Methodologies to Convert Other Modes of Travel to Vehicle Miles Traveled (VMT)

Requested by
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Executive Summary

Background

California Assembly Bill 32 (AB 32) established a cap-and-trade program in California to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020. Since GHG emissions and vehicle miles traveled (VMT) are directly related, Caltrans can help further the goals of AB 32 by measuring and reducing GHG emissions and VMT. In general, methodologies are accessible for measuring the impact of shifting vehicle trips to other modes of travel (such as light rail, heavy rail, commuter rail, bicycle and walking). But methods that measure the impact of mode shift from vehicle trips to local bus use are not readily available. Caltrans' Division of Mass Transportation is interested in measuring ridership changes by bus route while considering a range of variables, such as demographics and population density.

To assist Caltrans in identifying methods to quantify mode shift from vehicles to local buses, CTC & Associates reviewed research and guidance related to transit-oriented development (TOD) and smart mobility place types such as urban centers, compact communities and rural lands. To supplement this research, CTC contacted experts in the field for help in identifying measurement efforts underway nationally that were not readily available in the published literature.

Summary of Findings

We gathered information about measuring the impact of mode shift from vehicle trips to local bus use by interviewing representatives from the transportation community and conducting a literature search.

Consultation with Experts

To better understand the impact of changes in transit ridership and the variables related to these changes, we spoke with experts who were experienced in transit and travel demand forecasting:

- Steven Polzin, director of Mobility Policy Research at the Center for Urban Transportation Research, University of South Florida, said the presence or absence of transit is unlikely to significantly influence VMT because riders' alternatives would be to bike, walk, ride with someone else or forgo the trip. He recommended conducting a sensitivity analysis that looked at various transit variables (including density and changes in income levels) to understand current ridership and the demands for a bus route. Once the change in bus ridership is determined, Polzin suggested measuring the mode shift from vehicle to bus and the resultant impact to VMT.
- Jarrett Walker, author of the blog and book *Human Transit,* suggested investigating the variables related to transhistoric human needs (the need to get to places quickly), knowing that it is challenging to calibrate human preferences based on past behavior in past situations because human preferences and situations change.
- Bill Holloway, transportation policy analyst with the State Smart Transportation Initiative at the University of Wisconsin–Madison, suggested looking at changes in level of service or traffic counts on roads with new bus routes.

Related Research and Resources

We examined reports and guidance that address changes to transit ridership as well as methodologies for calculating reductions in VMT and GHG emissions. These resources are organized according to types of variables: social-demographic or transit service.

The most significant finding in our review of national research is Transit Cooperative Research Program (TCRP) Report 95, *Traveler Response to Transportation System Changes Handbook*, which addresses mode shift and its impact on VMT and the environment.

- Chapter 9, Transit Scheduling and Frequency, provides information about traveler response and related impacts associated with scheduling changes in bus and rail service.
- Chapter 10, Bus Routing and Coverage, addresses rider response and related impacts to changes in bus routes, bus system expansion and fare changes.
- Chapter 12, Transit Pricing and Fares, researchers concluded that transit fare changes had a negligible impact on VMT. However, when fare changes are combined with other strategies, particularly in congested areas with reliable transit service, the effect on traffic and the environment is more relevant.
- Chapter 14, Road Value Pricing, includes a discussion of traveler response factors, including selection of route, mode and time of day of travel, destination, auto ownership and land use patterns.
- Chapter 17, Transit Oriented Development, provides numerous case studies that present the results of mode shifts away from auto travel to transit.

In addition, a 2015 TCRP report finds that incremental improvements to transit service have measurable land use effects that can be quantified by increases in population density and resultant reductions in VMT, fuel use and GHG emissions. A 2009 American Public Transportation Association report offers a methodology that allows transit agencies to quantify and report emissions in a transparent, consistent and cost-effective manner.

Several state resources also provide guidance and methodologies for calculating the reduction in VMT. A 2015 University of California–Davis report analyzed travel survey data to quantify the effect on Californians' driving behavior in response to changes in land use and transport system variables. A 1995 report sponsored by Caltrans and the California Air Resources Board provides methodologies and emission factor tables specific to California to determine emission benefits related to Congestion Mitigation and Air Quality Program projects.

Tools

This section of the report includes tools and calculators for determining reductions in VMT and emissions. Among these resources are the VMT Spreadsheet Tool, which provides VMT estimates for built environment and travel scenarios in California; the Land Use Benefit Calculator, which measures the impact of transit service on compact development, energy use and air quality; and the Guidebook Emissions Calculator, an Excel-based resource that estimates GHG and other emissions based on transportation demand management policies and vehicle technologies.

However, there are limitations to the methodologies provided in this section, including:

- Models that do not consider latent demand on the roadways replacing the mode shift to bus use.

- Studies that refer to mode shift from vehicles to transit in which bus systems are not the only transit mode considered. Even then, much of the bus-focused transit research gives more consideration to bus rapid transit systems.

Several studies also reference the relatively small impact that investing in bus systems has on VMT reduction, in part because:

- A large proportion of transit dependents are using bus services. This group of riders does not have a choice in mode of travel, such as a car. Thus, if a transportation agency adds new service or improves the frequency of existing service, a significant drop in VMT is unlikely.
- Transit investments typically aim to serve commute trips. But commuting accounts for only 27 percent of total VMT. Noncommute trips are much less likely than commute trips to use transit. Thus, increased transit investment and commute ridership could displace, at best, only a fraction of total VMT.

Gaps in Findings

- Guidance is unavailable for determining the potential latent demand that replaces the reduction in VMT due to a mode shift to bus use.
- References to state- or transit authority-sponsored research or projects in progress were unavailable.

Next Steps

Moving forward, Caltrans may wish to consider:

- Reviewing the tools provided in this report to determine their usability in California-based scenarios.
- Contacting one of the Federal Transit Administration's New Starts and Small Starts sponsors because they are required to do rigorous alternatives analysis before they receive funding. This evaluation is based on criteria and measures that are carefully defined, including measures for mode shift and impact on VMT. Contacting a Small Starts project is particularly recommended since these projects are more likely to address improvements related to bus systems.

Detailed Findings

Consultation with Experts

To gather information about the impact of mode shift to local bus use, specifically, considering a range of variables that influence ridership, CTC consulted with experts in transit and travel demand forecasting. These conversations are summarized below. All of these experts agreed that while information is available to quantify general mode shift to transit service, it is much more difficult to determine mode shift specific to bus service.

Center for Urban Transportation Research

Contact: Steven Polzin, Director, Mobility Policy Research, Center for Urban Transportation Research, University of South Florida, 813-974-9849, polzin@cutr.usf.edu.

We spoke with Steven Polzin, who recommended conducting a sensitivity analysis that included various transit variables to understand current ridership and the demands for a bus route. He suggested looking at the model coefficients and determining the ridership impact associated with higher values of density, changes in income levels and other variables.

After determining the change in bus ridership, Polzin suggested measuring the mode shift from vehicle to bus and the resultant impact to VMT, which requires an understanding of the alternative behavior in the absence of using transit. Polzin estimated that in general, approximately half of bus transit riders don't have access to a household vehicle. Thus, the presence or absence of transit is unlikely to significantly influence VMT because riders' alternatives would be to bike, walk, ride with someone else or forgo the trip. But the marginal choice traveler new to bus service would likely have an impact on VMT. Polzin concluded that some share of new trips are introduced (i.e., they would not have been made in the absence of the new service); some are shifts from shared rides, walking or biking; and some are shifts from driving.

Jarrett Walker and Associates

Contact: Jarrett Walker, President, Jarrett Walker and Associates, 503-208-4249, jarrett@jarrettwalker.com.

We interviewed Jarrett Walker, author of the book *Human Transit* and blog of the same name. Walker said any travel demand modeler could investigate the variables inside of current ridership models. But it is much more helpful to separate out factors that refer to transhistoric human needs (the need to get to places quickly). He noted that this process can be complicated because trying to calibrate human preferences based on past behavior in past situations is open to challenge both because human preferences change and because the situations being used for calibration may not accurately describe those situations in the future.

State Smart Transportation Initiative

Contact: Bill Holloway, Transportation Policy Analyst, State Smart Transportation Initiative, Center on Wisconsin Strategy, University of Wisconsin–Madison, 608-265-5899, holloway@ssti.us.

We spoke with Bill Holloway, a transportation policy analyst with the State Smart Transportation Initiative, who concurred that the difficulty in obtaining accurate VMT reduction data lies in the secondary effects of the mode shift to local bus use since researchers don't know whether new riders were previously carpooling, biking, walking, driving alone or weren't making the trip. Holloway suggested looking at level of service or traffic counts on roads with new bus routes to see how that changed. But if former drivers are now riding the bus, then latent demand may take their place, and the buses on the corridor could potentially aggravate traffic congestion.

Related Research and Resources

Below we highlight reports and guidance for determining VMT reduction values, including several chapters from a TCRP handbook that addresses mode shift and its impact on VMT and the environment.

Social-Demographic Variables

National Guidance

"Survey Results," *Rising Fuel Costs: Impacts on Transit Ridership and Agency Operations*, American Public Transportation Association, September 2008.
http://www.apta.com/resources/reportsandpublications/Documents/fuel_survey_0809.pdf
This report provides insights into how significant increases in fuel costs can impact transit ridership. The results of a survey of transit operators indicate that 86 percent of respondents report an increase in ridership (ranging from 2 percent to 30 percent) with two-thirds reporting increases in both peak and off-peak hours. Of particular note is the increase in off-peak ridership.

"Chapter 14—Road Value Pricing," John Evans, Kiran Bhatt and Katherine Turnbull, *Traveler Response to Transportation System Changes Handbook*, third edition, Transit Cooperative Research Program Report 95, 2003.
http://www.trb.org/Publications/Blurbs/161219.aspx

From the overview and summary:

> The [roadway value pricing] concept involves charging higher prices for roadway use during peak travel periods. Drivers may choose not to travel or select an alternative time, route, or mode of travel if they are unwilling to pay. Drivers who pay receive the value of being able to drive, when they choose to, with reduced congestion.

Included in this chapter is a discussion of the underlying traveler response factors (page 14-26 of the report, page 37 of the PDF). In the short term, roadway pricing may affect riders' selection of route, mode and time of day of travel, choice of personal activity and destination. In the long term, it can affect auto ownership, residential and employment location, and land use patterns.

Table 14-11 on page 14-49 of the report (page 61 of the PDF and reproduced below) forecasts how congestion pricing may impact VMT, delay and emissions in four California urban regions.

Estimated Year 2010 Impacts of Road Pricing on California Urban Regions

Region	Average Fee	VMT	Trips	Delay	Fuel Consumed	ROG Emissions
San Francisco Bay Area	$.13	-2.8%	-2.7%	-27.0%	-8.3%	-6.9%
Sacramento	$.08	-1.5%	-1.4%	-16.5%	-4.8%	-3.9%
San Diego	$.09	-1.7%	-1.6%	-18.5%	-5.4%	-4.2%
South Coast	$.19	-3.3%	-3.1%	-32.0%	-9.6%	-8.1%

Average Fee = average congestion fee per mile in 1996 dollars applied to vehicle travel on congested roads. VMT = change in total vehicle mileage. Delay = change in congestion delay. Fuel Consumed = change in fuel consumption. ROG Emissions = reduction in a criterion air pollutant.

Source: G. Harvey and E. Deakin, "The STEP Analysis Package: Description and Application Examples," Appendix B, *Technical Methods for Analyzing Pricing Measures to Reduce Transportation Emissions*, U.S. Environmental Protection Agency, 1998.

"Chapter 17—Transit Oriented Development," John Evans, Richard Pratt, Andrew Stryker and J. Richard Kuzmyak, *Traveler Response to Transportation System Changes Handbook*, third edition, Transit Cooperative Research Program Report 95, 2007.
http://www.trb.org/Publications/Blurbs/159049.aspx

From the overview and summary:

> Transit oriented development (TOD) generally refers to higher-density development, with pedestrian priority, located within easy walking distance of a major public transit station or stop(s). TODs are viewed as offering the potential to boost transit ridership, increase walking activity, mitigate sprawl, accommodate growth, and create interesting places.

Included in this chapter of the handbook are numerous case studies that revealed the following results as related to mode shifts away from auto travel to transit. From page 17-93 of the report (page 104 of the PDF):

- The small number of explicitly published quantitative observations range from 2 to 16 percentage points increases in the transit mode share for the commute trip. Net reported effects on auto use for commuting range from just one side or the other of no change to a 14 percentage points decrease in auto commuting overall.

  (*Note:* References to "transit" include rail service as well. The mode shift from auto to bus was typically only about 1 percent to 2 percent.)

- [A] station-area survey and 2000 Census analysis [found] that commute shares of residents within a 0.5-mile radius around the rail stations of TODs differ from the shares of those outside. The statewide weighted average difference in transit shares compared against the surrounding 0.5 mile to 3.0 mile donut was nearly fourfold—27 percent transit inside the 0.5-mile radius and 7 percent outside.

  (*Note:* These findings also relate to rail service.)

California Resources

Improved Data and Tools for Integrated Land Use—Transportation Planning in California, Jerry Walters, Chris Breiland, Gus Jimenez and Richard Lee. University of California–Davis, Urban Land Use and Transportation Center, September 24, 2012.
http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california
From the web site's project overview:

> The primary goal of this project was to obtain and analyze available data on quantitative relationships between the built environment and travel in various parts of California, and to incorporate the results into software tools available for use in local and regional integrated land use-transportation scenario planning processes.

This web page also includes a reference to the VMT Spreadsheet Tool. (See **Tools** in this report.)

Quantifying the Effect of Local Government Actions on Vehicle Miles Traveled (VMT), Deborah Salon, University of California–Davis, February 2014.
Available at: http://www.arb.ca.gov/research/single-project.php?row_id=64861
From the abstract:

> This research uses empirical analysis of travel survey data to quantify how much Californians will change the amount that they drive in response to changes in land use and transport system variables. Our study improves upon past research in three key ways. First, we assemble and use a dataset that consists of merged information from five California-based household travel surveys that were conducted between 2000 and 2009. Second, we develop and employ a novel approach to control for residential self-selection, categorizing neighborhoods into types and using these as the alternatives in a predictive model of neighborhood type choice. Third, we focus on understanding heterogeneity in effects of variables on VMT across two important dimensions—neighborhood type and trip type.

This web page also includes a reference to the VMT Impact Tool. (See **Tools** in this report.)

Other Resources

"Longitudinal Analysis of Transit's Land Use Multiplier in Portland (OR)," Reid Ewing and Shima Hamidi, *Journal of the American Planning Association*, Vol. 80, Issue 2, pages 123-137, 2014.
Available at: http://www.tandfonline.com/doi/abs/10.1080/01944363.2014.949506
From the abstract:

> [The authors] estimate a transit multiplier of 3.04, meaning that transit reduces VMT by three vehicle miles in total for every vehicle mile reduced due to transit ridership. The direct effect occurs through increases in transit ridership and associated reductions in household VMT. The indirect effect is achieved primarily through increased walking around stations and secondarily through increased densities around stations. Fixed-guideway transit in tandem with comprehensive public policies that promote transit-oriented development (TOD) around transit stations on one hand, and highway corridors on the other, produce different transportation outcomes.

Although the case study used for this project involved a light rail system, the indirect effects of compact and TOD-style development are relevant to all modes of transit, assuming they follow with the same compact design and supportive development policies.

Tools for Estimating VMT Reductions from Built Environment Changes, Anne Vernez Moudon and Orion Stewart, Urban Form Lab, University of Washington, June 2013.
http://www.wsdot.wa.gov/research/reports/fullreports/806.3.pdf
Although this report focuses primarily on nonmotorized travel, it does review the built environment characteristics associated with travel and the tools available that use these built environment characteristics to estimate travel and related outcomes such as vehicle emissions and health co-benefits.

Transit Service Variables

National Guidance

Quantifying Transit's Impact on GHG Emissions and Energy Use—The Land Use Component, Frank Gallivan, Eliot Rose, Reid Ewing, Shima Hamidi and Thomas Brown, Transit Cooperative Research Program Report 176, 2015.
http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_176.pdf
In this report, incremental improvements to transit service have measurable, incremental land use effects at the regional and neighborhood levels, as measured by increases in population density and resultant reductions in VMT, transportation fuel use and GHG emissions. Researchers used the Land Use Benefit Calculator (see **Tools** in this report), an Excel-based sketch-modeling tool that allows transit agencies, metropolitan planning organizations and other stakeholders to estimate the land use effects (such as population density, VMT reduction, fuel use and GHG emissions) of existing or planned projects with a minimal amount of input data required. Default data inputs are provided from more than 300 urbanized areas and metropolitan regions from the year 2010.

Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit, APTA Climate Change Standards Working Group, American Public Transportation Association, August 14, 2009.
http://www.apta.com/resources/hottopics/sustainability/Documents/Quantifying-Greenhouse-Gas-Emissions-APTA-Recommended-Practices.pdf
This report provides a methodology for quantifying GHG emissions generated by transit and the potential reduction of emissions through efficiency and displacement, allowing transit agencies to report emissions in a transparent, consistent and cost-effective manner.

Section 6 of this report provides methodologies for calculating the impact of mode shift to transit on GHG emissions, which, along with congestion relief and the land-use multiplier, contributes "displaced emissions" as private vehicle travel is reduced.

"Chapter 9—Transit Scheduling and Frequency," John Evans, *Traveler Response to Transportation System Changes Handbook*, third edition, Transit Cooperative Research Program Report 95, 2004.
http://www.trb.org/Publications/Blurbs/154748.aspx
This chapter of the handbook provides information about traveler response and related impacts to scheduling changes to bus and rail service. From page 9-2 of the report (page 13 of the PDF):

> Scheduling and frequency modifications are among the most common service changes that transit operators make to improve service effectiveness. Both cost effectiveness and service quality are primary goals, [however, related actions may include] improving the reliability of the service, reducing both real and perceived passenger wait times, and lowering passenger anxiety.

According to the report, travel demand research suggests that combining transit wait time, transfer time and walk time as "out-of-vehicle time" may be at least on the order of twice as important in mode choice as an equal time spent in the transit vehicle. Confounding factors also make outcomes more difficult to measure, including:

- Travelers changing routes, which make measuring elasticity difficult because of a change in scheduling and/or frequency.
- Transit dependents, who do not have a choice in mode, such as a vehicle.

Other considerations included in the report:

- Response to service frequency changes is apparently least when the service modifications primarily affect lower income areas, when the prior service was relatively frequent, and when the travel market served is characterized by long trips (page 9-11 of the report, page 22 of the PDF).
- Sometimes, more important to the riding public is the extension of service hours, not the increase in bus frequency.

Regarding the effects of transit scheduling and frequency on energy consumption and the environment (from page 9-27 of the report, page 38 of the PDF), the researchers note:

> Modeled rather than observed traveler response is the only available basis for evaluation of the impacts of transit service frequency changes acting alone on vehicle miles of travel (VMT), energy consumption and pollutant emissions. A hypothetical example of changes in vehicle headways for a corridor with 4 bus stops per mile and 1,000 person trips per hour indicates the potential VMT reduction benefits that might accrue at the corridor level.

Table 9-12 on page 9-27 of the report (page 38 of the PDF and reproduced below) summarizes the results of this hypothetical example using early 1980s emissions standards. Applying today's emissions control technology and no- or low-emissions cars and buses might significantly change these results.

Hypothetical Corridor Bus Frequency Impacts on VMT and Emissions			
Transit Headway (minutes)	Bus VMT	Automobile	
		VMT	Trips
30	24	2360	708
15	48	2160	649
5	144	2070	622

Source: J Horowitz, *Air Quality Analysis*, The MIT Press, 1982.

"Chapter 10—Bus Routing and Coverage," Richard Pratt and John Evans, *Traveler Response to Transportation System Changes Handbook*, third edition, Transit Cooperative Research Program Report 95, 2004.
http://www.trb.org/Publications/Blurbs/154974.aspx
In this chapter of the handbook, researchers address rider response and related impacts of changes to bus routes, including individual route and system level changes, new bus systems and system closures, bus system expansion and retrenchment, increases and decreases in geographic coverage, and fare changes.

Table 10-23 on page 10-50 of the report (page 61 of the PDF) estimates the impact of new and expanded bus services on VMT in 10 locations: four large cities (Seattle; Miami; Portland, OR; and San Diego) and six smaller cities (Madison, WI; Eugene, OR; Raleigh, NC; Bakersfield, CA; Bay City, MI; and Greenville, NC). The table below summarizes the combined average from these locations. The results show a minimal reduction in equivalent VMT as a result of the improved transit service, averaging 0.13 percent in large cities and 0.03 percent in smaller cities.

Impacts of Transit Service Expansion on Equivalent VMT

	Annual VMT (millions)[a]	Annual New Bus Miles	Annual New Bus Passengers	Annual New Bus Passenger Miles	Annual Vehicle Miles if by Auto[b]	Annual Equivalent Vehicle Miles Reduced[c]	Equivalent Percent Reduction in VMT
Average for larger cities	6,075	2,729,000	5,076,000	15,425,000	12,899,000	7,397,000	0.13%
Average for smaller cities	697	520,000	844,000	1,783,000	1,486,000	446,000	0.03%

[a] Based on 1972 DOT National Transportation Study.
[b] Assuming average auto occupancy is 1.2 persons per auto.
[c] Assuming one bus mile is equal to two equivalent passenger-car miles.

Source: F.A. Wagner and K. Gilbert, *Transportation System Management: An Assessment of Impacts*, interim report, prepared for the Urban Mass Transportation Administration, U.S. DOT, by Alan M. Voorhees & Associates, Inc., McLean, VA, November 1978.

Table 10-24 on page 10-51 of the report (page 62 of the PDF and reproduced below) addresses the fuel savings associated with the transit service expansions from Table 10-23. The fuel efficiency and emissions rates of vehicles and buses are out of date, but the trade-offs are still worth noting.

Impacts of Transit Service Expansion on 1970s Energy Consumption

Parameter		Average 4 Largest Cities	Average 6 Smaller Cities
Average population		1,212,000	136,000
Fuel savings (gal. annually)[a]	Auto @ 15 mpg	857,000	99,000
	Bus @ 5 mpg	-545,800	-104,000
	Net savings	311,200	-5,000
% urban transportation fuel savings		0.08%	Marginally negative

[a] Negative sign indicates additional consumption.

Source: F.A. Wagner, *Energy Impacts of Urban Transportation Improvements*, Institute of Transportation Engineers, Arlington, VA, August 1980.

"Chapter 12—Transit Pricing and Fares," Brian McCollom and Richard Pratt, *Traveler Response to Transportation System Changes Handbook*, third edition, Transit Cooperative Research Program Report 95, 2004.
http://www.trb.org/Publications/Blurbs/152419.aspx
In this chapter, researchers noted that the impacts on VMT (and corresponding impact on energy consumption and air quality) are negligible in response to transit fare changes by themselves. When fare changes are combined with other strategies, particularly when they are applied in congested areas with good transit service, the effect on traffic and environment becomes more relevant.

California Resource

Emission Reduction Calculation Methodologies. Caltrans and the California Air Resources Board, December 1995.
http://www.dot.ca.gov/hq/transprog/federal/cmaq/CMAQCAL.pdf
This report offers simplified methodologies provided by the Federal Highway Administration and added emission factor tables specific to California that can be used to determine emission benefits related to Congestion Mitigation and Air Quality (CMAQ) Program-funded projects. Although not comprehensive, the methodologies address the more common types of CMAQ projects for which air emissions can be determined.

On page 3 of the report (page 3 of the PDF), researchers provide the following calculation developed for purchasing a bus to provide new transit service:

(0.5) (new bus ridership) (auto trip end emiss factor)

plus

(0.5) (new bus ridership) (aver auto trip length) (auto VMT emiss factor)

minus

(new bus service VMT) (bus emiss factor)

Researchers developed the following calculation for replacing old buses (page 4 of the report, page 4 of the PDF):

(bus VMT) (old bus emiss factor) *minus* (bus VMT) (new bus emiss factor)

This guidance provides all the related emissions factors referred to in these formulas.

Other Resources

"Modeling Land Use, Bus Ridership, and Air Quality: Case Study of the North River Industrial Corridor in Chicago," Jie Lin and Santosh Mishra, *TRB 85th Annual Meeting Compendium of Papers CD-ROM*, Paper #06-0055, 2006.
Abstract available at: http://trid.trb.org/view.aspx?id=776157
From the abstract:

> This paper presents a demonstrative study of predicting potential automobile VMT and emissions reductions due to transit service improvement by using a simple GIS-aid computer tool.

The method presented in this paper has several limitations. The ridership models presented in this study don't consider factors such as parking availability at destination; auto-transit travel cost; or household socio-economic status, such as income, automobile ownership and life cycle (i.e., with or without small children). The study also assumes perfect mode shift (100 percent) from automobile to bus and ignores latent demand.

Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior, Todd Litman, Victoria Transport Policy Institute, March 12, 2013.
http://www.vtpi.org/elasticities.pdf.
From the abstract:

> This report describes concepts related to transport demand, investigates the influence that factors such as prices and service quality have on travel activity, and how these impacts can be measured using elasticity values. It summarizes research on various types of transport elasticities and describes how to use this information to predict the impacts of specific transport price and service quality changes.

Making the Most of Transit: Density, Employment Growth, and Ridership around New Stations, Jed Kolko, Public Policy Institute of California, February 2011.
http://www.ppic.org/content/pubs/report/R_211JKR.pdf

Regarding whether investing in transit services reduces VMT (page 17 of the report), the researcher noted:

> Transit investments typically aim to serve commutes, which occur at peak times on the most congested routes. But commuting accounts for only 27 percent of total VMT. Non-commute trips like those to stores, schools, and family or social events are much less likely than commute trips to use transit. Thus, increased transit investment and commute ridership could displace, at best, only a fraction of total VMT.

Tools

Below we highlight several tools and calculators that can be used to determine reductions in VMT and emissions.

"Guidebook Emissions Calculator," *CCAP Transportation Emissions Guidebook*, Center for Clean Air Policy, 2005.
Available at: http://www.ccap.org/safe/guidebook/guide_complete.html
This Excel-based calculator estimates GHG and other emissions based on transportation demand management policies and vehicle technologies.

Energy and Emissions Reduction Policy Analysis Tool, Federal Highway Administration, 2011.
http://www.planning.dot.gov/FHWA_tool/
From the web site:

> The Energy and Emissions Reduction Policy Analysis Tool (EERPAT) was developed to assist state transportation agencies with analyzing greenhouse gas reduction scenarios and alternatives for use in the transportation planning process, the development of state climate action plans, scenario planning exercises, and to measure the reduction potential of various transportation strategies to meet state greenhouse gas reduction goals and targets.

"VMT Spreadsheet Tool," Jerry Walters, Chris Breiland, Gus Jimenez and Richard Lee. *Improved Data and Tools for Integrated Land Use—Transportation Planning in California*, University of California–Davis, Urban Land Use and Transportation Center, September 24, 2012.
http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california
(*Note:* Scroll down the page to 2.a) Scenario/sketch-planning Tools.)

This tool uses California-specific relationships of built environment and travel to provide VMT estimates that can be useful in scenario planning and evaluation.

"Local Sustainability Planning Tool," *2012-2035 Regional Transportation Plan/Sustainable Communities Strategy*, Southern California Association of Governments, undated.
Information available at: http://rtpscs.scag.ca.gov/Pages/Local-Sustainability-Planning-Tool.aspx
From the web site:

> [The Southern California Association of Governments] has developed the Local Sustainability Planning Tool to provide a sketch planning tool local jurisdictions and members of the public can utilize to analyze the impact of different land use scenarios on

vehicle ownership, vehicle miles traveled (VMT), mode-use, and their associated effects on GHG emissions.

STOPS—FTA's Simplified Trips-on-Project Software, Federal Transit Administration, April 29, 2015.
http://www.fta.dot.gov/grants/15682.html
This Federal Transit Administration (FTA) travel forecasting tool sponsors the FTA's New Starts and Small Starts projects and quantifies the measures used by the FTA to evaluate and rate projects. *Note:* In this evaluation, the tool used bus rapid transit projects for the bus-related projects.

"Land Use Benefit Calculator," Frank Gallivan, Eliot Rose, Reid Ewing, Shima Hamidi and Thomas Brown, *Quantifying Transit's Impact on GHG Emissions and Energy Use—The Land Use Component*, Transit Cooperative Research Program Report 176, 2015.
Abstract available at: www.trb.org/main/blurbs/172110.aspx
From the abstract:

> The calculator tool estimates the land use benefits of existing or planned transit projects. The report and tool will enable users to determine quantifiable impacts of transit service on compact development, energy use, and air quality in urbanized areas.

From the introduction:

> Specifically, the calculator allows the user to estimate
>
> - The land use benefits of the existing regional transit system
> - The land use benefits of a regional transit plan
> - The land use benefits of a new transit route or improved transit service along an existing corridor
> - The land use benefits of a new transit station or stop, or improved transit service to an existing station or stop
>
> All land use benefits are estimated in terms of the following metrics:
>
> - VMT reduction
> - Gasoline consumption reduced
> - GHG emissions saved

"VMT Impact Tool," Deborah Salon, *Quantifying the Effect of Local Government Actions on Vehicle Miles Traveled (VMT)*, University of California–Davis, February 2014.
Available at: http://www.arb.ca.gov/research/single-project.php?row_id=64861
The California Air Resources Board, through funded research, has developed the VMT Impact Tool, which is available to help cities, counties and regions estimate changes in VMT that are unique to their community and mix of neighborhood types. Changes in VMT are estimated for eight land use and transportation system variables that can be impacted by policies implemented at the local level.

Contacts

CTC contacted the individuals below to gather information for this investigation.

Transportation Research Organizations

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Other Organizations

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