This technical memorandum summarizes our assessment of new research related to transportation demand management (TDM) effectiveness for reducing vehicle miles of travel (VMT). The purpose of this work was to compile new TDM information that has been published in research papers since release of the *Quantifying Greenhouse Gas Mitigation Measures*, CAPCOA, August 2010 and to identify those strategies suited to WRCOG jurisdictions given the rural and suburban land use context. The matrix in Attachment A summarizes the overall evaluation of all the CAPCOA strategies while the matrix in Attachment B identifies the top seven strategies suited for the study area.

This information can be used as part of the SB 743 implementation to determine potentially feasible VMT mitigation measures for individual land use projects in the WRCOG area. An important consideration for the mitigation effectiveness is the scale for TDM strategy implementation. The biggest effects of TDM strategies on VMT (and resultant emissions) derive from regional policies related to land use location efficiency and infrastructure investments that support transit, walking, and bicycling. While there are many measures that can influence VMT and emissions that relate to site design and building operations, they have smaller effects that are often dependent on final building tenants. Figure 1 presents a conceptual illustration of the relative importance of scale.

*Figure 1: Transportation-Related GHG Reduction Measures*
Of the 50 transportation measures presented in the CAPCOA 2010 report *Quantifying Greenhouse Gas Mitigation Measures*, 41 are applicable at building and site level. The remaining nine are functions of, or depend on, site location and/or actions by local and regional agencies or funders. Table 1 summarizes the strategies according to the scope of implementation and the agents who would implement them.

### TABLE 1: SUMMARY OF TRANSPORTATION-RELATED CAPCOA MEASURES

<table>
<thead>
<tr>
<th>Scope</th>
<th>Agents</th>
<th>CAPCOA Strategies (see full CAPCOA list below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Operations</td>
<td>Employer, Manager</td>
<td>26 total from five CAPCOA strategy groups:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 3 from 3.2 Site Enhancements group</td>
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<tr>
<td></td>
<td></td>
<td>• 3 from 3.3 Parking Pricing Availability group</td>
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<td></td>
<td></td>
<td>• 15 from 3.4 Commute Trip Reduction group</td>
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<tr>
<td></td>
<td></td>
<td>• 2 from 3.5 Transit Access group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 3 from 3.7 Vehicle Operations group</td>
</tr>
<tr>
<td>Site Design</td>
<td>Owner, Architect</td>
<td>15 total from three strategy groups:</td>
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<tr>
<td></td>
<td></td>
<td>• 6 from 3.1 Land Use group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 6 from 3.2 Site Enhancements group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 1 from 3.3 Parking group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 2 from 3.6 Road Access group</td>
</tr>
<tr>
<td>Location Efficiency</td>
<td>Developer, Local Agency</td>
<td>3 shared with Regional and Local Policies</td>
</tr>
<tr>
<td>Alignment with Regional and Local Policies</td>
<td>Regional and local agencies</td>
<td>3 shared with Location Efficiency</td>
</tr>
<tr>
<td>Regional Infrastructure and Services</td>
<td>Regional and local agencies</td>
<td>6 total</td>
</tr>
</tbody>
</table>

Of these strategies, only a few are likely to be effective in a rural or suburban setting such as the WRCOG area. To help winnow the list, we reviewed how land use context could influence each strategy’s effectiveness and identified the seven for more detailed review. These strategies are described in Attachment B and listed below. Please note that disruptive trends, including but not limited to, transportation network companies (TNCs), autonomous vehicles (AVs), internet shopping, and micro-transit may affect the future effectiveness of these strategies.

1. **Increase diversity of land uses** – This strategy focuses on inclusion of mixed uses within projects or in consideration of the surrounding area to minimize vehicle travel in terms of both the number of trips and the length of those trips.

2. **Provide pedestrian network improvements** – This strategy focuses on creating a pedestrian network within the project and connecting to nearby destinations. Projects in the WRCOG area range in size, so the emphasis of this strategy for smaller projects would likely be the construction of network improvements that connect the project sites directly to nearby destinations. For larger projects, this strategy could focus on the development of a robust pedestrian network within the
project itself. Alternatively, implementation could occur through an impact fee program such as
the TUMF or benefit/assessment district based on local or regional plans.

3. **Provide traffic calming measures and low-stress bicycle network improvements** – This strategy
combines the CAPCOA research focused on traffic calming with new research on providing a low-
stress bicycle network. Traffic calming creates networks with low vehicle speeds and volumes that
are more conducive to walking and bicycling. Building a low-stress bicycle network produces a
similar outcome. Implementation options are similar to strategy 2 above. One potential change
in this strategy over time is that e-bikes (and e-scooters) could extend the effective range of travel
on the bicycle network, which could enhance the effectiveness of this strategy.

4. **Implement car-sharing program** – This strategy reduces the need to own a vehicle or reduces the
number of vehicles owned by a household by making it convenient to access a shared vehicle for
those trips where vehicle use is essential. Note that implementation of this strategy would require
regional or local agency implementation and coordination and would not likely be applicable for
individual development projects.

5. **Increase transit service frequency and speed** – This strategy focuses on improving transit service
convenience and travel time competitiveness with driving. While the WRCOG area has fixed route
rail and bus service that could be enhanced, it’s also possible that new forms of low-cost
demand-responsive transit service could be provided. The demand-responsive service could be
provided as subsidized trips by contracting to private TNCs or Taxi companies. Alternatively, a
public transit operator could provide the subsidized service but would need to improve on
traditional cost effectiveness by relying on TNC ride-hailing technology, using smaller vehicles
sized to demand, and flexible driver employment terms where drivers are paid by trip versus by
hour. This type of service would reduce wait times for travelers and improve the typical in-vehicle
travel time compared to traditional transit. Note that implementation of this strategy would
require regional or local agency implementation, substantial changes to current transit practices,
and would not likely be applicable for individual development projects.

6. **Encourage telecommuting and alternative work schedules** – This strategy relies on effective
internet access and speeds to individual project sites/buildings to provide the opportunity for
telecommuting. The effectiveness of the strategy depends on the ultimate building tenants and
this should be a factor in considering the potential VMT reduction.

7. **Provide ride-sharing programs** – This strategy focuses on encouraging carpooling and vanpooling
by project site/building tenants and has similar limitations as strategy 6 above.

Because of the limitations noted above, strategies 1, 2, 3, 6, and 7 are initially considered the highest
priorities for individual land use project mitigation subject to review and discussion with the project team
and advisory committee.
The VMT reduction strategies can be quantified using CACPOA calculation methodologies and recent ARB research findings. Attachment C provides calculation methodologies for each of the mitigations provided above, along with their range of effectiveness.

Please review this information and let us know if you have any follow up questions.
### New Information Since CAPCOA Was Published in 2010

<table>
<thead>
<tr>
<th>CAPCOA Category</th>
<th>CAPCOA #</th>
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<th>New Information</th>
<th>Change in VMT reduction compared to CAPCOA</th>
<th>Literature or Evidence Cited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use/Location</td>
<td>3.1.1</td>
<td>LUT-1 Increase Density</td>
<td>0.8% - 30% VMT reduction due to increase in density</td>
<td>Adequate</td>
<td>Increasing residential density is associated with lower VMT per capita. Increased residential density in areas with high jobs access may have a greater VMT change than increases in regions with lower jobs access. The range of reductions is based on a range of elasticities from -0.04 to -0.22. The low end of the reductions represents a -0.04 elasticity of demand in response to a 10% increase in residential units or employment density and a -0.22 elasticity in response to 50% increase to residential/employment density.</td>
<td>0.4% - 10.75%</td>
<td>Primary sources: Boarnet, M. and Handy, S. (2014). Impacts of Residential Density on Passenger Vehicle Use and Greenhouse Gas Emissions - Policy Brief and Technical Background Document. California Air Resources Board. Retrieved from: <a href="https://arb.ca.gov/cc/sb375/policies/policies.htm">https://arb.ca.gov/cc/sb375/policies/policies.htm</a> Secondary source: Stevens, M. (2017). Does Compact Development Make People Drive Less? Journal of the American Planning Association, 83(1), 7-18.</td>
</tr>
<tr>
<td>Land Use/Location</td>
<td>3.1.9</td>
<td>LUT-9 Improve Design of Development</td>
<td>1.0% - 21.3% reduction in VMT due to increasing intersection density vs. typical ITE suburban development</td>
<td>Adequate</td>
<td>No update to CAPCOA literature, advise applying CAPCOA measure only to large developments with significant internal street structure.</td>
<td>Same</td>
<td>N/A</td>
</tr>
</tbody>
</table>
## Comparison of CAPCOA Strategies Versus New Research Since 2010

### CAPCOA Reduction

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<tr>
<td>Land Use/ Location</td>
<td>3.1.5</td>
<td>LUT-5 Increase Transit Accessibility</td>
<td>0.5%-24.6% reduce in VMT due to locating a project near high-quality transit</td>
<td>Adequate</td>
<td>1] VMT reduction when transit station is provided within 1/2 mile of development (compared to VMT for sites located outside 1/2 mile radius of transit): Locating high density development within 1/2 mile of transit will facilitate the use of transit by people traveling to or from the Project site. The use of transit results in a mode shift and therefore reduced VMT. 2] Reduction in vehicle trips due to implementing TOD: A project with a residential/commercial center designed around a rail or bus station, is called a transit-oriented development (TOD). The project description should include, at a minimum, the following design features: • A transit station/stop with high quality, high-frequency bus service located within a 5-10 minute walk (or roughly 1⁄3 mile from stop to edge of development), and/or • A rail station located within a 20 minute walk (or roughly 1⁄2 mile from station to edge of development) • Fast, frequent, and reliable transit service connecting to a high percentage of regional destinations: • Neighborhood designed for walking and cycling</td>
<td>0%-5.8% 2] 0%-7.3%</td>
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<tr>
<td>Land Use/Location</td>
<td>3.1.6</td>
<td>LUT-6 Integrate Affordable and Below Market Rate Housing</td>
<td>0.04%-1.20% reduction in VMT for making up to 30% of housing units BMR</td>
<td>Weak - Should only be used where supported by local data on affordable housing trip generation.</td>
<td>Observed trip generation indicates substantial local and regional variation in trip making behavior at affordable housing sites. Recommend use of ITE rates or local data for senior housing.</td>
<td>N/A</td>
<td>Draft Memorandum: Infill and Complete Streets Study, Task 2.1: Local Trip Generation Study. Measuring the Miles: Developing new metrics for vehicle travel in LA. City of Los Angeles, April 19, 2017.</td>
</tr>
<tr>
<td>Neighborhood Site Enhancements</td>
<td>3.2.1</td>
<td>SDT-1 Provide Pedestrian Network Improvements</td>
<td>0%-2% reduction in VMT for creating a connected pedestrian network within the development and connecting to nearby destinations</td>
<td>Adequate</td>
<td>VMT reduction due to provision of complete pedestrian networks. Only applies if located in an area that may be prone to having a less robust sidewalk network.</td>
<td>0.5%-5.7%</td>
<td>Handy, S. et al. (2014). Impacts of Pedestrian Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions - Policy Brief and Technical Background Document. California Air Resources Board. Retrieved from: <a href="https://arb.ca.gov/cc/sb375/policies/policies.htm">https://arb.ca.gov/cc/sb375/policies/policies.htm</a></td>
</tr>
<tr>
<td>Neighborhood Site Enhancements</td>
<td>3.2.2</td>
<td>SDT-2 Provide Traffic Calming Measures</td>
<td>0.25%-1% VMT reduction due to traffic calming on streets within and around the development</td>
<td>Adequate</td>
<td>Reduction in VMT due to expansion of bike networks in urban areas. Strategy only applies to bicycle facilities that provide a dedicated lane for bicyclists or a completely separated right-of-way for bicycles and pedestrians. Project-level definition: Enhance bicycle network citywide (or at similar scale), such that a building entrance or bicycle parking is within 200 yards walking or bicycling distance from a bicycle network that connects to at least one of the following: at least 10 diverse uses; a school or employment center; the project total floor area is 50% or more residential; or a bus rapid transit stop, light rail station, or ferry terminal. All destinations must be 3-mile bicycling distance from project site. Include educational campaigns to encourage bicycling.</td>
<td>0%-1.7%</td>
<td>Zahabi, S. et al. (2016). Exploring the link between the neighborhood typologies, bicycle infrastructure and commuting cycling over time and the potential impact on commuter GHG emissions. Transportation Research Part D: Transport and Environment. 47, 89-103.</td>
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<th>Literature or Evidence Cited</th>
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</thead>
<tbody>
<tr>
<td>Neighborhood Site Enhancements</td>
<td>3.4.9</td>
<td>TRT-9 Implement Car-Sharing Program</td>
<td>0.4% - 0.7% VMT reduction due to lower vehicle ownership rates and general shift to non-driving modes</td>
<td>Adequate</td>
<td>Vehicle trip reduction due to car-sharing programs; reduction assumes 1%-5% penetration rate. Implementing car-sharing programs allows people to have on-demand access to a shared fleet of vehicles on an as-needed basis, as a supplement to trips made by non-SOV modes. Transit station-based programs focus on providing the &quot;last-mile&quot; solution and link transit with commuters’ final destinations. Residential-based programs work to substitute entire household-based trips. Employer-based programs provide a means for business/day trips for alternative mode commuters and provide a guaranteed ride-home option. The reduction shown here assumes a 1%-5% penetration rate.</td>
<td>0.3%-1.6%</td>
<td>Lovejoy, K. et al. (2013). Impacts of Carsharing on Passenger Vehicle Use and Greenhouse Gas Emissions - Policy Brief and Technical Background Document. California Air Resources Board. Retrieved from: <a href="https://arb.ca.gov/cc/sb375/policies/policies.htm">https://arb.ca.gov/cc/sb375/policies/policies.htm</a></td>
</tr>
<tr>
<td>Parking Pricing</td>
<td>3.3.1</td>
<td>PDT-1 Limit Parking Supply</td>
<td>5%-12.5% VMT reduction in response to reduced parking supply vs. ITE parking generation rate</td>
<td>Weak - not recommended. Fehr &amp; Peers has developed new estimates for residential land use only that may be used.</td>
<td>CAPCOA reduction range derived from estimate of reduced vehicle ownership, not supported by observed trip or VMT reductions. Evidence is available for mode shift due to presence/absence of parking in high-transit urban areas; additional investigation ongoing</td>
<td>Higher</td>
<td>Fehr &amp; Peers estimated a linear regression formula based on observed data from multiple locations. Resulting equation produces maximum VMT reductions for residential land use only of 35% in suburban locations and 50% in urban locations based on parking supply percentage reductions.</td>
</tr>
<tr>
<td>Parking Pricing</td>
<td>3.3.2</td>
<td>PDT-2 Unbundle Parking Costs from Property Cost</td>
<td>2.6% -13% VMT reduction due to decreased vehicle ownership rate</td>
<td>Adequate - conditional on the agency not requiring parking minimums and pricing/managing on-street parking (i.e., residential parking permit districts, etc.)</td>
<td>Reduction in VMT, primarily for residential uses, based on range of elasticities for vehicle ownership in response to increased residential parking fees. Does not account for self-selection. Only applies if the city does not require parking minimums and if on-street parking is priced and managed (i.e., residential parking permit districts).</td>
<td>2%-12%</td>
<td>Victoria Transport Policy Institute (2009). Parking Requirement Impacts on Housing Affordability. Retrieved March 2010 from: <a href="http://www.vtpi.org/park-hou.pdf">http://www.vtpi.org/park-hou.pdf</a></td>
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</table>
## Comparison of CAPCOA Strategies Versus New Research Since 2010

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</tr>
</thead>
<tbody>
<tr>
<td>Parking Pricing</td>
<td>3.3.3</td>
<td>PDT-1 Implement Market Price Public Parking</td>
<td>2.0%-5.5% VMT reduction due to “park once” behavior and disincentive to driving</td>
<td>Adequate</td>
<td>Implement a pricing strategy for parking by pricing all central business district/employment center retail center on-street parking. It will be priced to encourage parking avoidance behavior. The benefits of this measure above that of paid parking at the project only is that it deterring parking spillover from project supplied parking to other public parking nearby, which undermine the vehicle miles traveled (VMT) benefits of project pricing. It may also generate sufficient area-wide mode shifts to justify increased transit service to the VMT reduction applies to VMT from visitor/customer trips only. Reductions higher than top end of range from CAPCOA report apply only in conditions with highly constrained on-street parking supply and lack of comparably-priced off-street parking.</td>
<td>2.8%-14.5%</td>
<td>Clinch, J.P. and Kelly, J.A. (2003). Temporal Variance Of Revealed Preference On-Street Parking Price Elasticity. Dublin: Department of Environmental Studies, University College Dublin. Retrieved from: <a href="http://www.uci.edu/gppp/research/workingpaper/2004-04-02.pdf">http://www.uci.edu/gppp/research/workingpaper/2004-04-02.pdf</a>. Cited in Victoria Transport Policy Institute (2017). Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior. Retrieved from: <a href="http://www.vtpi.org/bids/bidfl.htm">http://www.vtpi.org/bids/bidfl.htm</a></td>
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<tr>
<td>Commute Trip Reduction</td>
<td>TRT-4</td>
<td>Implement Subsidized or Discounted Transit Program</td>
<td>0.3%-20% commute VMT reduction due to transit subsidy of up to $5/day</td>
<td>Adequate - Effectiveness is building/tenant specific. Do not use with “TRT-5 Implement CTR Program - Voluntary” or “TRT-2 Implement CTR Program - Required Implementation/Monitoring.”</td>
<td>1) Reduction in vehicle trips in response to reduced cost of transit use, assuming that 50% of new bus trips replace vehicle trips; 2) Reduction in commute trip VMT due to employee benefits that include transit. 3) Reduction in all vehicle trips due to reduced transit fares system-wide, assuming 25% of new transit trips would have been vehicle trips.</td>
<td>0.3%-14% 0.2%-16% 12.3%-4.9%</td>
<td>1) Victoria Transport Policy Institute. (2017). Understanding Transport Demands and Elasticity. Online TDM Encyclopedia. Retrieved from: <a href="http://www.vtpi.org/tdm/tdm11.htm">http://www.vtpi.org/tdm/tdm11.htm</a></td>
</tr>
<tr>
<td></td>
<td>TRT-11</td>
<td>Provide Employer-Sponsored Vanpool/ Shuttle</td>
<td>0.3%-14.4% commute VMT reduction due to employer-sponsored vanpool and/or shuttle service</td>
<td>Adequate - Effectiveness is building/tenant specific.</td>
<td>1) Reduction in commute vehicle trips due to implementing employer-sponsored vanpool and shuttle programs; 2) Reduction in commute vehicle trips due to vanpool incentive programs; 3) Reduction in commute vehicle trips due to employer shuttle programs.</td>
<td>0.5%-6.0% 2.0%-7.4% 1.4%-6.8%</td>
<td>6) Concoe, Simon, Winter, Phillip, Wambolda, Frank, (2005). Fare Pricing Elasticity, Subsidies, and Demand for Vanpool Services. Transportation Research Record: Journal of the Transportation Research Board 1924, pp 215-223.</td>
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**New Information Since CAPCOA Was Published in 2010**

- **Primary sources:**

- **Secondary sources:**
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<tr>
<th>TDM STRATEGY EVALUATION - DRAFT V 1.0</th>
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<td>Commute Trip Reduction</td>
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<td>Commute Trip Reduction</td>
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<td>Not Applicable - not a CAPCOA strategy</td>
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### Relevant Strategies for Implementation in WRCOG Jurisdictions Due to Land Use Context

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<tr>
<td>Neighborhood Site Enhancements</td>
<td>3.2.2</td>
<td>SDT-2 Provide Traffic Calming Measures</td>
<td>0.25%-1% VMT reduction due to traffic calming on streets within and around the development</td>
<td>Adequate</td>
<td>Reduction in VMT due to building out a low-stress bike network; reduction in VMT due to expansion of bike networks in urban areas.</td>
<td>0%-1.7%</td>
<td><a href="http://www.wsdot.wa.gov/research/reports/fullreports/765.1pdf">Zhang, Wengia et al. “Short- and Long-Term Effects of Land Use on Reducing Personal Vehicle Miles of Travel.”</a></td>
</tr>
<tr>
<td>Neighborhood Site Enhancements</td>
<td>3.4.9</td>
<td>TRT-9 Implement Car-Sharing Program</td>
<td>0.4%-0.7% VMT reduction due to lower vehicle ownership rates and general shift to non-driving modes</td>
<td>Adequate</td>
<td>Vehicle trip reduction due to car-sharing programs; reduction assumes 1%-5% penetration rate. Car sharing effect on VMT is still evolving due to TNC effects. UCD research showed less effect on car ownership due to car sharing participation and an uncertain effect on VMT.</td>
<td>0.5%-1.6%</td>
<td><a href="https://arb.ca.gov/cc/capandtrade/auctionproceeds/ctc_atp_finalqm_16-17.pdf">Spears, S. et al. (2014). Impacts of Land-Use Mix on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief and Technical Background Document. California Air Resources Board. Retrieved from: https://arb.ca.gov/cc/capandtrade/auctionproceeds/ctc_atp_finalqm_16-17.pdf</a></td>
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<tr>
<td>Transit System</td>
<td>3.5.4</td>
<td>TST-4 Increase Transit Service Frequency/Speed</td>
<td>0.02%-2.5% VMT reduction due to reduced headways and increased speed and reliability</td>
<td>Adequate</td>
<td>Reduction in vehicle trips due to increased transit frequency/decreased headway.</td>
<td>0.3%-3.3%</td>
<td><a href="https://arb.ca.gov/cc/capandtrade/auctionproceeds/ctc_atp_finalqm_16-17.pdf">Handy, S. et al. (2013). Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions - Policy Brief and Technical Background Document. California Air Resources Board. Retrieved from: https://arb.ca.gov/cc/capandtrade/auctionproceeds/ctc_atp_finalqm_16-17.pdf</a></td>
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<tr>
<td>Commute Trip Reduction</td>
<td>TRT-3</td>
<td>Provide Ride-Sharing Programs</td>
<td>1%-15% commute VMT reduction due to employer ride share coordination and facilities</td>
<td>Adequate - Effectiveness is building/tenant specific. Do not use with “TRT-1 Implement CTR Program - Voluntary” or “TRT-2 Implement CTR Program - Required Implementation/Monitoring.”</td>
<td>Commute vehicle trips reduction due to employer ride-sharing programs</td>
<td>2.5%-8.3%</td>
<td>Victoria Transport Policy Institute. (2015). Ridesharing: Carpooling and Vanpooling. Online TDM Encyclopedia. Retrieved from: <a href="http://vtpi.org/tdm/tdm34.htm">http://vtpi.org/tdm/tdm34.htm</a></td>
</tr>
</tbody>
</table>

**NOTES:**

(1) For specific VMT reduction ranges, refer to the cited literature.
Increase Diversity of Urban and Suburban Developments (Mixed Use)

Range of Effectiveness:

0 – 12% vehicle miles traveled (VMT) reduction due to a mix of land uses within a single development (Ewing and Cervero, 2010).

0.3 – 4% VMT reduction due to change in land use entropy index (i.e., land use mix) within a project’s sphere of influence (Zhang).

Measure Description:

Having different types of land uses near one another can decrease VMT since trips between land use types are shorter and may be accommodated by non-auto modes of transport. For example, when residential areas are in the same neighborhood as retail and office buildings, a resident does not need to travel outside of the neighborhood to meet his/her trip needs. A description of diverse uses for urban and suburban areas is provided below (CAPCOA 2010, p. 162)

Urban:

An urban project is predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential, are combined in a single building or on a single site in an integrated development project with functional interrelationships and a coherent physical design. These mixed-use developments should encourage walking and other non-auto modes of transport from residential to office/commercial/institutional locations (and vice versa). The residential units should be within a quarter mile of parks, schools, or other civic uses. These projects minimize the need for external trips by including services/facilities for day care, banking/ATM, restaurants, vehicle refueling, and shopping (CAPCOA 2010, p. 162).

Suburban:

A suburban project has at least three of the following on site and/or offsite within a quarter mile: residential development, retail development, park, open space, or office. These mixed-use developments should encourage walking and other non-auto modes of transport from residential to office/commercial locations (and vice versa). These projects minimize the need for external trips by including services/facilities for day care, banking/ATM, restaurants, vehicle refueling, and shopping (CAPCOA 2010, p. 162).

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context (unless the project is a master-planned community)
- Appropriate for mixed-use projects

Inputs:

The following information needs to be provided by the project applicant:
- Percentage of each land use type in the project

**Mitigation Method:**

\[
\% \text{ VMT Reduction} = \frac{\text{Land Use} \times E_{Diversity}}{15\% \text{ for non-work trips and } 25\% \text{ for commute trips}}
\]

Where:

\[
\text{Land Use} = \frac{(\text{Land Use Index} - 0.15)}{0.15} \text{ (not to exceed 500\% increase)}
\]

\[
\text{Land Use Index} = -a/\ln(6)
\]

\[
a = \sum_{i=1}^{6} a_i \times \ln(a_i) \text{ (Song and Knaap, 2004)}
\]

\[
a_i = \text{Building floor area of land use } i / \text{total square feet of project land area}
\]

- \(a_1 = \text{Single family residential}\)
- \(a_2 = \text{Multifamily residential}\)
- \(a_3 = \text{Commercial}\)
- \(a_4 = \text{Industrial}\)
- \(a_5 = \text{Institutional}\)
- \(a_6 = \text{Park}\)

\[
E_{Diversity} = \text{Elasticity of VMT with respect to land use index} = 0.02 \text{ to } 0.08 \text{ [4]}
\]

If land use \(a_i\) is not present, set \(a_i\) equal to 0.01

**Discussion:**

In the above calculation, a land use index of 0.15 is used as a baseline representing a development with a single land use. There are two separate maxima that should be noted: an effective cap of 500\% on the allowable percentage increase of land use index and a cap of 15\% and 25\% on percent VMT reduction for non-work and commute trips, respectively. The 500\% cap reflects the expected change in a land use index from 0.15 to 0.90, or from single use to a nearly equal balance of all six uses included in this method. The purpose for the 15\% and 25\% caps is to limit the influence of any single environmental factor (such as diversity). This emphasizes that community designs that implement multiple land use strategies (such as density, design, diversity, etc.) will show more of a reduction than relying on improvements from a single land use factor (CAPCOA 2010, p. 164).

The land use (or entropy) index measurement looks at the mix of land uses of a development. An index of 0 indicates a single land use while 1 indicates a full mix of uses. The preferred elasticity of VMT with respect to the land use mix index for Riverside County is 0.02, per work examining policy effects on VMT conducted by Salon et al for the Air Resource Board.

**Example:**

Sample calculations are provided below:
90% single family homes, 10% commercial

- Land use index = \(- [0.9 \times \ln(0.9) + 0.1 \times \ln(0.1) + 4 \times 0.01 \times \ln(0.01)]/\ln(6) = 0.3\)
- Low Range % VMT Reduction = \((0.3 - 0.15)/0.15 \times 0.02 = 2\%\)

1/6 single family, 1/6 multi-family, 1/6 commercial, 1/6 industrial, 1/6 institutional, 1/6 parks

- Land use index = \(- [6 \times 0.17 \times \ln(0.17)]/\ln(6) = 1\)
- High Range % VMT Reduction (land use index = 1)
- Land use = \((1 - 0.15)/0.15 = 5.6\) or 566%. Since this is greater than 500%, set to 500%
- % VMT Reduction = \((5 \times 0.02) = 10\%

References:


http://urban.csuohio.edu/~sugie/papers/RSUE/RSUE2005_Measuring%20the%20effects%20of%20mixed%20land%20use.pdf


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.1.3 Increase Diversity of Urban and Suburban Developments (Mixed Use).
Zhang, Wengia et al. "Short- and Long-Term Effects of Land Use on Reducing Personal Vehicle Miles of Travel."
**Provide Pedestrian Network Improvements**

**Range of Effectiveness:**

0.5 – 5.7% VMT reduction

**Measure Description:**

Providing pedestrian access at and near a project site encourages people to walk instead of drive, presuming that desirable destinations exist within walking distance of the project. This mode shift results in people driving less and thus a reduction in VMT. The pedestrian access network should internally link all uses and connect to all existing or planned external streets and pedestrian facilities contiguous with the project site. It should also minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, landscaping, and slopes that impede pedestrian circulation should be eliminated (CAPCOA 2010, p. 186).

**Measure Applicability:**

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects
- Reduction benefit only occurs if the project has both pedestrian network improvements on site and connections to the larger off-site network. All calculations should incorporate the status of the network in the project’s walkshed (i.e., within a ¼ mile radius).
- Desirable destinations external to the project site must be within walking distance (i.e., preferably within a ¼ mile and no greater than ½ mile).

**Inputs:**

The project applicant must provide information regarding pedestrian access and connectivity within the project and to/from off-site destinations. The change in sidewalk coverage should represent the share of quality sidewalk and pedestrian facilities available in the surrounding area; for instance, if one block-face of ten is missing sidewalks, the existing coverage is 90%. This measure is not effective in reducing VMT in locations with already fully-developed, high quality sidewalk networks.

**Mitigation Method:**

\[
\% \text{ VMT Reduction} = E_{\text{PedAccess}} \times \text{Sidewalk Delta}
\]

Where:

\[
E_{\text{PedAccess}} = \% \text{ Change in VMT per } \% \text{ Increase in Sidewalk Coverage}
\]

\[
\text{Sidewalk Delta} = \text{Assumed change in sidewalk coverage compared to background condition}
\]

**Detail:**

\[
E_{\text{PedAccess}} = 0.0 \text{ to } 0.14 \quad (0.07 \text{ preferred in absence of other data})
\]

\[
\text{Sidewalk Delta} = 5\% \text{ to } 100\%
\]
Discussion:

Pedestrian Access Elasticity varies at the local level and is dependent on many factors such as the urban form of the immediate area and population characteristics. When reliable studies are available and applicable to the project area, this elasticity should be calculated. Otherwise, 0.07 is recommended based on the range provided by Handy, S. et al.

References:


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.2.1 Provide Pedestrian Network Improvements.
Provide Traffic Calming Measures

Range of Effectiveness:

0 – 1.7% VMT reduction

Measure Description:

Providing traffic calming measures encourages people to walk or bike instead of using a vehicle. This mode shift results in a decrease in VMT. Project design should include pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways should be designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips with traffic calming features. Traffic calming features may include: marked crosswalks, count-down signal timers, curb extensions, speed tables, raised crosswalks, raised intersections, median islands, tight corner radii, roundabouts or mini-circles, on-street parking, planter strips with street trees, chicanes/chokers, etc. (CAPCOA 2010, p. 190).

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Inputs:

The following information needs to be provided by the project applicant:

- Percentage of streets within project with traffic calming improvements
- Percentage of intersections within project with traffic calming improvements

Mitigation Calculation:

The VMT reduction is a function of the percentage of streets and intersections within the project with traffic calming improvements based on the following look up table.

<table>
<thead>
<tr>
<th>% of Intersections with Improvements</th>
<th>% VMT Reduction</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td></td>
<td>0.425%</td>
<td>0.425%</td>
<td>0.85%</td>
<td>0.85%</td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td>0.425%</td>
<td>0.85%</td>
<td>0.85%</td>
<td>1.275%</td>
</tr>
<tr>
<td>75%</td>
<td></td>
<td>0.85%</td>
<td>0.85%</td>
<td>1.275%</td>
<td>1.275%</td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td>0.85%</td>
<td>1.275%</td>
<td>1.275%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>
Discussion:

The table above allows the project applicant to calculate a VMT reduction estimate based on the project’s street and intersection design with respect to traffic calming. The applicant should look at the rows on the left and choose the percent of intersections within the project which will have traffic calming improvements. Then, the applicant should look at the columns along the top and choose the percent of streets within the project which will have traffic calming improvements. The intersection cell of the row and column selected in the matrix is the VMT reduction estimate.

Though the literature provides some difference between a suburban and urban context, the difference is small and thus the lower VMT reduction estimate was used to be applied to all contexts. Rural context is not specifically discussed in the literature but is presumed to have little to no effect on VMT reduction due to the long-distances between trip origins and destinations.

Research by Zahabi, S. et al. attributes up to a 1.7% VMT reduction to traffic calming measures. The table above illustrates the range of VMT reductions based on the percent of streets and intersections with traffic calming measures implemented. CAPCOA 2010 used a range of 0.25% to 1% for VMT reduction. The VMT reductions were updated using the same methodology to allow for reductions up to 1.7%.

Because of the high potential for double-counting, caution should be used when combining this measure with “Provide Pedestrian Network Improvements.”

References:


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.2.2 Provide Traffic Calming Measures.

**Implement Car-Sharing Program**

**Range of Effectiveness:**

0.3 – 1.6% VMT reduction

**Measure Description:**

Implementation of a car-sharing program allows people to have on-demand access to a shared fleet of vehicles on an as-needed basis. VMT reduction occurs due to reductions in private vehicle ownership, lower convenience associated with indirect vehicle access, and the transparent cost of vehicle use. User costs are typically determined through mileage or hourly rates, with deposits and/or annual membership fees. The car-sharing program could be created through a local partnership or through one of many existing car-share companies. Car-sharing programs may be grouped into three general categories: residential- or citywide-based, employer-based, and transit station-based. Transit station-based programs focus on providing the “last-mile” solution and link transit with commuters’ final destinations. Residential-based programs work to substitute entire household-based trips. Employer-based programs provide a means for business/day trips for alternative mode commuters and provide a guaranteed ride home option (CAPCOA 2010, p. 245).

**Measure Applicability:**

- Urban and suburban context
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

**Inputs:**

The following information needs to be provided by the project applicant:

- % reduction in car share member annual VMT
- Number of car share members per household

**Mitigation Method:**

\[
\% \text{ VMT Reduction} = P_{\text{CarShare}} \times \text{Adoption Rate}
\]

Where:

\[
P_{\text{CarShare}} = \% \text{ reduction in car share member annual VMT}
\]

\[
\text{Adoption Rate} = \text{number of car share members per household}
\]

**Detail:**

\[
P_{\text{CarShare}} = 26.9 \text{ to } 37\%
\]

\[
\text{Adoption Rate} = 1\% \text{ to } 2\%
\]
**Discussion:**

The applicant must consider the demand for car-shares in a community before calculating a VMT reduction. If a community cannot support the proposed number of cars deployed, VMT reduction may be overestimated.

The percent reduction in car share member annual VMT is dependent on characteristics of the community, its residents, and for what purposes the car-sharing program is to be used for. Analysts should consult the literature to understand how these variables affect the range of reductions prior to completing the calculation of VMT reduction.

**References:**


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.4.9 Implement Car-Sharing Program
Increase Transit Service Frequency/Speed

Range of Effectiveness:

0.03 – 6.3% VMT reduction.

Measure Description:

This measure reduces transit-passenger travel time through reduced headways and increased speed and reliability. This makes transit service more attractive and may result in a mode shift from auto to transit which reduces VMT (CAPCOA 2010, p. 280).

Inputs:

The following information needs to be provided by the project applicant:

- Percentage reduction in headways (increase in frequency) for applicable transit routes
- Level of implementation
- Project setting: urban center, urban, suburban
- Existing transit mode share

Mitigation Method:

\[
\% \text{ VMT Reduction} = \text{Headway} \times B \times C \times \text{Mode}
\]

Where:

- \( \text{Headway} \) = \% reduction in headways
- \( B \) = Elasticity of transit ridership with respect to increased frequency of service
- \( C \) = Ratio of vehicle trips reduced to number of new transit riders
- \( \text{Mode} \) = Existing transit mode share

Detail:

- \( B = 0.50 \)
- \( C = 25\% \) to 75\%

Discussion:

A 1% reduction in headways leads to 0.5% increase in transit ridership. This change is translated into a VMT reduction by applying a mode shift adjustment to account for new transit trips that do not represent displaced vehicle trips in addition to considering the existing transit mode share.

Variable C should be calculated based on local data. It is calculated by taking the length of an average transit trip within the sphere of influence of the project divided by the average vehicle trip length within the sphere of influence of the project.
References:


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.5.4 Implement Transit Service Frequency/Speed
**Encourage Telecommuting and Alternative Work Schedules**

**Range of Effectiveness:**

0.2 – 4.5% commute VMT reduction.

**Measure Description:**

Encouraging telecommuting and alternative work schedules reduces the number of commute trips and therefore VMT traveled by employees. Alternative work schedules could take the form of staggered starting times, flexible schedules, or compressed work weeks (CAPCOA 2010, p. 236).

**Measure Applicability:**

- Urban, suburban, and rural context
- Appropriate for retail, office, industrial, and mixed-use projects
- VMT reduction is dependent on the performance of individual building tenants and may change over time. On-going monitoring and adjustment is necessary to achieve sustained reductions in VMT.

**Inputs:**

The following information needs to be provided by the project applicant:

- Percentage of employees participating (1 – 25%)
- Telecommute elasticity (see discussion below)

**Mitigation Method:**

\[
\% \text{ Commute VMT Reduction} = E_{\text{Telecommute}} \times \text{Telecommute Delta}
\]

Where:

\[
\text{Telecommute Delta} = \% \text{ change in workers telecommuting with TDM Program}
\]

\[
E_{\text{Telecommute}} = \% \text{ change in VMT per } \% \text{ change in workers telecommuting}
\]

\[
E_{\text{Telecommute}} = 0.18 \text{ to } 0.90
\]

**Discussion:**

Telecommute Delta and \(E_{\text{Telecommute}}\) should consider the potential for building tenants to change over time. Higher values require the employer at the site to be known and unlikely to change over time. \(E_{\text{Telecommute}}\) will be lower in places with higher non-drive alone mode share, and higher in places with more drive alone vehicle mode share.
References:


Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.4.6 Encourage Telecommuting and Alternative Work Schedules
Provide Ride-Sharing Programs

Range of Effectiveness:
2.5 – 8.3% commute VMT reduction.

Measure Description:
Increasing vehicle occupancy by ride-sharing results in fewer cars driving the same trip, and thus a decrease in VMT. Projects must implement a ride-sharing program as well as a permanent transportation management association membership and funding requirement to see VMT benefits. Funding may be provided by Community Facilities, District, or County Service Area, or other non-revocable funding mechanism (CAPCOA 2010, p. 227). Projects should promote ride-sharing programs through a multi-faceted approach such as:

- Designating a certain percentage of parking spaces for ride sharing vehicles
- Designating adequate passenger loading and unloading and waiting areas for ride-sharing vehicles
- Providing a web site or message board for coordinating rides
- Providing a guaranteed ride home program to carpool participants

Measure Applicability:
- Urban and suburban context
- Negligible impact in many rural contexts, but can be effective when a large employer in a rural area draws from a workforce in an urban or suburban area, such as when a major employer moves from an urban location to a rural location
- Appropriate for residential, retail, office, industrial, and mixed-use projects
- VMT reduction is dependent on the performance of individual building tenants and may change over time. On-going monitoring and adjustment is necessary to achieve sustained reductions in VMT.

Inputs:
The following information needs to be provided by the project applicant:
- Percent reduction in commute VMT
- Shared trips to VMT factor

Mitigation Method:

\[
% \text{ VMT Reduction} = \% \text{ reduction in commute VMT} \times \text{Shared trips to VMT factor}
\]

Where:

\[
\% \text{ reduction in commute VMT} = 1.0\% \text{ to } 20.0\%
\]

\[
\text{Shared Trips to VMT Factor} = 0.25 \text{ to } 0.50
\]
**Discussion:**

The extent of reduction in VMT and the number of employees sharing a car is dependent on the employer, characteristics of employee's commutes and their home communities.

**References:**

Quantifying Greenhouse Gas Mitigation Measures, California Air Pollution Control Officers Association (CAPCOA), 2010. Chapter 3.4.3 Provide Ride-Sharing Programs

