T-26. Increase Transit Service Frequency

GHG Mitigation Potential

11.3%

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.
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- 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.