Project 2314 | December 2024

SJSU SAN JOSÉ STATE UNIVERSITY

MTI MINETA TRANSPORTATION INSTITUTE

Consistent VMT Mapping and Modeling in California: How Can We Better Assess the VMT Impacts of State and Local Transportation Projects?

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CSU TRANSPORTATION CONSORTIUM
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Report 24-39

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A publication of the
Mineta Transportation Institute
Created by Congress in 1991

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
24-39</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Consistent VMT Mapping and Modeling in California: How Can We Better Assess the VMT Impacts of State and Local Transportation Projects?</td><td colspan="2">5. Report Date
December 2024</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Authors
Serena E. Alexander, PhD
Shams Tanvir, PhD
Syed Tanvir Ahmed
Annie Jones</td><td colspan="2">8. Performing Organization Report
CA-MTI-2314</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
ZSB12017-SJAUX</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
State of California SB1 2017/2018
Trustees of the California State University
Sponsored Programs Administration
401 Golden Shore, 5th Floor
Long Beach, CA 90802</td><td colspan="2">13. Type of Report and Period Covered</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplemental Notes
10.31979/mti.2024.2314</td></tr>
<tr><td colspan="4">16. Abstract
Despite California's ambitious target to achieve carbon neutrality by 2045, the state is not reducing greenhouse gas (GHG) emissions from personal vehicle travel, and per capita Vehicle Miles Traveled (VMT) and GHG emissions continue to increase. One central challenge of climate planning facing California is the lack of consistent methods to measure the VMT impacts of transportation projects. Using both qualitative and quantitative data, this research answers the question: "What are the advantages and limitations of existing VMT calculators to determine the climate impacts of transportation projects to help meet California's climate goals?" Research methods included: (1) a quantitative analysis of the existing VMT tools in practice, particularly in California, by identifying and analyzing the attributes of each tool and clustering the tools into distinct methods based on their similarities in principles, inputs, and outputs; and (2) a qualitative analysis of perspectives of transportation professionals regarding VMT as a metric and VMT tools. Findings indicate that the consistency, contextual relevance, complexity, data accuracy, and the user-friendliness of the VMT tools vary significantly based on their design and methodology, and each tool presents a set of limitations and advantages making it suitable for a specific use or context but not necessarily for another. Recommendations for the state include to: (1) improve access to accurate, validated data for creating and inputting into VMT models and tools; (2) help create context sensitive VMT tools capable of capturing local context and change over time; (3) strengthen dialogue between jurisdictions to share information and tools; and (4) encourage the use of an integrated approach to VMT analysis—which often combines use of different tools and datasets for various stages of decision-making and scenario planning. VMT tools help planners and policymakers estimate VMT and understand the impacts of transportation projects and policies. By improving our understanding of these tools and their advantages and disadvantages, we can choose the best tool for the specific need, ensuring accurate VMT assessments and empowering California to further its climate goals.</td></tr>
<tr><td>17. Key Words
Vehicle miles traveled (VMT), VMT tools, Greenhouse gas (GHG) emissions, Induced demand, Transportation impact analysis.</td><td colspan="3">18. Distribution Statement
No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
70</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72)

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DOI: 10.31979/mti.2024.2314

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Acknowledgments

The authors sincerely thank Julia Kingsley from the California State Assembly for serving as a project advisor, the interviewees for sharing their expertise on the subject, the anonymous reviewers for their constructive feedback, and MTI leadership and staff for their support throughout this project.

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Despite California's ambitious target to achieve carbon neutrality by 2045, the state is not reducing GHG emissions from personal vehicle travel, and per capita Vehicle Miles Traveled (VMT) and Greenhouse Gas (GHG) emissions continue to increase. One central challenge of climate planning facing California is the lack of consistent methods to measure the VMT impacts of transportation projects. Using both qualitative and quantitative data, this research aims at answering the question of "what are the advantages and limitations of existing VMT calculators to determine the climate impacts of transportation projects to help meet California's climate goals?" An evaluation of different VMT tools for specific scenarios shows that each has its strengths and weaknesses. These tools help planners and policymakers estimate VMT and understand the impacts of transportation projects and policies. This report examines their consistency, context of use, data usage, complexity, ease of use, and potential for misuse or misinterpretation. By understanding these factors, users can choose the best tool for their needs and ensure accurate VMT assessments.

Methods

This study divides the evaluation of VMT impacts into two main steps:

The first step is the qualitative analysis of the advantages and limitations of the existing VMT mapping and modeling tools. This step includes reviewing the current tools in practice to identify potential best practices and innovative approaches and interviewing 24 transportation professionals in California to learn about the technical and practical advantages and limitations of existing VMT tools and metrics from their standpoint.

In the second step, the VMT mapping and modeling tools are analyzed quantitatively. The primary aim of this analysis is to provide practical insights into how different VMT assessment tools and methods can impact decision-making about transportation projects. This includes project selection, prioritization, and mitigation recommendations. By establishing a cluster of tools and a common application scenario, we can understand the advantages and limitations of one tool over another, the types of data used as inputs, and the sensitivity and usability of these tools. For example, the induced travel calculators are categorized as research and data-based empirical models, whereas WRCOG VMT tool is a spreadsheet model based on a travel demand model. OPR Site Check and VMT+ are web-based models for quick and intuitive analysis. This clustered data is helpful for planners, engineers, or policymakers in choosing the appropriate tool for their projects. Lastly, the report explores applications of these tools by developing appropriate hypothetical scenarios for each tool and analyzing the results. These results provide a general understanding of the advantages and limitations of each tool. For example, each tool offers unique benefits, such as user-friendliness, context sensitivity, and initial planning application. However, they also present challenges related to the tool's response (i.e., static or dynamic), data limitations, and the potential scope of application.

Summary of Major Findings

Findings indicate that the consistency of the VMT tools (i.e., the reliability and spatio-temporal transferability of the results) varies significantly based on their design and methodology. For example, using fixed elasticity values and conservative estimates in the NCST tool can lead to inconsistencies among scenarios developed in different geographical locations. On the other hand, a spreadsheet-based tool, WRCOG, relies on generalized criteria that result in consistent output when applied to that specific scenario. The OPR Site Check Map and VMT+ provide baseline and comparative insights, leading to consistent results within their limited scopes but cannot dynamically adapt to evolving scenarios. In contrast, VisionEval, with its detailed scenario-planning capabilities, offers a high degree of consistency in exploring various futures, making it robust for policy impact analysis despite its complexity.

Users of VMT tools should select the most appropriate tool for their specific needs and context. Interviewees often stressed that context sensitivity is vital for accurate VMT analysis; therefore, one-size-fits-all tools may not be appropriate for every region. The NCST Induced Travel Calculator is particularly suited for the initial planning stages of capacity expansion projects on major arterials. The WRCOG VMT Tool serves local jurisdictions, specifically in Riverside County, for initial VMT impact screening. The OPR Site Check Map is beneficial for preliminary site assessments across a variety of development projects. VMT+ excels in providing detailed VMT insights at granular geographic levels and is useful for comparative regional analysis. Conversely, VisionEval, designed for comprehensive scenario planning, is most suitable for strategic long-term planning, offering detailed and holistic insights into potential future outcomes.

The data used and the model complexity of each tool impact the accuracy and relevance of the results and the usability and depth of analysis. For example, the NCST Induced Travel Calculator and WRCOG VMT Tool are relatively straightforward and user-friendly, making them suitable for initial assessments. The OPR Site Check Map and VMT+ are also user-friendly but provide limited depth in their analysis. In contrast, VisionEval is the most complex of the tools, requiring significant training and extensive data inputs. However, this complexity allows VisionEval to offer detailed scenario planning and comprehensive analysis capabilities, making it a powerful tool for long-term strategic planning despite its demanding requirements.

Interviews with transportation professionals in California indicate the need for more context-sensitive tools, as well as a desire for stronger communication across the state regarding VMT. Interviewees often stressed that a one-size-fits-all approach may not be appropriate given contextual differences between different areas within the state. Also, there was no consensus on what tools or methods are considered best practices in VMT tools use. Interviewees also shared their concerns regarding the difficulty of VMT reduction and the challenges of SB 743 implementation and thought that better communication across the state and information sharing between jurisdictions could help improve practices.

Recommendations

Recommendations for the state include to: (1) improve access to accurate, validated data for creating and inputting into VMT models and tools; (2) help create context sensitive VMT tools capable of capturing local context and change over time; (3) strengthen dialogue between jurisdictions to share information and tools; (4) encourage use of an integrated approach to VMT analysis—which often combines use of different tools and datasets for various stages of decision-making and scenario planning.

1. Introduction

Despite California's ambitious target to achieve carbon neutrality by 2045, the latest progress report published by California Air Resources Board suggests that the state is not reducing GHG emissions from personal vehicle travel, and per capita Vehicle Miles Traveled (VMT) and Greenhouse Gas (GHG) emissions continue to increase.[1] Emissions from transportation sources are predominantly a product of miles driven by internal combustion engine vehicles; therefore, GHG proportionately increases with an increase of VMT. With the Bipartisan Infrastructure Law directing substantial funds into the nation's transportation infrastructure, including roads, bridges, and mass transit, it is exceedingly important to accurately measure and address the VMT impacts of transportation projects. One central challenge that California faces is a lack of consistent methods to measure the VMT impacts of transportation projects. Without consistent metrics and methods to measure both the VMT impacts of transportation projects as well as the VMT reduction potential of proposed mitigation measures, California cannot accurately assess the outcomes of state and local projects. This research compiles and evaluates existing VMT calculators and other methods to determine the climate impacts of transportation projects and offers a clearer path forward for verifying and addressing the VMT impacts of transportation projects to help meet the state's climate goals.

1.1 Definition of VMT

Vehicle miles traveled (VMT) is a metric used to describe the number of miles driven on a roadway system within a particular region over a specified time period. For example, ten cars each travelling 20 miles in one day is a VMT of 200 for that day going around the city. It can also be calculated at various geographic scales (e.g., city, county, state, or country). It is usually measured every day, month, or year, depending on the purpose of the analysis.

1.2 Uses and Applications of VMT

VMT plays a significant role in the field of transportation planning and demand management. VMT can help us examine the demand for both passenger and commercial travel. It helps planners in designing and prioritizing transportation infrastructure projects, such as road expansions and new highways. Planners can also use VMT as a metric to justify investment in alternative modes of transportation, such as transit and active transportation, to address demand for mobility. Additionally, VMT is often used as a metric for traffic management. Transportation professionals can study traffic patterns and congestion and formulate effective traffic management strategies based on VMT data. Thus, VMT is an important metric in shaping our transportation system.

VMT is essential not only for transportation planning and demand management, but also for evaluating environmental impacts. Specifically, VMT can be used to estimate vehicle emissions since it is correlated with air pollutants and GHG emissions. Therefore, by analyzing VMT data, we can estimate the impact of driving on air quality and climate change. It is to be noted that California Senate Bill 743 (SB 743), passed in 2013, mandated the use of VMT as a measure of the environmental impacts of transportation projects subject to the California Environmental Quality Act (CEQA) review.

There is a lot of recent interest both in California and at the federal level in assessing the VMT and climate impacts of new roadway construction or capacity expansion, which are often justified for their potential economic or traffic reduction benefits. Yet, many studies have consistently shown that adding new lanes or building new roads in congested areas can increase network-wide VMT, reducing or eliminating congestion benefits within a few years.[2]

1.3 Definition of Induced Demand

The term "induced demand" is often used to explain the phenomenon that highway improvement projects—particularly roadway capacity expansions—can generate additional traffic because people choose driving over alternative modes or not traveling at all.[3] Yet, for decades, a lack of accurate and accessible induced demand tools has resulted in an overestimation of highway expansion benefits and an underestimation of the environmental impacts of such projects.[4] As a result, both California and the federal government have recently emphasized the importance of developing and implementing improved tools to measure and address induced demand.

1.4 Evaluation of Induced Demand

The terms induced demand, induced travel, and induced VMT are often used interchangeably. In the literature, three broad methods have been identified to study induced travel: (a) elasticity-based models that are specifically designed to examine the effects of transportation investment projects on induced travel (e.g., California's Induced Travel Calculator);[5] (b) travel demand models that have been developed for traffic forecasting but have the capability to estimate the share of induced travel;[6] and (c) case studies that investigate travel growth over time and its causes and consequences in specific geographic areas or particular transportation corridors.[7]

There are several limitations and challenges associated with these three methods. For example, elasticity-based models, such as California's Induced Travel Demand Calculator, are often not sensitive to project context (e.g., land use patterns, density, route options, modal choices, etc.);[8] yet case studies (method c) clearly show that the context matters.[9] While National Cooperative Highway Research Program's NCHRP 934 report titled "Traffic Forecasting Accuracy Assessment"[10] provides extensive research and guidance on travel demand modeling (method b), one key challenge related to existing travel demand models (TDM) is inconsistency in their level of sophistication and accuracy. Traditional trip-based TDMs are not capable of predicting long-term behavioral changes such as induced demand from additional infrastructure development. Moreover, trip-based TDMs reflect a "snapshot" of a scenario, and the outputs do not consider the temporal dynamics happening within the modeled scenario. Lastly, while case studies are context-sensitive and can provide an in-depth analysis of the impacts of highway capacity expansions on the surrounding communities, their generalizability is often questioned.

The State of California has already made several efforts to develop new sophisticated tools, such as the Induced Travel Calculator, but in practice, it has proved difficult to implement an agreed-upon tool for the entire state. Some communities have challenged the results of the Induced Travel Calculator, and some have proposed to develop their own tool. Other communities are more comfortable using their regional travel demand models or other metrics to evaluate the VMT impacts of transportation projects. Interviews with local planners suggest that some are not confident in using a single model or tool to determine the VMT impacts of transportation projects or the VMT reduction potential of proposed mitigation measures.[11] As such, there is a clear need to take a step back to better understand the practical challenges that local and state professionals face in assessing the VMT impacts of transportation projects.

1.5 Objectives

Through an analysis of common VMT tools and interviews with transportation professionals, this research aims at addressing three main objectives, which are to:

1. compile and evaluate the existing VMT calculation tools and other relevant modeling tools and metrics,

2. examine practical challenges associated with calculating or verifying the VMT impacts of transportation projects, and

3. offer recommendations for the State of California to account for and address VMT and other environmental impacts of transportation infrastructure investments.

1.6 Overview of the Report

In the pages that follow, this research offers an analysis of common tools and the challenges and opportunities of using existing tools from the perspective of transportation professionals. Chapter 2 focuses on methodology, and Chapter 3 offers the results of the VMT tool analysis. Interview methods and findings are summarized in Chapter 4. Lastly, Chapter 5 offers a summary of major findings, conclusions, and recommendations, as well as directions for future studies.

2. Methodology of Analysis

This study divides the evaluation of VMT impacts into two main steps. The first step is the qualitative analysis of the advantages and limitations of the existing VMT mapping and modeling tools. This step includes reviewing the current tools in practice and interviewing transportation professionals to learn about their practical experience in California. Here, we compiled existing VMT assessment tools and metrics and identified innovative tools and best practices for assessing the VMT impacts of transportation projects. We also interviewed 24 professionals to understand the technical and practical advantages and limitations of existing VMT mapping and modeling tools and metrics from their standpoint in California.

In the second step, the VMT mapping and modeling tools are analyzed quantitatively. The primary aim of this analysis is to provide practical insights on how different VMT assessment tools and methods can impact decision-making about transportation projects. This includes project selection, prioritization, and mitigation recommendations. By establishing a cluster of tools and a common application scenario, we can understand the advantages and limitations of one tool over another, the types of data used as inputs, and the sensitivity and usability of these tools.

2.1 VMT tools

VMT tools often estimate VMT for different land use and transportation scenarios. Public and private agencies have developed different types of tools for VMT estimation. These agencies develop software or models for transportation planning and environmental assessments. Examples include public agencies such as the California Air Resources Board (CARB), the Environmental Protection Agency (EPA), and the National Center for Sustainable Transportation (NCST), while examples of private entities include StreetLight Data, Inc., Fehr & Peers, and the Rocky Mountain Institute (RMI). There are different types of VMT tools used to evaluate the transportation and land use impacts of a project or plan. Some of these tools can predict future VMT and its associated environmental impacts, such as GHG emissions, whereas some are only used to calculate baseline (current) VMT. These include travel demand models, sketch models, spreadsheet models, and empirical approaches using elasticity. Table 1 lists VMT tools in practice with their attributes. The scope of the tools are discussed in section 2.3.

Table 1. List of VMT Tools in Practice and Tool Attributes

VMT tools	Developer	Emission Mitigation/VMT	Link	Transportation Demand Management (TDM)	Zero-emissions Vehicle Strategies (ZEV)	Active Transportation Improvements	Transit Improvements	Operational Improvements	Infrastructure Rehabilitation	Highway Expansion	Freight Operations Improvements
NCST's induced travel calculator	National center for sustainable transportation (UC Davis)	VMT	https://ncst.ucdavis.edu/research/tools	No	No	No	No	Yes	No	Yes	No
Colorado induced travel calculator	Rocky Mountain Institute	Both	https://rmi.org/colorado-induced-travel-calculator/	No	No	No	No	Yes	No	Yes	No
SHIFT calculator	Rocky Mountain Institute	Both	SHIFT Calculator (rmi.org)	No	No	No	No	Yes	No	Yes	No
Central Transportation Planning Staff (CTPS) travel demand forecasting model	Boston Region Metropolitan Planning Organization	Emission Mitigation	https://www.boston.gov/sites/default/files/file/2020/08/CFB_Transportation_Technical_Report_051619_0.pdf	No	Yes	Yes	Yes	No	No	Yes	Yes
Sketch model	Carbon free Boston Project	Both	CFB_Transportation_Technical_Report_051619_0.pdf (boston.gov)	No	Yes	No	Yes	No	No	No	No
Annual Energy Outlook	U.S. Energy Information Administration (EIA)	Both	Annual Energy Outlook 2023 - U.S. Energy Information Administration (EIA)	No	No	No	No	No	No	No	No
Energy Emissions Reduction and Policy Analysis Tool (EERPAT)	Federal Highway Administration	Both	GitHub - RSGInc/FHWA_EERPATv4: FHWA's Energy and Emissions Reduction Policy Analysis Tool (EERPAT)	No	Yes	Yes	Yes	No	No	No	No
Motor Vehicle Emissions Simulator (MOVES)	Environmental Protection Agency (EPA)	Emission Mitigation	MOVES Versions in Limited Current Use | US EPA	No	No	Yes	Yes	No	No	No	Yes
Transit Greenhouse Gas (GHG) Emissions Estimator	Federal Transit Administration (FTA)	Emission Mitigation	Transit Greenhouse Gas Emissions Estimator v3.0: User Guide - April 2022 (dot.gov)	No	No	No	Yes	No	Yes	No	No
CMAQ Emissions Calculator Toolkit	Federal Highway Administration	Both	Toolkit - CMAQ - Air Quality - Environment - FHWA (dot.gov)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

VMT tools	Developer	Emission Mitigation/VMT	Link	Transportation Demand Management (TDM)	Zero-emissions Vehicle Strategies (ZEV)	Active Transportation Improvements	Transit Improvements	Operational Improvements	Infrastructure Rehabilitation	Highway Expansion	Freight Operations Improvements
CAPCOA Toolkit	California Air Pollution Control Officers Association (CAPCOA)	Both	Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity (caleemod.com)	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Western Riverside Council of Governments (WRCOG) VMT Tool	Western Riverside Council of Governments (WRCOG)	VMT	VMT Mitigation | WRCOG, CA	No	No	No	No	No	No	No	No
VMT+	Fehr & Peers	VMT	SLD VMT Final (arcgis.com)	No	No	No	Yes	No	No	Yes	No
OPR Site Check Map	Department of Housing and Community Development	VMT	Site Check ✓ (ca.gov)	No	No	No	No	No	No	No	No
VisionEval	Oregon Department of Transportation (ODOT)	Both	Welcome | VisionEval User Guide	Yes	No	Yes	No	No	No	No	No

2.2 Clustering of VMT Impact Assessment Methods

There are multiple parties involved in the development and use of VMT tools. The planners, engineers, and policy makers use these tools developed by the public and private agencies. It is often difficult for the users to fully investigate the principles, inputs, and outputs, as well as their significance for an individual tool. For example, VMT+ is a sketch tool that calculates Home-based VMT (i.e., automobile vehicle trips that are traced back to the residence of the trip-maker) and Home-based Work VMT (i.e., vehicle trips between residence of the trip-maker and their workplace) by utilizing StreetLight data, and this tool is suitable for project impact assessment at the initial planning stage. Note that Home-based Work VMT is a subset of the Home-based VMT. Since work-based trips are an important component of total VMT and are directly affected by socio-economic and infrastructural interventions, VMT from those trips requires specific consideration. Therefore, we clustered the tools in methods based on their similarities in principles, inputs, and outputs so that end users can review this report before using a specific tool. In the following section, the clustered VMT impact assessment methods along with the principals and usage are discussed.

2.2.1 Travel Demand Models

Travel demand models are essential for evaluating how land use and transportation projects affect travel behavior. These models are trip-, tour-, or activity-based. They can help estimate VMT by simulating travel patterns based on factors such as land use, demographics, economic conditions, and transportation infrastructure.

Travel demand models have different uses in practice. These models predict the number and distribution of trips generated by new developments for land-use projects. This allows planners to foresee changes in VMT, traffic congestion, and travel patterns caused by changes in population density, employment locations, and land use diversity. Such predictions can help planners make informed decisions to minimize negative impacts on transportation. For transportation projects, travel demand models assess the effects of infrastructure changes, such as new roads, transit lines, or bike lanes, on travel behavior and mode choice. They evaluate how these changes influence VMT, traffic flow, congestion, and accessibility. Trip-based models focus on individual trips, tour-based models consider linked trips, and advanced activity-based models simulate an individual's daily schedule, providing a comprehensive understanding of travel behavior and its underlying intentions.

2.2.2 Sketch Models / Web-based model

Sketch models provide a quick and intuitive way to assess the potential impacts of land use and transportation projects, especially in the early stages of planning and design. These are digital maps which require selecting an area of interest, selecting the filtering criteria, sorting through a database, and displaying the results that are used for further analysis.

These models allow for rapid scenario testing and sensitivity analysis, enabling stakeholders to explore different design alternatives and assess their transportation implications. Moreover, these are useful at the initial stage of planning. Users do not need in-depth technical knowledge to use these tools.

2.2.3 Spreadsheet models

These simplified models are used in transportation planning to estimate the impact of land use and transportation policies on VMT. Spreadsheet models can stand alone or depend on complex travel-demand model inputs. Users can download these models into their system and customize them if necessary.

These models are more appropriate for localized plans or individual projects. Additionally, these are developed by incorporating the socioeconomic characteristics of a local area. Therefore, one tool which is developed for a city or county cannot be used in other places. The main benefit is that users can input their project details to run scenarios quickly.

2.2.4 Research and data-based empirical models

The empirical approach develops elasticity by analyzing historical data to estimate the changes in VMT as a result of changes in transportation projects. Researchers use statistical techniques to estimate the elasticity of VMT. Once elasticity values are determined, they can be applied to forecast the potential impact of proposed transportation projects on VMT. Empirical models should be validated against observed data to ensure their reliability.

These tools are available on the websites of the agencies that developed them. Users can easily access these tools and input lane miles, geography, and base year to get additional VMT for those lane miles after a certain year. Some of these tools help to estimate the amount of emissions due to additional VMT. These tools are designed for urban areas and for specific classes of roads according to the Federal Highway Administration (FHWA).

2.2.5 Integrated Approach

The integrated approach of calculating VMT involves combining multiple data sources and methodologies to provide a comprehensive and more accurate estimation of vehicle miles traveled. This approach can consider various factors influencing travel behavior and patterns.

In summary, travel demand models, sketch models, spreadsheet models, and the empirical approach using elasticity are versatile tools for assessing the impacts of both land use and transportation projects on VMT and travel behavior. By employing a combination of these methods such as an integrated approach, planners and decision-makers can make informed choices to promote sustainable, efficient, and equitable development of transportation systems and land use patterns.

2.3 Scope of the VMT tools

During the calculation of VMT, two primary types of projects are considered: roadway capacity expansion projects and land use development projects. Roadway capacity expansion projects involve increasing the capacity of existing roadways, such as adding lanes or constructing new roads, to accommodate more vehicles and reduce congestion. Land use development projects focus on changes in land use, such as new residential, commercial, or mixed-use developments, which influence economic activity and travel behavior and subsequently impact VMT. Understanding the implications of both types of projects is crucial for accurate VMT estimation and effective transportation planning. However, VMT can be influenced by other factors such as fuel cost, income, change in vehicle technologies, and a change in policies, such as parking policies on transit use. Most of the VMT tools in practice do not consider these factors while calculating VMT. Some VMT tools can predict future VMT, whereas some show only the baseline VMT of a specified area. There are some tools which do not give a specific numerical value of VMT, but only display a comparison with thresholds such as regional averages. Integrated approach tools can simulate household demographics and calculate VMT and consequent emissions based on that.

2.4 Procedures/ VMT assessment plan

We selected potential VMT tools which are widely used in California as mentioned by the interviewees. These are NCST Induced Travel Calculator, SHIFT Calculator, Colorado Induced Travel Calculator, WRCOG VMT tool, OPR Site Check Map, and VMT+. Additionally, we chose to include VisionEval—used by ODOT (Oregon Department of Transportation)—in our analysis, for its exceptional ability to consider various factors which influence VMT. After selecting the tools, we installed the tool or used a web browser for web-based tools to build different project scenarios. Finally, conclusions were drawn based on the output of those hypothetical scenarios. We checked certain aspects such as the types of data used, the scope of application, usability, context sensitivity, accuracy, and dynamics to determine the performance of each tool.

Next, we aligned the reviewed VMT assessment plans with the identified cluster of tools and created multiple transportation project scenarios, such as highway expansions and land use development, to test the performance of these tools. The purpose of this analysis was to find ways to better assess the VMT impacts of state and local transportation projects.

Lastly, we aligned the reviewed VMT assessment plans with an identified cluster of tools and created multiple transportation project scenarios, such as highway expansions combined with operational improvements, to test the performance of these tools.

3. Analysis of Test Scenarios and Results

In this chapter, we analyze the tools identified in Chapter 2. With the exception of VisionEval, which was developed by Oregon Department of Transportation, the analyzed tools are predominantly California-based. We chose VisionEval in our list (Table 1) for analysis because it is one of the most dynamic tools in practice. Some tools, such as induced travel calculators outside of California, are built based on the principles of the NCST Induced Travel Calculator. Therefore, we also added SHIFT and the Colorado Induced Travel Calculator to our analysis to see the differences between them. Additionally, we analyzed web-based tools, such as OPR's Site Check and VMT+.

In this chapter, for each tool, multiple transportation project scenarios are created to assess the tool's performance. Then, VMT assessment methods and assumptions are summarized, variations evaluated, and project selection differences under various approaches are described. How VMT calculation parameters impact project selection, prioritization, and mitigation initiatives were also determined by the team. The aim was to help enhance the accuracy and reliability of VMT calculations for effective transportation planning and environmental impact assessments. Table 2 presents the VMT tools categorized according to the type of projects.

Table 2. Selected VMT Tools for Scenario Analysis

Project Type	**VMT tools**	**Output / Metric**	**Classification**
Roadway capacity expansion	NCST Induced Travel Calculator	Induced VMT	Empirical elasticity-based
	Colorado Induced Travel Calculator	Induced VMT	Empirical elasticity-based
	SHIFT Calculator	Induced VMT	Empirical elasticity-based
	VMT +	Baseline VMT	Baseline VMT tool based on streetlight data
	OPR Site Check Map	Baseline VMT	
Land use development	WRCOG VMT toolkit		Integrated approach/Build scenario VMT estimates based on RIVTAM model

Different travel calculators are discussed with their mechanism and usage in the subsequent sections.

3.1 Induced Travel Calculator

The Induced Travel Calculator is a research and data-based empirical model created by the National Center for Sustainable Transportation (NCST). It estimates the additional VMT when roadways are expanded. The Institute of Transportation Studies at the University of California (UC), Davis has provided technical assistance to Caltrans in implementing the Calculator within its Transportation Analysis Framework. The Calculator's methodology has been utilized in projects in California and other states such as Colorado. It shows that annual VMT is induced by capacity expansion.

The following equation[5] (Eq. 1) is used to calculate VMT for induced travel:

$$\%\Delta \text{ Lane Miles x Existing VMT x Elasticity = Project-Induced VMT} \qquad \text{(Eq. 1)}$$

$$\text{Elasticity} = \frac{\text{\% Change in VMT}}{\text{\% Change in lane miles}} \qquad \text{(Eq.2)}$$

The elasticity value for class 1[12] is 1.0, and, for classes 2 and 3, it is 0.75[13]. According to FHWA, class 1 is interstate highway, and classes 2 and 3 are freeways and expressways respectively. It gives long-run estimates, which can occur after 3–10 years of construction. It uses lane mileage and VMT data from 2016, 2017, 2018, and 2019. It needs three inputs for calculation—geography, project length, and base year. All the induced travel calculators are built on the analysis and methodology first published by Jamey Volker and Susan Handy at UC Davis to develop the NCST Induced Travel Calculator.

3.1.1 NCST Induced Travel Calculator

The NCST Induced Travel Calculator is a tool designed to estimate the annual additional VMT resulting from roadway capacity expansion projects. This calculator is particularly useful for transportation planners, engineers, and policymakers to understand the potential impact of new road projects on travel behavior, congestion, and emissions.

3.1.1.1 Project Scenario of NCST Calculator

We selected one rural area and one urban area for building project scenarios. Kings County is considered one of the rural areas in California. Hence, the VMT calculated in Kings County represents the VMT of a rural area. On the other hand, the calculated VMT for Los Angeles County represents the VMT of an urban area. The lane miles input for both class 1 and class 2 or 3 facilities are set to 10 miles.

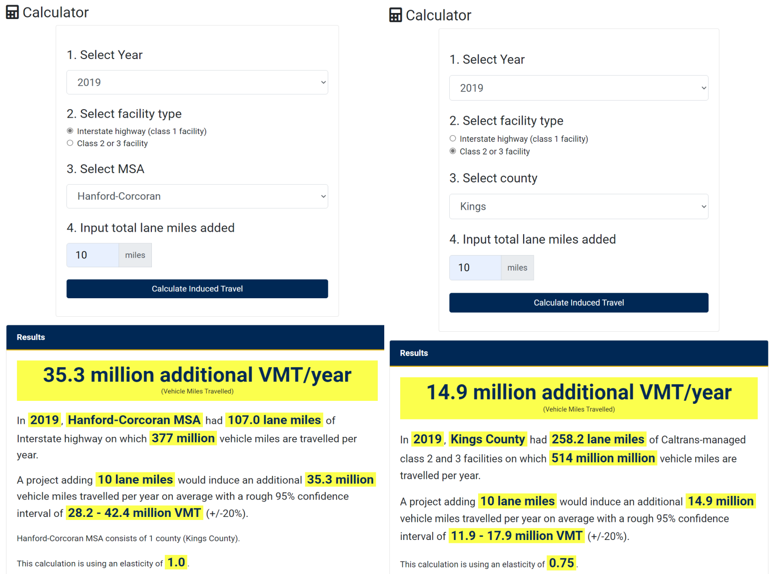

Figure 1. VMT Calculation of Rural Areas

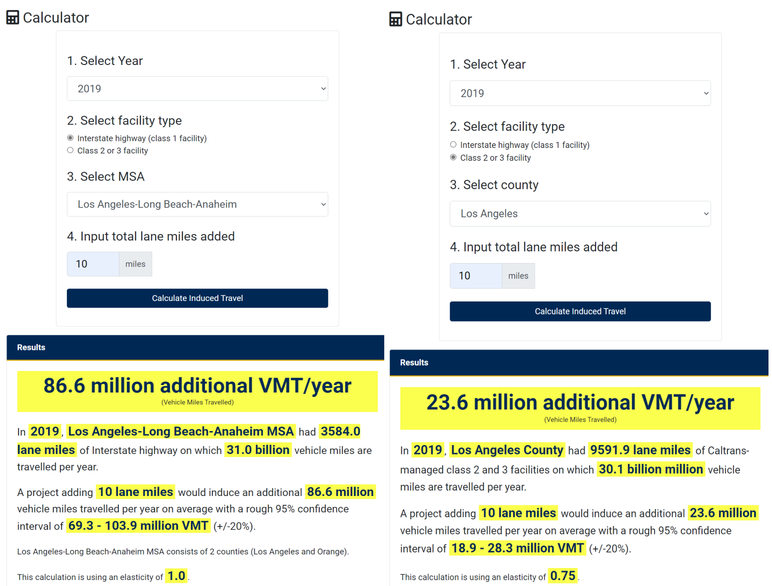

Figure 2. VMT Calculation of Urban Areas

This calculator shows how many miles an area had in 2019 as well as the VMT at that time. It also shows how many additional VMT would be generated if we add 10 lane miles (Figure 2). In Kings County, an addition of 10 miles to the interstate results in 35.3 million additional VMT/year and 14.9 million additional VMT/year for class 2 or 3 facilities (Figure 1). Whereas, in the Los Angeles area, the additional VMT/year amount is significantly larger: 86.6 million for interstate and 23.6 million for class 2 or 3 facilities. This calculator uses elasticity value 1 for class 1 and 0.75 for classes 2 and 3.

3.1.2 SHIFT Calculator

The SHIFT Calculator, developed by the Rocky Mountain Institute (RMI), is a sophisticated tool designed to evaluate the net impacts of roadway capacity expansions on VMT and associated emissions. It also assesses the effects of class 1 (interstate) road widening in US Metropolitan Statistical Areas (MSAs) and classes 2 or 3 roadways in urbanized counties.

3.1.2.1 Project Scenario of SHIFT Calculator

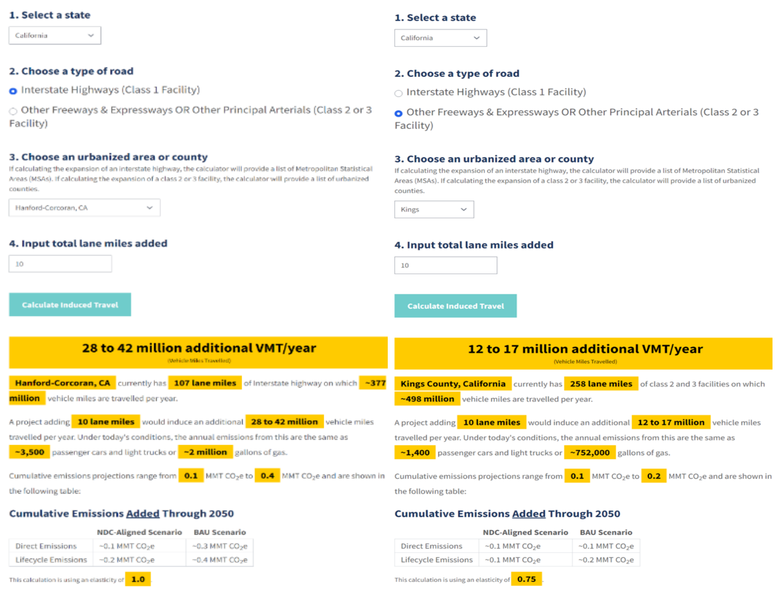

Figure 3. VMT Calculation of Rural Areas

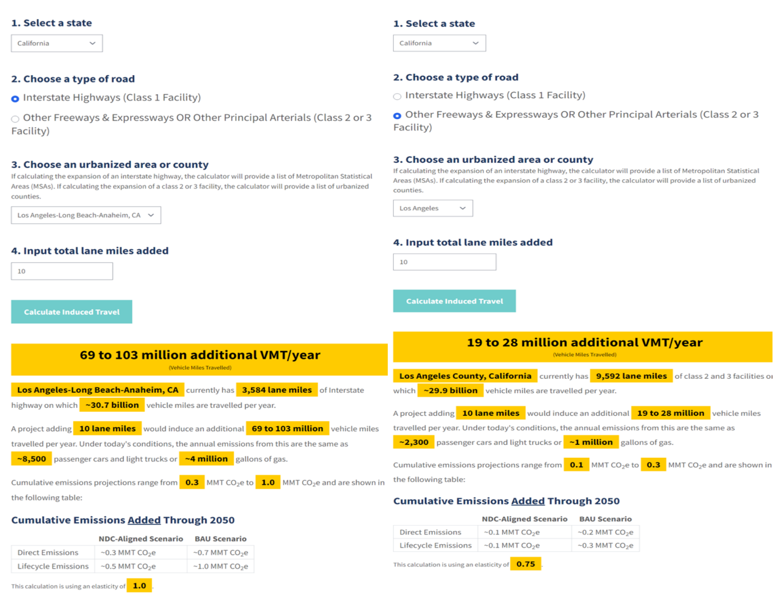

Figure 4. VMT Calculation of Urban Areas

The main difference between the NCST and the SHIFT calculator is that SHIFT converts the VMT into the equivalent number of passenger cars and light trucks or gallons of gas. It also calculates the projected range of emissions associated due to additional VMT.

3.1.3 Colorado Induced Travel Calculator

The Colorado Induced Travel Calculator[15] was also developed by RMI specifically for the state of Colorado to estimate the VMT induced annually. Moreover, similar to the SHIFT calculator, it allows users to estimate the subsequent emissions impact.

3.1.3.1 Project Scenario of Colorado Calculator

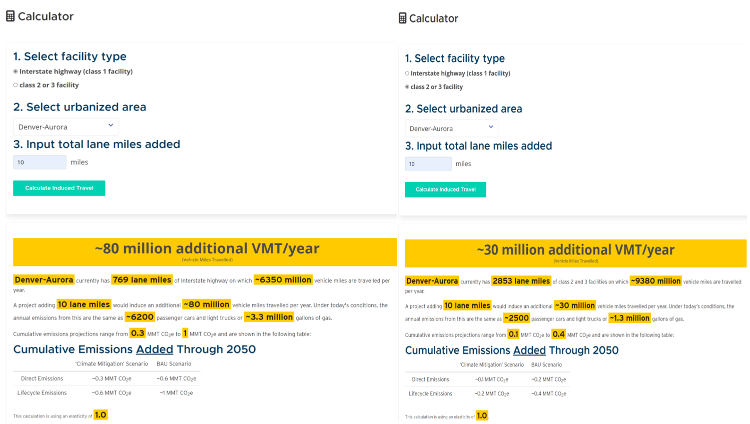

Figure 5. VMT Calculation for Urban Areas

The difference between this tool and the previously discussed calculators is that it sets the elasticity value to 1 regardless of the road classification.

It is evident from the results of all three calculators that VMT generally increases more in urban areas than in rural areas when the same lane miles are added in both areas. For several reasons, VMT on interstate highways is significantly higher in urban areas than rural ones. First, the higher population density in cities means more people are traveling within a smaller area, naturally increasing VMT. Second, urban centers are hubs of economic activity, resulting in more commuting, deliveries, and business-related travel. Additionally, cities have extensive road networks that can support higher traffic volumes, including public transit, private cars, taxis, and ride-sharing services. Travel patterns also play a significant role as many people travel from rural or suburban areas to city centers for work and other activities, contributing to higher VMT. Urban areas also offer various services, entertainment options, and amenities that draw people from within the city and nearby areas, further increasing travel. Tourism and visitors attending business, leisure, and cultural events add to the VMT in cities. Lastly, urban centers are critical locations for freight and logistics operations, with goods being transported to and from various facilities, boosting the VMT for commercial vehicles.

3.1.4 Advantages and Limitations of the Induced Travel Calculators

Advantages

1. Estimation of Induced VMT: The calculator allows users to estimate the VMT induced annually because of expanding class 1, 2, and 3 roadways. These roadways include general-purpose, high-occupancy vehicle (HOV), and high-occupancy toll (HOT) lanes.

2. Initial Planning: The tool equips planners and policymakers with a comprehensive understanding of the potential impacts of roadway capacity expansion on VMT at the initial stage, enabling them to make informed decisions that can shape the future of transportation.

3. User-Friendliness: The tool has an easily accessible and user-friendly interface. It allows users to input project details such as project length, geography, and base year to obtain an induced VMT estimate.

Limitations

1. Scope of Application: The calculator is limited for capacity expansions (lane additions). It cannot be used to estimate the VMT effects of capacity reductions or lane-type conversions. The tool applies only to facilities with FHWA functional classifications of 1, 2, or 3, corresponding to interstate highways, other freeways, and expressways, and other principal arterials respectively. It cannot be used for toll lanes, minor arterials, and local roads. Users are not able to calculate VMT outside of metropolitan statistical area (MSA). In other words, induced travel demand calculators cannot be used to estimate the VMT effects of highway capacity expansions in rural counties.

2. Data Limitations: Users can input the most recent base year, 2019, which could potentially give a misleading VMT output because travel behavior and patterns have changed during and after the COVID-19 pandemic.

3. Sensitivity: The calculator provides conservative estimates and may not fully capture the complexity of induced travel effects in all scenarios. It only calculates VMT based on additional lane miles to be added. Therefore, the calculator does not capture the effects of land use changes. Moreover, it uses fixed elasticity values for classes 1, 2, and 3 roads regardless of the location, which can lead to error-prone analysis.

4. Granularity: More sensitive tools are recommended for in-depth analysis.

3.2 WRCOG VMT Tool

The Western Riverside Council of Governments (WRCOG) and the Southern California Association of Governments (SCAG) collaborated to develop a VMT impact screening tool with a VMT calculator and implementation guidelines to support leading agencies in western Riverside County with the implementation of SB 743. The screening tool is a web map that filters potential VMT impacts related to specific land use projects in the WRCOG planning region per the California Environmental Quality Act (CEQA) Guidelines and the SB 743 modifications to the CEQA statute.

The VMT calculator is a Microsoft Excel spreadsheet used to estimate VMT based on land-use projects. It is meant to review VMT results calculated by consulting agencies and is used when a project does not meet screening requirements.[16]

3.2.1 Project Scenario of WRCOG VMT Tool

To evaluate the sensitivity, we calculated the VMT of different land-use projects using these tools. First, the web map was used to find whether the Assessor's Parcel Numbers (APN) is in the low VMT region or in a TPA (Transit Priority Area). In the following step, the land use project inputs were entered into the model to calculate the potential VMT generated by that project. Three cities are taken into consideration, i.e., Riverside, Murrieta, and Hemet. We used one approved mixed-use development project in Riverside as the land use project input for all three cities.[17]

Table 3. Mixed-use Development Project in Riverside

Project land use information	**Units**
Multi-family homes	388 Dwelling units
Office	4500 Square feet
Retail	25320 Square feet

Three APNs were selected from three cities randomly. However, the area of the parcels was assured so that they can accommodate this project. The results of VMT for the different scenarios are shown in Table 4 below.

Table 4. Project VMT in All Three Cities

Cities	**VMT per service population**
Riverside	28.1
Murrieta	14.9
Hemet	17.9

In Figure 6, the tool's interface with the inputs and outputs are shown for Riverside. The project inputs on the left are user defined whereas the socioeconomic inputs in the middle are by default. On the right of the figure, the VMT result is shown as a bar graph with the threshold limits for comparison. In Riverside, the VMT due to this mix use development project is equal to the OPR Guidance (15% below existing) threshold. On the other hand, for the same project, the VMT is far below that threshold in Murrieta. That means that the project has a more significant effect on VMT in Riverside than in Murrieta. The project VMT in Hemet is close to the OPR threshold. Figures 6, 7, and 8 show the detailed results of all three counties.

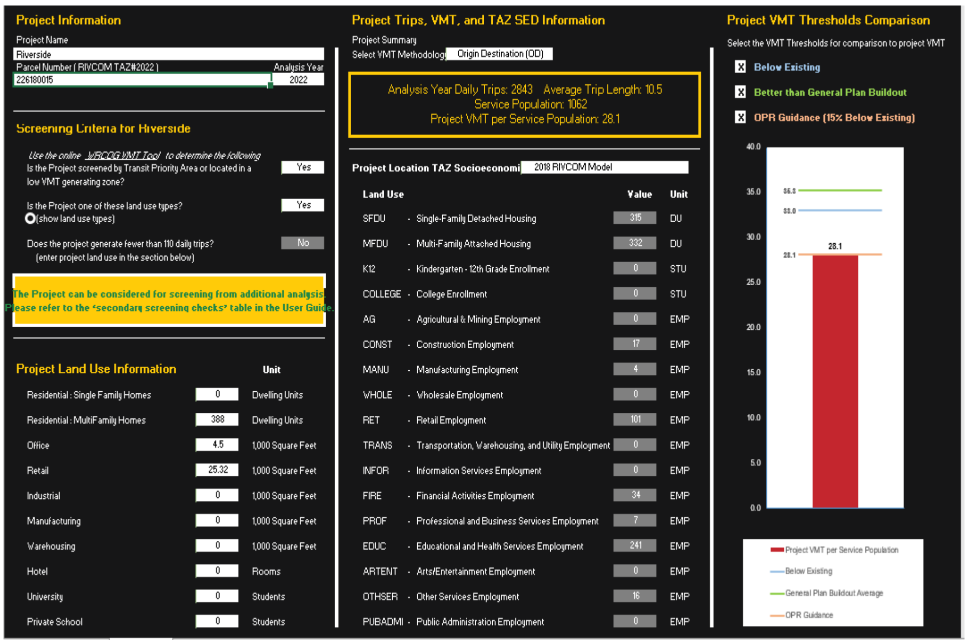

Figure 6. VMT of Riverside Mix Use Development

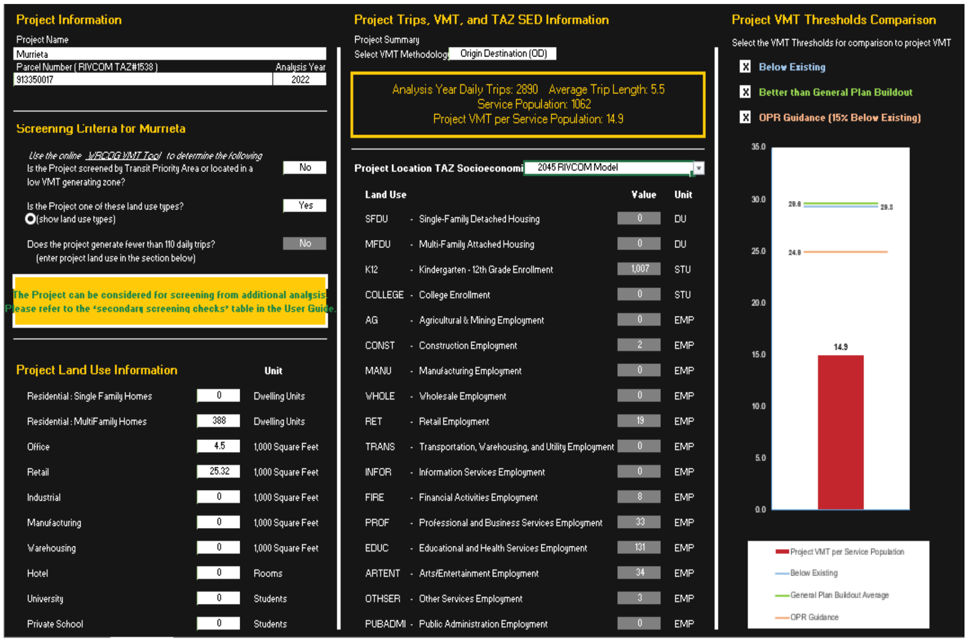

Figure 7. VMT of Murrieta Mix Use Development

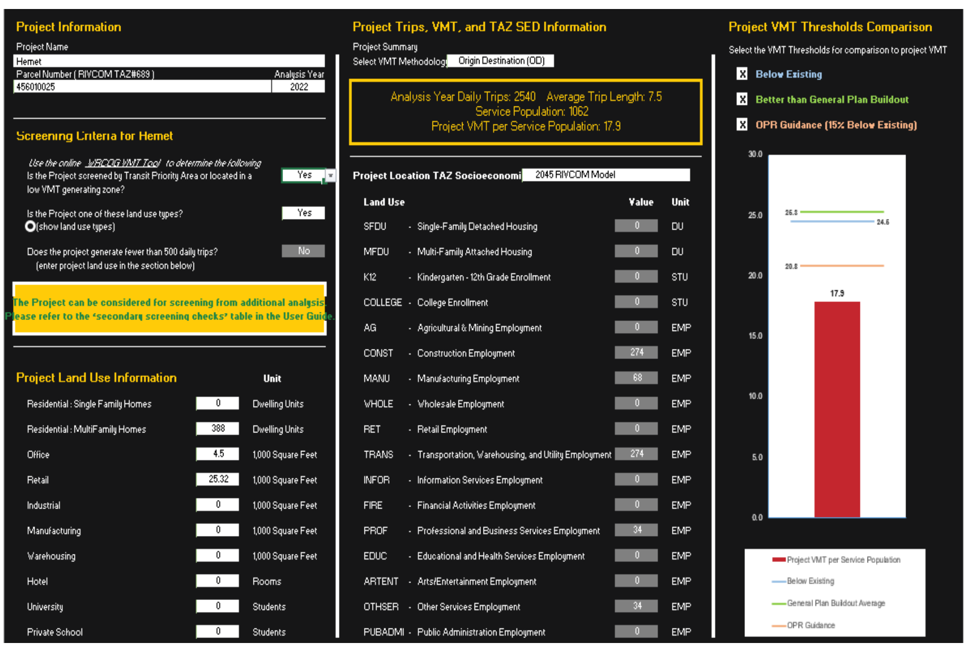

Figure 8. VMT of Hemet Mix Use Development

The following equation (Eq. 3) is used to calculate VMT:

$$VMT = \text{Analysis Year Daily Trips} / \text{Service Population} * \text{Trip Length} \quad \text{(Eq 3)}$$

3.2.1 Advantages and Limitations of the WRCOG VMT Tool

The following advantages and limitations are based on user experience.

Advantages

1. User-Friendly: It is an open-source tool set. The web map is available online, and users can download the spreadsheet to calculate VMT for different scenarios, making it easier for local jurisdictions to estimate VMT without running complex models.

2. Screening Tool: It serves as an initial screening tool for potential VMT impacts, identifying projects that may require further analysis.

Limitations

1. Temporal and spatial transferability: This tool is only applicable for the parcels in Riverside. If a user wants to apply this tool outside of Riverside County, it should be customized based on the context of that area. The parameters of this tool are taken from a static scenario of a travel demand model developed for Riverside—the Riverside County Traffic Analysis Model (RIVTAM). This model does not consider any feedback on trip characteristics based on the land use changes modeled in the tool.

2. Trip Length Dependency: In this tool, the trip length does not change based on the project's location. Trip lengths only depend on the size of the project. However, the trip lengths could be affected by different factors such as different service populations, locations, land use, and availability of public transit.

3. Single APN Limitation: Only one APN can be used as a project location. Moreover, all parcels are not the same size. Therefore, the user should check the size of the project and parcel before testing a scenario because one project that fits in one parcel might not fit in another.

4. Generalized Screening Criteria: The screening criteria used in this method state that if the project is situated in a Transit Priority Area (TPA) or a low VMT region, it has a less than significant effect. It is a generalized statement about the impact of VMT, and developers can take advantage of these loopholes.

5. Sensitivity: The tool is less sensitive to small-scale land-use projects and the influences of the land-use context.

These advantages and limitations provide a comprehensive overview of the WRCOG VMT tools and their effectiveness in VMT estimation and mitigation.

3.3 OPR Site Check Map

The California Office of Planning and Research (OPR) makes it easy to understand different development projects, environmental efforts, and community plans in California with the "Site Check Map." This online map is designed to provide easy access to information about different projects happening across the state.

It is a web-based tool that functions as a digital map where various projects, such as road construction, housing developments, or nature conservation efforts, can be explored.18 Specific locations or project types can be selected, and details about their progress and potential environmental impacts are displayed.

3.3.1 Project Scenario OPR Site Check Map

In general, the per-capita VMT can be displayed on a map comparing the regional average. The map in Figure 9 shows the MPOs in California and their VMTs. It is obvious from this map that most of the low VMT regions are in metropolitan areas, whereas high VMT areas are in NON-MPO areas. One possible explanation for this is that people living in non-urbanized or non-MPO areas are more likely to travel a considerable distance for jobs, businesses, entertainment, and amenities.

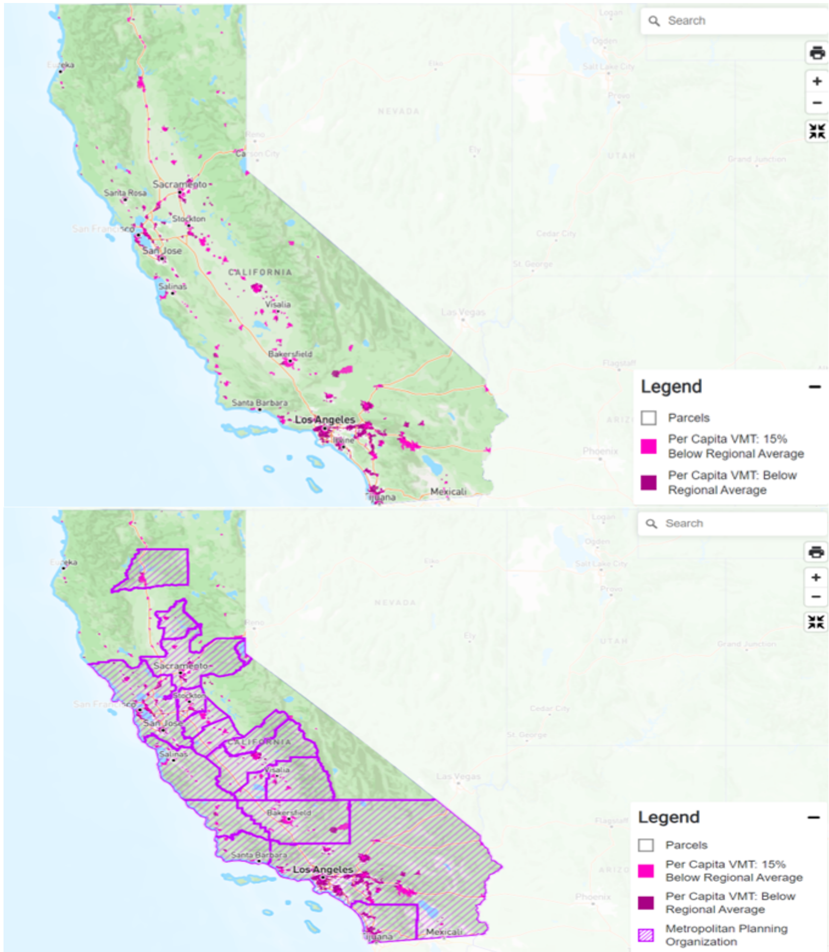

Figure 9. VMT on OPR Site Check Map

3.3.2 Advantages and Limitations of OPR Site Check Map

The following advantages and limitations are based on user experience.

Advantages

1. User-Friendly: The tool is designed to be intuitive and easy to navigate, making it accessible for individuals from various backgrounds.

2. Initial Planning: It provides rapid insights into proposed project sites, which can be valuable for preliminary evaluations. The map allows users to assess the current situation before building various development projects, including transportation infrastructure, residential, and commercial developments. By knowing where these projects are located, planners can assess their potential impact on VMT patterns.

Limitations:

1. Baseline VMT: While it shows the baseline VMT, it does not provide an assessment of the VMT impact post-construction.

2. Limited Detail: The information provided is not detailed, which means it may not be sufficient for in-depth analysis or final decision-making.

3.4 VMT+

VMT+ is a web-based tool developed by Fehr & Peers, specifically for the entire state of California.[19] This tool is designed to help users understand how the location and type of residential development contribute to VMT outcomes, particularly for environmental impact analysis purposes. It focuses on two primary metrics:

1. Home-Based VMT (HBX): The VMT associated with trips to and from residential homes.

2. Home-Based Work (HBW): The VMT related to trips directly between home and work.

To calculate the VMT, this web-based tool utilizes StreetLight mobile device data, specifically trip estimates from March through May 2019. This tool maps each metric by census block group, allowing for detailed geographic analysis.

3.4.1 Project Scenario of VMT+

The VMT+ tool is primarily designed to provide detailed, location-specific data on VMT. Users can select specific geographic areas, such as block groups or custom-defined windows, to view the current status of VMT in those areas. This functionality allows for a focused analysis of travel patterns within targeted regions.

We considered two block groups—one in Los Angeles County and another one in Kings County—to design two scenarios for urban and rural areas which are shown in Figures 10–15.

The tool offers visual representations of VMT data, such as maps and charts, to help users understand the intensity and distribution of vehicle travel.

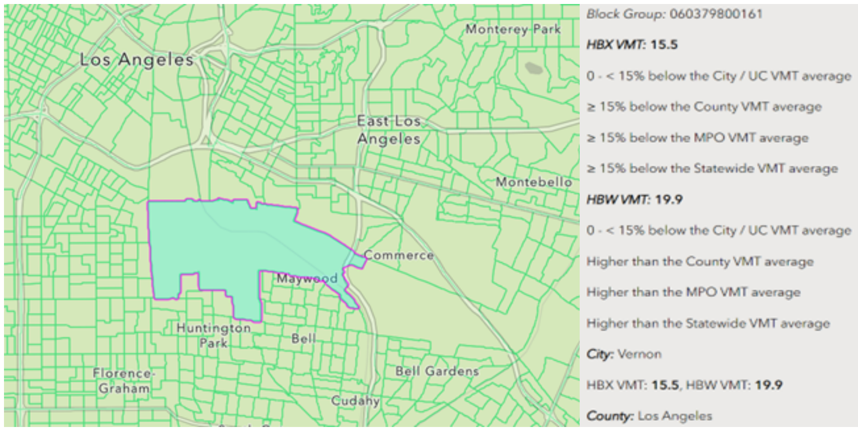

Figure 10. Block Group in an Urban Area on the Web Map

It utilizes GIS technology to map VMT data, enabling spatial analysis and visualization of vehicle travel across different areas, as shown in Figures 10 and 13. Users can compare VMT data across various regions or time periods to identify trends and changes in travel behavior, as seen in Figures 11, 12, 14, and 15.

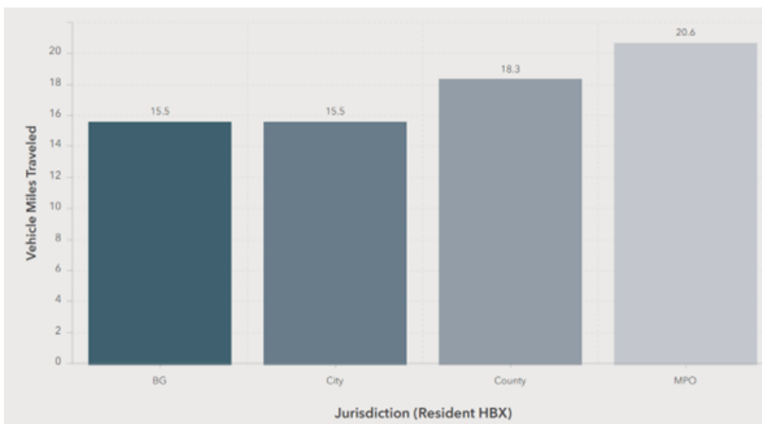

Figure 11. Comparison of Home Based VMT (urban area)

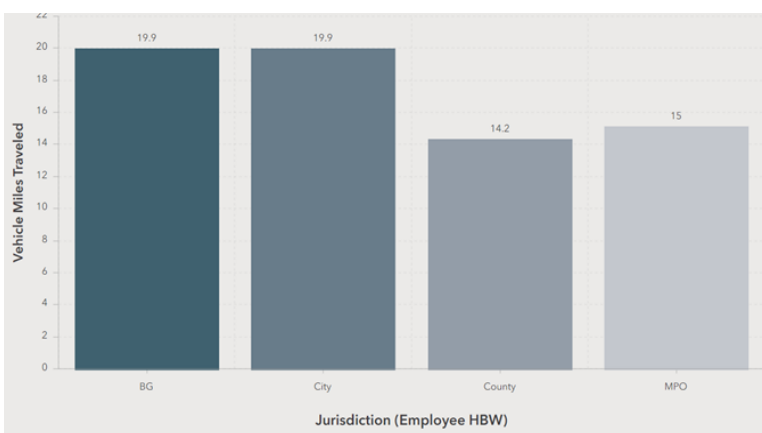

Figure 12. Comparison Home Based Work VMT (urban area)

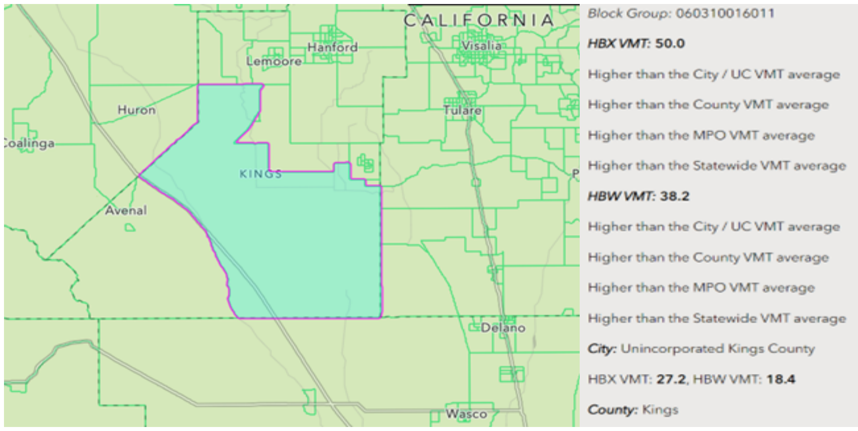

Figure 13. Block Group in a Rural Area on Web Map

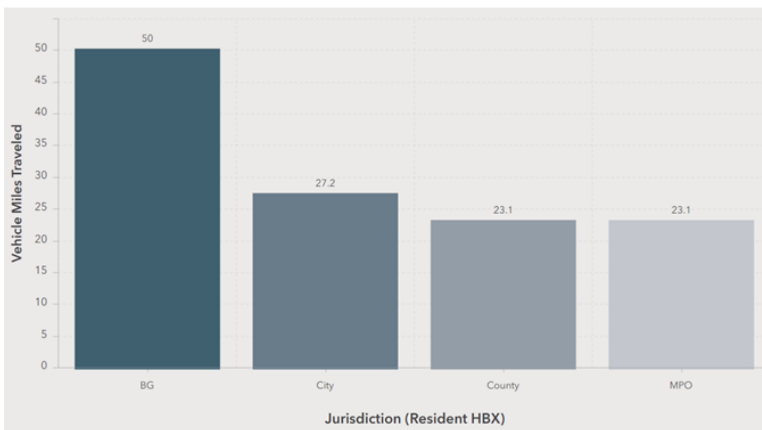

Figure 14: Comparison of Home Based VMT (rural area)

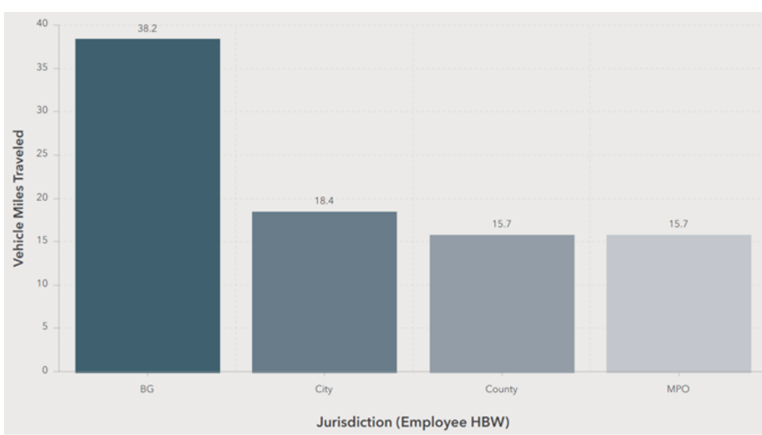

Figure 15. Comparison Home Based Work VMT (rural area)

3.4.2. Advantages and Limitations of VMT+

The following advantages and limitations are based on user experience.

Advantages

Detailed Insights: VMT+ provides detailed insights into VMT per capita at the state, regional, and local levels, down to the Census Block Group (CBG) level.

Comparative Analysis: VMT+ allows for comparisons of VMT per capita across different regions and the entire state, helping planners understand variations and make informed decisions.

Limitations

Static analysis: The VMT+ tool does not support dynamic scenario analysis where users can input hypothetical changes, such as new infrastructure projects, policy implementations, or economic shifts.

Data Limitation: The tool relies on StreetLight data from 2019, which may not fully reflect current travel conditions or recent changes in transportation patterns.

3.5 VisionEval

VisionEval[20] is a strategic planning tool that was originally developed by the Oregon Department of Transportation. It is designed to assist with long-range planning, especially in situations where funding is limited and future uncertainties need to be considered (Figure 16).

One of the key capabilities of VisionEval is its ability to forecast the interactions between various factors such as parking policies and transit use. It then calculates key metrics such as VMT, energy consumption, and GHG emissions.

VisionEval is particularly useful for scenario planning. State departments and Metropolitan Planning Organizations (MPOs) can use it to assess the impact of different policy options and guide growth towards a preferred future.

Additionally, VisionEval includes interactive tools for public participation. This allows stakeholders to understand the trade-offs and outcomes of different policy scenarios, fostering greater community engagement in the planning process.

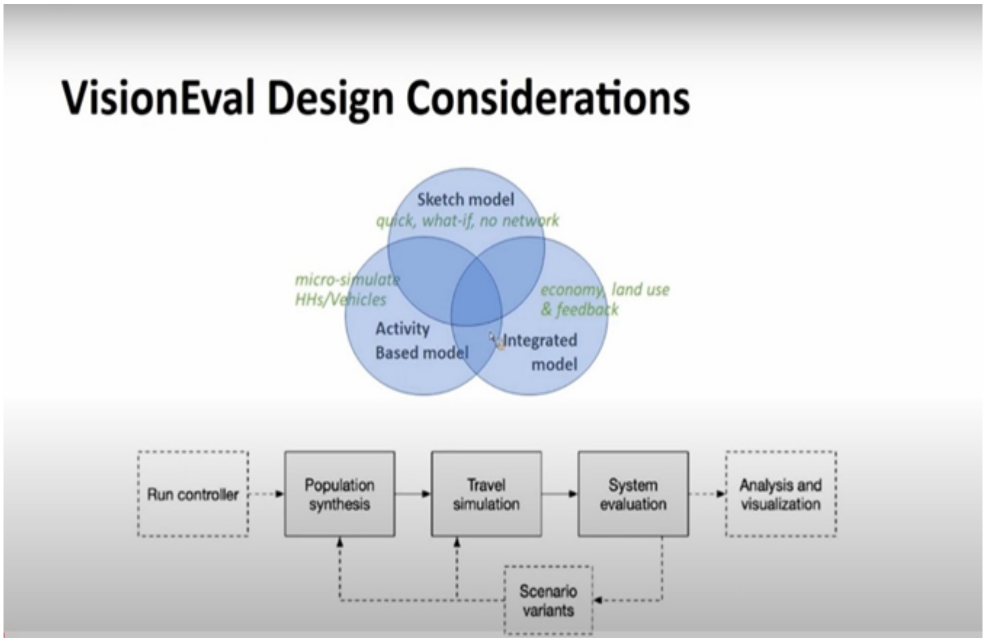

Figure 16. Design Consideration of VisionEval[21]

3.5.1 Project Scenario of VisionEval

The VisionEval's models and the underlying software framework are all written in R, a statistical programming language known for its open-source design and free libraries. This allows the models to be created in a plug-and-play fashion from modules that are distributed as R packages. The following codes were used in R console to run and extract the results:

```
rspm <- installModel("VERSPM")

rspm$run()

results <- rspm$results()

results$export()

query <- rspm$query("Full-Query")

query$run()

query$export()
```

This model has data default data from the Rouge Valley MPO in Oregon. After running the model, we exported the results into CSV files; to obtain the summary of the results, we ran a query. This tool calculates proportions, average, and per capita daily VMT of households with different income levels.

The VisionEval model requires various inputs to accurately simulate scenarios and their impacts. These inputs include the regional context, which considers demographics, income growth, fuel price, and future housing types. Local actions, such as parking fees, transit service, and bicycling infrastructure are also considered. Collaborative actions focus on strategies such as travel demand management, car sharing, and education on driving efficiency. The design of the community, including intelligent transportation systems, vehicle fuel economy, fuel types, and commercial fleet information, is another important input. Lastly, pricing factors such as pay-as-you-drive insurance, gas taxes, and road user fees are included. These diverse inputs allow VisionEval to provide a comprehensive analysis of vehicle travel and greenhouse gas emissions under various scenarios.

The various outputs generated by VisionEval can evaluate impacts on the environment, energy, finances, economy, and community. These are categorized by geographic levels and stored in three files: Azone.csv, Bzone.csv, and Marea.csv. Key outputs include daily miles traveled by different types of vehicles (vans, buses, rail, autos, light trucks, and heavy trucks) in various regions (urbanized, non-urbanized, and town areas) and for different purposes (household travel, commercial services). This comprehensive data helps understand transportation patterns and their impacts across different regions. In Table 5, the outputs related to VMT only are presented with the units and description.

This tool simulates household demographics and estimates their travel based on factors like income, age, location, gas prices, and vehicle information. It allows planners to test the impacts of various policies on vehicle travel and greenhouse gas emissions, providing insights into how different policy options might affect future community development and transportation investment. This helps guide strategic decision-making and fosters community involvement in the planning process. In essence, VisionEval is helping us understand how today's decisions can shape our future travel habits and environmental impact.

Table 5. VMT Metrics among the Outputs of VisionEval

Measure	**Units**	**Description**
MareaCarSvcAutoDvmtProp	Proportion	Average proportion car service vehicle DVMT in autos used by households residing in the Marea
MareaCarSvcLtTrkDvmtProp	Proportion	Average proportion car service vehicle DVMT in light trucks used by households residing in the Marea
MareaHouseholdCarSvcDvmt	Miles per day	Total DVMT in car service vehicles of persons in households and non-institutional group quarters in Marea
UrbanAveHhDVMT	Vehicle Mile Travel	Average household DVMT in urban area
UrbanBusDvmt	Miles per day	Daily vehicle miles traveled by Bus in the Urban area.
UrbanComSvcDvmt	Miles per day	Commercial service vehicle daily vehicle miles traveled attributable to the demand of households and businesses located in the urban area
UrbanHhDvmt	Miles per day	Daily vehicle miles traveled by households residing in the urban area
UrbanHhDvmt_MixNbrhd	Miles per day	Daily vehicle miles traveled by households residing in mixed use in the urban area
UrbanHhDvmtLowInc.100000.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area
UrbanHhDvmtLowInc.20000.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area
UrbanHhDvmtLowInc.40000.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area
UrbanHhDvmtLowInc.60000.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area
UrbanHhDvmtLowInc.80000.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area
UrbanHhDvmtLowInc.min.RVMPO	Miles per day	Daily vehicle miles traveled by low income (0to20K 2010$) households residing in the urban area

Measure	Units	Description
UrbanHvyTrkDvmt	Miles per day	Daily vehicle miles traveled by Heavy Truck in the Urban area.
UrbanLdvDmvtPerCap	Dvmt per person	daily vehicle miles traveled per person residing in the urban location.
UrbanLdvDmvtPerCapLowInc.100000.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDmvtPerCapLowInc.20000.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDmvtPerCapLowInc.40000.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDmvtPerCapLowInc.60000.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDmvtPerCapLowInc.80000.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDmvtPerCapLowInc.min.RVMPO	Dvmt per person	daily vehicle miles traveled per person in low income (0to20K 2010$) households residing in the urban area.
UrbanLdvDvmt	Miles per day	Sum of daily vehicle miles traveled by households residing in the urban area, commercial service travel attributable to the demand of urban area households and businesses, and on-demand transit van travel in the urban area.
UrbanRailDvmt	Miles per day	Daily vehicle miles traveled by Rail in the Urban area.
UrbanVanDvmt	Miles per day	Daily vehicle miles traveled by on-demand transit vans in the Urban area.

3.5.2 Advantages and limitations of VisionEval

Advantages

Scenario Planning: VisionEval allows planners to examine many possible future scenarios, which is especially important in an environment of limited funding and future uncertainties. It considers multiple variables, such as how much money people make, pricing rules, changes in vehicle technologies, and future fuel costs.

Detailed Analysis: VisionEval simulates the demographic attributes of every household in the region and combines this information with land use, travel demand management programs, household vehicles, and regional measures of road and transit service. Unlike most other models, VisionEval can check the impact of different rules and regulations, such as the effect of parking policies on transit use or different types of development on trip length.

Limitations

Data Requirements: The tool requires substantial data for accurate forecasting, which could be a limitation if the data quality is poor.

Complexity: Since this model is more detailed and complex, the users need more training to use this tool.

In summary, we performed an analysis of several VMT tools, primarily focusing on California-based options with the addition of VisionEval from Oregon. Through various project scenarios, the team evaluated the performance and assumptions underlying each tool, highlighting their strengths and limitations. This comprehensive comparison underscores the importance of selecting the appropriate tool for accurate VMT assessment, ultimately contributing to more effective transportation planning and environmental impact analyses.

4. Interviews

The previous chapters offered an analysis of a few different VMT tools that are used in California and across the United States, their advantages, and their limitations. This chapter offers an analysis of the perspectives of transportation professionals regarding VMT as a metric and VMT tools. The goal of this chapter is to provide additional context regarding the VMT tools from the perspective of professionals who use the tools regularly for project selection, planning, and evaluation, as well as policy development.

4.1 Methods and Goals of Conducting Interviews

4.1.1 Methods

Selecting Interviewees

An initial list of potential interviewees was provided by our project advisor, Julia Kingsley of the California State Assembly. Other interviewees were selected through the snowball method, where all interviewees were asked to recommend potential other interviewees at the end of each interview. All interviewees were transportation professionals such as planners, policy experts, modelers, and transportation engineers. Interviewees worked in various sectors including California's state government, regional transportation agencies, and private consulting firms. To the extent possible, we also selected interviewees in a way that various geographic areas or types of communities were represented. The list of interviewees and their affiliations can be found in Appendix A.

Interview Protocol and Administration

Interviewees were contacted via email, and all interviews were scheduled via email. Each interview lasted approximately 45 minutes, were conducted on Zoom, and recorded for transcription. Transcripts were generated using Sonix.ai software. Interviews were semi-structured with a list of pre-written questions and follow-up questions relevant to the discussion. We wrote the questions based on a preliminary analysis of VMT tools and a literature review. All questions were open-ended and focused on topics such as the purpose of VMT analysis, its technical limitations, the practical challenges of VMT tools and implementation, factors to consider in the development and implementation of VMT tools, best practices, and roles of local, regional, and state entities in the VMT sphere. The interview protocol and processes were approved by the San Jose State University Institutional Review Board (IRB). The list of questions can be found in Appendix B.

Analysis of Interview Data

Interview transcripts were coded using inductive and deductive reasoning. Key themes and sub-themes were identified during the analysis process. We also discussed how themes emerging from the interview data were related to findings from the analysis of tools or the literature.

4.1.2 Goals

Purpose of Conducting Interviews

The purpose of conducting interviews throughout this project was to understand the challenges and opportunities associated with VMT as a metric and existing VMT tools.

4.2 Interview Findings

4.2.1 VMT Tools and Metrics

Introduction

Analysis of data suggests that there is no consensus on what is considered best practice regarding VMT tools. There is a wide range of tools, but some tools, such as travel demand models (TDM), are more common than others. This section focuses on providing a brief overview of the purposes, advantages, and limitations of VMT tools discussed in interviews; opinions on what tools—if any—can be considered standard or best practices; interviewees' approaches to VMT based on jurisdiction; and discussion on using VMT as a metric for environmental indicators.

Different types of tools serve distinct purposes.

Interviewees discussed a variety of tools and their uses, advantages, and limitations. Although each tool provides a set of distinct advantages, it is important to consider the appropriateness of using a tool for a specific purpose, geography, or context. For example, a sketch tool or a simple VMT analysis Excel spreadsheet might be appropriate for a quick analysis to justify further study but may not be appropriate for drafting policy or for project selection/prioritization decisions. Similarly, a tool developed for urban areas might not be suitable for rural areas, especially if the tool does not allow for the consideration of contextual variables, such as land use features. This section summarizes the thoughts of transportation professionals related to the common tools used for VMT analysis in California:

1. The National Center for Sustainable Transportation California Induced Demand Calculator (NCST tool) is the state standard for VMT data collection. The tool utilizes elasticities to calculate VMT from class 1, 2, and 3 highways. This is beneficial for assessing congestion and changes in VMT on highways when roadway capacity is changed. However, many interviewees had critiques of the tool and its capabilities. First, the tool is only applicable to state highways, causing jurisdictions to create their own TDMs for other classifications of roadways. Second, several interviewees mentioned the lack of context-sensitivity within the tool. While the state says that the tool is not intended to be context-sensitive, interviewees call for more sensitivity so it can work for other road classifications and environments besides highly urbanized highways. For example, rural jurisdictions

mentioned that induced demand is very different in rural areas, limiting potential uses of the tool in those regions.[22] Rural regions have highways, but they might not be classified as class 1, 2, or 3 highways. The Caltrans Transportation Analysis Framework (TAF): Induced Travel Analysis lists all of the counties in California and whether the NCST Induced Travel Calculator can be used for induced travel analysis in each county.

2. TDMs assess both land use and transportation to assess traffic forecasting and induced demand. There are three- and four-step travel demand models. Accounting for land use is considered an advantage, as land use can be a contributing factor to higher VMT. Despite the advantage of land use inclusion, interviewees had critiques of TDM. First, TDMs tend to be for one particular region, excluding interregional travel. For example, a TDM for Riverside County may not account for travel from surrounding counties such as Orange County and Los Angeles County. Commuting across county lines for work is common across the state, thus emphasizing the importance of inter-regional travel demand modeling. Additionally, many models across the state are calibrated incorrectly, therefore producing incorrect results for many transportation projects. One interviewee stated, "Our travel demand model doesn't meet their [i.e., Caltrans'] requirements. They have a modeling checklist, and our model doesn't meet those requirements, nor do most models in the State. And also, the type of project we were analyzing, an express lane, couldn't be run through the NCST tool, which is their other recommended tool from Caltrans." The state is working on calibration standards, hoping to address this issue and increase model quality across the state.

3. Activity-based models (ABM) focus on a smaller scale than TDM. Activity-based models are intended for project-based or specific use and can include active transportation such as walking and biking. They are useful for varying travel modes, such as driving to a light rail station, taking light rail, and walking to the final destination. Activity-based models have been critiqued for being used in place of a TDM, which it is not intended for. For example, one interviewee explained, "If you're talking about people biking to a BART station and then walking, [then TDM is] not good for that. So, you may need an activity-based model for that. [Also,] transit modeling [is a] superior tool for anything involving VMT or roads."

4. Spreadsheet-based tools are simple tools that can be used in conjunction with TDM and land use models. Interviewees say that spreadsheet tools can be useful for short-term analysis, especially due to their simplicity and user-friendliness. Nonetheless, these tools are criticized for being overly simplistic. As stated by an interviewee, "I was cautioning everybody that a simple Excel tool cannot replicate the level of detail that goes into these travel demand models." The lack of detail means they're inappropriate to use on their own, especially for major decision-making, such as long-term planning, project selection, or prioritization.

5. VMT+ was developed by Fehr & Peers to fill gaps in state VMT regulations. This tool serves to combine streetlight data with residential development data to properly meet environmental impact analysis requirements.[19] Few interviewees discussed this tool; however, it does capture the whole state.

Opinions vary on which tool is considered best practice. With one state standard tool and different models in every jurisdiction, there is no consensus on one best practice tool for VMT mapping, modeling, and analysis. This is a significant finding and highlights the potential challenges of developing a consistent tool for the entire state. A large number of interviewees believe that we have not found clear best practices in VMT mapping and modeling. For example, when discussing best practices in VMT modeling, one interviewee mentioned: "I'm not aware of any [perfect tool]. I think we're all kind of struggling through this process. As much as I think our tool is cutting edge, [there are] limitations in addressing long-term induced demand."

Nonetheless, there were some preferences discovered during the interviews that professionals consider best practices given the tools we have now. For example, a few interviewees mentioned travel demand models as the best practice. One interviewee explained,

I think in terms of innovative practices, one of the things that many of the metropolitan planning organizations have done based on the state guidance from the [Caltrans Transportation] Analysis Framework is incorporate sort of that long-term induced demand effect feedback loop into their travel demand model so that they can capture potential additional land use that may occur based on the transportation improvement.

The NCST Calculator and Caltrans guidelines were also considered best practices. One interviewee considers the NCST tool a best practice for its "newer applications of how to really think about this work more from an economic perspective, in a supply and demand perspective versus a more traditional transportation modeling perspective." A few tools were mentioned as potential best practices: Rocky Mountain Institute Shift Calculator (RMI), Geospatial Economic Multimodal Transportation System (GEMS), activity-based modeling, and VMT+. Caltrans, regional transportation agencies, and private consulting firms are working to create best-practice VMT tools. Research projects such as this one are also important to improving VMT tools to suit the needs of various stakeholders.

A professional or agency's approach to VMT changes based on jurisdiction.

Our findings indicate that a professional or agency's approach to VMT changes based on jurisdiction. For example, professionals representing the state focused on selecting low VMT projects, while professionals from regional and county agencies and the private sector thought about VMT from a GHG and air quality standpoint under SB 375, and CEQA compliance respectively. The Sustainable Communities & Climate Protection Act (SB 375) requires MPOs to prepare sustainable community strategies (SCS) to reduce GHG emissions per CARB's target goals for their region.[23] This section summarizes the differences in options as it comes to approaches to VMT:

1. The state's approach to VMT focuses on reducing induced demand under the California Environmental Quality Act (CEQA) and choosing projects based on their reduced VMT. Caltrans works in conjunction with the California Air Resources Board (CARB) to reduce VMT for air quality and GHG emissions reduction. Under CEQA, "it's really about induced demand and trying to avoid induced demand," as stated by an interviewee. Regarding project selection, an interviewee explained, "When we select projects, we try to select projects that will reduce VMT as a whole." Additionally, the state is working on improving the validating process for transportation models to ensure the most accurate and useful models. Caltrans also updates state guidelines regarding VMT modeling, what VMT data is required for environmental impact analysis, and any other VMT-related standards.

2. Regional and county transportation agencies focus on VMT reduction for legal compliance. VMT estimations and mitigation efforts are required under CEQA. When asked why they are doing VMT analysis, one interviewee explained, "It's mainly because of CEQA for our major transportation projects; and then following Caltrans TAC and TAF guidelines." Agencies also are working to achieve state climate and air quality goals. VMT reduction and mitigation can help improve air quality and reduce GHG emissions, as VMT is closely tied to transportation emissions. As stated by an interviewee, "The number one reason that we do VMT analysis is in response to SB 375 and just the VMT being a proxy for GHG emissions."

3. Private consulting firms fill a different role than various government agencies but still must follow the same requirements. When asked why they're doing VMT analysis, one interviewee stated, "It's very simple; it's part of CEQA now." Consulting firms provide technical assistance for jurisdictions that may lack resources or technical support to ensure jurisdictions are following CEQA VMT guidelines. They can fill gaps by creating tools like VMT+ to help support local jurisdictions in their VMT reduction efforts. Private consulting can also focus on VMT mitigation and provide mitigation support.

Opinions are varied as to whether VMT is the best metric for environmental or climate analysis.

VMT was implemented as a metric to replace the old metric level of service (LOS). LOS focused on delay and congestion whereas VMT is a more versatile metric. VMT is often used for environmental assessment, particularly air quality and GHG emissions, and as a requirement under CEQA. As a result, VMT mitigation is often tied to GHG mitigation and reduction. However, interviewees expressed concern with VMT's ties to environmental monitoring. For example, a few interviewees mentioned the purpose of VMT once all personal vehicles in California become electric. One interviewee explained, I think maybe we're reaching a natural limitation of VMT as a metric. I think as our fleet turns over and cars become more efficient, the nexus between VMT and greenhouse gas emissions, that connection is going to lose its significance. So, I think the future of VMT is really looking for a different metric. The connection between VMT and GHG is going to be disentangled over time.

While interviews showed that VMT is considered a more versatile metric than LOS, its overarching purposes are unclear in the long run.

Several interviews explained that VMT mitigation and VMT numbers are often tied to receiving project funding. Projects that will produce a low amount of VMT or have solid VMT mitigation efforts are more likely to receive funding than those that report greater increases in VMT. Interviewees explained that higher VMT is often tied to GDP and is a sign of strong economic development. This contradicts state goals of reducing induced demand, which is often done through VMT reduction.

VMT and CEQA Exemptions

Although reporting significant VMT impacts and mitigation efforts of development projects are a requirement under CEQA, some projects can file for CEQA exemptions. Most importantly, use of CEQA exemptions for infill projects becomes easier under SB 743. When VMT is used a metric (as opposed to LOS), infill projects are far less likely to have significant transportation impacts. This can potentially encourage the construction of infill projects, such as much-needed housing projects within city limits.

Also, under SB 373, parking impacts of transit-oriented residential and mixed-use projects on an infill site are not considered significant environmental impact. This is because the promise of transit-oriented development is to discourage driving and facilitate the use of transit and the provision of housing and jobs with easy access to transit. Parking requirements are often considered counterproductive to the goal of reducing driving and increasing transit ridership.

4.2.2 Challenges and Limitations of VMT and SB 743

Introduction

While VMT is considered a more versatile metric than LOS, implementation of VMT under SB 743 is not without challenges and limitations. Analysis of the data suggests that a one-size-fits-all tool might not be an appropriate approach to addressing VMT in different jurisdictions. This section focuses on the challenges and limitations of implementing SB 743, challenges associated with data, discussion of using context when applying and creating VMT tools, and improving communication at all levels regarding VMT tools' guidelines and VMT tools' use.

Implementation of SB 743 is difficult under the existing state guidelines.

A large number of interviewees specifically mentioned the need for funding sources for SB 743 implementation. Implementing SB 743 is expensive, as models are costly to create and run, big data such as StreetLight and Replica require payment to gain access, and VMT mitigation is extremely costly. Larger jurisdictions expressed fewer financial struggles but mentioned concerns about smaller jurisdictions having enough resources to create models and maps for VMT analysis. One stated, “If the state has goals towards VMT reduction, then they need to fund it. They need to put research into it. And they need to have technical assistance or help to underfunded or under-resourced cities to implement [SB 743].”

Statewide tools for SB 743 are fairly limited, therefore jurisdictions create their own VMT tools and produce varied results. This makes it difficult to come to a consensus at the state level regarding the effectiveness of VMT tools. Each model is calibrated and validated differently. However, the state is working on model validation and calibration to improve model accuracy. Additionally, multiple interviewees explained that some models and tools will produce a different answer every time a model is run. For example, one interviewee stated:

Every single run is different because they're modeling a person making decisions, and that person might make this decision or that decision. Each model run that's done statistically so that it might happen this way or it might happen that way. And that means every trial, every model run provides a different answer.

As another interviewee explained, these models are run in good faith, but we are making large policy decisions based on tools that can potentially produce incorrect or misleading results.

Forecasting future VMT is a challenge with the tools and data currently available. Multiple interviewees explained that VMT tools are calibrated with pre-COVID data. Transportation patterns have changed as a result of the 2020 COVID-19 pandemic and some models still use this data in their VMT forecasts. Some interviewees mentioned that these models are also incorrect, but they are still used to predict future VMT. Additionally, we don’t know how transportation patterns will change in the future, so we never know how accurate our forecasts will be. One interviewee stated,

The forecasting of land use in the future where things are going to grow [is highly uncertain]. How much are they going to grow? That's where the error is. How are people going to work from home? Are they going to drive? What's their income? Or how many cars are they going to have available?

Access to quality data is limited.

VMT is a relatively new metric, making access to data challenging. While there is an existing body of research on VMT, interviewees mentioned that research is still fairly limited. This creates challenges when it comes to improving tools and metrics. As one interviewee mentioned, "I would say that the limitations tend to be that data is not typically that great. We have such high confidence that [even answering] just fundamental questions like how much VMT is generated in [a certain area] or on a given day is actually really hard." Data quality also varies greatly. Many tools generate incorrect results and existing data can be considered outdated. One interviewee stated, "in a lot of these situations, the VMT between the tool and the model is off by like seven, eight, ten times…. And the tool? The tool is like 8 to 10 times higher than what the model is showing." The cost of acquiring data from big data companies like Replica or Streetlight is prohibitive. This raises equity issues for jurisdictions with fewer resources.

Context is important when applying and creating VMT tools and metrics.

Most interviewees mentioned the need for local context to be taken into account when creating VMT tools. Every transportation corridor is different with different needs. Interviewees mentioned that many tools focus on urbanized areas, not taking into account the different transportation patterns of more rural or suburban regions. As one interviewee explained,

What works for a mid-sized metropolitan area is different than what might work in a rural area, which is different than what might work in a [dense] urban area. And so there needs to be multiple varieties and options that can be responsive to the local context and not try to impose one region's context into another region.

Interviewees believed that "a one-size-fits-all tool," such as the State's standard NCST tool, may not be appropriate for every jurisdiction. For example, rural jurisdictions mentioned that it cannot be used for their VMT analysis. Tools that are calibrated for a specific region and its transportation needs may be more impactful.

Bridging the gap in communication.

Some interviewees expressed a desire for more communication across the state regarding VMT. Since VMT is a relatively new metric, some jurisdictions are still struggling to implement VMT analysis and VMT tools in their region. Interviewees discussed an interest in sharing tools and information on SB 743 deployment across jurisdictions to help improve practices. The interviewees also expressed interest in more communication and collaboration with the state. One interviewee said,

I think one of the biggest things is that local and regional governments understand their region and local governments better than the state. They understand what context sensitivity exists at the ground level. And so, if we can better engage in dialogues with the State of California, so we're not both developing plans or metrics or tools in a vacuum that can go a long way to ensuring local and regional buy-in when the state is promulgating, like new rules or new tools and metrics.

There are committees such as the rural task force that work with the state to communicate their needs, but rural jurisdictions are still struggling to implement SB 743.

4.2.3 VMT mitigation

Introduction

VMT mitigation is various methods used to cause a net-zero or lower reduction in VMT produced by new development. The data suggests a strong correlation between climate and GHG emissions reduction goals. This section focuses on the methods used to mitigate VMT, the implications of mitigating VMT, and the challenges involved in implementing VMT mitigation.

VMT mitigation has a variety of methods and implications.

VMT mitigation has a strong connection with climate change mitigation. VMT is often used as a metric to measure GHG emissions reduction. State climate mitigation goals emphasize GHG emissions reduction in the transportation sector. Reducing VMT in turn reduces GHG emissions. VMT reduction is also tied to air quality. Cars produce other emissions besides greenhouse gases that can contribute to poor air quality. Some of these pollutants include nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOC).[24] VMT mitigation methods are varied and creative. Development impact fees can provide funds for mitigating VMT caused by a project. Bus lanes and tolls can be applied at the highway level. VMT banks can be used as a way of investing in VMT-reducing strategies, such as public transportation. Mitigated VMT can be collected into a bank to be purchased by projects or regions that are unable to mitigate their own VMT, similar to a GHG mitigation bank. All these methods can be combined for the most robust approach to VMT mitigation.

Mitigation in the context of a region was also discussed by a few interviewees. As different regions have different needs, mitigation can and should look different depending on the location. For example, exurban or rural areas that are highly dependent on metro areas for jobs, amenities, and services will naturally have higher VMT, which is more difficult to mitigate because induced demand is also different compared to an urban environment. Interviewees mentioned research on mitigation within different contexts is limited. An interviewee from a rural jurisdiction illustrated,

One of the biggest concerns or impetuses behind the rural induced demand study is kind of the policies move forward to not prioritize projects that significantly increase VMT. Many of the rural regions felt that they had projects that, based on the context of the corridor, aren't likely to induce VMT, but [when] a one-size-fits-all [approach] gets lumped into that, and then as we're applying for grant funding through the state, you know, those projects are being unfairly disadvantaged when really, it's like, oh, well, this is a strategic capacity improvement that doesn't induce significant demand. This is something we should invest in.

VMT mitigation is difficult to execute.

Several interviewees discussed how VMT mitigation is a challenge. The cost of mitigation is extremely high, according to the interviewees. A few interviewees said that VMT mitigation can cost more than a project itself. This delays projects and makes them difficult to complete. As one interviewee explained, "some of the mitigation costs on Caltrans projects is more than the project itself, and we're talking hundreds of millions and hundreds of millions of dollars, potentially." Furthermore, developers tend to want mitigation efforts to be directly on-site rather than in other parts of the same jurisdiction. Sometimes projects are developed in areas that already have low VMT and mitigation efforts would be better served in other areas, but developer preference prevents this from happening. For example,

On the land use side, people, especially the developers all want the mitigations to occur right at their development as opposed to like spending the money on a much more efficient VMT reducing project somewhere else. The same on the transportation side; people want the mitigations right there where it may not always make sense to have the mitigation there.

Communicating VMT and VMT mitigation to key decision-makers is also complicated. VMT and mitigation are complex subjects and assuring proper understanding before political decisions are made.

5. Conclusion and Recommendation

Evaluating different Vehicle Miles Traveled (VMT) tools for specific scenarios in Chapter 3 shows that each has its strengths and weaknesses. These tools help planners and policymakers estimate VMT and understand the impacts of transportation projects and policies. This project examined their consistency, context of use, data usage, complexity, ease of use, and potential for misuse or misinterpretation. By understanding these factors, users can choose the best tool for their needs and ensure accurate VMT assessments.

5.1 Summary of Major Findings

5.1.1 Consistency of the VMT Tools

Consistency in VMT tools refers to the reliability and spatio-temporal transferability of the results produced by the VMT tools, and this varies significantly based on their design and methodology. For example, using fixed elasticity values and conservative estimates in the NCST tool can lead to inconsistencies among scenarios developed in different geographical locations. On the other hand, a spreadsheet-based tool, WRCOG, relies on generalized criteria that result in consistent output when applied to that specific scenario. The OPR Site Check Map and VMT+ provide baseline and comparative insights, leading to consistent results within their limited scopes but cannot dynamically adapt to evolving scenarios. In contrast, VisionEval, with its detailed scenario planning capabilities, offers a high degree of consistency in exploring various futures, making it robust for policy impact analysis despite its complexity.

5.1.2 Context of Use

Users of VMT tools should select the most appropriate tool for their specific needs and context. Interviewees often stressed that context sensitivity is vital for accurate VMT analysis; therefore, one-size-fits-all tools, may not be appropriate for every region. The NCST Induced Travel Calculator is particularly suited for the initial planning stages of capacity expansion projects on major arterials. The WRCOG VMT Tool serves local jurisdictions, specifically in Riverside County, for initial VMT impact screening. The OPR Site Check Map is beneficial for preliminary site assessments across a variety of development projects. VMT+ excels in providing detailed VMT insights at granular geographic levels and is useful for comparative regional analysis. Conversely, VisionEval, designed for comprehensive scenario planning, is most suitable for strategic long-term planning, offering detailed and holistic insights into potential future outcomes.

5.1.3 Data Used in The Tools

The data used in these tools is a crucial factor in the accuracy and relevance of the results. The NCST Induced Travel Calculator relies on 2019 data and fixed elasticity values, which might not reflect current travel behaviors accurately. The WRCOG VMT Tool uses parcel-specific data but is geographically limited to Riverside County. The OPR Site Check Map provides baseline VMT data without post-construction impact analysis, limiting its depth. In contrast, VMT+ utilizes StreetLight data from 2019, offering detailed yet static insights. Lastly, VisionEval requires substantial and detailed data inputs, including demographic, economic, and transportation metrics, making it data-intensive but highly informative for comprehensive planning and scenario analysis.

5.1.4 Model Complexity

The complexity of the models used in various VMT tools varies, impacting the usability and the depth of analysis they can provide. The NCST Induced Travel Calculator and WRCOG VMT Tool are relatively straightforward and user-friendly, making them suitable for initial assessments. The OPR Site Check Map and VMT+ are also user-friendly but provide limited depth in their analysis. In contrast, VisionEval is the most complex of the tools, requiring significant training and extensive data inputs. However, this complexity allows VisionEval to offer detailed scenario planning and comprehensive analysis capabilities, making it a powerful tool for long-term strategic planning despite its demanding requirements.

5.1.5 Ease of Use

Usability is a critical factor in the practical application of these tools. The NCST Induced Travel Calculator and WRCOG VMT Tool are designed with user-friendly interfaces, making them accessible to planners and policymakers. Additionally, the VMT+ and OPR Site Check Map are highly intuitive and beneficial for users from various backgrounds. Conversely, VisionEval requires more expertise and data handling capabilities, which can limit its accessibility to users without specialized training or resources.

5.1.6 Loopholes in The Tools

Potential for exploitation or loopholes exists in some of the VMT tools. The NCST Induced Travel Calculator might potentially produce misleading results due to its conservative estimates and fixed elasticity values. The results from the WRCOG VMT Tool could be misinterpreted due to its generalized screening criteria and single APN limitation. The lack of post-construction impact assessments by OPR Site Check Map might overlook significant VMT changes. VMT+ provides static analysis, potentially ignoring recent or future shifts in travel patterns. In contrast, VisionEval minimizes loopholes through its detailed and comprehensive scenario analysis, though its complexity could lead to misinterpretation of the findings. Overall, understanding these vulnerabilities helps ensure the tools are applied appropriately and effectively.

Through the analysis of test results and the process of interviewing transportation professionals under various jurisdictions, types of professions, and transportation needs, we have gained a better understanding of the different tools used to analyze VMT. As a result of the varying population sizes and geographies in California, different regions have distinct needs. Our findings show that there is no consensus on what tools or methods are considered best practices in VMT tools use. VMT reduction and SB 743 are challenging to implement, as VMT is a relatively new metric. Lack of model accuracy and consistency, shortage of quality data, limited access to context-sensitive tools, and a shortage of communication between different jurisdictions and the state has made SB 743 implementation difficult at all levels. VMT mitigation is generally a challenge due to its cost, complexity, and stakeholder intervention.

5.2 Recommendations

5.2.1 State actions

Help provide access to accurate, validated data for creating and inputting into models and tools.

The state is already working toward model validation standards to ensure accurate modeling practices across the state. Working with jurisdictions to validate and/or create their own models can ensure they meet state standards and produce the best possible results. Providing access to data via funding streams for accessing big data, creating a state VMT data bank, or funding new research can help improve model quality across the state.

Help create tools that can be more context sensitive.

Many interviewees expressed a need for tools to adapt to their local context in order to properly assess VMT. State-sponsored research can help pilot programs for creating and testing new tools in different regions to understand how local context impacts different transportation needs. Additionally, researching VMT mitigation methods and their impacts can help reduce the cost of VMT mitigation and make mitigation efforts more accessible. Providing support for locally developed, context sensitive tools can ensure that jurisdictions are making the best tools and models for their needs.

5.2.2 Other actions

Strengthen dialogue between jurisdictions to share information and tools.

The transportation field and VMT estimation and mitigation are an evolving sphere, emphasizing the importance of cross-jurisdictional communication. Regions with various needs can collaborate and share tools and information to create robust tools that work for their jurisdictions. Exchanging information can lead to innovation and a better understanding of best practices in VMT tools analysis and use.

Use an integrated approach to VMT analysis.

Using an integrated approach to VMT analysis can make for a more context-sensitive approach to using VMT tools. For an in-depth analysis, the user needs to choose tools carefully. There is no one tool that perfectly fits all situations. The user can customize their own tool based on the context of an area. At the initial stage of planning, one can use tools such as VMT+, which can assess the current situation and make comparisons of a location, and then use an integrated approach. An integrated approach considers multiple factors (land use development, transportation infrastructure development, changes in policies, etc.) that influence VMT. This creates for a more thorough, context-based approach for assessing what factors may influence VMT.

5.3 Direction to Future Studies

In this study an evaluation of various VMT tools is presented. Each tool has its unique strengths and weaknesses, which impact how effectively planners and policymakers can estimate VMT and understand the potential effects of transportation projects and policies. By examining these tools, the report provides valuable insights into selecting the most appropriate tool for specific needs. To build on these findings and address the challenges identified, this section outlines the direction for future studies which can explore several key areas to enhance the effectiveness and applicability of VMT tools.

Enhancing Model Accuracy and Consistency

Future research should prioritize improving the accuracy and consistency of VMT tools. This can be achieved by developing and validating new methodologies that consider dynamic changes in travel behavior and land use. Additionally, incorporating more recent data and flexible elasticity values will help in creating more reliable models that can adapt to various scenarios.

Developing Context-Sensitive Tools

As the report highlights, one-size-fits-all tools may not be suitable for every region. Future studies should explore the creation of context-sensitive tools that can be customized to the unique characteristics of different areas. This includes understanding local travel patterns, land use, and demographic factors. Pilot programs and state-sponsored research can play a crucial role in testing and refining these tools.

Improving Data Quality and Accessibility

Accurate and up-to-date data is crucial for effective VMT modeling. Future research should focus on enhancing data collection methods and creating comprehensive data banks that are easily accessible to planners and policymakers. This includes leveraging big data and using technologies to gather real-time travel information. Additionally, efforts should be made to ensure that all regions have access to high-quality data, possibly through state funding and support.

Promoting Cross-Jurisdictional Communication

To promote innovation and best practices in VMT analysis, future studies should emphasize the importance of communication and collaboration between different jurisdictions. Creating platforms for information exchange and tool sharing can help regions learn from each other's experiences and develop more effective VMT assessment methods.

Developing Optimal Integrated Approaches to VMT Analysis

Future research should help develop optimal integrated approaches to VMT analysis that considers multiple influencing factors such as land use, transportation infrastructure, and policy changes. Studies should explore how different tools can be combined to provide a comprehensive assessment of VMT impacts. This approach will ensure a more thorough and context-sensitive evaluation, helping planners make informed decisions that align with regional transportation and development goals.

Addressing VMT Mitigation Challenges

Given the complexities and costs associated with VMT mitigation, future studies should investigate innovative and cost-effective mitigation strategies. This includes researching the impacts of various mitigation methods and identifying best practices that can be implemented across different contexts. Additionally, developing guidelines and tools to support VMT mitigation efforts will help make these strategies more accessible and effective for jurisdictions facing diverse challenges.

By focusing on these areas, future research can significantly enhance the tools and methodologies used for VMT assessment, leading to better-informed transportation planning and policy decisions in California.

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Appendix A

Elasticities of Vmt with Respect to Highway Capacity Increases

Table A.1 Parameter Estimates from Induced-Travel Regression Models Cited in Noland and Hansen, 2013

		Fixed effects			Elasticities	
Reference	Scale	Area	Time	Causality	Short-term	Long-term
Models with aggregate data: all with lane mile elasticities						
(Hansen et al. 1993)	Facility	X			0.2–0.3	0.3–0.4
(Hansen, Huang 1997)	County	X	X	Lag model	0.21	0.6–0.7
(Hansen, Huang 1997)	Metro	X	X	Lag model	0.19	0.9
(Fulton et al. 2000)	County	X	X	Granger test	0.2–0.6	
(Noland, Cowart 2000)	Metro	X	X	Instrumental variable model	0.28	0.90
(Noland 2001)	States	X	X	Distributed lag model	0.2–0.5	0.7–1.0
(Cervero, Hansen 2002)	County			Simultaneous equations		
VMT dependent	County	X	X	Granger test	0.59	0.79
LM dependent	County	X	X	Granger test	0.33	0.66
(Cervero 2003)						
Direct	Facility	X	X	4-element path model	0.24	0.81
Indirect	Facility	X	X	4-element path model	0.10	0.39
(Duranton, Turner 2009)	States	Cross-sectional		Instrumental variable model	0.92–1.32	
(Hymel, Small, & VanDender 2010)	States	X	X	3-stage least squares	0.037	0.186
(Rentziou, Gkritza, & Souleyrette 2011)	States	Random effects		Error component model	Urban, 0.256	Rural, 0.068

Models with disaggregate

Data	Scale	Type of elasticity	Elasticities
Strathman et al. (2000)			
Direct	Corridor	Lane-miles	0.29
Indirect	Corridor	Lane-miles	0.033
Barr (2000)	Corridor	Travel time	−0.3 to −0.5

Table A.2 Long-term Elasticity Estimates Using Travel-Demand Models Cited in Noland and Hansen, 2013

Model	Method	Scale	Type	Long-term Elasticities
DeCorla-Souza (2000) No Feedback	Four step	Facility	Travel time	-0.7
Feedback	Four step	Facility	Travel time	−1.1
Rodier et al. (2001) 25 years	MEPLAN	Metro	Lane-miles	0.8
50 years	MEPLAN	Metro	Lane-miles	1.1

Table A.3 Change in VMT/ Change in Lane Miles

Study	Study location	Study year(s)	Results: Change in VMT/ change in lane miles	Results: Time period
Duranton and Turner, 2011	U.S.	1983 - 2003	1.03	10 years
Cervero, 2003	California	1980 - 1994	0.1	Short term
			0.39	Long term
Cervero and Hansen, 2002	California	1976 - 1997	0.59	Short term (1 year)
			0.79	Intermediate term (5 years)
Noland, 2001	U.S.	1984 - 1996	0.30 to 0.60	Short term
			0.70 to 1.00	Long term
Noland and Cowart, 2000	U.S.	1982 - 1996	0.28	Short term
			0.9	Long term
Hansen and Huang, 1997	California	1973 - 1990	0.2	Short term
			0.60 to 0.70	Long term – counties
			0.9	Long term – metro areas

From Handy and Boarnet, 2014

Table A.4 Review of Induced Travel Elasticities

		Lane km elasticity		Travel time elasticity**		
Paper	Data used	Short-term*	Long-term*	Short-term	Long-term	Improvement type
Cervero, Hansen 2001	32 CA counties	0.56	0.78			Widening
Hansen, Huang 1997	CA counties	0.3	0.68			Not specified
Hansen, Huang 1997	CA metro level	0.5	0.94			Not specified
Marshall, 1996	TTI Congestion Study	-	.76 - .85			Not specified
Rodier, et al 2001	Sacramento regional	-	.8 - 1.1			New road and widening
Strathman, et al 2000	Nationwide NPTS data	-	0.29			Not specified
Cervero, 2001	24 CA corridors	0.29	0.64			Widening
Fulton, et al 2000	MD, VA, NC, DC counties	.3 - .5	.47 - .89			Not specified
Hansen, et al 1993	CA highway	.2 - .3	.3 - .6			Widening
Mokhtarian, et al 2000	CA highway	0.0	-			Widening
Noland 2001	State-level	.3 - .68	.7 – 1.0			New road and widening
Noland 2001	State -level	-	.5 - .8			New road and widening
Noland, Cowart 2000	Nationwide metro level	-	.81 – 1.0			Not specified
Noland, Cowart 2000	Nationwide metro level	0.3	-			Not specified
Cervero 2002	24 CA corridors	0.1	0.39			Not specified
Hansen, et al 1993	California county	.46 - .5	-			Widening
Hansen, et al 1993	California metro level	.54 - .61	-			Widening
Goodwin 1996	Petrol price evaluation			-0.5	-1.0	Not specified
Barr 2000	Nationwide NPTS data			-0.3	-0.4	Not specified

Overall	Range	.0 - .68	.29 – 1.1	-.3 – -.5	-.4– -1.0
	Average	0.35	0.69	-0.4	-0.7
Widening projects	Range	.0 - .58	.45 - .78		
	Average	0.36	0.62		

*Depending on the study, "short-term" is generally one to five years; "long-term" is generally five to ten years.

**Travel time elasticities compare induced traffic to savings in travel time. An elasticity of -.5 means that a reduction in travel time of 10% will increase traffic volumes by 5%.

From Currie and Delbosc, 2010, Citing Schiffer et al., 2005

Appendix B

Interviewees and Affiliations

Table B.1 Interviewees and Affiliations

Heading	Year
Jeanie Ward-Waller	Formerly Caltrans
Darwin Moosavi	California State Transportation Authority (CalSTA)
Jim Damkowitch	DKS Sacramento
Tim Haile	Contra Costa Transportation Authority (CCTA)
Stephanie Hu	Contra Costa Transportation Authority (CCTA)
Matt Kelly	Contra Costa Transportation Authority (CCTA)
Donald Hubbard	GHD
Kristine Cai	LSA Associates
Ambarish Mukherjee	LSA Associates
Bhudpendra Patel	Association of Monterey Bay Area Governments (AMBAG)
Eric Sundquist	California Department of Transportation (Caltrans)
Ron Milam	Fehr & Peers
Chris Ganson	California Air Resources Board (CARB)
Annie Nam	Southern California Association of Governments (SCAG)
Hsi-Hwa Hu	Southern California Association of Governments (SCAG)
Warren Whiteaker	Southern California Association of Governments (SCAG)
Chris Gray	West Riverside Council of Governments (WRCOG)
Egon Terplan	Formerly SCG, University of California Berkeley
Rob Ball	Kern Council of Governments (Kern COG)
Ben Raymond	Kern Council of Governments (Kern COG)
Julio Perucho	LA Metro
Mike Woodman	Nevada County Transportation Commission
Lisa Zorn	Bay Area Metropolitan Transportation Commission (MTC)
Krute Singa	Bay Area Metropolitan Transportation Commission (MTC)

Appendix C

Prompts for the research questions during the interview

- Can you tell us about your experience working with VMT tools development or use?
- Why are you doing VMT analysis? In other words, what are the common uses of VMT Analysis Tools?
- What are the technical limitations and practical challenges involved with the development and use of VMT mapping and modeling tools?
- What are the factors that we should consider in the development and implementation of VMT tools and metrics?
- Are you aware of any innovative VMT tools or best practices of VMT modeling?
- How can the State of California help local and regional entities accurately measure the VMT impacts of transportation projects?
- What specific role can local and regional organizations play to accurately measure and consider the VMT impacts of transportation projects?
- What are the advantages of common existing VMT metrics and tools?
- What factors should inform the development of future VMT estimation tools?
- In your opinion, what would be some of the future applications of VMT analysis or VMT modeling?
- Is there anything else you would like to add?
- Is there anyone else we should contact regarding VMT?
- Can you share any helpful materials such as links to your VMT tools, guidelines, reports suggesting the use of specific tools, state or federal mandates you are required to follow, etc.?

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