

TRANSPORTATION IMPACT ANALYSIS GUIDELINES

VEHICLE MILES TRAVELED (VMT) MEMO APPENDICES



San Francisco
Planning

Screening Criteria (SB 743 Checklist)

The Planning Department created a SB743 Checklist in response to California Environmental Quality Act (CEQA) Section 21099 – Modernization of Transportation Analysis for Transit Oriented Projects and Planning Commission Resolution 19579. Planning Commission Resolution 19579 replaces automobile delay with vehicle miles traveled analysis. This appendix lists out the screening criteria from the SB743 Checklist used by the Planning Department to identify types, characteristics or locations of projects and a list of transportation project types that would not result in significant transportation impacts under the VMT metric. These screening criteria are consistent with CEQA Section 21099 and the screening criteria recommended by OPR. If a project would generate VMT, but meets the screening criteria in Tables 1 and 2, or falls within the types of transportation projects listed in Table 3, then a detailed VMT analysis is not required for a project.

Attachment A to this appendix provides definitions related to the these screening criteria, and Attachment B to this appendix would be customized for each project to show major transit stops within a half mile radius of the project site.

TABLE 1

Vehicle Miles Traveled Analysis – Screening Criterion	
If a project meets the screening criterion listed below, then a detailed <u>VMT</u> analysis is not required. See Attachment A for definitions and other terms.	
<input checked="" type="checkbox"/>	<p>Criterion 1. Is the proposed project site located within the “map-based screening” area?</p> <p>[Identify regional, and transportation analysis zone (TAZ) VMT per efficiency metric. Consult with transportation planner if project does not meet this screening criterion.]</p>

Note: Projects with a substantial amount of parking may not meet screening criterion.

TABLE 2

Vehicle Miles Traveled Analysis – Additional Screening Criteria	
Identify whether a project meets any of the additional screening criteria. See Attachment A for definitions and other terms.	
<input checked="" type="checkbox"/>	<p>Criterion 1. Does the proposed project qualify as a “small project”? or</p> <p>[Identify number of daily vehicle trips from whole of the project – show your work]</p>
<input checked="" type="checkbox"/>	<p>Criterion 2. Proximity to Transit Stations (must meet all four sub-criteria)</p> <p>Is the proposed project site located within a half mile of an existing major transit stop; and</p> <p>[NOTE: this is definition is different than transit priority area, as it does not include planned major transit stops. Add transit stop headway/schedule, or other applicable qualifying information such as nearby rail transit station or multi-modal ferry terminal.]</p> <p>Would the proposed project have a floor area ratio of greater than or equal to 0.75, and</p> <p>Would the project result in an amount of parking that is less than or equal to that required or allowed by the Planning Code without a conditional use authorization, and</p> <p>Is the proposed project consistent with the Sustainable Communities Strategy?</p> <p>[NOTE: if project site is located in priority development area, reference that. Refer to Attachment 1 of 2013 staff report for San Francisco’s priority development areas: http://www.sf-planning.org/ftp/files/plans-and-programs/emerging_issues/scs/Plan-Bay-Area-Memo-5_02_13.pdf.) As noted by footnote, however, a project site does not need to be within a priority development area to be consistent. All land within San Francisco, except for parks and open spaces was considered for development in Plan Bay Area.]</p>

TABLE 3

Induce Automobile Travel Analysis	
If a project contains transportation elements and fits within the general types of projects described below, then a detailed VMT analysis is not required. See Attachment A for definitions and other terms.	
<input checked="" type="checkbox"/>	<p>Project Type 1. Does the proposed project qualify as an “active transportation, rightsizing (aka Road Diet) and Transit Project”? or</p> <p>[Specify how project meets this criterion – state n/a if no transportation elements]</p>
<input checked="" type="checkbox"/>	<p>Project Type 2. Does the proposed project qualify as an “other minor transportation project”?</p> <p>[Specify how project meets this criterion – state n/a if no transportation elements]</p>

ATTACHMENT A
DEFINITIONS

Active transportation, rightsizing (aka road diet) and transit project means any of the following:

- Reduction in number of through lanes
- Infrastructure projects, including safety and accessibility improvements, for people walking or bicycling
- Installation or reconfiguration of traffic calming devices
- Creation of new or expansion of existing transit service
- Creation of new or conversion of existing general purpose lanes (including vehicle ramps) to transit lanes
- Creation of new or addition of roadway capacity on local or collector streets, provided the project also substantially improves conditions for people walking, bicycling, and, if applicable, riding transit (e.g., by improving neighborhood connectivity or improving safety)

Employment center project means a project located on property zoned for commercial uses with a floor area ratio of no less than 0.75 and that is located within a transit priority area. If the underlying zoning for the project site allows for commercial uses and the project meets the rest of the criteria in this definition, then the project may be considered an employment center.

Floor area ratio means the ratio of gross building area of the development, excluding structured parking areas, proposed for the project divided by the net lot area.

Gross building area means the sum of all finished areas of all floors of a building included within the outside faces of its exterior walls.

Infill opportunity zone means a specific area designated by a city or county, pursuant to subdivision (c) of Section 65088.4, that is within one-half mile of a major transit stop or high-quality transit corridor included in a regional transportation plan. A major transit stop is as defined in Section 21064.3 of the Public Resources Code, except that, for purposes of this section, it also includes major transit stops that are included in the applicable regional transportation plan. For purposes of this section, a high-quality transit corridor means a corridor with fixed route bus service with service intervals no longer than 15 minutes during peak commute hours.

Infill site means a lot located within an urban area that has been previously developed, or on a vacant site where at least 75 percent of the perimeter of the site adjoins, or is separated only by an improved public right-of-way from, parcels that are developed with qualified urban uses.

Lot means all parcels utilized by the project.

Major transit stop is defined in CEQA Section 21064.3 as a rail transit station, a ferry terminal served by either a bus or rail transit service, or the intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods.

Map-based screening means the proposed project site is located within a transportation analysis zone that exhibits low levels of VMT.

Net lot area means the area of a lot, excluding publicly dedicated land and private streets that meet local standards, and other public use areas as determined by the local land use authority.

Other land use projects mean a land use other than residential, retail, and office. OPR has not provided proposed screening criteria or thresholds of significance for other types of land uses, other than those that meet the definition of a small project.

- Student housing, single room occupancy hotels, and group housing land uses should be treated as residential for screening and analysis.
- Tourist hotel workers, childcare, K-12 schools, post-secondary institutional (non-student housing), Medical, and production, distribution, and repair (PDR) land uses should be treated as office for screening and analysis.
- Tourist hotels, grocery stores, local-serving entertainment venues, religious institutions, parks, and athletic clubs land uses should be treated as retail for screening and analysis.
- Public services (e.g., police, fire stations, public utilities) and do not generally generate VMT. Instead, these land uses are often built in response to development from other land uses (e.g., office and residential). Therefore, these land uses can be presumed to have less-than-significant impacts on VMT. However, this presumption would not apply if the project is sited in a location that would require employees or visitors to travel substantial distances and the project is not located within ½ mile of a major transit stop or does not meet the small project screening criterion.
- Event centers and regional-serving entertainment venues would **most likely require a detailed VMT analysis**. Therefore, no screening criterion is applicable.

Other minor transportation project means any of the following:

- Rehabilitation, maintenance, replacement and repair projects designed to improve the condition of existing transportation assets (e.g., highways, roadways, bridges, culverts, tunnels, transit systems, and bicycle and pedestrian facilities) and that do not add additional motor vehicle capacity
- Installation, removal, or reconfiguration of traffic lanes that are not for through traffic, such as left, right, and U-turn pockets, or emergency breakdown lanes that are not used as through lanes
- Conversion of existing general purpose lanes (including vehicle ramps) to managed lanes (e.g., HOV, HOT, or trucks) or transit lanes
- Grade separation to separate vehicles from rail, transit, pedestrians or bicycles, or to replace a lane in order to separate preferential vehicles (e.g. HOV, HOT, or trucks) from general vehicles
- Installation, removal, or reconfiguration of traffic control devices, including Transit Signal Priority (TSP) features
- Traffic metering systems
- Timing of signals to optimize vehicle, bicycle or pedestrian flow on local or collector streets
- Installation of roundabouts
- Adoption of or increase in tolls
- Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes
- Addition of transportation wayfinding signage
- Removal of off- or on-street parking spaces

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- Adoption, removal, or modification of on-street parking or loading restrictions (including meters, time limits, accessible spaces, and preferential/reserved parking permit programs)

Small project means the project would not result in over 100 vehicle trips per day or would have less than or equal to a 10,000 square feet of retail.

Transit priority area means an area within one-half mile of a major transit stop that is existing or planned, if the planned stop is scheduled to be completed within the planning horizon included in a Transportation Improvement Program adopted pursuant to Section 450.216 or 450.322 of Title 23 of the Code of Federal Regulations.

Vehicle miles traveled measures the amount and distance that a project might cause people to drive and accounts for the number of passengers per vehicle.

ATTACHMENT B MAJOR TRANSIT STOPS

[insert map showing stops within a half-mile radius of the project site]

Vehicle Miles Traveled Sketch Tools

This appendix provides an overview of existing sketch tools and spreadsheet tools for estimating VMT based on land use and transportation characteristics. For each tool, this appendix provides a summary of the its functionality, inputs and outputs, and where the tool has been applied. The Planning Department provides this appendix for informational purpose and does not endorse these tools. Please consult Planning Department staff prior to using any of the tools for VMT analysis.

ASAP (Plan+, MXD+, TDM+)

- Developer: Fehr & Peers, Measures: VMT and Transportation-related GHG, Year: 2013, Cost: Paid, URL: <http://asap.fehrandpeers.com/tools/sustainable-development/plan>
- While the trip generation rates are manually adjustable, the MXD+ tool calculates reduced trip generation rates
- The Plan+ tool takes into account built environment and transit characteristics that reduce VMT
- Outputs are VMT (Daily, AM, PM), Trips (Daily, AM, PM), CO₂e (Metric tons per day)

Bay Area Simplified Simulation of Travel, Energy and Greenhouse Gases (BASSTEGG)

- Developed by the Bay Area Metropolitan Transportation Commission
- GIS simulation of Regional VO, VMT, and GHG based on TAZ-level BE and SES
- <ftp://ftp.abag.ca.gov/pub/mtc/planning/forecast/BASSTEGG/>
- Used in the Bay Area, CA

CalEEMod 2013 & 2016

- Developer: California Air Pollution Control Officers Association (CAPCOA), Measures: GHG and VMT, Year: 2013, Cost: Free, Format: Downloadable program, URL: <http://www.caleemod.com>
Documentation: <http://www.aqmd.gov/caleemod/user's-guide>
- Adjustment to VMT based on elasticities
- Applicable to commercial (subset), educational, industrial, recreational, residential, retail (subset).
- Any context area
- Measures in CAPCOA Quantifying GHG Mitigations Report
- Uses this method with elasticities taken from the Quantifying GHG Mitigation Measures report published by the California Air Pollution Control Officers Association (CAPCOA)
- Calculates transportation-related VMT using estimates of trips based on the traditional ITE trip generation rates multiplied by trip lengths
- The tool includes default trip lengths based on the 1999 California Household Survey, but it allows users to input other trip lengths

- With its focus on project rather than area characteristics, the tool may not be well suited to the analysis of plans
- VMT projections are made for each land use in a project as well as the entire projects
- It reports household VMT per day, which can be aggregated to the project and year levels within the web interface
- CalEEMod offers a platform for entirely customizable travel parameters such as trip lengths by trip purpose and trip generation rates (new, diverted, pass-by) allowing customization to reflect the local travel patterns in the area of a project.

California SmartGrowth Trip Generation (SGTG) Adjustment Tool

- Developer: UC Davis ULTRANS, Measures: Trips Generated, Year: 2012, Cost: Free, Format: Spreadsheet, URL: <http://ultrans.its.ucdavis.edu/projects/smart-growth-trip-generation>
- Developed by researchers affiliated with the Institute of Transportation Studies at UC Davis calculates an adjustment factor based on eight variables related to land use characteristics and transit availability
- Adjustment factors are based on data collected at 50 project sites in California and were validated using data from another sample of California sites
- The reduced trip projections from this tool should be used only for projects that meet certain “smart growth” criteria and can be multiplied by trip lengths to calculate VMT

CNT (2015)/Green Trip Connect

- Developer: Center for Neighborhood Technology, Measures: Trip Generation Rate Adjustments, Year: 2016, Cost: Free, Format: Web tool URL: <http://connect.greentrip.org/>
- Statistically-based reduction in VMT
- Residential applicability using any context area
- Outputs VMT using location (surrounding land use and transportation characteristics, parking spaces/charges, presence of affordable housing/rents, offers of residential transit passes/carshare/bikeshare)
- GreenTrip Connect produces only a partial estimate of VMT impacts for mixed-use projects

Envision Tomorrow

- Developed by Fregonese Associates
- GIS tool that tests financial feasibility of development regulations and their impact on indicators
- Allows planners to model land use scenarios based on aggregate building level data and assess area outcomes such as housing and jobs (mix and density), jobs-housing balance, land consumption (vacant, agricultural, infill), impervious surface, open space, housing affordability, resource usage (energy and water), waste production (water, solid, carbon), transportation (travel mode choice, vehicle miles traveled), fiscal impact (local revenue and infrastructure costs), balanced housing index (how a scenario’s housing mix matches the expected future demographic profile)
- www.frego.com/services/envision-tomorrow/
- Used in various locations, including Mountlake Terrace, WA

Envision Tomorrow + Tool

- Developer: Fregonese Associates / University of Utah, Year: 2013, Cost: Free, Format: Spreadsheet and ArcGIS extension, URL 1: <http://www.arch.utah.edu/cgi-bin/wordpress-etplus/> URL 2: <http://www.envisionutah.org/wasatch-choice-toolbox/tool-et>
- Incorporates two models, one that calculates trip generation reductions for mixed-use project sites and one for mixed-use districts
- Based on the EPA MXD method
- District level model is based on studies by Reid Ewing of the Center for Metropolitan Studies at the University of Utah
- Key variables are project land use characteristics, surrounding land use characteristics, street network, land values, population and economic data
- Outputs are vehicle miles traveled (VMT), vehicle trips, walk trips, bike trips, transit trips, greenhouse gas and pollutant emissions, and many other additional outputs

H+T (Housing and Transportation) Affordability Index

- It uses census and other nationally available datasets to estimate auto ownership, auto use (VMT), and transit use
- From these three estimates, it calculates various downstream outcomes, such as transportation costs and GHG emissions
- Auto ownership data was obtained from the ACS as a ratio of autos and occupied households per block group
- Auto use data came from Massachusetts odometer readings from 2005-2007 at a 250-meter grid cell level
- Transit data were measured from the ACS as the percent of commuters using transit at the block group level
- All three regression models employ 11 explanatory variables derived from readily available national and regional databases: (1) median income, (2) per capita income, (3) average household size, (4) average commuters per household, (5) residential density, (6) gross density, (7) average block size, (8) intersection density, (9) transit connectivity, (10) transit access shed, and (11) employment access
- Its ease of use is limited to displaying current conditions; the underlying regression model coefficients would have to be used to explore how planned changes to the built environment (BE) might affect travel outcomes

Improved Data and Tools for Integrated Land Use-Transportation Planning in California

- Developed by UC Davis
- Uses California-specific relationships of Built Environment (BE) and travel for scenario planning at multiple scales using various tools
- Original research was then conducted on the relationship between BE and travel demand and a suite of software tools was developed for use in local and regional integrated land use-transportation scenario planning processes in California. Three tools were developed: (1) a sketch planning spreadsheet, (2) a GIS-integrated sketch planning tool, and (3) a travel demand forecasting model post-processor

- The suite of tools was based on three statistical models for different regions: (1) small/medium MPOs, (2) large MPOs, and (3) major rail corridors. The models were fitted using GIS and travel survey data (NHTS and regional) from 13 smaller and medium-size MPOs, two major metropolitan areas, and several sub-regions within the two largest MPOs in California
- The models quantified the influence of built environment “D” variables captured within a half-mile buffer around a household and household demographics on three outcomes: vehicle ownership (VO), vehicle trip generation (VT), and vehicle miles travelled (VMT)
- VMT was estimated through multiple steps: a binary logistic regression model to estimate the probability that a household will make a vehicle trip; then either one linear regression model to estimate household VMT or two linear regression models to estimate the number of vehicle trips and the average vehicle trip length, the product of which is VMT
- This tool addressed two of the major limitations of previous sketch planning tools: (1) Travel mode choice differences associated with the BE at workplace and shopping destinations were modeled in addition to those at home locations; and (2) separate models were developed for study regions of varying sizes, which resulted in different relationships between the BE and travel
- <http://ultrans.its.ucdavis.edu/projects/improved-data-and-toolsintegrated-land-use-transportation-planning-california>
- Used in various locations in California

Local Sustainability Planning Tool

- Developed by Southern California Association of Governments (SCAG)
- GIS tool to model land use scenarios on VO, VMT, mode share, and GHG emissions
- <http://rtpscs.scag.ca.gov/Pages/Local-SustainabilityPlanning-Tool.aspx>
- Used in various communities in Southern California

Low-carb Land Tool

- Developed by Sonoma Technology, Inc.
- Web tool for examining VMT and GHG under various growth and land use scenarios
- <http://www.sonomatech.com/project.cfm?uprojectid=672>
- Used by Thurston County, WA and Marin County, CA

MXD

- Developer: Envision Tomorrow, Measures: Trip Generation Rate Adjustments, Year: 2014, Cost: Free, Format: Spreadsheet, URL: <http://www.envisiontomorrow.org/district-level-travel-model/>
- A spreadsheet-based tool built by the transportation consulting firm Fehr & Peers and hosted by the Environmental Protection Agency
- Statistically-based reduction in trips
- Applicability is residential, retail, office, industrial (subset), commercial (subset), educational, other
- Any context area
- Calculated VMT is a result of MXD’s adjusted trip generation rates multiplied by the average trip length by trip purpose

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- Trip length input source is important and can drastically influence the results
 - Important input data may be difficult to find

Rapid Fire Tool

- Developed by Calthorpe Associates
- Models VMT, GHG emissions, etc. based on land use scenarios
- <http://www.calthorpe.com/>
- Used in California and Honolulu

Sketch 7

- Developer: Fehr & Peers, Sacramento Area Council of Governments, UC Davis Urban Land Use and Transportation Center (ULTRANS), Measures: Change in VMT, transit trips per capita, bicycle and walk trips per capita, Year: 2012, Cost: Free, Format: Spreadsheet and Web-based GIS Application, URL: <http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california>
- Spreadsheet tool that estimates VMT based on seven land use and transportation characteristics
- Primarily used and maintained in the Sacramento region
- Projects VMT for several situations including a given project, the surrounding area (the context area) in a before-and-after project scenario, and compares the project scenarios to the regional VMT averages
- Key variables are seven D's of land use and transportation (auto/ transit accessibility, jobs/housing balance, residential density/diversity, street pattern, demographics)
- Its use is limited to the Sacramento region without investment from other regional planning agencies to develop the needed inputs
- Is able to estimate transit, bike and walk trips
- The proper functioning of Sketch7 requires development maintenance of a parcel database to use as baseline data
- Regional TAZ data used to calibrate tool may be difficult to obtain

UrbanFootprint

- Developer: Calthorpe Associates/Calthorpe Analytics, Year: 2012, Cost: Free, Format: Browser-based downloadable program, URL: <http://www.scag.ca.gov/Documents/UrbanFootprintTechnicalSummary.pdf>
- Open-source downloadable software program, analyzes fiscal, environmental, public health, and transportation impacts of plans and policies
- Runs a sketch-level travel model based on land use and transportation system characteristics that outputs VMT
- Uses land use, road network, transit data demographic and economic data for determining rates

VMT Reduction: Phase One

- Developed by WSDOT
- Estimates neighborhood residential VMT and CO₂ based on BE and demographic factors
- Estimates household-level vehicle use (VMT in miles per day, month, year or other unit of time) and related CO₂ emission (grams per unit time) as well as the 95% confidence interval around each estimate
- It can be used for baseline and forecasted estimates based on changes to input variables.
- Estimates are based on the relationships found in two Ordinary Least Squares (OLS) linear regression models of household VMT and CO₂. The OLS linear regression models were fitted using data from 1,929 households that responded to the 2006 PSRC household travel survey and who lived in King County jurisdictions where sidewalk data were available.
- It relies on models of VMT and CO₂ based only on household neighborhood urban form, it does not account for the effect of destination 17 urban form characteristics on VMT. The tool also does not estimate travel for non-residential land uses in the planning area.
- It was developed from a sample of households located in a limited number of jurisdictions in King County, and therefore may not be generalizable to other parts of the state.
- <http://www.wsdot.wa.gov/research/>
- Used in Rainier Beach and Bitter Lake, Seattle

VMT +

- Developer: Fehr & Peers, Measures: VMT and Transportation-related GHG, Year: 2013, Cost: Free, Format: Calculator on website, URL: <http://www.fehrandpeers.com/vmt>
- VMT is estimated by a multiplication of trips generated multiplied by trip lengths
- Outputs are VMT (per household per day), CO₂e (MT per day)

Sources:

<http://depts.washington.edu/trac/bulkdisk/pdf/806.3.pdf>

<https://rosap.ntl.bts.gov/view/dot/32750>

Combined Vehicle Miles Traveled Research Annotated Bibliography

This appendix documents existing research on travel behavior and vehicle miles traveled (VMT). The first portion presents research that supports significance assumptions under SB 743. Based on existing research, certain transportation projects are not considered likely to lead to a substantial or measurable increase in VMT. The second portion summarizes the relationship between VMT and density, land use context, and access to parking at home and work.

Contents of this Appendix

1. Projects with assumed less-than-significant VMT impacts under SB 743
2. Parking access, land use context, density, and VMT

1. Projects with assumed less-than-significant VMT impacts under SB 743

In January 2016, the California Office of Planning and Research (OPR) published for public review and comment a *Revised Proposal on Updates to the CEQA Guidelines on Evaluating Transportation Impacts in CEQA*¹. The document includes a list of transportation project types that would not likely lead to a substantial or measurable increase in vehicle miles traveled (VMT). If a project fits within the general types of projects (including combinations of types) described below, then it is presumed that VMT impacts would be less than significant and a detailed VMT analysis is not required. Some of these types of projects are reducing the number of through lanes, creating new or expanding transit services, adoption of tolls, and removal of on- or off-street parking. Each project type is listed in Table 1; project types have been grouped together by the City and County of San Francisco.

This appendix documents existing research that supports and furthers the substantial evidence in the Technical Advisory document regarding these projects' presumed less-than-significant VMT impacts. Some papers address more than one type of project; Table 1 lists sources that address each project type's VMT contributions. This document is and will continue to be a working draft; new research that advances understanding of these projects' VMT impacts will inform future drafts.

¹ This document is available online at: https://www.opr.ca.gov/s_sb743.php.

Table 1: Transportation projects not likely to lead to a substantial or measurable increase in VMT, and reviewed references that support this conclusion

Project Type	References
<i>Active Transportation, Rightsizing (aka Road Diet), and Transit Projects</i>	
Reduction in number of through lanes	2, 4, 9, 11, 15, 16
Infrastructure projects, including safety and accessibility improvements, for people walking or bicycling	8, 15, 16
Creation of new or expansion of existing transit service	5, 8, 9, 14
Creation of new or conversion of existing general purpose lanes (including vehicle ramps) to transit lanes	9, 14
<i>Other Minor Transportation Projects</i>	
Adoption of or increase in tolls	8
Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes	1, 3, 7, 10
Removal of off- or on-street parking spaces	6, 12, 13
Adoption, removal, or modification of on-street parking or loading restrictions (including meters, time limits, accessible spaces, and preferential/reserved parking permit programs)	13

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1. Goodwin, Phil, Carmen Hass-Klau, and Sally Cairns. "Evidence on the effects of road capacity reduction on traffic levels." *Traffic Engineering+ Control* 39.6 (1998): 348-54.
http://nacto.org/docs/usdg/traffic_impact_highway_capacity_cairns.pdf

Reduction in number of through lanes

This report was a meta-analysis of over 100 studies of projects that reduced vehicular capacity on roadways (popularly termed "road diets"). The overall sample of studies showed an average reduction in traffic in the treatment area by 41%, with *less than half* reappearing on alternative routes or at different times of day. There were 7 cases of overall traffic increase.

The paper does list some potential caveats:

- Drivers could have rerouted to longer diversions that were not captured by the projects' designated "study area." However, most studies were conducted by local professionals who tried to account for reasonable diversion possibilities.
- Partial sampling is also an issue; that is, surveying pre-project road users who stop using the road but not capturing the anyone who began driving on the road after the project.

In spite of possible sources of bias and error in particular cases, the authors conclude that, taken as a whole, the sum of case studies seems to point to a proportion of traffic possibly "disappearing" when capacity is reduced. They conclude: "The balance of evidence is that measures which reduce or reallocate road capacity, when well-designed and favoured by strong reasons of policy, need not automatically be rejected for fear that they will inevitably cause unacceptable congestion." Although the focus of the paper is congestion, it does have findings that support the idea that a reduction in vehicular capacity does not generate additional VMT.

2. Walker, G. Wade, Walter M. Kulash, and Brian T. McHugh. *Downtown Streets: Are We Strangling Ourselves in One-Way Networks?*. No. E-C019, 2000.

Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes

The author, a transportation consultant, enumerates the drawbacks of one-way street networks relative to two-way street networks. Although the author presents a cogent argument, it is unclear where exactly he draws his conclusions from – no data is presented when citing "our experience."

As stated previously, one of the inherent disadvantages with one-way streets is that they force additional turning movements at the intersections caused by motorists who must travel "out-of-direction" to reach their destination. These additional turning movements increase the chance of a vehicular-pedestrian conflict at any given intersection, and also result in a systemwide increase in VMT over a comparable two-way system due to the amount of recirculating traffic.... Our experience shows that a one-way system usually yields approximately 120 to 160% of the turning movements when compared to a two-way system, and the travel distance between portal and destination is usually 20 to 50 percent greater in a one-way street system.

3. Meng, Lum Kit, and Soe Thu. "A microscopic simulation study of two-way street network versus one-way street network." *Journal of the Institution of Engineers, Singapore* 44 (2004): 111-122.

Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes

The authors conducted CORSIM simulations with a created network and compared one-way coordinated signal timings and two-way. They found a statistically significant difference among the following findings:

Measures of Effectiveness at the systemwide level	Two-way Results (compared to one-way)
VMT	Lower
Veh-hr of delay	Higher
Avg speed	Lower
Fuel consumption rate	Lower
Emission rate (HC, CO, NOx)	Higher
Emissions amount	Lower

The table of results shows that the emissions rate is higher in the two-way network. However, because fewer miles are driven, overall emissions are lower. The simulation was conducted using a user equilibrium (rather than a system optimal equilibrium) in which every simulation agent searches for the shortest path between a prescribed origin and destination. However, the paper does not clarify whether a path’s cost is measured in purely distance or distance plus delay time due to congestion. Therefore, it is not obvious whether the additional VMT includes route diversions due to congestion or just network circuitry.

This simulation supports the idea that one-way to two-way conversion does not substantially increase VMT (and in fact, may decrease it).

4. Cervero, Robert; Junhee Kang & Kevin Shively (2009) "From elevated freeways to surface boulevards: neighborhood and housing price impacts in San Francisco." *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, 2:1, 31-50, <http://dx.doi.org/10.1080/17549170902833899>

Reduction in Number of Through Lanes

The paper details the conversion of the Central Freeway in San Francisco to an arterial street (Octavia Boulevard), contrasting doomsday predictions of perpetual gridlock with what is instead described as a relatively smooth transition.

A study conducted shortly after the Central Freeway's 1996 closure revealed that in the short term, most drivers redistributed onto parallel routes. One year after the closure, surveys mailed to 8,000 drivers formerly identified driving the freeway revealed:

- 76% used another freeway
- 11% used city streets entirely
- 3% used a combination of freeways and transit
- 3% no longer made the trip that used the freeway.
- 2% switched to transit
- 2% used freeways and surface streets instead
- 1% used freeways still, and took fewer trips.

The paper concludes with the idea of "triple divergence," to explain how travel behavior reacts to the reduction of vehicular capacity:

"The survey also found that 19.8% of survey respondents stated they made fewer trips since the freeway closure. Most were discretionary trips, such as for recreation. Also, average one-way trip length increased by 7.7% (from 21.2 to 22.8 miles). . . . This might be thought of as 'triple divergence,' the obverse of Downs's 'triple convergence' explanation as to why freeways remain congested when new capacity is added. Just as adding capacity prompts traffic to redistribute itself to maintain similar levels of service, withdrawing capacity likely unleashes a similar response – motorists shift routes, modes, and times of travel to maintain a homeostasis."

Although the average one-way trip length increased by 7.7%, that increase was swamped by the 19.8% of people who made fewer trips (given that the average trip length was 21.8 miles). Therefore, these findings and Cervero's theory of triple divergence substantiate the idea of no significant increase in VMT with the reduction of vehicular capacity.

5. Duranton, Gilles, and Matthew A. Turner. *"The fundamental law of road congestion: Evidence from US cities."* *The American Economic Review* 101.6 (2011): 2616-2652.
<http://www.nber.org/papers/w15376.pdf>

Creation of new or expansion of existing transit service

The authors hypothesize that the addition of public transit service miles, to the extent that it attracts drivers to ride transit instead, will only free up extra lane miles for traffic congestion to revert to equilibrium levels – a corollary to the well-known "fundamental law of traffic congestion" (which offers the same hypothesis for lane-miles rather than transit service miles).

Conducting ordinary least squares (OLS) regressions using number of buses and lane kilometers of service at the metropolitan statistical area (MSA) scale, the authors found inconsistent and mostly statistically insignificant estimates for the coefficient of "number of large buses." In other words, an increased public transit supply (as measured by the count of large buses at the MSA level) was not associated with a reduction or increase in vehicle-kilometers traveled (VKT).

This research supports the idea that an increased the supply of public transit does not contribute to a significant increase in VMT.

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6. Weinberger, Rachel. "Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive." *Transport Policy* 20 (2012), doi:10.1016/j.tranpol.2011.08.002

Removal of off- or on-street parking spaces

The author created a data set monitoring home parking provision in three New York City boroughs, combining a tax lot database and aerial images to estimate the presence of off-street parking in a number of census tracts. They used that data to estimate a regression model explaining the percentage of commuters who drive to work in a census tract as a function of the tract's built environment characteristics, socioeconomic and demographic characteristics, and an on-site parking per dwelling unit rate.

They describe their results thusly:

"The research shows a clear relationship between guaranteed parking at home and the greater propensity to use the automobile for journey to work trips even between origin and destinations pairs that are reasonably well and very well served by transit. Because journey to work trips to the downtown are typically well served by transit, we infer from this finding that trips for other purposes from these areas of higher on-site, off-street parking are also made disproportionately by car."

These findings support the conclusion that the provision of off-street parking spaces is associated with additional VMT, implying that the removal of them would not be associated with such.

7. Gayah, Vikash V. "Two-way street networks: More efficient than previously thought?." *ACCESS Magazine* 1.41 (2012).

Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes

The author explains that in a downtown, a one-way street network may have higher vehicle-moving capacity (i.e., the ability to move more cars through a point or series of points) than a two-way street network. However, the one-way network will have a lower trip-serving capacity, because trips through and within the network are more circuitous: "Thus, the use of one-way street networks increases the average driving distance between any paired origin-destination points and will result in more vehicle miles traveled (VMT). Increased VMT means increased fuel consumption, emissions, and exposure to accidents."

The author does explain that in a larger downtown or network, the difference in trip lengths between one-way and two-way networks approaches a negligible amount. Even so, the two-way network is always associated with lower VMT.

The paper is a thought experiment, with supporting evidence like what is shown in Figure 3 below. This research supports the idea that converting a street (or couplet, or network of streets) from one-way to two-way would lower VMT.

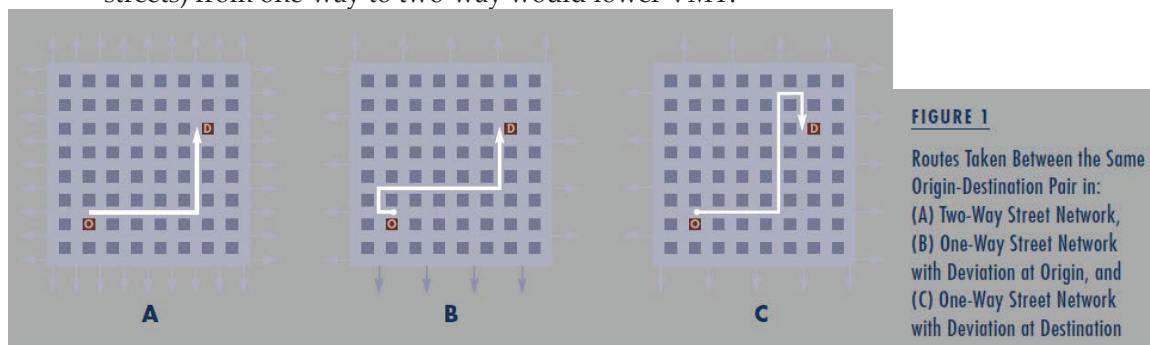


Figure 1: Illustration of the additional circuitry of a one-way network compared to a two-way network

8. Salon, D., Boarnet, M. G., Handy, S., Spears, S., & Tal, G. (2012). *How do local actions affect VMT? A critical review of the empirical evidence. Transportation Research Part D: Transport and Environment, 17(7), 495-508.* DOI: 10.1016/j.trd.2012.05.006

This paper provides an assessment of existing research concerning land use, policy, and programmatic decisions that “local-level policymakers can take . . . that are likely to affect vehicle miles traveled.” The paper covers research on many topics, pointing out what appears to be known about the effect on VMT and also discussing gaps in the research. Pertinent topics are listed below.

Infrastructure projects, including safety and accessibility improvements, for people walking or bicycling

The authors list the results of various studies on bicycle infrastructure and surrogate measures of such:

Study Authors	Measure Studied	Estimate
Dill and Carr (2003)	Elasticity of bicycle commute mode share with respect to bike lane density <i>or</i> per capita bicycle spending	0.32
Parsons Brinckerhoff (1993)	Elasticity of VMT with respect to with respect to a measure of pedestrian quality	-0.19
Kitamura et al (1997)	Number of vehicle trips (person level) given the presence of sidewalks in a neighborhood	-0.14%
Guo and Gandavarapu (2010)	VMT with respect to sidewalk presence	-0.645 VMT per mile of roadway with sidewalks within 1 mile of a person’s home

The authors note that a link between increased bicycling and reductions in VMT does not appear to have been established in the literature, in part because bicycle trips are relatively short (i.e., they compete with walking trips rather than driving) and the effects of infrastructure closely concentrated (sub-regional, and perhaps sub-city level).

The authors conclude with the following assessment of the state of research into these two areas:

Estimates of the effect on VMT of both pricing strategies and strategies that make alternatives to the auto more attractive (transit and non-motorized transport) are generally lacking. In our estimation, these areas represent the largest gap in the literature.

However, the survey of research finds evidence that sidewalk presence, bicycle infrastructure, and a positive pedestrian quality are associated with lower VMT and therefore may reduce VMT.

Creation of new or expansion of existing transit service

The authors convey findings that show positive elasticities for transit ridership, but no studied effect on VMT:

- 0.5 ridership elasticity with respect to increased service frequency;
- 0.7 ridership elasticity with respect to increases in service miles or hours; and
- -0.4 ridership elasticity with respect to fare increases.

Regarding the missing link to VMT effects, the authors explain: “We expect that as transit ridership increases, VMT will decrease, but the effect is likely to be less than one-to-one, both because new transit trips do not always replace car trips and because of latent demand for road space.”

Adoption of or increase in tolls

These research findings are based on a per-mile toll, or a VMT charge:

- “Deakin et al (1996) reported a simulated price elasticity of VMT of between -0.2 and -0.25 based on models of the San Francisco and Los Angeles metropolitan areas.”
- “Rodier (2002) found that a simulated 5 cent per mile VMT charge in the Sacramento area would result in a 10% VMT reduction.”
- “Safirova (2007) found that a simulated 10 cent per mile VMT charge in the Washington DC area would result in a 14.5% drop in VMT.”
- “The Oregon pilot program yielded similar-sized VMT reductions from an experimental distance charging scheme that replaced gas tax and therefore was designed to be revenue neutral (Rufolo and Kimpel, 2008).”

The authors highlight that even in the revenue-neutral scheme discussed above, designed not to change the average cost of driving, drivers showed responsiveness to being tolled on a per-mile basis. These findings support the idea that adopting or increasing tolls reduces VMT.

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9. Van Ness BRT Final EIS/EIR (Chapter 3). <http://www.sfcta.org/van-ness-avenue-bus-rapid-transit-planning-and-environmental-studies#DOW>. Accessed 6/27/2016.

Reduction in number of through lanes

Creation of new or expansion of existing transit service

Creation of new or conversion of existing general purpose lanes (including vehicle ramps) to transit lanes

Air Quality analysis displayed that each of the alternatives would result in a net decrease in Citywide VMT. Terry A. Hayes Associates Inc., Air Quality Technical Report and Addendum, 2013.

10. Wang, Jinghui, Lei Yu, and Fengxiang Qiao. "Micro Traffic Simulation Approach to the Evaluation of Vehicle Emissions on One-way vs. Two-way Streets: A Case Study in Houston Downtown." 92nd annual meeting of the Transportation Research Board in Washington DC. 2013.

Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes

The authors used the street network and real traffic volumes for downtown Houston, Texas, but created an entirely one-way street network and an accompanying two-way street network. They conducted simulations in VISSIM and reported the simulation outputs, for both peak and off-peak travel conditions.

Per-mile emissions in the two-way network were higher across the board, but the reduction in VMT relative to the one-way network generally overwhelms that difference such that overall emissions are lower for the two-way network (with the sole exception of peak condition HC emissions). However, the difference in per mile emissions factors is exacerbated in peak hour conditions (owing to more friction and delay in the two-way network). As such, peak condition emissions for the two-way versus one-way network are much closer.

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11. Kattan, Lina, Alexandre G. de Barros, and Hina Saleemi. "Travel behavior changes and responses to advanced traveler information in prolonged and large-scale network disruptions: A case study of west LRT line construction in the city of Calgary." *Transportation Research Part F: Traffic Psychology and Behaviour* 21 (2013): 90-102. <http://www.sciencedirect.com/science/article/pii/S1369847813000697>

Reduction in Number of Through Lanes

Construction of a light rail transit line in Calgary, Alberta, Canada reduced capacity along an 8.2 kilometer corridor for three years. As a preemptive mitigation measure, the City of Calgary implemented a temporary bus rapid transit (BRT) service along an alignment similar to the future light rail line and also provided up-to-date disruption information through internet, radio, and message display signs. As construction progressed, the capacity interruptions varied. The authors conducted surveys of users of the main road affected by the construction of the West Light Rail Transit (LRT) line in Calgary, Alberta, Canada. Among the findings:

- "Despite the significant increase in self-reported travel time, the total demand for travel in the area did not seem to decrease or result in rescheduled trip departure times. In response to pre-trip information disseminating road closure information, only 1.5% of trips were reported to be cancelled or have rescheduled departure times."
- "A substantial shift towards public transport was reported as a result of pre-trip information. This reported shift towards transit can be attributed to the presence of both incentives for taking transit (i.e., the added high-frequency transit service and the presence of pre-trip information for transit) and disincentives for driving (i.e., the road capacity reduction resulting from road/lane closures)." Note here that the authors are referring to the temporary BRT service implemented along the corridor.
- "...there was a decrease in the percentage of respondents who reported private vehicles as their first choice and an increase in the percentage of respondents who preferred public transit as their first and second choices."

Although this paper does not explicitly mention VMT, it seems that this disruption in the network did not contribute substantial additional VMT. This conclusion can be drawn from two points:

- "The characteristics of the grid network that consists of urban arterials and major collectors giving several alternative route choices to travelers," i.e, diversions were short and plentiful rather than circuitous; and
- The reported mode shifting behavior during the disruption among respondents, with many switching from driving to transit.

The authors did not observe travel behavior once the light rail transit line opened.

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12. McCahill, Chris, et al. "Effects of Parking Provision on Automobile Use in Cities: Inferring Causality." (2015).

This study used longitudinal citywide parking supply data from seven US cities from three decades: the 1950s, the 1980s, and the 2000s. In short, they find that “an increase in parking provision from 0.1 to 0.5 parking spaces per resident and employee is associated with an increase in commuter automobile mode share of roughly 30 percentage points . . . **we infer that parking provision in cities is a likely cause of increased driving among residents and employees.**” (bold emphasis added).

13. Chatman, Daniel G. "Does Transit-Oriented Development Need the Transit?." ACCESS Magazine 1.47 (2015).

Removal of off- or on-street parking spaces

The author conducted a mail survey of households within two miles of rail stations in New Jersey. The households and neighborhoods varied in design, age, distance to rail, and on- and off-street parking supply (which was collected through observation). The data was regressed thrice, with different dependent variables in each case:

- 1) **Auto ownership.** When proximity to rail is controlled for with the other factors listed above, its effect was not a significant predictor of auto ownership. Instead, “When the effects of more bus stops and low on- and off-street parking availability were combined, they reduce auto ownership by 44 percent. Most of this effect is due to parking availability.”
- 2) **Commuting to work.** “Scarce off-street parking (having less than one parking space per adult in the household) was associated with a 40 percent reduction in auto commuting . . . ”
- 3) **Grocery store visits.** Scarce on- and off-street parking was associated with a 25 percent reduction in grocery store trips made by driving. The two parking types were not significant independently, as the author explains: “This makes sense, because carrying groceries is inconvenient on foot or via transit, so only significant impediments to auto ownership and use are likely to make a difference.”

Although the study uses cross-sectional data and thus cannot make causal claims in a before-and-after manner, the author concludes with the following two conclusions (among others):

- “What does reduce car ownership and use? **Lower parking availability**, better bus service, smaller housing units, more rental housing, more destinations within walking distance, better proximity to downtown, and higher population and employment density all reduce car ownership and use.” (emphasis added)
- “At the very least, [transit-oriented developments] should be developed with less parking. If they are not, they will not reduce auto use.”

This paper supports the conclusion that the removal of off- and/or on-street parking will reduce VMT.

14. San Francisco County Transportation Authority. Geary Corridor Bus Rapid Transit Project Draft EIS/EIR, Section 4.10 Air Quality and Greenhouse Gases, 2015.
<http://www.sfcta.org/sites/default/files/content/Planning/GearyCorridorBusRapidTransit/DraftEIR/Geary%20Corridor%20Bus%20Rapid%20Transit%20Project%20Draft%20EIS%20EI%20R.pdf>

Creation of new or expansion of existing transit service

Creation of new or conversion of existing general purpose lanes (including vehicle ramps) to transit lanes

Air Quality analysis displayed that each of the alternatives (all of which include bus rapid transit on Geary Blvd.) would result in a net decrease of <1%, or a negligible change, in Regional VMT. Model outputs for VMT are shown in Figure 1 and Figure 2 (split out by travel mode in the latter). This study supports the idea that implementation of bus rapid transit system with dedicated lanes does not contribute to an increase in VMT.

SCENARIO	REGIONAL VEHICLE MILES TRAVELED (VMT)	AVERAGE SPEED (MILES PER HOUR)
EXISTING CONDITIONS		
2020 No Build Alternative	9,220,000	21
2020 Alternative 2	9,210,000	21
2020 Alternative 3	9,200,000	21
2020 Alternative 3-Consolidated	9,190,000	21
Hybrid Alternative	9,200,000	21
FUTURE YEAR BUILDOUT		
2035 No Build Alternative	11,160,000	17
2035 Alternative 2	11,140,000	17
2035 Alternative 3	11,130,000	17
2035 Alternative 3-Consolidated	11,120,000	17
Hybrid Alternative	11,120,000	17

Source: SFCTA, March 2014

Figure 2: Travel Model output displaying regional VMT levels associated with the proposed Geary Corridor Bus Rapid Transit System

	2020 ANNUAL VMT (MILLIONS)			REGIONAL ENERGY EQUIVALENT IN MILLION MBTUS	INCREASE/DECREASE RELATIVE TO NO BUILD	% CHANGE FROM NO BUILD
	AUTO	BUS	TOTAL			
No Build Alternative	3,186	1.9	3,188	9,291	-	-
Alternative 2 (Side-Lane BRT)	3,184	2.6	3,186	9,298	+7	+0.1%
Alternative 3 (Center-Lane BRT with Dual Medians and Passing Lanes)	3,180	2.6	3,183	9,288	-3	-<0.1%
Alternative 3-Consolidated (Center-Lane with Dual Medians and Passing Lanes)	3,178	2.5	3,180	9,280	-11	-0.1%
Hybrid Alternative	3,181	2.5	3,183	9,289	-3	-<0.1%
	2035 ANNUAL VMT (MILLIONS)			ENERGY EQUIVALENT IN MILLION MBTUS	INCREASE/DECREASE RELATIVE TO NO BUILD	% CHANGE FROM NO BUILD
	AUTO	BUS	TOTAL			
No Build Alternative	3,857	1.9	3,859	8,998	-	-
Alternative 2	3,850	2.6	3,853	8,998	+0	+<0.01%
Alternative 3	3,848	2.6	3,851	8,993	-5	-0.1%
Alternative 3-Consolidated)	3,843	2.5	3,845	8,979	-19	-0.2%
Hybrid Alternative	3,842	2.5	3,845	8,979	-19	-0.2%

Source: Terry A. Hayes Associates Inc., 2014

Figure 3: Travel model output displaying regional VMT levels associated with the proposed Geary Corridor Bus Rapid Transit System (broken out by travel mode)

- San Jose, California: Lincoln Avenue Road Diet Trial Data Collection Report. 6/1/2015. <https://sanjoseca.gov/DocumentCenter/View/44259> . Accessed 6/27/2016.

This is a study conducted for a road diet along Lincoln Avenue in San Jose, California. The project involved the conversion of four travel lanes (two in each direction) to three (one in each direction, with a two-way left turn lane). At the time the road diet was a temporary pilot project, and this study was conducted to inform decision makers whether to make the project permanent.

Reduction in number of through lanes

Infrastructure projects, including safety and accessibility improvements, for people walking or bicycling

The report indicates that traffic volumes were 3 to 13% lower throughout the corridor after project implementation. Neighboring local streets experienced relatively negligible changes (up or down by approximately 50 vehicles, variations that are “within expected daily variations for local streets”). Eight other streets saw meaningful decreases of traffic. These data were collected and averaged over three days (Tuesday, Wednesday, Thursday) of the same week.

The preliminary findings of this report indicate that this road diet project likely reduced VMT.

16. Road Diet Case Studies. Federal Highway Administration.

https://safety.fhwa.dot.gov/road_diets/. Modified July 2016. Accessed 6/28/2016.

Reduction in number of through lanes

Infrastructure projects, including safety and accessibility improvements, for people walking or bicycling

The FHWA case study document details several road diet projects and lists outcomes of the projects without much detail. Some highlights are below.

Grand Rapids, Michigan Division Street Road Diet: Grand Rapids Michigan reported increased emissions as a result of road diet project (+19.8% AM, +1.1% off-peak, and -5.3% PM).

Los Angeles Seventh Street Road Diet: “After the completion of the Seventh Street Road Diet, LADOT received positive feedback from users, and a before-and-after bicycle count conducted by the Los Angeles County Bicycle Coalition showed that bicycle use in the corridor tripled once the Road Diet and new bicycle lanes were completed. LADOT also conducted some traffic analyses at several key intersections along the corridor and found that the results were satisfactory.” It’s unclear (and not explained) if these are **new** bicycle trips—genuine mode shift—or if they are diversions by cyclists to use the new facility. Either way, these results indicate that in response to the project, VMT likely remained the same or decreased (rather than increasing).

Reston, Virginia (Lawyers Road): “47 percent of respondents bicycled on Lawyers Road more often than before, indicating that the Road Diet encourages bicycling as a travel mode.” The same logic may be applied here from the Los Angeles Seventh Street Road Diet results regarding a significant increase in VMT.

These case studies do not explicitly address VMT changes, but the evidence provided (with the exception of the Grand Rapids case) indicates that VMT likely did not increase.

2. Parking access, land use context, density, and VMT

The amount of available parking, land use context, and travel mode choice are intricately linked. The research presented below supports the conclusion that more off-street vehicular parking is linked to more driving and that people without dedicated parking spaces are less likely to drive. One article indicates that an area with more available parking in residential areas influences a higher demand for more automobile use. Another study found a direct relationship between the availability of free on-street parking supply and the number of cars per household. The remaining research examines techniques and results of attempting to reduce vehicle miles traveled through transit access, reduced parking availability, and shifting locational context (dense vs. suburban).

1. Weinberger, Rachel. "Death by a thousand curb-cuts: Evidence on the effect of minimum parking requirements on the choice to drive." *Transport Policy* 20 (2012), doi:10.1016/j.tranpol.2011.08.002

Weinberger examines the relationship between the availability of residential parking in three New York boroughs and residents' choices to drive their personal vehicles to work in the Manhattan Core. First, the author estimated the amount of parking per dwelling unit for Census tracts in Queens, the Bronx, and Brooklyn; the amount of residential parking per unit was regressed against 'Journey to Work' mode split data, as reported in the Census, using a generalized linear model with a logit link function. The regression was used to explain the factors that increase or decrease the percentage of people driving to transit accessible work destinations.

The author concludes that Census tracts with higher levels of on-site parking have higher levels of drive mode share to the transit rich Manhattan Core. Thus, guaranteed parking at home is a contributing factor to a worker's decision to drive to work. From this the author infers that driving to other activities is also likely to be higher.

2. California Air Pollution Control Officers Association (CAPCOA), *Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emissions Reductions from Greenhouse Gas Mitigation Measures*, August 2010.

This report focuses on quantifying various strategies for greenhouse gas (GHG) reduction. Below are summaries of policies related to land use context, density, and parking access, with the range of effectiveness equaling both the reduction in the VMT as well as the reduction in GHG emissions.

Land Use / Location 1 – Increase Density – Range of effectiveness: 0.8– 30%

The range of effectiveness is derived from looking at the effects of increasing density in urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects. The Transportation Research Board Special Report 298 literature suggests that doubling neighborhood density across a metropolitan area might lower household VMT by about 5

to 12 percent, and perhaps by as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measure.

Land Use / Location 2 – Increase location efficiency to reduce VMT – Range of effectiveness: 10–65%

The range of effectiveness is derived from looking at the effects of increasing location efficiency in urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects.

Land Use / Location 3 – Increase density of urban and suburban developments (mixed use) – Range of effectiveness: 9–30%

The range of effectiveness is derived from looking at the effects of increasing density of urban and suburban developments. The effectiveness in rural contexts was negligible unless the project is a master-planned community. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects. Project would need to provide the percentage of each land use type in the project to calculate a land use index.

Land Use / Location 4 – Increase destination accessibility – Range of effectiveness: 6.7–20%

The range of effectiveness is derived from looking at the effects of increasing destination accessibility in the urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects.

Land Use / Location 5 – Increase transit accessibility – Range of effectiveness: 0.5–24.6%

The range of effectiveness is derived from looking at the effects of increasing transit accessibility in the urban and suburban contexts. The effectiveness in rural contexts was appropriate if development site is adjacent to commuter rail station with convenient rail service to a major employment center. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects. Project would need to provide the distance to transit station.

Parking Policy / Pricing 1 - Limit Parking Supply – Range of effectiveness: 5 – 12.5%

The range of effectiveness is derived from looking at the effects of limiting parking supply in urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects. The reduction in VMT can only be counted if spillover parking is controlled via residential permits and on-street metering.

Parking Policy / Pricing 2 - Unbundle parking costs from property cost – Range of effectiveness: 2.6 - 13%

The range of effectiveness is derived from looking at the effects of limiting parking supply in urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects. A complimentary strategy is Workplace Parking Pricing. Though not required, implement workplace parking pricing ensures the market signal from unbundling parking is transferred to the employee.

Parking Policy / Pricing 3 - Implement Market Price Public Parking (on-street) – range of effectiveness: 2.8 – 5.5%

The range of effectiveness is derived from looking at the effects of limiting parking supply in urban and suburban contexts. The effectiveness in rural contexts was negligible. The strategy is appropriate for retail, office, and mixed-use projects. The strategy is only applicable in an area or general plan context, usually in downtown areas, and reductions can only be counted if spillover parking is controlled via residential permits in surrounding neighborhoods.

Parking Policy / Pricing 4 - Require Residential Area Parking Permits – range of effectiveness: Grouped strategy, see 1-3.

The range of effectiveness is derived from looking at the effects of limiting parking supply in urban context. The strategy is appropriate for residential, retail, office, industrial, and mixed-use projects.

3. Guo Zhan, Residential Street Parking and Car Ownership. *Journal of the American Planning Association*, 79:1, 32-48, May 9 2013.

Zhan reviews the oversupply of on-street parking and resident travel and parking behavior. Using various aerial and street-level publicly available online mapping programs, the author identified off-street parking supply and on-street parking supply and crowding.

The author found that residential proximity to a train station was associated with a reduction in car ownership at the levels of one or two cars, but not for households with three or more cars. Furthermore, excess off-street parking encourages a higher level of car ownership: the relationship between increased availability of on-street parking (less crowded street parking) and increased car ownership is statistically significant (even when off-street parking is available).

On-street parking increases total parking supply for a household, thus households are able to buy more cars than just the off-street parking would allow. Finally, having on-

street parking readily available in front of one's residence may provide some advantages that off-street parking is unable to offer: households use their garages as an extension of their home square footage, for storage or other non-vehicle storage purposes, and use the on-street parking for their vehicle as an additional amenity.

4. Daniel Chatman, Does Transit-Oriented Development Need the Transit?, *Access*, Fall 2015.

Chatman questions whether the transit oriented development (TOD) necessarily requires transit (defined as rail), or whether other variables (such as dense urban form or residential choice) account for lower car ownership. The author conducted a household survey within two mile radius of ten rail stations in New Jersey. Households with less than one off-street parking space per adult had 0.16 fewer vehicles per adults. Households with both low on- and off-street parking availability had 0.29 fewer vehicles per adult. The other significant variable was the number of bus stops within a mile of the home (doubling the number of bus stops within a mile radius around the average home was associated with 0.08 fewer vehicles per adult). When the effects of more bus stops and low on- and off-street parking availability were combined, they reduce auto ownership by 44 percent.

If access to rail is not a primary factor in reducing auto use, it could be a blessing, not only because rail infrastructure is expensive, but also because the amount of available land near rail stations is limited. That said, allowing higher housing density and scarce on- and off-street parking everywhere could increase congestion if not carefully managed (Chatman, p. 21).

5. Chris McCahill, et al., Effects of Parking Provision on Automobile Use in Cities: Inferring Causality, *Transportation Research Board*, November 13, 2015.

McCahill examines whether a causal relationship between parking and driving exists, asking: does the provision of parking over time influence driving to work or are minimum parking requirements an appropriate response to rising auto use for workers? Using Census 'Journey to Work' mode split data and aerial photos of nine cities from 1960 to 2000, McCahill applied the Bradford Hill general theory of causality (a method from the field of epidemiology) to assess changes in parking availability and mode choice over time.

At the city scale, the authors found that an increase in parking provision from 0.1 to 0.5 parking spaces per resident and employee is associated with an increase in commuter automobile mode share of roughly 30 percentage points. The authors conclude that the findings suggest that policies to restrict and reduce parking capacity in cities are warranted.

6. Fehr and Peers, Parking Analysis and Methodology Memo to San Francisco Planning – Final, April 2015.

The relationship between parking availability or automobile orientation and auto mode share was examined for three different land use types in San Francisco: residential, retail, and office. Fehr and Peers utilized survey data collected at three land use types to develop the linear regression statistical model.

- The researchers found that the AM residential model predicts the absence of parking to be associated with a 60% reduction in auto mode share; and the PM residential predicts the absence of parking to be associated with a 50% reduction in auto mode share.
- For office use at a site with moderate auto orientation, the absence of free or subsidized parking is associated with a 65% reduction in auto mode share.
- For the retail use, the AM morning model predicts that for a site with moderate auto orientation, the absence of parking is associated with 12% reduction in auto mode share; the PM evening retail model predicts that for a site with moderate auto orientation, the absence of parking is associated with a 25% reduction in auto mode share.

Guidance on Quantitative Analysis for Transportation Projects

The following methodology is based on OPR's Technical Advisory and provides an estimate of VMT effects of lane mile additions can be used to estimate the VMT effects of proposed roadway expansions (or other capacity increasing transportation projects)

Projects should first analyze the percent change in lane miles is calculated by dividing project lane miles by the total lane miles of the applicable functional classes to yield a percent change in lane miles (in %). This percentage is multiplied by the baseline VMT on those facilities and elasticity from the academic studies (typically 1.0) to yield the total induced travel.

Formula:

$$\text{Elasticity} = [\% \text{ change in VMT}] / [\% \text{ change in lane-miles}]$$

or

$$\text{VMT Impact} = [\% \text{ change in lane-miles}] * [\text{baseline VMT on those lane-miles}] * [\text{elasticity}]$$

Planning Code Compliance Checklist

Below is a planning code compliance checklist template as it relates to all transportation topics. In addition to the project’s transportation demand management program application, land use table, and worksheet, please fill out and include as an appendix to the transportation study.

Project Description: [Briefly describe the proposed project]

Use District: [Include the use district(s)]

Topic	Planning Code Reference	Planning Code Requirement	Proposed Project	Existing Conditions
Parking Pricing Requirements	§ 155(g) Required	[Add applicable information]	[Add applicable information]	n/a
Bicycle Parking	§ 155.2 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Shower Facilities and Lockers	§ 155.4 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Transportation Management Programs and Transportation Brokerage Services	§ 163 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Child-Care Plans and Child Care Brokerage Services	§ 165	[Add applicable information]	[Add applicable information]	n/a
Car Sharing	§ 166 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Parking Costs Separated from Housing Costs in New Residential Buildings	§ 167 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Transportation Demand Management Program (provide the TDM application as an appendix)	§ 169 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Institutional Master Plans (transportation strategies)	§ 304.5 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]
Housing Requirements for Residential and Live/Work Development Projects (affordable housing)	§ 415 Required	[Add applicable information]	[Add applicable information]	[Add applicable information]

n/a = not applicable

Transportation Demand Management Measures

The following are a list of Transportation Demand Management measures identified by the Planning Department that can be used by projects to meet their Transportation Demand Management target. More information can be found at <http://sf-planning.org/transportation-demand-management-program>.

- Provide streetscape improvements to encourage walking (ACTIVE-1)
- Provide secure bicycle parking, more spaces given more points (ACTIVE-2)
- Provide on-site showers and lockers (ACTIVE-3)
- Provide a bike share membership to residents and employees for one point, another point given for each project within the bike share network (ACTIVE-4)
- Provide on-site bicycle repair station (ACTIVE-5A)
- Provide on-site bicycle maintenance services (ACTIVE-5B)
- Provide fleet of bicycles (ACTIVE-6)
- Provide bicycle valet parking (ACTIVE-7)
- Offer car-share parking and membership (CSHARE-1)
- Provide delivery supportive amenities (DELIVERY-1)
- Provide delivery services (DELIVERY-2)
- Offer family TDM amenities (FAMILY-1)
- Provide on-site childcare (FAMILY-2)
- Provide Family TDM package (FAMILY-3)
- Provide contributions or incentives for sustainable transportation (HOV-1)
- Provide shuttle bus service (HOV-2)
- Offer vanpool programs (HOV-3)
- Provide multimodal wayfinding signage (INFO-1)
- Provide real time transportation information display (INFO-2)
- Provide tailored transportation marketing services (INFO-3)
- Provide healthy food retail in underserved area (LU-1)
- Provide on-site affordable housing (LU-2)
- Offer unbundled parking (PKG-1)
- Offer short term daily parking provision (PKG-2)
- Offer parking cash out: non-residential tenants (PKG-3)
- Reduce parking supply (PKG-4)