# Methodology: GreenTRIP Strategies

## Impact of Car Sharing Membership, Transit Passes, Bike Sharing Membership and Parking Limitations on Vehicle Miles Traveled

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## Purpose

Provided is a detailed accounting of the methods utilized to calculate the impact of car sharing membership, bike sharing membership, the provision of transit passes, and parking limitations on household vehicle miles traveled (VMT). Additionally, references to some additional research examined are provided.

## General Background

The primary VMT model used by GreenTRIP Connect uses many variables, such as proximity to jobs, to predict future VMT associated with a new residential development (for a full description of this model see: Income, Location Efficiency, and VMT: Affordable Housing as a Climate Strategy). Yet the VMT prediction does not account for on-site GreenTRIP strategies, such as provision of transit passes (also known as on-site Transportation Demand Management or TDM strategies). Therefore, research of current literature was conducted to derive methods to account for the VMT reduction of GreenTRIP Strategies. Once the primary model predicted VMT, the reductions from these GreenTRIP strategies were applied.

Before providing details on the methodology for each GreenTRIP strategy there are two important considerations that need to be explained. The first is that all people that are provided with amenities will not necessarily use them. For example the building owner may offer a free car share membership but some of the residents choose to not join, thus there needs to be an estimate of "uptake" for each of the GreenTRIP Strategies. Note that there is not good data on this uptake ratio because the GreenTRIP Strategies are relatively new, and no comprehensive research has yet been done to estimate this ratio. The uptake ratio used for each strategy is listed below, and is meant to be a conservative estimate.

Second, for our purposes the GreenTRIP strategies impacts are presented as per participant reductions. For example, for every transit pass used the VMT will be reduced by 4.5%. However, this does not mean that the second member within a household will contribute another 4.5% off of the original VMT predicted by the primary VMT model. Rather an additional 4.5% reduction taken is from the already reduced VMT resultant from the first household member. In order to include multiple and fractional members of a household that participates in any program a power law is used. This method is used when there are several fractional improvements made in a given situation. As an analogy, if adding plastic to a window cuts down heat loss by 50% and caulking the window cuts heat loss by 50%; doing both does not reduce heat loss by 100%, it reduces heat loss by 75% (the plastic cuts it by 50% then the caulk cuts that by another 50%, giving an overall heat reduction of 75%). As such, a first transit pass will reduce VMT by 4.5%; this is done by multiplying the original VMT by 0.955 (or 1-0.045) thus, $VMT_1 = VMT * 0.955$ then the second transit pass will reduce that by another 4.5% or $VMT_2 = VMT_1 * 0.955$ which is $VMT_2 = VMT*(0.955)^2$. This can be generalized by the following equation:

$$\boldsymbol{VMT_r = VMT \times (1 - f)^n}$$

**Equation 1: Generalized Formula to Account for VMT Reduction for any Given GreenTRIP Strategy**

Where:

- $\boldsymbol{VMT_r}$ is the reduced Vehicle Miles Traveled
- $\boldsymbol{VMT}$ is the original Vehicle Miles Traveled
- $\boldsymbol{f}$ is the fraction of VMT reduction from the GreenTRIP Strategy per household
- $\boldsymbol{n}$ is the number of participants in the GreenTRIP Strategy per household

This method is used for the several GreenTRIP Strategies discussed below.

## Car Sharing

### Background

To determine impact of car sharing membership on household VMT, findings from *San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts*[i] were implemented. This 2006 study by Cervero et al was built on previous studies beginning in 2001, and examined the longer term impacts of the City CarShare program on travel demand and car ownership. The findings document significantly reduced daily VMT for carsharing members.

Cervero's study provides a best-fitting multiple regression equation predicting average daily VMT. All else being equal, City CarShare membership typically lowered daily travel by 7 vehicle miles. Residing in dense, transit-friendly San Francisco reduced the figure by another 3 vehicle miles. Owning a bicycle cut down on daily travel by nearly an additional 4 vehicle miles. Every additional car added per household member, however, raised daily VMT by 13. Four years into the City CarShare program, the combination of being a CarShare member, owning a bicycle, and reducing car ownership all serve to shrink the transportation sector's ecological footprint in the San Francisco Bay Area.[ii]

The table below provides the variables and their coefficients, the standard error and probability, as well as the GreenTRIP Connect data source where applicable. This model was applied to determine car share membership impact on household VMT. The coefficients of Cervero's study provides the VMT reduction in miles, this is then divided by the modeled VMT to get the fraction of VMT reduction ($\boldsymbol{f}$

from the General Background section above) from one CarShare membership. It is then assumes that just 50% of residents would take advantage of the carshare memberships (i.e., an uptake ratio of 50%.)

**Regression Model for Predicting Respondents' Average Daily VMT**
**Survey #5, All Trip Purposes, All Day Types**

| Variable | Coefficient Estimate | Standard Error | Probability | GreenTRIP Connect Data Source |
|---|---|---|---|---|
| **Member Status:** | | | | |
| City CarShare Member (1=yes; 0=no) | -7.08 | 3.46 | 0.04 | User Input |
| **Socio-Economic Controls:** | | | | |
| No. of Vehicles Per Household Member | 13.07 | 2.09 | 0 | |
| Owns a bicycle (1=yes; 0=no) | -3.784 | 1.89 | 0.046 | User Input |
| Age (years) | 0.75 | 0.432 | 0.083 | PUMS |
| Age squared | -0.008 | 0.005 | 0.077 | |
| Personal income, annual (in $1000s) | -0.086 | 0.056 | 0.127 | PUMS |
| Personal income, annual (in $1000s), squared | 0.0004 | 0.00025 | 0.095 | |
| Resides in San Francisco (0=no; 1=yes) | -3.064 | 2.03 | 0.132 | User Selection of Site |
| Constant | 4.206 | 10.232 | 0.681 | |
| **Summary Statistics** | | | | |
| Number of Cases | | | 459 | |
| R-Square | | | .148 | |
| F Statistics (probability) | | | 8.214 (.000)[iii] | |

Given that this study was carried out on the first and longest running car sharing program in the US, is a longitudinal study beginning with the CarShare program's inception, on a California-based car sharing program, and provides a rigorous examination that includes a regression analysis and formula, this study was deemed appropriate to use in our analysis to understand car sharing membership's impact on household VMT.

Additional studies reviewed included *The Impact of Carsharing on Household Vehicle Ownership,* (Elliot Martin and Susan Shaheen 2011); *The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data* (Elliot Martin * and Susan Shaheen 2011).

## Implementation

The reduction in VMT is calculated using the following process:

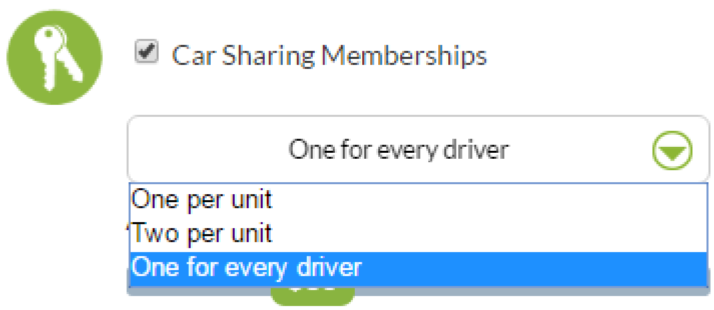
1. The VMT is modeled using the inputs from the building definition including affordable units and level of affordability;

2. From the model described above use the Coefficient (Value = 7.08 miles) for the *"City CarShare Member (1=yes; 0=no)"* as an estimate of VMT reduction for one Car Share membership;
3. This Coefficient is divided by the modeled VMT to calculate the fraction of VMT reduction from one Car Share membership:

$$f_{CarShare} \equiv \frac{7.08}{VMT_{modeled}}$$

4. The number of Car Share members offered per household is obtained from the user's choice from the Car Sharing menu on GreenTRIP Connect:

**Figure 1: Options Available for Car Share Membership**




5. Compare this with the adults per unit (average number of people over 18 year old) in the building, and use the following logic to determine the possible Car Share members per household (**$p_{cs}$**):
   a. If "One per Unit" set **$p_{cs}$ = 1**
   b. If "Two per Unit" and the number of adults per unit is greater than 2 set **$p_{cs}$ = 2**
   c. If "Two per Unit" and the number of adults per unit is less than 2 set **$p_{cs}$ = adults per unit**
   d. If "One for every Driver" set **$p_{cs}$ = adults per unit**
6. Then use as an uptake ratio of 50% - thus $n_{cs}$ = 0.5 * **$p_{cs}$**
7. The final VMT adjusted for Car Share GreenTRIP Strategy is:

$$VMT_{carshare\ adjusted} = VMT_{modeled} * (1 - f_{CarShare})^{n_{cs}}$$

## Transit Passes

### Background

Findings from *Do Employee Commuter Benefits Reduce Vehicle Emissions and Fuel Consumption? Results of the fall 2004 Best Workplaces for Commuters* were the basis for determining the impact of transit passes on household VMT. This 2005 study by Herzog et al, utilized survey results to determine the difference between the commuting patterns of employees receiving employee commuter benefits and those who do not. It was found that where employers provide employees with incentives to commute by means other than driving alone, significant percentages of them take advantage of these benefits. Resulting savings in vehicle trips, VMT, emissions and fuel consumption were then calculated. VMT reductions of 4.16 to 4.79 percent were found.

More comprehensive benefit packages available to commuters in the Best Workplaces for Commuters group, including financial incentives, services (such as guaranteed ride home, carpool matching, etc.) and informational campaigns, appear to produce reductions of trips, VMT, pollutants, and fuel consumption of around 15 percent even under conservative assumptions. Benefits packages offering services and information, but not financial incentives, appear to produce reductions of around 7 percent under conservative assumptions.

While Herzog's study examines changes in driving patterns for an employer-based, not a resident-based program, no such evaluation of resident-based programs on VMT was found, so GreenTRIP Connect uses the employer-based results of 4.16 to 4.79 percent VMT reduction range as a proxy.

Of interest is an ongoing program in Boulder, Colorado. Eco Pass currently gives employees of participating businesses and residents of participating neighborhoods unlimited rides on Regional Transportation District buses. Nearly 40,000 residents and workers participate in the program. However, a study of results on VMT reduction is not available. Furthermore, Boulder officials are looking at the feasibility of expanding the popular Eco Pass program to the entire community. Further information and detailed analysis is available in the *Countywide EcoPass Feasibility Study, Boulder County*, January 2014.

While there have been several studies of the effectiveness of employer-based trip reduction programs at reducing vehicle trips and/or increasing the share of alternative modes, only a few have estimated reductions in vehicle miles traveled (VMT) or GHG emissions[iv]. A good overview of employer-based programs is *Impacts of Employer-Based Trip Reduction Programs and Vanpools on Passenger Vehicle Use and Greenhouse Gas Emissions*, September 2014.

## Implementation

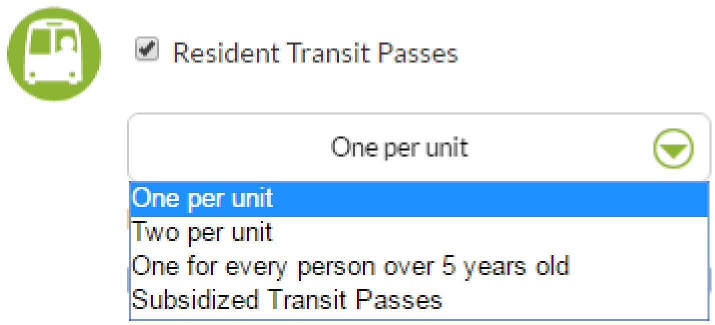
The reduction in VMT is calculated using the following process:

1. The $VMT_{carshare\ adjusted}$ is used as the baseline VMT;
2. This VMT is adjusted down by 4.475 percent (the average of the range given above) for each transit pass:

$$f_{tp} \equiv 0.04475$$

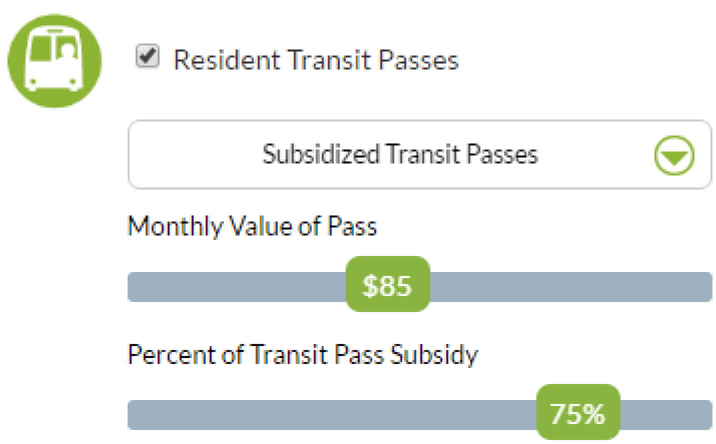
3. The number of Transit Passes offered per household is obtained from the user's choice from the Resident Transit Passes menu on GreenTRIP Connect:

**Figure 2: Options Available for Resident Transit Passes**




4. Compare this with the potential users of these passes per unit (average number of people over 5 years old) in the building, and use the following logic to determine the possible Transit Pass Users per household (**$n_{tp}$**):
   a. If "One per Unit" set **$n_{tp}$ = 1**
   b. If "Two per Unit" and potential users per unit is greater than two set **$n_{tp}$ =2**
   c. If "Two per Unit" and potential users per unit is less than two set **$n_{tp}$ = potential users per unit**
   d. If "One for every person over 5 years old" set **$n_{tp}$ = potential users per unit**
   e. If "Subsidized Transit Passes" set **$n_{tp}$ = "Percent of Transit Pass Subsidy" slider value;** in the example below set **$n_{tp}$ = 0.75**

**Figure 3: Options Available for Resident Transit Passes on GreenTRIP Connect if Subsidized Passes is Selected**




5. The Uptake Ratio for Transit Pass is assumed to be 100% unless the building is not offering fully "Subsidized Transit Passes," as in the example showing a 75% subsidy above. In this case the uptake is considered to be the percent of the transit pass subsidy, i.e. only a fraction of units will use the reduced priced pass, and this fraction is assumed to be the same as the subsidy;

6. The following formula is used to estimate the final VMT adjusted for Car Sharing and Transit Pass GreenTRIP Strategies:

$$VMT_{trasit\ pass\ adjusted} = VMT_{carshare\ adjusted} * (1 - f_{tp})^{n_{tp}}$$

# Bike Sharing

## Background

Findings from the paper *"Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia (Fishman and Washington 2015)"* were used to determine impact of bike sharing membership on household VMT. The paper examines the degree to which car trips are replaced by bike share, through an examination of survey and trip data from bike share programs in Melbourne, Brisbane, Washington, D.C., London, and Minneapolis/St. Paul.

The following table shows the impact car substitution has on estimated car travel reduction. Car travel reduction has been estimated by multiplying the estimated distance traveled by the car substitution rate.

Bike share size, usage and car travel reduction.

| | Melbourne | Brisbane | Washington, D.C. | Minnesota | London[*] |
|---|---|---|---|---|---|
| Bikes[a] | 600 | 1800 | 1800 | 1325 | 8000 |
| Trips[b] (2012) | 138,548 | 209,232 | 2,008,079 | 268,151 | 9,040,580 |
| Trips per day per bike | 0.6 | 0.3 | 3.0 | 0.9 | 3.1 |
| Regional population[2] | 3,999,980 | 2,065,998 | 5,860,342 | 3,759,978 | 7,170,000 |
| Mean trip duration[b] | 22.0 | 16.2 | 15.8 | 17.5 | 17.5 |
| Est. travel speed (km/h) | 12 | 12 | 12 | 12 | 12 |
| Est. distance traveled per trip (KM) | 4.4 | 3.2 | 3.1 | 3.5 | 3.5 |
| Est. distance traveled per system 2012 (KM) | 609,611 | 677,912 | 6,345,530 | 940,152 | 31,642,029 |
| Car substitution | 19% | 21% | 7% | 19% | 2% |
| Est. car travel reduction (KM) | 115,826 | 142,361 | 444,187 | 182,390 | 632,841 |
| Est. car travel reduction per bike (KM) | 193 | 79 | 247 | 135 | 79 |
| Annual members | 921 | 1926 | 18,000 | 3500 | 76,283 |

Applying this methodology to data from Bay Area Bike Share household VMT reductions for bike share users were calculated as shown in the table below. The 19 % car substitution rate utilized for GreenTRIP Connect was based on the Minneapolis substitution rate.

| | Bay Area Bike Share |
|---|---|
| **Distance (km) for system in year** | 61,7640 km |
| **Car substitution rate** | 19% |
| **Est car travel reduction** | 117,351.60 km |
| **Annual members** | 8,539 |
| **Km/year/member** | 13.74 km |
| **Km/day/member** | 0.0376 km |
| **Miles per day per member** | 0.0234 Miles |

Additional references include Public Bikesharing in North American: Early Operator and User Understanding (Susan A. Shaheen, PH.D., Elliot W. Martin, Ph.D., Adam P. Cohen, Rachel S. Finson, June 2012); Public Bikesharing in North America During a Period of Rapid Expansion: Understanding Business Models, Industry Trends and User Impacts (Susan A. Shaheen, Ph.D., Elliot W. Martin, Ph.D., Nelson D. Chan, Adam P. Cohen, Mike Pogodzinski, Ph.D., October 2014)

This seemingly low level of VMT reduction from Bike Sharing is explained in the Fishman and Washington paper as:

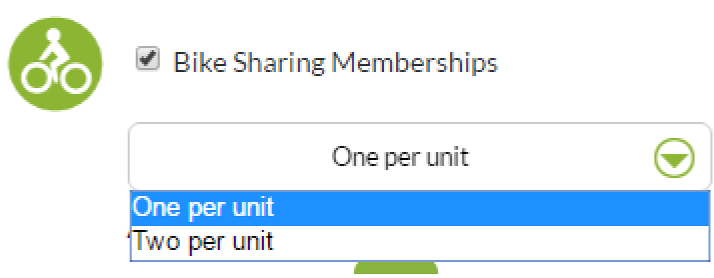
> "…This was largely due to a low car mode substitution rate and substantial truck use for rebalancing of bicycles. As bike share programs mature, evaluation of their effectiveness in reducing car use may become increasingly important. Researchers can adapt the analytical approach proposed in this paper to assist in the evaluation of current and future bike share programs."

## Implementation

The reduction in VMT is calculated using the following process:

1. The $VMT_{transit\ pass\ adjusted}$ is used as the baseline VMT;
2. For each bike share membership per unit the daily VMT is adjusted down by 0.0234 miles, this is divided by $VMT_{transit\ pass\ adjusted}$ to calculate the fraction of VMT reduction from one bike share membership:
$$f_{bs} \equiv \frac{0.0234}{VMT_{transit\ pass\ adjusted}}$$
3. The number of Bike Share members offered per household is obtained from the user's choice from the Bike Sharing menu on GreenTRIP Connect :

**Figure 4: Options Available for Bike Sharing Membership**




4. Compare this with the adults per unit (average number of people over 18) in the building, and use the following logic to determine the possible Bike Share members per household (**$p_{bs}$**):
   a. If "One per Unit" set **$p_{bs}$ = 1**
   b. If "Two per Unit" and the number of adults per unit is greater than 2 set **$p_{bs}$ = 2**
   c. If "Two per Unit" and the number of adults per unit is less than 2 set **$p_{bs}$ = adults per unit**
5. Then use as an uptake ratio of 100% - thus $n_{bs}$ = **$p_{cs}$**

6. The final VMT adjusted for Bike Share GreenTRIP Strategy is:

$$VMT_{bike\ share\ adjusted} = VMT_{trasit\ pass\ adjusted}\ *$$

## Parking Limitations

### Background

To determine the impact of the availability of parking as well as price of parking on VMT, GreenTRIP Connect applies guidance from the 2016 *"CAPCOA Quantifying Greenhouse Gas Mitigation Measures"*[v]...

For unbundled parking cost the following recommendation is from the guidance[vi]:

"…

% Reduction in VMT = Change in vehicle cost * elasticity * A

Where:

- -0.4 = elasticity of vehicle ownership with respect to total vehicle costs (lower end per VTPI)
- Change in vehicle cost = monthly parking cost * (12 / $4,000), with $4,000 representing the annual vehicle cost per VTPI
- A: 85% = adjustment from vehicle ownership to VMT ""

To estimate the VMT reductions from reduced parking supply, the CAPCOA guidance considers a reduction in VMT if the parking supply is below the ITE recommended spaces per unit. The ITE recommendation for multi-unit buildings ranges from 1.2 and higher[vii]:

"…

$$\%\ \text{VMT Reduction} = \frac{\text{Actual parkingprovision ITE parkinggenerationrate}}{\text{ITE parkinggenerationrate}} \times 0.5$$

…"

Finally, the overall VMT reduction from parking cannot be greater than 20%[viii] .

### Implementation

For parking price reduction, the following formula is used:

$$S_{pricing} \equiv 1 - \frac{P_{parking} \times 12}{\$4000} \times 0.85\ \times 0.4$$

$P_{parking}$ is the monthly cost of parking entered by the user in the unbundled parking section of GreenTRIP Connect. And for supply considerations the following formula is used if the supply is less than 1.2 spaces per unit:

$$S_{parking\ supply} \equiv 1 - \left\{\frac{1.2 - PS}{1.2} \times 0.5\right\}$$

PS is the parking supply given by the user. Then the product of these is then applied to the bike sharing adjusted VMT, however, it is first checked to make sure that the reduction is less than or equal to 20%, or:

$$S \equiv\ S_{pricing} \times\ S_{parking\ supply}\ |\ if\,(S < 0.8)\ then(S = 0.8)$$

It is feasible that extremely limited parking and/or very high costs for parking may result in reductions larger than the 20% in some situations, but, like CAPCOA, this approach tries to guard against predicting excessive reductions for a few reasons. The first is that it is important to understand whether, and how much, residents can park nearby, and at what cost. Free and easy nearby on-street parking, for example, may mean VMT would only be slightly reduced, while extremely limited and expensive parking nearby (say in a downtown), may mean the ultimate VMT reductions could be somewhat greater.

The final value for VMT is:

$$VMT_{Parking\ Adjusted} = S\ \times\ VMT_{bike\ share\ adjusted}.$$

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[i] Cervero. "San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts," n.d.

[ii] Cervero. "San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts," n.d., pg 38

[iii] Cervero. "San Francisco City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts," n.d., pg 38

[iv] Marlon G. Boarnet , University of Southern California, Hsin-Ping Hsu, University of California, Irvine, and Susan Handy, University of California, Davis. "Impacts of Employer-Based Trip Reduction Programs and Vanpools on Passenger Vehicle Use and Greenhouse Gas Emissions," September 30, 2014. pg. 3.

[v] Barbara Lee, NSCAPCD. "Quantifying Greenhouse Gas Mitigation Measures, A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures," August, 2010. http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf

[vi] Barbara Lee, NSCAPCD. "Quantifying Greenhouse Gas Mitigation Measures, A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures," August, 2010. http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf. pgs. 211-212.

[vii] Barbara Lee, NSCAPCD. "Quantifying Greenhouse Gas Mitigation Measures, A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures," August, 2010. http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf. pgs. 207-209.

[viii] Barbara Lee, NSCAPCD. "Quantifying Greenhouse Gas Mitigation Measures, A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures," August, 2010. http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf. pg. 55.