased vehicle ownership and, therefore, a reduction in VMT and GHG emissions. Unbundling may not be available to all residential developments, depending on funding sources.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Parking costs must be passed through to the vehicle owners/drivers utilizing the parking spaces for this measure to result in decreased vehicle ownership.

Cost Considerations

Unbundling residential parking costs from property costs may decrease revenue for property owners. This loss may be partially offset by reduced costs needed to maintain parking facilities with less car occupancy and the potential for non-resident parking as a supplementary income stream. For residents, reduced fees and the ability to go without owning a car is a major cost benefit. Municipalities also benefit from a reduction of cars on the road, which can lead to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Pair with Measure T-19-A or T-19-B to ensure that residents who eliminate their vehicle and shift to a bicycle can safely access the area's bikeway network.

GHG Reduction Formula

$$A = \frac{B}{C} \times D \times E$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–15.7	%	calculated
User Inputs				
B	Annual parking cost per space	[ ]	$ per year	user input
Constants, Assumptions, and Available Defaults				
C	Average annual vehicle cost	$9,282	$ per year	AAA 2019
D	Elasticity of vehicle ownership with respect to total vehicle cost	-0.4	unitless	Litman 2020
E	Adjustment factor from vehicle ownership to VMT	1.01	unitless	FHWA 2017

Further explanation of key variables:

- (B) – For most projects, this represents a monthly parking fee multiplied by 12. For deeded parking spaces, an estimate of the additional cost to a mortgage may be used, or the total cost may be prorated over 30 years. Costs to park will vary widely based on location; however, this value should consider if other nearby offsite parking options are available at lower cost. See Table T-16.1 in Appendix C for examples of monthly parking prices for different facility types.
- (C) – The average vehicle cost per year in 2019 was $9,282, based on a car driven 15,000 miles per year. Costs include gasoline, maintenance, insurance, license and registration, loan finance charges, and depreciation but do not include parking (AAA 2019).
- (D) – A synthesis of literature reported that, on the low end, a 0.4 percent decrease in vehicle ownership occurs for every 1 percent increase in total vehicle costs (Litman 2020).
- (E) – The adjustment factor from vehicle ownership to VMT is based on the following (FHWA 2017):
  - The average Californian household with 1 vehicle drives 11,117 miles per vehicle while households with 2 vehicles drives 11,223 miles per vehicle.
  - The reduction of 1 vehicle from a 2-vehicle household leads to a 0.94 percent decrease in VMT per vehicle.
  - So, $E = 1 - \left(\frac{11{,}117 \frac{\text{miles}}{\text{vehicle}} - 11{,}223 \frac{\text{miles}}{\text{vehicle}}}{11{,}223 \frac{\text{miles}}{\text{vehicle}}} \right) = 1.01$

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from unbundled parking is capped at 15.7 percent, which is based on the use of (B_{max}) in the GHG reduction formula.

(B_{max}) The annual cost of parking space is capped at $3,600, or $300 per month. At monthly costs above $300, the cost of parking represents more than a 30 percent increase in total vehicle cost. In addition, this reflects the upper maximum of observed parking prices outside of extremely dense downtown areas (such as San Francisco's SOMA neighborhood).

Subsector Maximum

($\sum A_{max_{T\text{-}14 \text{ through } T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user reduces VMT by unbundling the parking costs from property costs of a project, discouraging vehicle ownership, and therefore reducing VMT. In this example, the annual parking cost per space is $1,800 (B), which would reduce GHG emissions from project study area VMT (as compared to the same project with bundled parking costs) by 7.8 percent.

$$A = \left(\frac{\$1{,}800}{\$9{,}282}\right) \times -0.4 \times 1.01 = -7.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- AAA. 2019. *Your Driving Costs.* September. Available: https://exchange.aaa.com/wp-content/uploads/2019/09/AAA-Your-Driving-Costs-2019.pdf. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey – 2017 Table Designer.* Annual VMT / Vehicle by Count of Household Vehicles in California. Available: https://nhts.ornl.gov/. Accessed: March 2021.
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T-17. Improve Street Connectivity

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving street connectivity could increase route redundancy, allowing faster and more efficient travel during extreme weather events, evacuations, or for emergency vehicles requiring access to hazard sites.

Health and Equity Considerations

Multiple active modes routing options allows vulnerable road users to choose based on perceived safety, comfort, speed, and other factors.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of vehicle intersections compared to the average intersection density in the U.S. Increased vehicle intersection density is a proxy for street connectivity improvements, which help to facilitate a greater number of shorter trips and thus a reduction in GHG emissions.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Projects that increase intersection density would be building a new street network in a subdivision or retrofitting an existing street network to improve connectivity (e.g., converting cul-de-sacs or dead-end streets to grid streets).

Cost Considerations

Capital and infrastructure costs for improved street connectivity may be high. Depending on the location, losses may also be incurred through the reduction of sellable land due to the increased street footprint. Benefits come mainly from the reduction of traffic on arterial streets, which reduces congestion and allows for safer use of nonmotorized transportation, such as bikes. These outcomes, in turn, can reduce car usage, which provides costs savings to commuters and municipalities.

Expanded Mitigation Options

Pair with Measure T-18, *Provide Pedestrian Network Improvement*, to best support use of the local pedestrian network.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–30.0	%	calculated
User Inputs				
B	Intersection density in project site with measure	[ ]	intersections per sq mile	user input
Constants, Assumptions, and Available Defaults				
C	Average intersection density	36	intersections per sq mile	Fehr & Peers 2009
D	Elasticity of VMT with respect to intersection density	-0.14	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The average intersection density is based on the standard suburban intersection density in the U.S. (Fehr & Peers 2009). This density is approximately equivalent to block faces of 750 to 800 feet, or cul-de-sac–style built environments, which are appropriate for suburban areas.
- (D) – A meta-regression analysis of 15 studies found that a 0.14 percent decrease in VMT occurs for every 1 percent increase in intersection density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose of the 30 percent cap is to limit the influence of any single built environmental factor (such as intersection density).

Subsector Maximum

Same as (A_{max}). Measure T-17 is the only measure at the Plan/Community scale within the Land Use subsector.

Example GHG Reduction Quantification

The user reduces VMT by constructing their project with a higher intersection density than the surrounding city. In this example, the project intersection density (B) would be 72 intersections per square mile (sq mile), which would reduce GHG emissions from project VMT by 14 percent.

$$A = \frac{72\ \frac{\text{int}}{\text{sq mile}} - 36\ \frac{\text{int}}{\text{sq mile}}}{36\ \frac{\text{int}}{\text{sq mile}}} \times -0.14 = -14\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

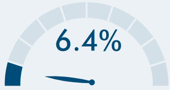
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Fehr & Peers. 2009. *Proposed Trip Generation, Distribution, and Transit Mode Split Forecasts for the Bayview Waterfront Project Transportation Study*.
- Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Available: https://www.researchgate.net/publication/309890412_Does_Compact_Development_Make_People_Drive_Less. Accessed: January 2021.

T-18. Provide Pedestrian Network Improvement

GHG Mitigation Potential



Up to 6.4% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving pedestrian networks increases accessibility of outdoor spaces, which can provide health benefits and thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Ensure that the improvements also include accessibility features to allow for people of all abilities to use the network safely and conveniently. Ensure that sidewalks connect to nearby community assets, such as schools, retail, and healthcare.

Measure Description

This measure will increase the sidewalk coverage to improve pedestrian access. Providing sidewalks and an enhanced pedestrian network encourages people to walk instead of drive. This mode shift results in a reduction in VMT and GHG emissions.

Subsector

Neighborhood Design

Locational Context

Urban, suburban, rural

Scale of Application

Plan/Community

Implementation Requirements

The GHG reduction of this measure is based on the VMT reduction associated with expansion of sidewalk coverage expansion, which includes not only building of new sidewalks but also improving degraded or substandard sidewalk (e.g., damaged from street tree roots). However, pedestrian network enhancements with non-quantifiable GHG reductions are encouraged to be implemented, as discussed under *Expanded Mitigation Options*.

Cost Considerations

Depending on the improvement, capital and infrastructure costs may be high. However, improvements to the pedestrian network will increase pedestrian activity, which can increase businesses patronage and provide a local economic benefit. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When improving sidewalks, a best practice is to ensure they are contiguous and link externally with existing and planned pedestrian facilities. Barriers to pedestrian access and interconnectivity, such as walls, landscaping buffers, slopes, and unprotected crossings should be minimized. Other best practice features could include high-visibility crosswalks, pedestrian hybrid beacons, and other pedestrian signals, mid-block crossing walks, pedestrian refuge islands, speed tables, bulb-outs (curb extensions), curb ramps, signage, pavement markings, pedestrian-only connections and districts, landscaping, and other improvements to pedestrian safety (see Measure T-35, *Provide Traffic Calming Measures*).

GHG Reduction Formula

$$A = \left(\frac{C}{B} - 1\right) \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from household vehicle travel in plan/community	0–6.4	%	calculated
User Inputs				
B	Existing sidewalk length in study area	[ ]	miles	user input
C	Sidewalk length in study area with measure	[ ]	miles	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of household VMT with respect to the ratio of sidewalks-to-streets	-0.05	unitless	Frank et al. 2011

Further explanation of key variables:

- (B and C) – Sidewalk length should be measured on both sides of the street. For example, if one 0.5-mile-long street has full sidewalk coverage, the sidewalk length would be 1.0 mile. If there is only sidewalk on one side of the street, the sidewalk length would be 0.5 mile. The recommended study area is 0.6 mile around the pedestrian network improvement. This represents a 6- to 10-minute walking time.
- (D) – A study found that a 0.05 percent decrease in household vehicle travel occurs for every 1 percent increase in the sidewalk-to-street ratio (Frank et al. 2011; Handy et al. 2014).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 3.4 percent, which is based on the following assumptions:

- 35.2 percent of vehicle trips are short trips (2 mile or less, average of 1.29 miles) and thus could easily shift to walking (FHWA 2019).
- 64.8 percent of vehicle trips are longer trips that are unlikely to shift to walking (2 miles or more, average of 10.93 miles) (FHWA 2019).
- So $A_{max} = \frac{35.2\% \times 1.29 \text{ miles}}{64.8\% \times 10.93 \text{ miles}} = 6.4\%$

Subsector Maximum

($\sum A_{max_{T\text{-}18\ through\ T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces household VMT by improving the pedestrian network in the study area. In this example, the existing sidewalk length (B) is 9 miles, and the sidewalk length with the measure (C) would be 10 miles. With these conditions, the user would reduce GHG emissions from household VMT within the study area by 0.6 percent.

$$A = \left(\frac{10\ \text{miles}}{9\ \text{miles}} - 1\right) \times -0.05 = -0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in household VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the Integrated Transport and Health Impact Model (ITHIM) (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2019. *2017 National Household Travel Survey Popular Vehicle Trip Statistics*. Available: https://nhts.ornl.gov/vehicle-trips. Accessed: January 2021.

- Frank, L., M. Greenwald, S. Kavage, and A. Devlin. 2011. *An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy*. WSDOT Research Report WA-RD 765.1, Washington State Department of Transportation. April. Available: www.wsdot.wa.gov/research/reports/fullreports/765.1.pdf. Accessed: January 2021.
- Handy, S., S. Glan-Claudia, and M. Boarnet. 2014. *Impacts of Pedestrian Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief.* September. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Pedestrian_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-19-A. Construct or Improve Bike Facility

GHG Mitigation Potential

0.8%

Up to 0.8% of GHG emissions from vehicles parallel roadways

Co-Benefits (icon key on pg. 34)

Climate Resilience

Constructing and improving bike facilities can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that the bicycle facility connects to a larger existing bikeway network that accesses destinations visited by low-income or underserved communities.

Measure Description

This measure will construct or improve a single bicycle lane facility (only Class I, II, or IV) that connects to a larger existing bikeway network. Providing bicycle infrastructure helps to improve biking conditions within an area. This encourages a mode shift on the roadway parallel to the bicycle facility from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. When constructing or improving a bicycle facility, a best practice is to consider local or state bike lane width standards. A variation of this measure is provided as T-19-B, *Construct or Improve Bike Boulevard*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community. This measure reduces VMT on the roadway segment parallel to the bicycle facility (i.e., the corridor). An adjustment factor is included in the formula to scale the VMT reduction from the corridor level to the plan/community level.

Implementation Requirements

The bicycle lane facility must be either Class I, II, or IV. Class I bike paths are physically separated from motor vehicle traffic. Class IV bikeways are protected on-street bikeways, also called cycle tracks. Class II bike lanes are striped bicycle lanes that provide exclusive use to bicycles on a roadway.

Cost Considerations

Capital and infrastructure costs for new bike facilities may be high. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Implement alongside Measures T-22-A, T-22-B, and/or T-22-C to ensure that micromobility users can ride safely along bicycle lane facilities and not have to ride along pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = -B \times \frac{\frac{F}{I} \times (C + D) \times E \times G}{H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from displaced vehicles on roadway parallel to bicycle facility	0–0.8	%	calculated
User Inputs				
B	Percent of plan/community VMT on parallel roadway	0–100	%	user input
C	Active transportation adjustment factor	Table T-19.1	unitless	CARB 2020
D	Credits for key destinations near project	Table T-19.2	unitless	CARB 2020
E	Growth factor adjustment for facility type	Table T-19.3	unitless	CARB 2020
Constants, Assumptions, and Available Defaults				
F	Annual days of use of new facility	Table T-19.4	days per year	NOAA 2017
G	Existing regional average one-way bicycle trip length	Table T-10.1	miles per trip	FHWA 2017
H	Existing regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017
I	Days per year	365	days per year	standard

Further explanation of key variables:

- (B) – The percent of total plan/community VMT within the roadway parallel to the bike facility should represent the expected total VMT generated by all land use in that area, including office, residences, retail, schools, and other uses. The most appropriate source for this data is from a local travel demand forecasting model. An alternate method uses VMT per worker or VMT per resident as calculated for SB 743 compliance and screening purposes multiplied by the population in the area.
- (C, D, and E) – The active transportation adjustment factor, key destination credit, and growth factor adjustment should be looked up by the user in Tables T-19.1 through T-19.3 in Appendix C. The active transport adjustment factor is based on the existing annual average daily traffic (AADT) of the facility, length of the proposed bike facility, and the city population. The key destination credit is based on the number of key destinations within 0.5-mile of the facility. The growth factor is based on the type of proposed bicycle facility.
- (F) – The annual days of use for the new facility should be looked up by users in Table T-19.4 based on the county in which the project is located. The days of use is based on the number of days per year where there is no rainfall (i.e., <=0.1 inches) (NOAA 2017).

- (G and H) – Ideally, the user will calculate bicycle and vehicle trip lengths for the corridor at a scale no larger than the surrounding census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input regional average one-way bicycle and vehicle trip lengths for one of the six most populated CBSAs in California provided in Table T-10.1 in Appendix C (FHWA 2017).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Table T-10.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.8 percent. This is based on a neighborhood project the size of a large corridor (B = 100%) within the CBSA of Sacramento-Roseville-Arden-Arcade that uses the highest values for (C, D, and E) in Tables T-19.1 through T-19.3 and annual use days for Sacramento County (F) in Table T-19.4. This maximum scenario is presented in the below example quantification.

(C_{max}) The active transportation adjustment factor (C) was determined for roadways with AADT ranging from 1 to 30,000 (CARB 2020). Roadways with AADT greater than 30,000 are generally not appropriate for bicycle facilities. Care should be taken by the user in interpreting the results from this equation for a project roadway with AADT greater than 30,000.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces VMT by constructing a bicycle facility that displaces vehicle trips with bicycle trips. In this example, the following assumptions are made to obtain inputs from Tables T-19.1 through T-19.3 in Appendix C:

- Percent of plan/community VMT on parallel roadway (B) = 100%. The project would establish a bike corridor the whole length of a central commercial thoroughfare. It is assumed this main street makes up the entire neighborhood.
- Active transportation adjustment factor (C) = 0.0207. Existing AADT on the roadway parallel to the proposed bicycle facility is 10,000, the facility length is 2.5 miles, and the project site is in a university town with a population of 200,000.
- Key destination credit (D) = 0.003. There are 10 key destinations within 0.25 mile of the project site.
- Growth factor adjustment (E) = 1.54. The bike facility would be a new Class IV bikeway.

The project is within the Sacramento-Roseville-Arden-Arcade CBSA and the user does not have project-specific values for average bicycle and vehicle trip lengths. Accordingly, the inputs of 2.9 miles and 10.9 miles, respectively (G and H), from Table T-10.1 in Appendix C are assumed. The user would displace GHG emissions from project study area VMT by 0.8 percent.

$$A = \mathbf{-100\%} \times \left(\frac{\frac{307 \text{ days}}{365 \text{ days}} \times (\mathbf{0.0207} + \mathbf{0.003}) \times \mathbf{1.54} \times 2.9 \text{ miles}}{10.9 \text{ miles}} \right) = -0.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB). 2020. *Quantification Methodology for the Strategic Growth Council's Affordable Housing and Sustainable Communities Program*. September. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/draft_sgc_ahsc_qm_091620.pdf. Accessed: January 2021.
- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

- National Oceanic and Atmospheric Administration (NOAA). 2021. *Global Historical Climatology Network–Daily (GHCN-Daily), Version 3*. 2015-2019 Average of Days Per Year with Precipitation >0.1 Inches. Available: https://www.ncei.noaa.gov/access/search/data-search/daily-summaries?bbox=38.922,-120.071,38.338,-119.547&place=County:1276&dataTypes=PRCP&startDate=2015-01-01T00:00:00&endDate=2019-01-01T23:59:59. Accessed: May 2021.

T-19-B. Construct or Improve Bike Boulevard

GHG Mitigation Potential

0.2%

Up to 0.2% of GHG emissions from vehicles on roadway

Co-Benefits (icon key on pg. 34)

Climate Resilience

Constructing and improving bike boulevards can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that the bicycle boulevard connects to a larger existing bikeway network that accesses destinations visited by low-income or underserved communities.

Measure Description

Construct or improve a single bicycle boulevard that connects to a larger existing bikeway network. Bicycle boulevards are a designation within Class III Bikeway that create safe, low-stress connections for people biking and walking on streets. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. A variation of this measure is provided as T-19-A, *Construct or Improve Bike Facility*, which is for Class I, II, or IV bicycle infrastructure.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community. This measure reduces VMT on the roadway segment parallel to the bicycle facility (i.e., the corridor). An adjustment factor is included in the formula to scale the VMT reduction from the corridor level to the plan/community level.

Implementation Requirements

The following roadway conditions must be met.

- Functional classification: local and collector if there is no more than a single general-purpose travel lane in each direction.
- Design speed: <= 25 miles per hour.
- Design volume <= 5,000 average daily traffic.
- Treatments at major intersections: both directions have traffic signals (or an effective control device that prioritizes pedestrian and bicycle access such as rapid flashing beacons, pedestrian hybrid beacons, high-intensity activated crosswalks, TOUCANs), bike route signs, "sharrowed" roadway markings, and pedestrian crosswalks.

Cost Considerations

Capital and infrastructure costs for new bike boulevards may be high, though lower than implementing the same length of protected bicycle lanes (Class IV). After the bike boulevard is complete, the local municipality may achieve cost savings from reduced infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Construct boulevards with forced turns for vehicles every few blocks to minimize through traffic while ensuring that speed and volume metrics are met. Implement alongside Measures T-22-A, T-22-B, and/or T-22-C to ensure that micromobility users can ride safely along bicycle lane facilities and not pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = B \times \frac{D \times (F - (C \times F))}{E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from displaced vehicles on roadway with bicycle boulevard	0–0.2	%	calculated
User Inputs				
B	Percent of plan/community VMT on roadway to have bicycle boulevard	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Bike mode adjustment factor	1.14	unitless	Schwartz 2021
D	Existing bicycle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
E	Existing vehicle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
F	Existing bicycle mode share for work trips in region	Table T-10.2	%	FHWA 2017a
G	Existing vehicle mode share for work trips in region	Table T-10.2	%	FHWA 2017a

Further explanation of key variables:

- (C) – The bike mode adjustment factor is based on a database of before/after bicycle counts for 10 projects in four U.S. cities that invested in bicycle boulevards. Bicycle ridership increased on average by 114 percent (Schwartz 2021).
- (D and E) – Ideally, the user will calculate bicycle and vehicle trip lengths for the corridor at a scale no larger than the surrounding census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input regional average one-way bicycle and vehicle trip lengths for one of the six most populated CBSAs in California provided in Table T-10.1 in Appendix C (FHWA 2017a).
- (F and G) – Ideally, the user will calculate bicycle and auto mode share for work trips for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average mode shares for bicycle and vehicle work trips for one of the six most populated CBSAs in California, as presented in Table T-10.2 in Appendix C (FHWA 2017b). If the project study area is not within the listed

CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. For areas not covered by the listed CBSAs, which represent the denser areas of the state, bicycle mode share is likely to be lower and vehicle share higher than presented in Table T-10.2.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Tables T-10.1 and T-10.2 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.2 percent. This is based on a neighborhood project the size of a large corridor (B = 100%) within the CBSA of San Jose-Sunnyvale-Santa Clara that uses the highest values for (C, D, and E) in Tables T-19.1 through T-19.3 and annual use days for Sacramento County (F) in Table T-19.4. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18\text{ through }T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces VMT by providing a bicycle boulevard on the targeted roadway, which encourages bicycle trips in place of vehicle trips. In this example, it is assumed this main street makes up the entire plan area, i.e., (B) is 100 percent. The project is within San Jose-Sunnyvale-Santa Clara CBSA and the user does not have project-specific values for trip lengths and mode shares for bicycles and vehicles. Per Tables T-10.1 and T-10.2, inputs for these variables are 2.8 miles, 11.5 miles, 4.1 percent, and 86.6 percent, respectively (D, E, F, and G). GHG emissions from plan/community VMT would be reduced by 0.2 percent.

$$A = \mathbf{100\%} \times \frac{2.8 \text{ miles} \times \left(4.1\% - (1.14 \times 4.1\%)\right)}{11.5 \text{ miles} \times 86.6\%} = \text{-}0.2\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Schwartz, S. 2021. *Planning for Stress Free Connections: Estimating VMT Reductions.* February.

T-20. Expand Bikeway Network

GHG Mitigation Potential

0.5%

Up to 0.5% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Expanding bikeway networks can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that destinations visited by low-income or underserved communities are served by the network.

Measure Description

This measure will increase the length of a city or community bikeway network. A bicycle network is an interconnected system of bike lanes, bike paths, bike routes, and cycle tracks. Providing bicycle infrastructure with markings and signage on appropriately sized roads with vehicle traffic traveling at safe speeds helps to improve biking conditions (e.g., safety and convenience). In addition, expanded bikeway networks can increase access to and from transit hubs, thereby expanding the "catchment area" of the transit stop or station and increasing ridership. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. When expanding a bicycle network, a best practice is to consider bike lane width standards from local agencies, state agencies, or the National Association of City Transportation Officials' *Urban Bikeway Design Guide*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The bikeway network must consist of either Class I, II, or IV infrastructure.

Cost Considerations

Capital and infrastructure costs for expanding the bikeway network may be high. Construction of these facilities may also increase vehicle traffic, leading to more congestion and temporarily longer trip times for motorist. However, the local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

As networks expand, ensure safe, secure, and weather-protected bicycle parking facilities at origins and destinations. Also, implement alongside T-22-A, T-22-B, and/or T-22-C to ensure that micromobility options can ride safely along bicycle lane facilities and not have to ride along pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = -1 \times \frac{\left(\frac{C - B}{B}\right) \times D \times F \times H}{E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee commute vehicle travel in plan/community	0–0.5	%	calculated
User Inputs				
B	Existing bikeway miles in plan/community	[ ]	miles	user input
C	Bikeway miles in plan/community with measure	[ ]	miles	user input
Constants, Assumptions, and Available Defaults				
D	Bicycle mode share in plan/community	Table T-20.1	%	FHWA 2017
E	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017
F	Average one-way bicycle trip length in plan/community	Table T-10.1	miles per trip	FHWA 2017
G	Average one-way vehicle trip length in plan/community	Table T-10.1	miles per trip	FHWA 2017
H	Elasticity of bike commuters with respect to bikeway miles per 10,000 population	0.25	unitless	Pucher & Buehler 2011

Further explanation of key variables:

- (B) – The existing bikeway miles in a plan/community should be calculated by measuring the distance of all Class I, II, III, and IV bikeways within the plan/community. This information can sometimes be found in a city's bicycle master plan, if a plan has been prepared and is up to date.
- (D, E, F, and G) – Ideally, the user will calculate bicycle and auto mode share and trip length for a plan/community at the city scale. Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares and trip lengths for bicycles and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1, T-10.2, and T-20.1 in Appendix C. Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state. Similarly, it is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and bicycle mode shares lower than the values provided in the tables.
- (H) – A multivariate analysis of the impacts of bike lanes on cycling levels in the 100 largest U.S. cities found that a 0.25 percent increase in commute cycling occurs for every 1 percent increase in bike lane distance (Pucher & Buehler 2011).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Tables T-3.1, T-10.2, and T-20.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.5 percent. This is based on a project within the CBSA of San Jose-Sunnyvale-Santa Clara that has no existing bike lane infrastructure. This maximum scenario is presented in the below example quantification.

($\frac{C-B}{B}_{max}$) The maximum percent increase in bike lane miles in the plan/community is conservatively capped at 1000 percent. If there is no existing bike lane infrastructure in the plan/community, (B) should be set to (1/11×C), resulting in a percentage change of 1000 percent.

Subsector Maximum

($\sum {A_{max}}_{T\text{-}18 \text{ through } T\text{-}22\text{-}C} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces employee commute VMT by increasing the length of a bicycle network within a plan/community, which displaces commute vehicle trips with bicycle trips. In this example, the existing bikeway length in the plan/community (B) is 0 miles and the length with the measure (C) is 11 miles. The project is within the San Jose-Sunnyvale-Santa Clara CBSA, yielding the following inputs from Tables T-3.1, T-10.2, and T-20.1 in Appendix C.

- Bicycle mode share (D) = 0.79 percent.
- Vehicle mode share (E) = 91.32 percent.
- Average one-way bicycle trip length (F) = 2.8 miles.
- Average one-way vehicle trip length (G) = 11.5 miles.

The user would displace GHG emissions from project study area employee commute VMT by 0.5 percent.

$$A = -1 \times \left(\frac{(1000\%) \times 0.79\% \times 2.8 \text{ miles} \times 0.25}{91.32\% \times 11.5 \text{ miles}}\right) = -0.5\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in employee commute VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Pucher, J., and Buehler, R. 2011. *Analysis of Bicycling Trends and Policies in Large North American Cities: Lessons for New York*. March. Available: http://www.utrc2.org/sites/default/files/pubs/analysis-bike-final_0.pdf. Accessed: January 2021.

T-21-A. Implement Conventional Carshare Program

GHG Mitigation Potential

0.15%

Up to 0.15% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Carshare programs can increase accessibility and provide redundancy to vehicles that can be used to evacuate or obtain resources during an extreme weather event. Carshare programs can allow residents to give up or avoid car ownership, leading to cost savings that can help build economic resilience.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will increase carshare access in the user's community by deploying conventional carshare vehicles. Carsharing offers people convenient access to a vehicle for personal or commuting purposes. This helps encourage transportation alternatives and reduces vehicle ownership, thereby avoiding VMT and associated GHG emissions. A variation of this measure, electric carsharing, is described in Measure T-21-B, *Implement Electric Carshare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing one-way carsharing service with a free-floating operational model. This measure should be applied with caution if using a different form of carsharing (e.g., roundtrip, peer-to-peer, fractional).

Cost Considerations

The costs incurred by the carshare program service manager (typically a municipality or carshare company) may include the capital costs of purchasing vehicles; costs of storing, maintaining, and replacing the fleet; and costs for marketing and administration. Some of these costs may be offset by income generated through program use.

Expanded Mitigation Options

When implementing a carshare program, best practice is to discount carshare membership and provide priority parking for carshare vehicles to encourage use of the service.

GHG Reduction Formula

$$A = \frac{B \times (E - D)}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.15	%	calculated
User Inputs				
B	Number of vehicles deployed in plan/community	[ ]	integer	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
Constants, Assumptions, and Available Defaults				
D	Conventional VMT avoided with measure	68.2	VMT per day per vehicle	Martin and Shaheen 2016
E	Conventional VMT added with measure	24.4	VMT per day per vehicle	Martin and Shaheen 2016

Further explanation of key variables:

- (B) – The number of cars in the carshare program is selected by the carshare provider, but its magnitude is relative to the size of the service area. A study of several carsharing programs (Martin and Shaheen 2016) documented a range of carshare fleet sizes for different North American cities: Calgary (590), San Diego (406), Seattle (640), Vancouver (920), Washington, D.C. (626).
- (C) – The total plan/community VMT should represent the expected total VMT generated by all land use in that area. The most appropriate source for this data is from a local travel demand model.
- (D) – Conventional VMT avoided per deployed carshare vehicle was derived based on a study of conventional-engine based car share programs in Calgary, Seattle, Vancouver, and Washington, D.C. It accounts for VMT avoided from carshare users who sold their personal vehicles and carshare users who decided not to purchase a personal vehicle, both directly because of the availability of carshare (Martin and Shaheen 2016).
- (E) – Conventional VMT added per deployed carshare vehicle was derived based on a study of conventional-engine based car share programs in Calgary, Seattle, Vancouver, and Washington, D.C. It accounts for the VMT of the carshare vehicles (Martin and Shaheen 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 0.15 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying carshare vehicles. In this example, the project would be in the city of San Diego, which in 2017 had a VMT per day of 24,101,089 miles (C) (SANDAG 2019). Assuming twice the number of vehicles used in the Car2go San Diego program (B), the GHG emissions from plan/community VMT would be reduced by 0.15 percent.

$$A = \frac{\mathbf{812\ vehicles} \times (24.4\ \frac{VMT}{day \cdot vehicle} - 68.2\ \frac{VMT}{day \cdot vehicle})}{\mathbf{24{,}101{,}089\ \frac{VMT}{day}}} = -0.15\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Martin, E. and S. Shaheen. 2016. *The Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities.* July. Available: https://tsrc.berkeley.edu/publications/impacts-car2go-vehicle-ownership-modal-shift-vehicle-miles-traveled-and-greenhouse-gas. Accessed: March 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document.* June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-21-B. Implement Electric Carshare Program

GHG Mitigation Potential

0.18%

Up to 0.18% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Electric carshare programs can increase accessibility and provide redundancy to vehicles that can be used to evacuate or obtain resources during an extreme weather event. Electric vehicles also provide fuel redundancy by allowing an alternative fuel source if an extreme event disrupts other fuel sources; however, they may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will increase carshare access in the user's community by deploying electric carshare vehicles. Carsharing offers people convenient access to a vehicle for personal or commuting purposes. This helps encourage transportation alternatives and reduces vehicle ownership, thereby avoiding VMT and associated GHG emissions. This also encourages a mode shift from internal combustion engine vehicles to electric vehicles, displacing the emissions-intensive fossil fuel energy with less emissions-intensive electricity. Electric carshare vehicles require more staffing support compared to conventional carshare programs for shuttling electric vehicles to and from charging points. A variation of this measure, conventional carsharing, is described in Measure T-21-A, *Implement Conventional Carshare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing one-way carsharing service with a free-floating operational model. This measure should be applied with caution if using a different form of carsharing (e.g., roundtrip, peer-to-peer, fractional).

Cost Considerations

Costs incurred by the service manager (e.g., municipality, carshare company) may include the capital costs of purchasing vehicles; costs of storing, maintaining, and replacing the fleet; and costs for marketing and administration. Some of these costs may be offset by income generated through program use. Participants' recurring costs of renting a carshare vehicle may be offset by the cost savings from access to cheaper transportation.

Expanded Mitigation Options

When implementing a carshare program, best practice is to discount carshare membership and provide priority parking for carshare vehicles to encourage use of the service.

GHG Reduction Formula

$$A = -1 \times \frac{B \times ((E \times G \times H \times I \times J) - (D \times F))}{C \times F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.18	%	calculated
User Inputs				
B	Number of electric vehicles deployed in plan/community	[ ]	integer	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
Constants, Assumptions, and Available Defaults				
D	Conventional VMT avoided with measure	54.8	VMT per day per EV	Martin and Shaheen 2016
E	Electric VMT added with measure	13.7	VMT per day per EV	Martin and Shaheen 2016
F	Emission factor of non-electric light duty fleet mix	307.5	g CO_2e per mile	CARB 2020a
G	Energy efficiency of carshare electric vehicle	0.327	kWh per mile	CARB 2020b; U.S. DOE 2021
H	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from lb to g	454	g per lb	conversion
J	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The number of cars in the carshare program is selected by the carshare provider, but its magnitude is relative to the size of the service area. A study of several carsharing programs (Martin and Shaheen 2016) documented a range of carshare fleet sizes for different North American cities: Calgary (590), San Diego (406), Seattle (640), Vancouver (920), Washington, D.C. (626).
- (C) – The total plan/community VMT should represent the expected total VMT generated by all land use in that area. The most appropriate source for this data is from a local travel demand forecasting model.
- (D) – Conventional VMT avoided per deployed carshare vehicle was derived based on a study of an electric vehicle carshare program in San Diego. It accounts for VMT avoided from carshare users who sold their personal vehicles and carshare users who decided not to purchase a personal vehicle, both directly because of the availability of carshare (Martin and Shaheen 2016).

- (E) – Electric VMT added per deployed carshare vehicle was derived based on a study of an electric vehicle carshare program in San Diego. It accounts for the VMT of the carshare vehicles and includes staff-driven VMT needed to bring the vehicles to charging points (Martin and Shaheen 2016).
- (F) – The average GHG emission factor for non-electric vehicles was calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of LDA, LDT1, and LDT2 vehicles using diesel and gasoline fuel. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020a) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the GHG reduction formula.
- (G) – Scaled from light-duty automobile gasoline equivalent fuel economy (G from Measure T-14) based on energy efficiency ratio (EER) of 2.5 (CARB 2020b) and an assumption of 33.7 kWh electricity per gallon of gasoline (U.S. DOE 2021).
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 0.18 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying carshare vehicles. In this example, the project would be in the city of San Diego, which in 2017 had a VMT per day of 24,101,089 miles (C) (SANDAG 2019). Assuming twice the number of vehicles used in the Car2go San Diego program (B), and a commitment by the carshare service provider to purchase zero-carbon electricity for all carshare charging stations (H), the GHG emissions from plan/community VMT would be reduced by 0.18 percent.

$$A = -1 \times \frac{812 \times \left(\left(13.7 \frac{eVMT}{day \cdot vehicle} \times 0.327 \frac{kWh}{mile} \times 0 \frac{lb\ CO_2e}{MWh} \times 454 \frac{g}{lb} \times 0.001 \frac{MWh}{kWh}\right) - \left(54.8 \frac{cVMT}{day \cdot vehicle} \times 307.5 \frac{g\ CO_2e}{mile}\right)\right)}{24{,}101{,}089 \frac{VMT}{day} \times 307.5 \frac{g\ CO_2e}{mile}} = -0.18\%$$

Quantified Co-Benefits

Improved Local Air Quality

Local criteria pollutants will be reduced by the reduction in vehicle fuel consumption. Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from electric vehicles will not generate localized criteria pollutant emissions. Accordingly, the percent reduction in NO_X, CO, NO_2, SO_2, and PM (K) is calculated using a simplified version of the GHG reduction formula, as follows:

$$K = -1 \times \frac{B \times -D}{C}$$

Reductions in ROG emissions can be calculated by multiplying the percent reduction in other criteria pollutant emissions (K) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Fuel Savings (Increased Electricity)

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in criteria pollutant emissions (K). The percent increase in electricity use (L) from this measure can be calculated using a variation of the GHG reduction formula, as follows.

Electricity Use Increase Formula

$$L = \frac{B \times E \times G \times N}{M}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Increase in electricity from electric vehicles	[ ]	%	calculated
User Inputs				
M	Existing electricity consumption of plan/community	[ ]	kWh per year	user input
Constants, Assumptions, and Available Defaults				
N	Days per year carshare program operational	365	days per year	assumed

Further explanation of key variables:

- (M) – The user should take care to properly quantify building electricity using accepted methodologies (such as CalEEMod).
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

VMT Reductions

The percent reduction in VMT (O) is calculated using a simplified version of the GHG reduction formula that excludes the variables related to emission factors, as follows.

$$O = -1 \times \frac{B \times (E - D)}{C}$$

Sources

- California Air Resources Board (CARB). 2020a. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- California Air Resources Board (CARB). 2020b. Unofficial electronic version of the Low Carbon Fuel Stproved_unofficial_06302020.pdf
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- Martin, E. and Shaheen, S. 2016. *The Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities*. July. Available: https://tsrc.berkeley.edu/publications/impacts-car2go-vehicle-ownership-modal-shift-vehicle-miles-traveled-and-greenhouse-gas. Accessed: March 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. Download Fuel Economy Data. January. Available: https://www.fueleconomy.gov/feg/download.shtml. Accessed: January 2021.

T-22-A. Implement Pedal (Non-Electric) Bikeshare Program

GHG Mitigation Potential

0.02%

Up to 0.02% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Bikeshare programs can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish a bikeshare program. Bikeshare programs provide users with on-demand access to bikes for short-term rentals. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. Variations of this measure are described in Measure T-22-B, *Implement Electric Bikeshare Program*, and Measure T-22-C, *Implement Scootershare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution if using dockless (free-floating) bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or bikeshare company) may include the capital costs for purchasing a bicycle fleet; installing accessible and secure docking stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from the cost savings from access to cheaper transportation alternatives (compared to private vehicles, private bicycles, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount bikeshare membership and dedicate bikeshare parking to encourage use of the service. Also consider including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

This measure methodology does not account for the direct GHG emissions from vehicle travel of program employees picking up and dropping off bikes.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.02	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to bikeshare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to bikeshare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily bikeshare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to bikeshare substitution rate	19.6	%	McQueen et al. 2020
F	Bikeshare average one-way trip length	1.4	miles per trip	Lazarus et al. 2019
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to bikesharing is measured as the percent of residences in the plan/community within 0.25 mile of a bikeshare station. For dockless bikes, assume that all residences within 0.25 mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited.
- (E) – A literature review of several academic and government reports found that the average car trip substitution rate by bikeshare trips was 19.6 percent. This included bikeshare programs in Washington D.C., Minneapolis, and Montreal (McQueen et al. 2020).

- (F) – A case study on average trip lengths for pedal and electric bikeshare programs in San Francisco reported a one-way pedal bikeshare trip of 1.4 miles (Lazarus et al. 2019).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.02 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying bikesharing throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have bikeshare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.02 percent.

$$A = -1 \times \frac{(100\% - 0\%) \times 0.021 \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 19.6\% \times 1.4 \frac{\text{miles}}{\text{trip}}}{2.7 \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 9.72 \frac{\text{miles}}{\text{trip}}} = -0.02\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2018. *Summary of Travel Trends 2017–National Household Travel Survey*. July. Available: https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf. Accessed: January 2021.
- Lazarus, J., J. Pourquier, F. Feng, H. Hammel, and S. Shaheen. 2019. *Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete – A Case Study of San Francisco*. Paper No. 19-02761. Annual Meeting of the Transportation Research Board: Washington, D.C. Available: https://trid.trb.org/view/1572878. Accessed: January 2021.
- McQueen, M., G. Abou-Zeid, J. MacArthur, and K. Clifton. 2020. Transportation Transformation: Is Micromobility Making a Macro Impact on Sustainability? *Journal of Planning Literature*. November. Available: https://doi.org/10.1177/0885412220972696. Accessed: March 2021.
- Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report–Travel Modeling Report*. July. Available: http://2040.planbayarea.org/files/2020-02/Travel_Modeling_PBA2040_Supplemental%20Report_7-2017.pdf. Accessed: January 2021.

T-22-B. Implement Electric Bikeshare Program

GHG Mitigation Potential

0.06%

Up to 0.06% of GHG emissions vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Bikeshare programs can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event. However, they may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish an electric bikeshare program. Electric bikeshare programs provide users with on-demand access to electric pedal assist bikes for short-term rentals. This encourages a mode shift from vehicles to electric bicycles, displacing VMT and reducing GHG emissions. Variations of this measure are described in Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, and Measure T-22-C, *Implement Scootershare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution if using dockless (free-floating) bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or bikeshare company) may include the capital costs for purchasing a bicycle fleet; installing accessible and secure charging stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from the cost savings from access to cheaper transportation alternatives (compared to private vehicles, private bicycles, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount electric bikeshare membership and dedicate electric bikeshare parking to encourage use of the service. Consider also including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

The quantification methodology does not account for indirect GHG emissions from electricity used to charge the bicycles or direct GHG emissions from vehicle travel of program employees picking up and dropping off bikes.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.06	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to electric bikeshare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to electric bikeshare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily electric bikeshare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to electric bikeshare substitution rate	35	percent	Fitch et al. 2021
F	Electric bikeshare average one-way trip length	2.1	miles per trip	Fitch et al. 2021
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to electric bikesharing is measured as the percent of residences in the plan/community within 0.25-mile of an electric bikeshare station. For dockless bikes, assume that all residences within 0.25 mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited. Conventional bikeshare trip rate data was used due to lack of specific data for electric bikeshare.
- (E) – A study of dockless electric bike share in Sacramento found that the substitution rate of vehicles trips by electric bikeshare trips was 35 percent (Fitch et al. 2021).

- (F) – A study of dockless electric bike share in Sacramento found that the average one-way bikeshare trip was 2.1 miles (Fitch et al. 2021).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.06 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying electric bikesharing throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have bikeshare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.06 percent.

$$A = -1 \times \frac{(100\% - 0\%) \times 0.021 \frac{\text{trips}}{\text{day} \cdot \text{person}} \times 35\% \times 2.1 \frac{\text{miles}}{\text{trip}}}{2.7 \frac{\text{trips}}{\text{day} \cdot \text{person}} \times 9.72 \frac{\text{miles}}{\text{trip}}} = -0.06\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the increase in electricity used to charge the vehicles or the fuel consumption from vehicle travel of program employees picking up and dropping off bikes.

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the miles traveled from vehicle travel of program employees picking up and dropping off bikes.

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2018. *Summary of Travel Trends 2017–National Household Travel Survey*. July. Available: https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf. Accessed: January 2021.
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- Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report–Travel Modeling Report*. July. Available: http://2040.planbayarea.org/files/2020-02/Travel_Modeling_PBA2040_Supplemental%20Report_7-2017.pdf. Accessed: January 2021.

T-22-C. Implement Scootershare Program

GHG Mitigation Potential

0.07%

Up to 0.07% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Scootershare programs can incentivize more scooter use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish a scootershare program. Scootershare programs provide users with on-demand access to electric scooters for short-term rentals. This encourages a mode shift from vehicles to scooters, displacing VMT and thus reducing GHG emissions. Variations of this measure are described in Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, and Measure T-22-B, *Implement Electric Bikeshare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution given the likely higher popularity of scootershare compared to bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or scootershare company) may include the capital costs for purchasing a scooter fleet; installing accessible and secure docking stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from cost savings from access to cheaper transportation alternatives (compared to private vehicles, private scooters, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount scootershare membership and dedicate scootershare parking to encourage use of the service. Consider also including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

This measure methodology does not account for the indirect GHG emissions from electricity used to charge the scooters or direct GHG emissions from vehicle travel of program employees picking up and dropping off scooters.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.07	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to scootershare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to scootershare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily scootershare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to scootershare substitution rate	38.5	%	McQueen et al. 2020
F	Scootershare average one-way trip length	2.14	miles per trip	PBOT 2021
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to scootersharing is measured as the percent of residences in the plan/community within 0.25-mile of a scootershare station. For dockless scooters, assume that all residences within 0.25-mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited. Conventional bikeshare trip rate data was used due to lack of specific data for scootershare.
- (E) – A literature review of several academic and government reports found that the average car trip substitution rate by scootershare trips was 38.5 percent. This included scootershare programs in Santa Monica, Minneapolis, San Francisco, and Portland (McQueen et al. 2020).

- (F) – In Oregon, Portland's scootershare pilot data dashboard reports that the average trip length of scootershare trips is 2.14 miles (PBOT 2021).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.07 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}C}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-C. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying scootershare throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have scootershare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.07 percent.

$$A = -1 \times \frac{(\mathbf{100\% - 0\%}) \times 0.021\ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 38.5\% \times 2.14\ \frac{\text{miles}}{\text{trip}}}{2.7\ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 9.72\ \frac{\text{miles}}{\text{trip}}} = -0.07\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the increase in electricity used to charge the scooters or the fuel consumption from vehicle travel of program employees picking up and dropping off scooters.

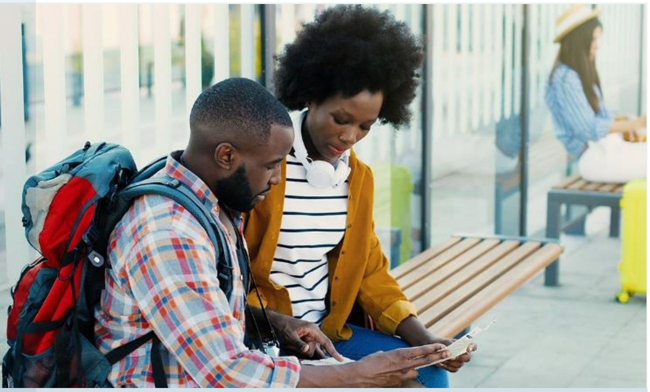
VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the miles traveled from vehicle travel of program employees picking up and dropping off scooters.

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2018. *Summary of Travel Trends 2017–National Household Travel Survey*. July. Available: https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf. Accessed: January 2021.
- Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report–Travel Modeling Report*. July. Available: http://2040.planbayarea.org/files/2020-02/Travel_Modeling_PBA2040_Supplemental%20Report_7-2017.pdf. Accessed: January 2021.
- McQueen, M., G. Abou-Zeid, J. MacArthur, and K. Clifton. 2020. *Transportation Transformation: Is Micromobility Making a Macro Impact on Sustainability?* Journal of Planning Literature. November. Available: https://doi.org/10.1177/0885412220972696. Accessed: March 2021.
- Portland Bureau of Transportation (PBOT). 2021. *Portland Bureau of Transportation E-Scooter Dashboard*. Available: https://public.tableau.com/profile/portland.bureau.of.transportation#!/vizhome/PBOTE-ScooterTripsDashboard/ScooterDashboard. Accessed: March 2021.

T-23. Provide Community-Based Travel Planning



GHG Mitigation Potential

2.3%

Up to 2.3% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Climate Resilience

CBTP can decrease vehicle use and thus improve air quality, resulting in health impacts that may increase the resilience of communities near freeways and roads. This can also increase the adaptive capacity of communities by informing them of travel alternatives if certain modes become disrupted due to extreme events.

Health and Equity Considerations

Outreach materials may need to be in multiple languages to address diverse linguistic communities.

Measure Description

This measure will target residences in the plan/community with community-based travel planning (CBTP). CBTP is a residential-based approach to outreach that provides households with customized information, incentives, and support to encourage the use of transportation alternatives in place of single occupancy vehicles, thereby reducing household VMT and associated GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

CBTP involves teams of trained travel advisors visiting all households within a targeted geographic area, having tailored conversations about residents' travel needs, and educating residents about the various transportation options available to them. Due to the personalized outreach method, communities are typically targeted in phases.

Cost Considerations

The main cost consideration for CBTP is labor costs for program managers and resident outreach staff plus material costs for development of educational material. The beneficiaries are the commuters who may be able to reduce vehicle usage or ownership. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Pair with any of the Measures from T-17 through T-22-C to ensure that residents that are targeted by CBTP who want to use alternative transportation have the infrastructure and technology to do so.

GHG Reduction Formula

$$A = \frac{C}{B} \times D \times -E \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from household vehicle travel in plan/community	0–2.3	%	calculated
User Inputs				
B	Residences in plan/community	[ ]	residences	user input
C	Residences in plan/community targeted with CBTP	[ ]	residences	user input
Constants, Assumptions, and Available Defaults				
D	Percent of targeted residences that participate	19	%	MTC 2021
E	Percent vehicle trip reduction by participating residences	12	%	MTC 2021
F	Adjustment factor from vehicle trips to VMT	1	unitless	assumed

Further explanation of key variables:

- (D) – Results from program evaluations of CBTP in several counties in Washington and Oregon across multiple years indicate that an average of 19 percent of residences targeted will participate (MTC 2021).
- (E) – Results from program evaluations of CBTP in several counties in Washington and Oregon across multiple years indicate that a 12 percent vehicle trip reduction will occur among participating residences (MTC 2021).
- (F) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum percent reduction in GHG emissions (A) is 2.3 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

Same as (A_{max}). Measure T-23 is the only measure at the Plan/Community scale within the Trip Reduction Programs subsector.

Example GHG Reduction Quantification

The user reduces household VMT by having residences in the plan/community participate in CBTP. In this example, all of the residences in a city of 5,000 are targeted (B and C), which would reduce GHG emissions from citywide household VMT by 2.3 percent.

$$A = \left(\frac{5{,}000\ \text{residences}}{5{,}000\ \text{residences}}\right) \times 19\% \times -12\% \times 1 = -2.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in household VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Metropolitan Transportation Commission (MTC). October 2021. *Plan Bay Area 2050, Forecasting and Modeling Report*. Available: https://www.planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_Forecasting_Modeling_Report_October_2021.pdf. Accessed: November 2021.

T-24. Implement Market Price Public Parking (On-Street)

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Implementing market price public parking could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. In addition, this reduces illegal loading/standing in bus stops and travel lanes. When these reductions occur during extreme weather events, they better allow emergency responders to access a hazard site.

Health and Equity Considerations

Pricing on-street parking at market rates reduces illegal loading/standing in bus stops and travel lanes, improving transit times.

Measure Description

This measure will price all on-street parking in a given community, with a focus on parking near central business districts, employment centers, and retail centers. Increasing the cost of parking increases the total cost of driving to a location, incentivizing shifts to other modes and thus decreasing total VMT to and from the priced areas. This VMT reduction results in a corresponding reduction in GHG emissions.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

When pricing on-street parking, best practice is to allow for dynamic adjustment of prices to ensure approximately 85 percent occupancy, which helps prevent induced VMT due to circling behaviors as individuals search for a vacant parking space. In addition, this method should primarily be implemented in areas with available alternatives to driving, such as transit availability within 0.5. mile or areas of high residential density nearby (allowing for increased walking/biking). If the measure is implemented in a small area, residential parking permit programs should be considered to prevent parking intrusion on nearby streets in residential areas without priced parking.

Cost Considerations

Municipalities may incur costs from installing the meter network, which may require meters at individual spaces or at more central terminals. There would also be staffing costs to monitor the metered spaces and collect payments. Residents also incur a cost by having to pay for on-street parking. A portion of costs to the municipality may be offset through revenue collected by the parking system.

Expanded Mitigation Options

Pricing on-street parking also helps support individual projects with priced onsite parking by removing potential alternative parking locations.

GHG Reduction Formula

$$A = \frac{B}{C} \times \frac{D - E}{E} \times F \times G \times H$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–30.0	%	calculated
User Inputs				
B	VMT in priced area without measure	[ ]	VMT per day	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
D	Proposed parking price	1.00–5.00	$ per hour	user input
E	Initial parking price	0.00–5.00	$ per hour	user input
F	Default percentage of trips parking on street	5–75	%	user input
Constants, Assumptions, and Available Defaults				
G	Elasticity of parking demand with respect to price	-0.4	unitless	Pierce and Shoup 2013
H	Ratio of VMT to vehicle trips	1	unitless	assumption

Further explanation of key variables:

- (B and C) – Total daily VMT in both the priced area and the plan/community area should represent the expected total VMT generated by all land use in that area, including office, residences, retail, schools, and other uses. The most appropriate source for this data is from a local travel demand forecasting model. An alternate method uses VMT per worker or VMT per resident as calculated for SB 743 compliance and screening purposes multiplied by the population in the area.
  - These variables for VMT by area are used to ensure that the percent GHG reduction from the priced area is at the same geographic scale as the vehicle travel in the plan/community. If the area priced is a business district and the analysis is limited to the business district, then the VMT would be equal (B=C).
- (D) – The proposed parking price can be presented in cost per minute, hour, or day, provided that the same units are used for variable (E)
- (E) – Because this is used to calculate the percent change in parking price, if parking is free under existing conditions, (E) should be set to (1/2×D), resulting in a percentage change of 100 percent. In areas where metered parking is common, E may instead by set to equal the average metered parking price in nearby areas or districts.
- (F) – On-street parking represents only a portion of the total available parking supply. An estimate will typically range from 5 percent (in locations with offsite parking garages available) to 75 percent (in locations where most parcels have little to no onsite parking for visitors). The user should provide a project-specific value within this range, by surveying the total on-street vs. off-street parking spaces within ¼ mile of the study area.

- (G) – An evaluation of the SFPark program in San Francisco found that a 0.4 percent decrease in parking demand occurs for every 1 percent increase in parking price (Pierce and Shoup 2013). Price elasticity of parking demand varies by location, day of the week, and time of day.
- (H) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The total reduction in VMT due to on-street parking pricing is capped at 30 percent, which is based on the following assumptions:

- $\left(\frac{D-E}{E}=100\%\right)$ – Parking prices double (i.e., increase by 100 percent) or parking pricing is introduced in previously free areas.
- (F) – 75 percent of all vehicle trips utilize on-street parking. Note that only within a small-scale commercial district is 75 percent of parking likely to occur on street.

This maximum scenario is presented in the below example quantification.

Subsector Maximum

Same as (A_{max}). Measure T-24 is the only measure at the Plan/Community scale within the Parking or Road Pricing/Management subsector.

Example GHG Reduction Quantification

The user reduces VMT by increasing hourly on-street parking costs. In this example, the hourly parking cost increases from $1.00 (E) to $2.00 (D) in a business district. The business district daily VMT is 1,000,000 (B), and the scale of implementation is the business district (B=C). If around 75 percent of the district's parking supply is on street (F), the user would reduce GHG emissions from VMT by 30 percent.

$$A = \frac{1{,}000{,}000\,\frac{VMT}{day}}{1{,}000{,}000\,\frac{VMT}{day}} \times \frac{\$2.00 - \$1.00}{\$1.00} \times 75\% \times -0.4 \times 1 = -30\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Pierce, G., and D. Shoup. 2013. Getting the Prices Right: An Evaluation of Pricing Parking by Demand in San Francisco. *Journal of the American Planning Association* 79(1)67–81. May. Available: https://www.tandfonline.com/doi/pdf/10.1080/01944363.2013.787307?needAccess=true. Accessed: January 2021.

T-25. Extend Transit Network Coverage or Hours

GHG Mitigation Potential

4.6%

Up to 4.6% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing transit network coverage or hours improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. They could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

This measure increases access to social, educational, and employment opportunities. Expansion of transit networks need to ensure equitable access by all communities to the transit system.

Measure Description

This measure will expand the local transit network by either adding or modifying existing transit service or extending the operation hours to enhance the service near the project site. Starting services earlier in the morning and/or extending services to late-night hours can accommodate the commuting times of alternative-shift workers. This will encourage the use of transit and therefore reduce VMT and associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

There are two primary means of expanding the transit network: by increasing the frequency of service, thereby reducing average wait times and increasing convenience, or by extending service to cover new areas and times.

Cost Considerations

Infrastructure costs for extending the physical network coverage of a transit system can be significant. Costs to expand track-dependent transit, such as light rail and passenger rail, are high and can require resource- and time-intensive advanced planning. Costs to expand vehicle-dependent transit, such as busses, are likewise high but may be limited to procurement of additional vehicles. Any expansion of transit, including just service hours, would increase staffing and potentially maintenance costs. A portion of these costs may be offset by increased transit usage and associated income. Commuters who may more easily be able to travel without a car may also observe cost savings from reduce vehicle usage or ownership.

Expanded Mitigation Options

This measure is focused on providing additional transit network coverage, with no changes to transit frequency. This measure can be paired with Measure T-26, *Increase Transit Service Frequency*, which is focused on increasing transit service frequency, for increased reductions.

GHG Reduction Formula

$$A = -1 \times \frac{C - B}{B} \times D \times E \times F \times G$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from plan/community VMT	0–4.6	%	calculated
User Inputs				
B	Total transit service miles or service hours in plan/community before expansion	[ ]	miles	user input
C	Total transit service miles or service hours in plan/community after expansion	[ ]	miles	user input
D	Transit mode share in plan/community	Table T-3.1	%	user input
Constants, Assumptions, and Available Defaults				
E	Elasticity of transit demand with respect to service miles or service hours	0.7	unitless	Handy et al. 2013
F	Statewide mode shift factor	57.8	%	FHWA 2017
G	Ratio of vehicle trip reduction to VMT	1	unitless	assumption

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel. Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users.
- (B and C) – Transit service miles are defined as the total service mileage. Service hours represent the hours of operation. Either metric can be used in the GHG reduction formula so long as both B and C use the same metric.
- (D) – The transit mode share for the six most populated CBSAs in California are provided in Table T-3.1 in Appendix C (FHWA 2017). If the project study area is not within the listed CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. It is likely for areas outside of the area covered by the listed CBSAs to have transit mode shares lower than the values provided in the table. Ideally, the user will calculate existing transit mode share for work trips or all trips at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. Care should be taken to not present the reported commute mode share as retrieved from the ACS, unless the land use is office or employment based and the ACS tables are based on work location (rather than home location).
- (E) – A policy brief summarizing the results of transit service strategies concluded that a 0.7 percent increase in transit ridership occurs for every 1 percent increase in service miles or hours (Handy et al. 2013).

- (F) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).
- (G) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from expanding the transit network is capped at 4.6 percent, which is based on the following assumptions:

- $\left(\frac{C-B}{B} \leq 100\%\right)$ – The transit network increase is capped at a doubling in size, or 100 percent (twice as many revenue miles are provided, for a 100 percent increase).
- (D) – The CBSA is San Francisco-Oakland-Hayward, which has a default transit mode share for all trips of 11.38 percent.

This maximum scenario is presented in the below example quantification.

Subsector Maximum

$(\sum A_{max_{T\text{-}25\ through\ T\text{-}29}} \leq 15\%)$ This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Example GHG Reduction Quantification

The user reduces VMT by extending an existing transit route or lengthening the service hours. In this example, the project in a neighborhood of the San Francisco-Oakland-Hayward CBSA and would increase transit coverage in the area from 20 miles (B) to 40 miles (C). If the existing transit mode share in the study area is 11.38 percent (D), the user would reduce GHG emissions from VMT by 4.6 percent.

$$A = -1 \times \frac{(40\ miles - 20\ miles)}{20\ miles} \times 11.38\% \times 0.7 \times 57.8\% \times 1 = -4.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

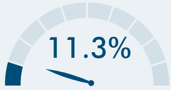
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, and S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-26. Increase Transit Service Frequency

GHG Mitigation Potential



Up to 11.3% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing transit service frequency improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. It could also incentivize more people to use transit, resulting in less traffic and better allow emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

This measure increases access to social, educational, and employment opportunities. Expansion of transit service needs to ensure equitable access by all communities to the transit system.

Measure Description

This measure will increase transit frequency on one or more transit lines serving the plan/community. Increased transit frequency reduces waiting and overall travel times, which improves the user experience and increases the attractiveness of transit service. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT and associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Increasing transit service frequency may require capital investment to purchase additional vehicles. Staff and maintenance costs may also increase. A portion of these costs may be offset by increased transit usage and associated income. Commuters who may more easily be able to travel without a car may also observe cost savings from reduce vehicle usage or ownership.

Expanded Mitigation Options

This measure is focused on providing increased transit frequency, with no changes to transit network coverage. This measure can be paired with Measure T-25, *Extend Transit Network Coverage or Hours*, which is focused on increasing transit network coverage, for increased reductions.

GHG Reduction Formula

$$A = -C \times \frac{B \times E \times D \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–11.3	%	calculated
User Inputs				
B	Percent increase in transit frequency	0–300	%	user input
C	Level of implementation	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of transit ridership with respect to frequency of service	0.5	unitless	Handy et al. 2013
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017b

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel. Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users. Users can calculate the absolute changes in passenger vehicle and bus VMT and emissions using the process described under *Co-Benefits*.
- (B) – Frequency is measured as the number of arrivals over a given time (e.g., buses per hour). Frequency is the inverse of transit headway, defined as the time between transit vehicle arrivals on a given route. This variable can be calculated as [transit frequency with measure minus existing transit frequency] divided by existing transit frequency.
- (C) – The level of implementation refers to the number of transit routes receiving the frequency improvement as a fraction of the total transit routes in the plan/community.
- (D) – A policy brief summarizing the results of transit service strategies concluded that a 0.5 percent increase in transit ridership occurs for every 1 percent increase in frequency (Handy et al. 2013).
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of

the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.

- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 11.3 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent change in transit frequency is capped at 300 percent (SANDAG 2019).

Subsector Maximum

($\sum {A_{max}}_{T\text{-}25 \text{ through } T\text{-}29} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects Measure T-28, *Provide Bus Rapid Transit*, and converts all transit routes in the plan/community to BRT, then the user cannot also take credit for this measure or Measure T-27, *Implement Transit-Supportive Roadway Treatments*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27 and/or Measure T-26 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, this measure and/or Measure T-27 could be applied to the remaining bus routes, and the measure reductions could be combined with Measure T-28 to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by increasing transit frequency, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in the San Francisco-Oakland-Hayward CBSA where the transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (E and F). Assuming the maximum increase in transit frequency of 300 percent (B) and implementation for all transit routes (100 percent) in the plan/community (C), the user would reduce plan/community GHG emissions from VMT by 11.3 percent.

$$A = -100\% \times \frac{300\% \times 11.38\% \times 0.5 \times 57.8\%}{86.96\%} = -11.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

VMT Reductions

The decrease in passenger vehicle miles (H) and increase in bus miles (L) by the measure can be calculated as follows.

Passenger Vehicle VMT Reduction Formula

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A). The absolute reduction in passenger VMT can be calculated using the following formula.

$$H = I \times E \times J \times B \times D \times G \times K$$

Passenger Vehicle VMT Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
H	Reduction in passenger vehicle miles in plan/community	[ ]	miles per year	calculated
User Inputs				
I	Total daily person trips in corridor(s)	[ ]	trips per day	user input
J	Vehicle trip length	[ ]	miles per trip	user input
Constants, Assumptions, and Available Defaults				
K	Days per year transit available	365	days per year	assumed

Further explanation of key variables:

- (I) – The total daily person trips in the corridor(s) represents the total daily trips by all modes between the bus route origin area and the bus route destination area. This may be obtained through travel demand modeling. If the strategy involves frequency improvements for more than one transit route, then the total person trips should reflect the sum of all the routes being improved.
- (J) – If the strategy involves frequency improvements for more than one transit route, then the trip length should reflect the average of all the routes being improved.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Bus VMT Increase Formula

The absolute increase in bus VMT can be calculated using the formula below. As noted above, the formula for the percent GHG reduction (A) does not reflect any increase in bus VMT and bus emissions. Users that wish to capture these impacts should calculate absolute changes.

$$L = P \times (M_2 - M_1) \times N \times O \times K$$

Bus VMT Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Increase in annual bus miles in plan/community	[ ]	miles per year	calculated
User Inputs				
M_1	Bus frequency without measure	[ ]	transit vehicle roundtrips per hour	user input
M_2	Bus frequency with measure	[ ]	transit vehicle roundtrips per hour	user input
N	Bus hours of operation	0–24	hours per day	user input
O	Bus route one-way length	[ ]	miles per route	user input
Constants, Assumptions, and Available Defaults				
P	One-way trips in a roundtrip	2	one-way trips per roundtrip	conversion

Further explanation of key variables:

- (L) – If the strategy involves frequency improvements for more than one transit route, then the increase in bus miles should be calculated separately for each route.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Energy and Fuel Savings

The decrease in passenger vehicle fuel consumption and increase in bus fuel consumption by the measure can be calculated as follows.

Passenger Vehicle Fuel Use Reduction Formula

Multiply the reduction in passenger vehicle miles (H) above by the fuel efficiency of the vehicle type (see Table T-30.2 in Appendix C) to output the change in fuel consumption.

Bus Fuel Use Increase Formula

The absolute increase in bus fuel consumption (Q) can be calculated using the formula below.

$$Q = L \times R$$

Bus Fuel Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
Q	Increase in annual bus fuel consumption in plan/community	[ ]	gal per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
R	Fuel economy of a transit bus, by fuel type	Table T-26.1	gal or kilowatt hour per mile	CARB 2020; U.S. DOE 2021

Further explanation of key variables:

- (R) – The average fuel economy for gasoline, diesel, and natural gas transit buses was calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of UBUS vehicles, disaggregated by fuel type (CARB 2020). The efficiency of electric buses was calculated based on the gasoline equivalent value (U.S. DOE 2021). The user should reference Table T-26.1 for the fuel economy of the appropriate fuel type for their location's transit system. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the fuel use increase formula.
- Please refer to the Bus VMT Increase Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Fuel Economy Datasets for All Model Years (1984-2021)*. January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

T-27. Implement Transit-Supportive Roadway Treatments

GHG Mitigation Potential

0.6%

Up to 0.6% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Implementing transit-supportive roadway treatments improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. It could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Furthermore, emergency responders can use queue jumps and dedicated bus lanes when needed.

Health and Equity Considerations

Transit facilities can have conflicts with cyclists. Consider appropriate treatments to minimize conflicts. Improved transit investments should be equitably distributed prioritizing areas with transit deficiencies in underserved communities.

Measure Description

This measure will implement transit-supportive treatments on the transit routes serving the plan/community. Transit-supportive treatments incorporate a mix of roadway infrastructure improvements and/or traffic signal modifications to improve transit travel times and reliability. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT and the associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Treatments can include transit signal priority, bus-only signal phases, queue jumps, curb extensions to speed passenger loading, and dedicated bus lanes.

Cost Considerations

Costs and savings of transit-supportive roadway treatments vary depending on the strategy pursued, ranging from low-cost route optimization changes to high-cost infrastructure projects (e.g., bus-only lanes). Reducing route cycle time without significantly increasing the number of transit vehicles can result in net cost savings for the transit system. Dedicated transit infrastructure will improve transit reliability and increase ridership. This supplements existing transit income streams for municipalities. Increased ridership similarly reduces vehicle use, which has cost benefits for both commuters and municipalities.

Expanded Mitigation Options

This measure could be paired with other Transit subsector strategies (Measure T-25 and Measure T-29) for increased reductions.

GHG Reduction Formula

$$A = -1 \times \frac{B \times C \times D \times E \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.6	%	calculated
User Inputs				
B	Percent of plan/community transit routes that receive treatments	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent change in transit travel time due to treatments	-10	%	TRB 2007
D	Elasticity of transit ridership with respect to transit travel time	-0.4	unitless	TRB 2007
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017b

Further explanation of key variables:

- (C) – A literature review of studies from the U.S. and United Kingdom indicates that the travel time savings associated with one type of transit-supportive roadway treatment—transit signal prioritization—typically ranged from 8 to 12 percent (TRB 2007). To account for the likelihood that a user would implement multiple transit-supportive treatments, the midpoint of this range is used for the measure formula. Use of the midpoint is still conservative given the additional travel time savings associated with other transit-supportive treatments. If the user can provide a project-specific value based on the suite of their treatments, then the user should replace this default in the GHG reduction formula.
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.

- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips as some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy) (FHWA 2017b).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (C_{max}), the maximum percent reduction in GHG emissions (A) is 0.6 percent. This maximum scenario is presented in the below example quantification.

(C_{max}) The percent reduction in transit travel time is capped at 20 percent, which is based on the values reported in a literature review of studies from the U.S. and United Kingdom (TRB 2007).

Subsector Maximum

($\sum A_{max_{T\text{-}25\text{ through }T\text{-}29}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects Measure T-28, *Provide Bus Rapid Transit*, and converts all transit routes in the plan/community to BRT, then the user cannot also take credit for this measure or Measure T-26, *Increase Transit Service Frequency*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27 and/or Measure T-26 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, this measure and/or Measure T-26 could be applied to the remaining bus routes, and the measure reductions could be combined with Measure T-28 to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by implementing transit-supportive roadway treatments that decrease transit travel time, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in San Francisco-Oakland-Hayward CBSA where the transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (E and G). Assuming the maximum decrease in transit travel time of 20 percent (C_{max}) and implementation for all transit routes (100 percent) in the plan/community (B), the user would reduce plan/community GHG emissions from VMT by 0.6 percent.

$$A = -1 \times \frac{100\% \times -20\% \times -0.4 \times 11.38\% \times 57.8\%}{86.96\%} = -0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in passenger vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Transportation Research Board (TRB). 2007. *Transit Cooperative Research Program Report 118: Bus Rapid Transit Practitioner's Guide*. Available: https://nacto.org/docs/usdg/tcrp118brt_practitioners_kittleson.pdf. Accessed: January 2021.

T-28. Provide Bus Rapid Transit

Photo Credit: LA Metro, 2021

GHG Mitigation Potential

13.8%

Up to 13.8% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing BRT can incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Furthermore, emergency responders can use queue jumps and dedicated BRT lanes when needed.

Health and Equity Considerations

Transit facilities can have conflicts with cyclists. Consider appropriate BRT components to minimize conflicts. Improved transit investments should be equitably distributed, prioritizing areas with transit deficiencies in underserved communities.

Measure Description

This measure will convert an existing bus route to a bus rapid transit (BRT) system. BRT includes the following additional components, compared to traditional bus service: exclusive right-of-way (e.g., busways, queue jumping lanes) at congested intersections, increased limited-stop service (e.g., express service), intelligent transportation technology (e.g., transit signal priority, automatic vehicle location systems), advanced technology vehicles (e.g., articulated buses, low-floor buses), enhanced station design, efficient fare-payment smart cards or smartphone apps, branding of the system, and use of vehicle guidance systems. BRT can increase the transit mode share in a community due to improved travel times, service frequencies, and the unique components of the BRT system. This mode shift reduces VMT and the associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The measure quantification methodology accounts for the increase in ridership from (1) improved travel times from transit signal prioritization, (2) increased service frequency, and (3) the unique ridership increase associated with a full-featured BRT service operating on a fully segregated running way with specialized (or stylized) vehicles, attractive stations, and efficient fare collection practices. To take credit for the estimated emissions reduction, the user should implement, at minimum, these components.

Cost Considerations

Providing BRT will require capital investment to purchase specialized vehicles, develop passenger information systems, and construct stations and busways. Total costs vary depending on the suite of BRT components pursued. Grade-separated busways are more expensive than at-grade busways and mixed flow lanes. Dedicated transit infrastructure will improve transit reliability and increase ridership. This supplements existing transit income streams for municipalities. Increased ridership similarly reduces vehicle use, which has cost benefits for both commuters and municipalities.

Expanded Mitigation Options

This measure could be paired with Measure T-25, *Extend Transit Network Coverage or Hours,* and Measure T-29, *Reduce Transit Fares,* for increased reductions.

GHG Reduction Formula

$$A = -C \times \frac{D \times F \times \left((B \times I) + (H \times J) + G\right)}{E}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–13.8	%	calculated
User Inputs				
B	Percent increase in transit frequency due to BRT	0–300	%	user input
C	Level of implementation	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
E	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Statewide mode shift factor	57.8	%	FHWA 2017b
G	Percent change in transit ridership due to BRT	25	%	TRB 2007
H	Percent change in transit travel time due to BRT	-10 to -20	%	TRB 2007
I	Elasticity of transit ridership with respect to frequency of service	0.5	unitless	Handy et al. 2013
J	Elasticity of transit ridership with respect to transit travel time	-0.4	unitless	TRB 2007

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel.[14] Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users. Users can calculate the absolute changes in passenger vehicle and bus VMT and emissions using the process described under *Co-Benefits*.
- (B) – Frequency is measured as the number of arrivals over a given time (e.g., buses per hour). Frequency is the inverse of transit headway, defined as the time between transit vehicle arrivals on a given route. This variable can be calculated as [transit frequency with measure minus existing transit frequency] divided by existing transit frequency.

[14] As discussed in Chapter 2, *Integrated and Resilient Planning*, the ICT regulation requires all public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040. Accordingly, combustion emissions from transit operation will decline as vehicle fleets move to achieve the state's zero-emission bus goals.

- (C) – The level of implementation refers to the number of transit routes receiving the frequency improvement as a fraction of the total transit routes in the plan/community.
- (D and E) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, the user has the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.
- (F) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).
- (G) – A BRT practitioner's guide summarizing the results of numerous BRT case studies concluded that, on top of the ridership gains from improved travel times and increased service frequency, an additional 25 percent increase in ridership would occur from a full-featured BRT service operating on a fully segregated running way with specialized (or stylized) vehicles, attractive stations, and efficient fare collection practices.
- (H) – A literature review of studies from the United States and United Kingdom indicates that the travel time savings associated with one type of BRT component—transit signal prioritization—typically average 10 percent (TRB 2007). If the user can provide a project-specific value based on the suite of BRT components, then the user should replace this default in the GHG reduction formula. Note that, as described below, (H) should not exceed 20 percent.
- (I) – A policy brief summarizing the results of transit service strategies concluded that a 0.5 percent increase in transit ridership occurs for every 1 percent increase in frequency (Handy et al. 2013).
- (J) – A BRT practitioner's guide summarizing the results of numerous BRT case studies concluded that a -0.4 percent decrease in transit ridership occurs for every 1 percent increase in transit travel time (TRB 2007).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 13.8 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent change in transit frequency is capped at 300 percent (SANDAG 2019).

(H_{max}) The percent reduction in transit travel time is capped at 20 percent, which is based on the values reported in a literature review of studies from the United States and United Kingdom (TRB 2007).

Subsector Maximum

($\sum A_{max_{T\text{-}25\text{ through }T\text{-}29}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29. The VMT reduction from the combined implementation of all the non–mutually-exclusive measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects this measure and converts all transit routes in the plan/community to BRT (B), then the user cannot also take credit for Measure T-26, *Increase Transit Service Frequency*, or Measure T-27, *Implement Transit-Supportive Roadway Treatments*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27 and/or Measure T-26 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, Measure T-26 and/or Measure T-27 could be applied to the remaining bus routes, and the measure reductions could be combined to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by implementing a full-featured BRT system, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in the San Francisco–Oakland–Hayward CBSA where transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (D and E). Assuming the maximum increase in transit frequency of 300 percent (B_{max}), the maximum decrease in transit travel time of 20 percent (H_{max}), and implementation for all transit routes (100 percent) in the plan/community (B), the user would reduce plan/community GHG emissions from VMT by 13.8 percent.

$$A = -100\% \times \frac{11.38\% \times 57.8\% \times ((300\% \times 0.5) + (-20\% \times -0.4) + 25\%)}{86.96\%} = -13.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

VMT Reductions

The decrease in passenger vehicle miles (K) and increase in BRT miles (O) by the measure can be calculated as follows.

Passenger Vehicle VMT Reduction Formula

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A). The absolute reduction in passenger VMT can be calculated using the following formula.

$$K = -\left(D \times \mathbf{L} \times \mathbf{M} \times N \times \left((\mathbf{B} \times I) + (H \times J) + G\right)\right)$$

Passenger Vehicle VMT Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
K	Reduction in passenger vehicle miles in plan/community	[ ]	miles per year	calculated
User Inputs				
L	Total daily person trips in corridor(s)	[ ]	trips per day	user input
M	Vehicle trip length	[ ]	miles per trip	user input
Constants, Assumptions, and Available Defaults				
N	Days per year BRT available	365	days per year	assumed

Further explanation of key variables:

- (L) – The total daily person trips in the corridor(s) represents the total daily trips by all modes between the BRT origin area and the BRT destination area. This may be obtained through travel demand modeling. If the strategy involves BRT for more than one route, then the total person trips should reflect the sum of all the routes being improved.
- (M) – If the strategy involves BRT for more than one transit route, then the trip length should reflect the average of all the routes being converted.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

BRT VMT Increase Formula

The absolute increase in BRT VMT can be calculated using the formula below. As noted above, the formula for the percent GHG reduction (A) does not reflect any increase in BRT VMT or BRT emissions. Users that wish to capture these impacts should calculate absolute changes.

$$O = S \times (P_2 - P_1) \times \mathbf{Q} \times \mathbf{R} \times N$$

BRT VMT Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
O	Increase in annual BRT miles in plan/community	[ ]	miles per year	calculated
User Inputs				
P_1	Bus frequency without measure	[ ]	transit vehicle roundtrips per hour	user input
P_2	BRT frequency with measure	[ ]	transit vehicle roundtrips per hour	user input
Q	BRT hours of operation	0–24	hours per day	user input
R	BRT route one-way length	[ ]	miles per route	user input
Constants, Assumptions, and Available Defaults				
S	One-way trips in a roundtrip	2	One-way trips per roundtrip	conversion

Further explanation of key variables:

- (O) – If the strategy involves frequency improvements for more than one transit route, then the increase in BRT miles should be calculated separately for each route.
- Please refer to the Passenger Vehicle VMT Reduction Calculation Variables table above for definitions of variables that have been previously defined.

Energy and Fuel Savings

The decrease in passenger vehicle fuel consumption and increase in BRT fuel consumption by the measure can be calculated as follows.

Passenger Vehicle Fuel Use Reduction Formula

Multiply the reduction in passenger vehicle miles (K) above by the fuel efficiency of the vehicle type (see Table T-30.2 in Appendix C) to output the change in fuel consumption.

BRT Fuel Use Increase Formula

The absolute increase in BRT fuel consumption (T) can be calculated using the formula below.

$$T = O \times U$$

BRT Fuel Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
T	Increase in annual BRT fuel consumption in plan/community	[ ]	gal per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
U	Fuel economy of BRT, by fuel type	Table T-26.1	gal or kilowatt hour per mile	CARB 2020; U.S. DOE 2021

Further explanation of key variables:

- (U) – The average fuel economy for gasoline, diesel, and natural gas transit buses was calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of UBUS vehicles, disaggregated by fuel type (CARB 2020). The efficiency of electric buses was calculated based on the gasoline equivalent value (U.S. DOE 2021). The user should reference Table T-26.1 for the fuel economy of the appropriate fuel type for their location's transit system. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the fuel use increase formula. Also, if the BRT vehicles are fueled by hydrogen, the user will need to calculate the increase in hydrogen fuel consumption using project-specific values, as hydrogen is currently not included as a fuel type in EMFAC.
- Please refer to the BRT VMT Increase Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
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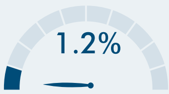
- Handy, S., K. Lovejoy, M. Boarnet, and S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.
- Transportation Research Board (TRB). 2007. *Transit Cooperative Research Program Report 118: Bus Rapid Transit Practitioner's Guide*. Available: https://nacto.org/docs/usdg/tcrp118brt_practitioners_kittleson.pdf. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Fuel Economy Datasets for All Model Years (1984-2021)*. January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

T-29. Reduce Transit Fares

GHG Mitigation Potential



Up to 1.2% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Reducing transit fares increases the capacity of low-income populations to use transit to evacuate or access resources during extreme weather events. Reduced fares could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access sites. This also reduces transit system disruptions due to extreme weather events. Lower transportation costs would also increase community resilience by freeing up resources for other purposes, such as increased cooling costs.

Health and Equity Considerations

Transit fare reduction programs should first prioritize routes with higher-volume potential in underserved communities and those most reliant on transit for travel (e.g., students, persons with disabilities, seniors).

Measure Description

This measure will reduce transit fares on the transit lines serving the plan/community. A reduction in transit fares creates incentives to shift travel to transit from single-occupancy vehicles and other traveling modes, which reduces VMT and associated GHG emissions.

This measure differs from Measure T-8, *Implement Subsidized or Discounted Transit Program*, which can be offered through employer-based benefits programs in which the employer fully or partially pays the employee's cost of transit.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Transit fare reductions can be implemented systemwide or in specific fare-free or reduced-fare zones.

Cost Considerations

Reducing transit fares will lower the per capita income of the transit service. This may be outweighed by increased ridership, and savings on infrastructure costs due to reduced car usage. Reduced fares can be targeted to specific populations or groups, depending on need. Individuals receiving the reduced fare will obtain a cost savings.

Expanded Mitigation Options

This measure could be paired with other Transit subsector strategies (Measure T-25, *Extend Transit Network Coverage or Hours,* and Measure T-26, *Increase Transit Service Frequency*) for increased reductions.

GHG Reduction Formula

$$A = \frac{B \times C \times D \times E \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–1.2	%	calculated
User Inputs				
B	Percent reduction in transit fare with measure	0–50	%	user input
C	Percent of plan/community transit routes that receive reduced fares	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of transit ridership with respect to transit fare	-0.3	unitless	Handy et al. 2013
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017a

Further explanation of key variables:

- (B) – The user can calculate the percent reduction in transit fare based on the percent difference between the existing fare price and the proposed fare price.
- (C) – The level of implementation refers to the fraction of transit routes that on which fare reductions are implemented. Typically, fare reductions are made system-wide, so this variable would be 100.
- (D) – A policy brief summarizing the results of transit service studies reported that a 0.3 to 1.0 percent increase in transit ridership occurs for every 1.0 percent decrease in transit fares (Handy et al. 2013). To be conservative, the low end of this range is cited.
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.
- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips as some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy) (FHWA 2017b).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 1.2 percent.

(B_{max}) The percent reduction in transit fare is capped at 50 percent (SANDAG 2019).

Subsector Maximum

($\sum A_{max_{T\text{-}25\ through\ T\text{-}29}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by reducing the costs associated with using transit, thereby encouraging a mode shift from single occupancy vehicles to transit and reducing VMT. In this example, the project is in the San Jose-Sunnyvale-Santa Clara CBSA, where the transit and vehicle mode shares would be 6.69 percent and 91.32 percent, respectively (E and F). Assuming the maximum decrease in transit fares of 50 percent (B) and implementation for all transit routes (100 percent) in the plan/community (C), the user would reduce plan/community GHG emissions from VMT by 0.6 percent.

$$A = \frac{\mathbf{50\%} \times \mathbf{100\%} \times -0.3 \times 6.69\% \times 57.8\%}{91.32\%} = -0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in passenger vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
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- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-30. Use Cleaner-Fuel Vehicles

GHG Mitigation Potential

100%

Up to 100% of GHG emissions from on-road vehicles

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using cleaner-fuel vehicles increases transportation resilience by providing a wider range of available vehicles if other fuels (like gasoline) become unavailable.

Health and Equity Considerations

While most cleaner fuels reduce both GHG and criteria air pollutants, a few may increase criteria pollutant emissions. The most prominent example of this is biodiesel, which generally results in higher NO_x emissions, but lower PM emissions compared to diesel.

Measure Description

This measure requires use of cleaner-fuel vehicles in lieu of similar vehicles powered by gasoline or diesel fuel. Cleaner-fuel vehicles addressed in this measure include electric vehicles, natural gas and propane vehicles, and vehicles powered by biofuels such as composite diesel (blend of renewable diesel, biodiesel, and conventional fossil diesel), ethanol, and renewable natural gas.

The full GHG emissions impact of cleaner fuels depends on the emissions from the vehicle's tailpipe as well as the emissions associated with production of the fuel (sometimes termed "upstream" emissions). For example, tailpipe GHG emissions from renewable natural gas are identical to tailpipe GHG emissions from conventional natural gas; the GHG benefits of renewable natural gas come from the fact that it is produced from biomass. Similarly, BEVs have zero tailpipe emissions, but properly accounting for their GHG impacts requires quantifying the emissions associated with the electricity generation needed to charge the vehicle's batteries.

Subsector

Clean Vehicles and Fuels

Locational Context

Non-applicable

Scale of Application

Project/Site or Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Capital costs to purchase cleaner fuel vehicles are high. Fueling infrastructure may be required, which will add to the upfront cost of transitioning to cleaner fuel vehicles. Fuel costs and savings compared to gasoline and diesel will vary depending on the type of fuel and market conditions. It is feasible to expect reduced fuel costs from cleaner fuels with an increased market and overall fuel cost savings over the life of the vehicle fleet.

Expanded Mitigation Options

If using electric vehicles, pair with Measure T-14 to ensure that electric vehicles have sufficient access to charging infrastructure.

GHG Reduction Formula

California has a well-defined process for quantifying the GHG emissions impacts of cleaner-fuel vehicles by virtue of the state's Low Carbon Fuel Standard (LCFS) program. An emissions calculation that considers both vehicle tailpipe and upstream fuel production emissions is sometimes referred to as a "well-to-wheels" analysis (A3 below). An emissions calculation that considers only vehicle tailpipe emissions is referred to as a "tank-to-wheels" analysis (A1 and A2 below).

The convention for project analysis under CEQA typically employs a hybrid approach. For natural gas, propane, and biofuels vehicles, the CEQA analysis quantifies only tailpipe emissions and does not seek to capture differences in emission associated with fuel production. However, for electric vehicles, CEQA analyses typically account for emissions associated with electricity generation (A1 and A2 below).

$$A1 = B \times \frac{(D \times E \times F \times G) - C}{C}$$

$$A2 = B \times \frac{(D \times E \times F \times G \times H) + \left(C \times \frac{1}{I} \times (1 - H)\right) - C}{C}$$

$$A3 = B \times \frac{J - K}{K}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Percent reduction in GHG emissions from on-road vehicle emissions for BEVs	0–100	%	calculated
A2	Percent reduction in GHG emissions from on-road vehicle emissions for PHEVs	0–64	%	calculated
A3	Percent reduction in well-to-wheels GHG emissions from cleaner fuels or vehicle technologies	0–100	%	calculated
User Inputs				
B	Percent of vehicle fleet being converted to cleaner fuels	1–100	%	user input
C	Emission factor for existing (conventional fuel) vehicle	[ ]	g CO_2e per mile	CARB 2020a
Constants, Assumptions, and Available Defaults				
D	BEV efficiency	Table T-30.1	kWh per mile	see note

ID	Variable	Value	Unit	Source
E	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
F	Conversion from lb to gram	454	g per lb	conversion
G	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
H	Percent of PHEV miles in electric mode	46	%	CARB 2020a
I	Ratio of average hybrid vehicle mpg to comparable gasoline vehicle mpg	1.5	unitless	see below
J	Well-to-wheels emission factor for cleaner vehicle/fuel	Table T-30.2	g CO_2e per mile	CARB 2020a, 2020b, 2020c; U.S. DOE 2021
K	Well-to-wheels emission factor for existing (conventional fuel) vehicle	Table T-30.2	g CO_2e per mile	CARB 2020a, 2020b, 2020c; U.S. DOE 2021

Further explanation of key variables:

- (A1 or A2) – Use of these equations is appropriate for a typical CEQA project analysis, which considers tailpipe GHG emissions and, for electric vehicles, electricity generation emissions.
- (A3) – Use of this equation is appropriate for a user interested in a well-to-wheels analysis for all fuel types. The user should determine the appropriate emission factors for the conventional fuel and cleaner fuel.
- (C) – The user should run EMFAC to output GHG emission factors (CO_2, CH_4, and N_2O) for the existing (conventional fuel) vehicles. The EMFAC run should be based on project-specific values for the region, project year, season, vehicle category, model year, speed, and fuel type (gasoline, diesel, or a weighted average).[15] To determine the CO_2e emission factor of the conventional fuel vehicle, the emission factors for CO_2, CH_4, and N_2O from EMFAC should be multiplied by the corresponding 100-year GWP values (1, 25, and 298, respectively) from the IPCC's Fourth Assessment Report (IPCC 2007) and then summed.
- (E) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for a future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.
- (H) – Based on the EMFAC2017 model (v1.0.3), 46 percent of miles traveled by PHEVs in California are in electric mode (eVMT), with 54 percent in gasoline mode (CARB 2020a).

[15] There are many different combinations of input variables a user could specify in EMFAC to result in a unique emission factor output. This report does not attempt to consolidate a standardized group of emission factor output into a database table for the user to refer to. It is recommended the user run EMFAC to obtain project-specific results.

- (I) – Assumes that a PHEV operating in gasoline mode is similar to a gasoline hybrid (non-plug-in) vehicle. A typical gasoline hybrid vehicle has 50 percent higher fuel economy (mpg) than a comparable gasoline vehicle, based on a comparison of the gasoline and hybrid Toyota Camry and Corolla models (U.S. DOE 2021).
- (J and K) – The average California values for fuel efficiency, energy density, and carbon intensity of typical vehicle and fuel types are provided in Table T-30.2 (CARB 2020a, 2020b, 2020c; U.S. DOE 2021). Table T-30.2 also provides the well-to-wheels emission factor, which can be calculated based on the product of the fuel efficiency, energy density, and carbon intensity. If the user can provide a project-specific value, then the user should replace in the GHG calculation formula one or more of these values that produces the emission factor.
- (D) – BEV energy efficiency varies by vehicle type. The average California values are provided in Table T-30.1 in Appendix C. If the user can provide a project-specific value, they should replace the default in the GHG reduction formula. BEV energy efficiency can be calculated as:

$$\text{BEV efficiency (kWh per mile)} = \frac{L}{M \times N}$$

Where,

- (L) – Gasoline to electricity conversion. Users can assume 33.7 kWh per gallon of gasoline, which is a standard conversion factor used by U.S. EPA and U.S DOE (U.S. EPA 2021).
- (M) – Fuel economy (mpg) of a comparable gasoline vehicle. Users can obtain this from Table T-30.2.
- (N) –EER for an electric vehicle. Users can assume 3.4, which is the EER established by CARB for electric vehicles as stated in the LCFS regulation. (CARB 2020b).

GHG Calculation Caps or Maximums

Measure Maximum

($A1_{max}$) The GHG reduction from the use of BEVs is capped at 100 percent, which assumes that 100 percent of the fleet would be converted (B) and that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (E).

($A2_{max}$) The GHG reduction from the use of PHEVs is capped at 64 percent, which assumes that 100 percent of the fleet would be converted (B) and that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (E).

($A3_{max}$) For a well-to-wheels analysis, the GHG reduction from the use of electric vehicles is capped at 100 percent, which assumes that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (L). Note that the maximum percent reduction for all other cleaner vehicles and fuels presented in Table T-30.2 will not reach this maximum.

Subsector Maximum

Same as (A_{max}). Measure T-30 is the only measure at the Plan/Community scale within the Clean Vehicles and Fuels subsector.

Example GHG Reduction Quantification

The user reduces vehicle emissions by avoiding the use of conventional fuels in place of cleaner fuels or vehicle technologies. In this example, a municipality that sources their electricity from an electricity provider powered 100 percent by renewables (E) is converting half of their fleet of gasoline light duty automobiles to BEVs (B). The user has run EMFAC for their county, vehicle category, and project year, and determined the fleet emission factor to be 400 g CO_2e (C). The user would reduce GHG emissions from the existing fleet by 50 percent.

$$A1 = \mathbf{50\%} \times \frac{(0.33\,\frac{kWh}{mi} \times 0\,\frac{lb\ CO_2e}{MWh} \times 454\,\frac{g}{lb} \times 0.001\,\frac{MWh}{kWh}) - \mathbf{400\,\frac{g\ CO_2e}{mi}}}{\mathbf{400\,\frac{g\ CO_2e}{mi}}} = -50\%$$

Quantified Co-Benefits

Improved Local Air Quality

(O1) – The use of BEVS in lieu of conventional vehicles would decrease local criteria pollutants. The percent reduction is equal to (B). Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state or outside the state, electricity consumption from vehicles charging typically will not generate localized criteria pollutant emissions on the project site or roadways traveled by the electric vehicles.

(O2) – The percent reduction in local criteria pollutants from use of PHEVs in lieu of conventional vehicles (A2) is equal to ($B \times A2_{max}$). See ($A2_{max}$) above, which assumes (E) is set to zero to nullify eVMT activity and vehicle fleet conversion (B_{max}) is set to 100 percent. ($A2_{max}$) is multiplied by the actual conversion of the vehicle fleet (B) to adjust the percent reduction calculated from ($A2_{max}$). Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state or outside the state, electricity consumption from vehicles charging typically will not generate localized criteria pollutant emissions.

(O3) – For a well-to-wheels analysis, the fuels produced by facilities within and outside of California will generate criteria pollutants. Because these facilities are dispersed, offsite of the project/site or plan/community, fuel production typically will not generate localized criteria pollutant emissions. Therefore, only the tank-to-wheels (i.e., tailpipe) portion of the vehicle criteria pollutant emissions should be quantified. For BEVs and PHEVs, this can be done using the methodologies described above (O1 and O2, respectively). For vehicles fueled by diesel, biodiesel, renewable diesel, and natural gas, the criteria pollutant emission factor can be outputted by EMFAC (see C). The criteria pollutant reductions from use of gasoline hybrid or flex fuel vehicles cannot be readily quantified within EMFAC as these fuel types are not inputs the user can specify.

Fuel Savings (Increased Electricity)

(P1 and Q1) – The use of BEVs in lieu of conventional vehicles would decrease vehicle fuel consumption and increase electricity use. The percent reduction in fuel use (P1) is equal to (B). The absolute increase in electricity use can be calculated using the below formula (Q1).

(P2 and Q2) – The use of PHEVs in lieu of conventional vehicles would decrease vehicle fuel consumption and increase electricity use. The percent reduction in fuel use (P2) is equal to $(B \times A2_{max})$. The absolute increase in electricity use (Q2) is equal to $(H \times Q1)$.

(P3 and Q3) – For gasoline, gasoline hybrid, flex fuel, diesel, biodiesel, renewable diesel, and natural gas, the percent reduction in fuel use of the existing (conventional fuel) vehicle is equal to (B). The absolute increase in the cleaner fuel/vehicle energy can be calculated using the below formula (P3).

BEV Electricity Use Increase Formula

$$Q1 = \mathbf{B} \times \mathrm{D} \times \mathbf{R}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
Q1	Increase in electricity from electric vehicles	[ ]	kWh per year	calculated
User Inputs				
R	Average annual VMT of all vehicles in fleet	[ ]	miles per year	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Cleaner Vehicle Energy Use Increase Formula

$$P3 = \mathbf{B} \times \mathbf{R} \times \frac{S}{T}$$

Cleaner Vehicle Energy Use Increase Variables

ID	Variable	Value	Unit	Source
Output				
P3	Increase in vehicle fuel use in fleet	[ ]	megajoules (MJ)	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
S	Energy density for cleaner fuel/vehicle	Table T-30.2	MJ per gal	CARB 2019, 2020a, 2020b, 2020c; U.S. DOE 2021
T	Fuel efficiency for cleaner fuel/vehicle	Table T-30.2	mpg	

Further explanation of key variables:

- (S and T) – The average California values for fuel efficiency and energy density of typical vehicle and fuel types are provided in Table T-30.2 (CARB 2019, 2020a, 2020b, 2020c; U.S. DOE 2021). If the user can provide a project-specific value, then the user should replace in the fuel use reduction formula one or more of these values that produces the energy consumption value (MJ).
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

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