# 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

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

## 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.

$$O = S \times (\mathbf{P_2} - \mathbf{P_1}) \times \mathbf{Q} \times \mathbf{R} \times N$$

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


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- 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.