Leaving Level-of-Service Behind:
The Implications of a Shift to VMT Performance Metrics for California's Built Environment

by

AMY E. LEE
Bachelor of Science (University of California, Davis) 2011

THESIS
Submitted in partial satisfaction of the requirements for the degree of
MASTER OF SCIENCE
in
TRANSPORTATION TECHNOLOGY & POLICY
in the
OFFICE OF GRADUATE STUDIES
of the
UNIVERSITY OF CALIFORNIA
DAVIS

Approved:

Dr. Susan L. Handy, Chair

Dr. Lisa Aultman-Hall

Dr. Alissa Kendall

Committee in Charge

2017

Amy E. Lee
March 2018
Transportation Technology & Policy

Abstract

Concern about climate change has led to policies in California that aim to decrease greenhouse gas (GHG) emissions from transportation. Although these policies mostly promote technological innovations, some policies aim to reduce GHG emissions by reducing the amount of driving, measured in vehicle miles traveled (VMT), through land use and transportation planning. The focus on VMT reduction represents a dramatic shift for the land use and transportation planning fields, which have traditionally prioritized reductions in vehicle delay, measured as level of service (LOS). California has taken the bold step to replace LOS with VMT as the metric of transportation impact in the environmental review process for land use and transportation plans and projects under the California Environmental Quality Act (CEQA). This study compares these two metrics – VMT and LOS – and their implications for three land use projects in Davis, California. We compare the LOS impacts analyzed in the environmental impact reports for the projects to forecasted VMT impacts that we quantify using several available VMT estimation models. Our analysis of LOS mitigation shows how the CEQA process per se impacts the built environment, often in ways that increase vehicle capacity and thus VMT. We find that a switch to VMT metrics may lead to streamlining for projects that reduce travel demand because of their location or design, whereas LOS metrics have led communities to build expensive, capacity-increasing mitigations measures to ease vehicle delay. Finally, we show that the vehicle capacity constructed to mitigate LOS may contravene the goals and aspirations of many communities in California, as well as the state's goals for GHG reductions, and is unlikely to solve the congestion problem caused by misplaced land use development.

Keywords: vehicle miles traveled, level of service, California, performance metrics

Table of Contents

1. Introduction

Several states across the U.S. have enacted policies to reduce greenhouse gas (GHG) emissions, including policies aimed at reducing emissions, from transportation. Many of these policies promote technological innovations, but some state and local policies also aim to reduce GHG emissions from transportation by reducing the amount of driving, measured in vehicle miles traveled (VMT), through land use and transportation planning.

Most notably, California Assembly Bill 32 of 2006 led to the creation of statewide targets for reducing GHG emissions, created a statewide cap-and-trade market for GHG emissions, and engendered a series of other policies and funding programs to help the state achieve its goals. In 2008, California Senate Bill 375 established targets for reducing GHG emissions in part by reducing VMT through coordinated land use and transportation planning at the regional level. Metropolitan Planning Organizations (MPOs) in California must demonstrate that their federally-required regional transportation plans and state-required Sustainable Communities Strategies will meet regional targets for VMT and GHG reductions. Moreover, because cities and counties hold authority to make land use decisions, the state enacted grant programs that encourage local implementation of the regional land use and transportation plans.

Other western states soon followed California in enacting policies to reduce VMT. Washington enacted House Bill 2815 in 2008 that aimed to reduce statewide passenger VMT, and Oregon's House Bill 2001 (2009) and Senate Bill 1059 (2010) established targets to reduce GHG emissions in part by efficient land use planning. On the other coast, Virginia's House Bill 2 (2014) established a statewide funding program that uses multi-modal accessibility, GHG emissions reductions, and "transportation efficient land use" (among other criteria) in project selection (VDOT 2015).

This focus on VMT reduction represents a dramatic shift for the land-use and transportation planning fields, which have traditionally prioritized reductions in vehicle delay, measured by level of service (LOS). The concept of measuring the carrying capacity and flow rate on transportation facilities was established in the first edition of the Highway Capacity Manual published in 1950 (Roess 1984). LOS was formally defined in the 1965 Highway Capacity Manual as a "qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating costs." LOS is measured with letter grades, from A to F, where F describes a "failure" of transportation system operations (Roess 1984). Simply put, it measures the amount of vehicle delay for a given time and location.

In California, LOS has been the primary measure of transportation-related "environmental impacts" for land development projects under the California Environmental Quality Act (CEQA) – the state-level equivalent to the U.S.'s National Environmental Policy Act (NEPA) – since at least the early 1970s (City of Orange v. Valenti 1974). CEQA has a broad reach in the development process, as it requires impact analyses and mitigations for those impacts for any development project requiring "discretionary action" (i.e. rather than ministerial actions of, say, issuance of building permits) and has arguably "had as much influence on land use patterns in California as any planning law" (Fulton and Shigley 2012). Nationally, a focus on LOS is implicit throughout the Federal Highway Administration's technical advisory for preparing environmental impact statements under NEPA. "Alleviating traffic congestion" is offered as an example of "project purpose and need," and improving traffic flow rate is listed as a potential energy conservation measure (FHWA 1987).

This practice met its first official challenge in 2013 when California's Senate Bill (SB) 743 triggered the removal of vehicle delay as an indicator of environmental impact for CEQA analyses. SB 743 (and the accompanying guidelines authored by the California Governor's Office of Planning and Research [OPR]) proposes to replace LOS with VMT as "the most appropriate metric of a project's potential transportation impacts" (Public Resources Code § 21099(b)(2), OPR 2016). OPR's Technical Advisory on Evaluating Transportation Impacts in CEQA: Implementing Senate Bill 743 ("technical advisory") offers detailed (though non-binding) suggestions for evaluating the VMT associated with land use development and transportation projects. CEQA analysis generally identifies both LOS-related and non-LOS-related transportation impacts; under SB 743, analysis of VMT impacts will replace the LOS-related impacts, though other transportation impacts – such as impacts to emergency access – will continue to be analyzed in the same way.

Though the revised CEQA Guidelines and accompanying technical advisory are still in the adoption process, three bold jurisdictions have already introduced VMT-based metrics and thresholds (standards for performance) in their CEQA analyses. The City of Pasadena adopted VMT-based thresholds in 2014 as an addition to its existing LOS-based thresholds (City of Pasadena 2015). San Francisco and Oakland replaced LOS-based thresholds with VMT-based thresholds in their respective transportation impact analysis guidelines in 2014 (San Francisco Planning Department 2016, Oakland City Planning Commission 2016).

The shift to VMT metrics raises many questions for CEQA analyses and the planning field more broadly. An important practical question is how to estimate project-level VMT. Many CEQA analyses – and, of course, regional transportation plans – use regional travel demand models to estimate the transportation and GHG implications of land use projects. However, these models are resource intensive and often require multiple runs to produce information that is useful at the scale of individual projects (Castiglione et al 2003). Analysts can instead make use of one of a number of available "sketch" VMT estimation methods. These methods are more efficient for local plans and individual projects, though they have notable limitations and enjoy little consensus regarding which is most accurate (Cervero 2006, Shafizadeh et al 2012, Zhao & Kockelman 2002).

The shift to VMT metrics also raises more fundamental questions for communities. One question has to do with VMT thresholds: how much VMT can a project add to a community before it is too much? Another important question is the degree to which replacing LOS with VMT within the environmental review process will change the types of environmental mitigations adopted for land development projects and perhaps even the types and location of land development projects that are proposed. Our goal in this analysis is to explore these questions with three recent development projects in Davis, California.

2. Review of Policy, Literature, and Methods

2.1. California Environmental Quality Act

The California Environmental Quality Act (CEQA) was a state-level response to the 1969 passage of the National Environmental Protection Act (NEPA) (California Natural Resources Agency 2014). The California State Assembly formed a legislative committee, which drafted *The Environmental Bill of Rights* in 1970. This *Bill of Rights* outlined a "California counterpart to NEPA" (California Natural Resources Agency 2014). The California legislature passed CEQA statute in 1970, and it was signed into law by then-Governor Ronald Reagan later the same year.

CEQA's overarching goal is to "develop and maintain a high-quality environment now and in the future, and take all action necessary to protect, rehabilitate, and enhance the environmental quality of the state" (Public Resources Code [PRC] § 21001). CEQA further aims to "provide the people of the state with clean air and water, enjoyment of aesthetic, natural, scenic, and historic environmental quality," to "prevent elimination of fish or wildlife species due to [hu]man's activities," to ensure "provision of a decent home and suitable living environment for every Californian," and to "require governmental agencies… to consider long-term benefits and costs" of actions that affect the environment (PRC § 21001).

The CEQA Process

CEQA accomplishes its goals through an environmental review process for both public and private "projects". Projects as defined by CEQA are activities that "receive some discretionary approval" (California Natural Resources Agency 2014). "Projects" range from "the approval of a general plan to the issuance of grading permits for major projects" (Fulton & Shigley 2005). Most land use development projects require approval by a public agency, though certain projects are "categorically exempt" from CEQA review. These include minor alterations to existing facilities and structures, construction of four or fewer dwelling units, construction of "small structures" (less than 10,000 square feet), "minor alterations to land" (e.g. change in landscaping, addition of bicycle lanes to existing right-of-way), minor land divisions, and certain urban infill development projects (California Code of Regulations [CCR] Title 14, Article 19, § 15300 – § 15333).

Projects that are subject to CEQA are assessed for any "significant" environmental impacts that they may cause. Lead agencies – in most cases local governments – hold discretion to "develop and publish thresholds of significance that the agency uses in the determination of the significance of environmental effects" (PRC § 15064.7). Put simply, each local government adopts its own "thresholds of significance" in accordance with its unique context.

Lead agencies prepare a "negative declaration" for projects found to have no significant environmental impacts. They prepare a "mitigated negative declaration" if all project impacts can be mitigated to a less-than-significant level. Lead agencies must prepare an environmental impact report (EIR) when there is "substantial evidence" that the project may have a "significant effect" on the environment (PRC § 21080). See Figure 1 for illustration of the CEQA process.

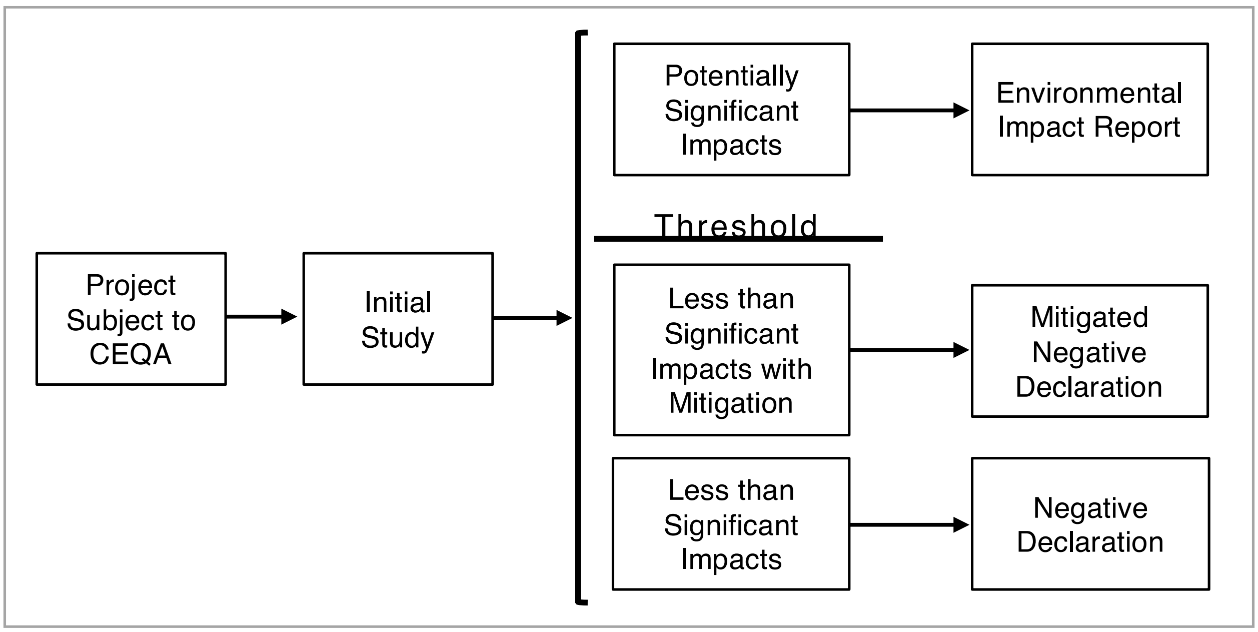

Figure 1: California's Environmental Review Process. Adapted from Fulton & Shigley 2005.

In the case that a project creates significant environmental impacts, lead agencies "shall mitigate or avoid" those impacts "whenever it is feasible to do so" (PRC § 21002.1). Mitigation measures may be deemed infeasible because of "economic, social, or other conditions", and the project "may nonetheless be carried out or approved at the discretion of a public agency if the project is otherwise permissible under applicable laws and regulations" (PRC § 21002.1). If mitigation measures are found to be infeasible, the lead agency can adopt a "statement of overriding considerations" – the "escape valve" that allows lead agencies to approve projects despite significant environmental impacts (Fulton & Shigley 2005).

Significance Thresholds – how much is too much?

Under CEQA, a "threshold of significance" is necessary to determine if an impact generated by the project is "significant" or not. Thresholds of significance are "identifiable quantitative, qualitative or performance level of particular environmental effect[s]" and are "adopted by ordinance, resolution, rule, or regulation … and must be supported by substantial evidence" (14 CCR § 15064.7). Significance thresholds are adopted by lead agencies for "general use" in their environmental review process – thresholds apply to all potential proposed projects, rather than being tailored to individual proposed projects or areas (14 CCR § 15064.7).

Thresholds of significance "play a critical role" in determining the extent of projects' review under CEQA (14 CCR § 15064). Restrictive thresholds engender more significant impacts and thus more EIRs and mitigation measures; permissive thresholds engender fewer significant impacts, mitigation measures, and more negative declarations. The restrictiveness of thresholds affects the practical, political, and financial feasibility of projects: preparation of EIRs, mitigation of impacts, and defense of legal challenges can all be cost- or politically-prohibitive elements of the CEQA process (Rothman 2011).

The state provides guidance on the setting of thresholds of significance. The CEQA statute requires OPR to "prepare and develop proposed guidelines for the implementation of [CEQA] by public agencies" (PRC § 21083(a)). The statute requires these "CEQA Guidelines" to "specifically include criteria for public agencies to follow in determining whether or not a proposed project may have a 'significant effect on the environment.'" (PRC § 21083(b)).

CEQA's reference to LOS, traffic congestion, and vehicle delay have resided within these specific criteria in the Guidelines – primarily the "Environmental Checklist" in the Guidelines' much-used Appendix G (14 CCR § 15063, App. G). The environmental checklist asks lead agencies two questions about a project's impacts to vehicle delay. Specifically, it asks if the project would:

> (a) "Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections)? and
> (b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?"

Lead agencies have been required to show how every project – infill development, bicycle plans, transit projects, et cetera – impacts vehicle traffic and congestion. LOS can calculate increased vehicle traffic from the addition of transit vehicles on roadways, as was the case of the Van Ness Avenue bus rapid transit project in San Francisco, and can thus indicate that transit causes "significant" environmental impacts (Jaffe 2014).

Enter Senate Bill 743.

SB 743 was authored by State Senator Darrell Steinberg and signed by Governor Jerry Brown in 2013. Among other things, SB 743 adds Chapter 2.7, "Modernization of Transportation Analysis for Transit-Oriented Development", to Division 13 (the "CEQA Guidelines") of the California Public Resources Code. Chapter 2.7 directs OPR to "develop … revisions to the guidelines … establishing criteria for determining the significance of transportation impacts" (PRC § 21099(b)(1)). The criteria in the revised guidelines "shall promote the reduction of greenhouse gas emissions, the development of multimodal networks, and a diversity of land uses," and "may include, but are not limited to, vehicle miles traveled, vehicle miles traveled per capita, automobile trip generation rates, or automobile trips generated" (PRC § 21099(b)(1)). Additionally, the bill text states that "automobile delay, as described solely as level of service or similar measures of vehicular capacity or traffic congestion, shall not be considered a significant impact on the environment" (PRC § 21099(b)).

With this statutory direction, OPR authored three drafts (in 2014, 2016, and 2017) of proposed revisions to the CEQA Guidelines that replaced LOS with VMT per capita as the environmental impact of concern. OPR also recommended significance thresholds for several types of land use and transportation projects in the accompanying, though non-regulatory, SB 743 Technical Advisory on Evaluating Transportation Impacts in CEQA.

The technical advisory recommends several "screening" thresholds based on project size, location "near transit," or location in a "low-VMT area." The lead agency could generally presume that "small projects" – generating fewer than 100 vehicle trips per day – and development near transit stations[1] cause less than significant transportation impacts (OPR 2016). Lead agencies could also generally presume that development in low-VMT areas would generate VMT at a similarly low level as its surroundings, and could thus be presumed to cause less-than-significant VMT impacts (OPR 2016).

[1] "Development near transit" includes projects "proposed within ½ mile of an existing rail transit station, a ferry terminal served by either a bus or rail transit service, or the intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods" (PRC § 21064.3).

Low-VMT areas for residential projects are identified by the average household VMT per capita of the transportation analysis zone (TAZ) in which the project is located. Low-VMT areas for office projects are similarly identified by the average commute VMT per employee of the project's TAZ. What is considered "low" VMT? The technical advisory suggests the following:

- Low-VMT residential areas are those with household VMT per capita that is 85 percent the regional average or less
- For offices, low-VMT areas are those with commute VMT per employee that is 85 percent of the regional average or less.

If a development project is not a small project, near transit, nor in a low-VMT area, the lead agency must estimate the amount of per capita VMT the project would generate and compare it to "numeric thresholds." The technical advisory recommends what may constitute significant transportation impacts:

- Residential development with household VMT per capita exceeding both 85 percent of the "existing city household VMT per capita" *and* 85 percent of the "existing regional household VMT per capita"
- Office development with VMT per employee exceeding 85 percent of the "existing regional VMT per employee"
- Retail projects that cause a "net increase in total VMT."

The technical advisory document expounds on the retail project threshold, suggesting that stores serving a local clientele, rather than drawing regional clientele (as would, say, an auto mall or large shopping center), "add retail opportunities to the urban fabric and thereby improve retail destination proximity" and thus "shorten trips and reduce VMT" (OPR 2016). The technical advisory defers to lead agencies to be "in the best position to decide when a project will likely be local serving," though it offers that locally-serving stores may generally be less than 50,000 square feet (OPR 2016). If retail stores exceed 50,000 square feet, then “lead agencies should undertake an analysis to determine whether the project might increase or decrease VMT” (OPR 2016).

In the case of development projects with a mix of land uses, each component of the project (e.g. residential, office, retail) would be analyzed individually and compared to the relevant significance threshold (OPR 2016). In the case that projects include land uses not specified in the technical advisory (e.g. industrial, research & development), the technical advisory encourages lead agencies to develop their own thresholds (OPR 2016). Further, lead agencies can choose to adopt different significance thresholds “recommended by other public agencies or experts” (OPR 2016). Lead agencies have discretion to choose their own thresholds – including the reference geography (region, county, city, et cetera) and the percent reduction in VMT – though are required to base those significance thresholds on “substantial evidence” (OPR 2016, 14 CCR § 15064.7).

Academic literature supports the technical advisory’s recommended retail threshold. Lovejoy et al. (2013) performed a quasi-experimental before-and-after study of the first “big box” store in Davis, California. They found that overall shopping VMT of survey respondents decreased by 20 percent after the project opened, due primarily to shoppers choosing the closer shopping option than was previously available. Handy and Clifton (2001) found more complex results from a survey of residents of several neighborhoods in Austin, Texas. Their results showed that local retail options proved to have minimal overall reduction in auto use, as residents “chose more distant stores enough of the time that they increase total driving significantly.” However, Handy and Clifton also found that the respondents’ usual mode of travel to local stores is “strongly correlated with their distance to local stores” – fewer people walk or bike to the grocery store when it is farther away. And, “most of the walks to stores did in fact appear to substitute for driving,” which is an important point for policy and GHG emission targets (Handy and Clifton 2001). A permissive threshold for locally-serving retail would likely decrease net VMT and thus GHG emissions: "if residents are given the opportunity to walk to the store, they will at least sometimes choose to walk rather than drive" (Handy and Clifton 2001).

2.2. The Legacy of LOS

LOS has reach well beyond CEQA review and, in fact, transportation. LOS standards exist for a range of public infrastructure – schools, wastewater treatment, parks, transit, of course roads – to compare their use volume to their capacity (Fulton & Shigley 2005). LOS standards come into play through various local planning mechanisms. Local ordinances (e.g. adequate public facilities ordinances) can require that new development only be allowed where there is "adequate" infrastructure to support it (Fulton & Shigley 2005). Further, local governments can require new development to "pay its own way" – in other words, to require development to pay for additional capacity (of roads, parks, schools) in proportion to its impact on the existing community (Fulton & Shigley 2005).

Traffic impact studies (TISs) are the ubiquitous planning mechanism to analyze the adequacy of roadways to accommodate additional automobile traffic generated by new development (Clifton and Currans 2005). TISs traditionally measure the impact of developments based on LOS, and have since the first volume of ITE's *Transportation Impact Analyses for Site Development* was released in 1950 (DeRobertis et al. 2014). Similar to the *Highway Capacity Manual*, TISs have paid increasing attention to multi-modal transportation and urban settings since the 1980s; however, TISs "in most parts of the country continue to be almost exclusively automobile LOS studies" (DeRobertis et al. 2014).

What, then, is the formula for LOS? In simplest terms, LOS is a measure of vehicle delay. It is a way to measure traffic congestion, where low LOS indicates high vehicle congestion, and is calculated by comparing vehicle volume to vehicle capacity. As volume increases compared to roadway capacity, increased vehicle density causes vehicle speeds to slow. Average vehicle delay is the measure of LOS at intersections. Average vehicle delay depends on signal timing, the number of lanes (vehicle capacity), the number of approaches (e.g. two-way versus four-way), as well as vehicle volumes. Further, LOS is very time and place specific. It is most often analyzed at peak commute times (morning and evening) when there are the highest volumes of vehicles on the road, and is a measure for individual roadway segments or intersections.

Different facility types (freeways, urban streets, intersections) have different level of service definitions based on criteria like vehicle speed and density. Performance according to these criteria have assigned letter grades between A and F – faster vehicle speeds, lower vehicle density, and less vehicle delay all correspond with higher service levels. Criteria for these grades at various roadway classes are shown in Table 1.

Table 1: Level of Service Definitions for Various Roadway Classifications (2000 Highway Capacity Manual)

LOS	Freeways		Urban Arterials	Urban Local	Signalized Intersections
	Vehicle Density (PVs/miles/lane)	Average Travel Speed (mi/hr)	Average Travel Speed (mi/hr)	Average Travel Speed (mi/hr)	Delay per Vehicle (sec/vehicle)
A	11	65	> 42	> 25	≤ 10
B	18	65	> 34 – 42	> 19 – 25	> 10 – 20
C	26	64.6	> 27 – 34	> 13 – 19	> 20 – 35
D	35	59.7	> 21 – 27	> 9 – 13	> 35 – 55
E	45	52.2	> 16 – 21	> 7 – 9	> 55 – 80
F	Variable	Variable	16	7	> 80

PV = passenger vehicle

CEQA analyses and TISs use these measures of delay and vehicle speed to evaluate project impacts. For example, a new land development is presumed to generate new automobile trips, which drive on the existing roadway network and increase the volume of vehicles. The additional vehicles increase the vehicle-to-capacity ratio (assuming no change in capacity), potentially decreasing vehicle speeds on certain links and increasing delay at certain intersections near the project site. If vehicle speeds decrease too much (i.e. below the threshold set by the local government, usually established for peak commute times), the project is presumed to have significant impacts on LOS at those particular segments intersections and is required to mitigate impacts to the extent feasible.

2.3. VMT and the Built Environment

VMT has a well-established relationship with built environment and land use characteristics. The theories of travel behavior that have developed over the last several decades form the basis of this relationship, particularly the concept that travel is a "derived demand." Mitchell and Rapkin seemingly first articulated this concept in their 1954 book *Urban Traffic: A Function of Land Use*, which describes how travel patterns – the amount and type of travel undertaken – is derived from the number and type of activities that are available. Land uses patterns, in turn, influence the "availability" of activities, and thus travel patterns.

Handy (2005) calls this relationship the "inextricable link" between land use and transportation and illustrates its complexities in Figure 2. The figure shows a fairly simple causal relationship between transportation policies and land development patterns, and between land development patterns and travel patterns. For example, this model implies that "development stretches out along highway corridors" (a highway being a transportation investment, and development following it) and that "separation between land uses in low-density developments makes driving a necessity" (low-density development being land development patterns, and driving being travel patterns) (Handy 2005). However, research has also shown more complicated relationships between transportation and land use development – "a system of endogenous relationships" – represented by the feedback loops from land use patterns to transportation policies, from travel patterns to transportation policies, et cetera (Handy 2005).

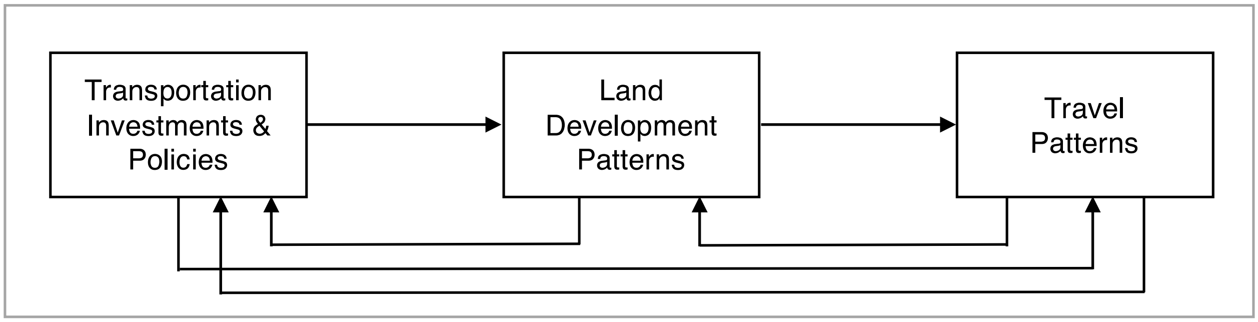

Figure 2: The Complex and "Inextricable Link" between Land Use and Transportation (Handy 2005)

Cervero (2003) quantified the strength of these relationships in a study of highway investments, land development, and VMT. He studied 24 highway expansion projects in small- to medium-sized suburban areas and found a significant positive connection between highway expansion and development patterns along the highway corridors (Cervero 2003). The increase in development activity, in conjunction with the initial increase in travel speeds provided by the expanded roadway, increased the short- and long-term travel demand along the corridor, and ultimately lead to increased VMT. Figure 3 depicts these relationships. When VMT on the new roadway increases enough to reach a critical vehicle density, roadway speeds will again slow and the expanded roadway will again congest.

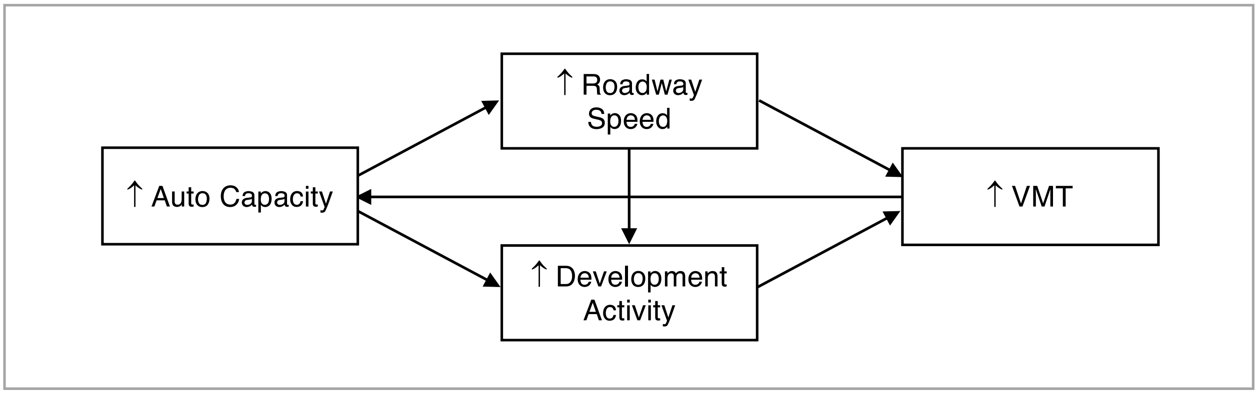

Figure 3: Auto Capacity and Induced VMT, adapted from Cervero 2003

The short-term behavioral shifts observed by Cervero (2003) confirm the "principle of triple convergence" (Downs 1962, 1992, 2004). This principle states that travel within a metropolitan region "almost automatically forms self-adjusting relationships among different routes, times, and modes" (Downs 2004). That is, if a roadway facility suddenly becomes less congested, some commuters will shift routes and time (i.e. redistribute) to take advantage of the faster-flowing roadway. The more-convenient roadway will also have a generative effect on VMT, inducing "new travel that did not previously exist in any form" (Cervero 2003). Even when all else is constant (population, demographics, et cetera), this induced VMT represents "previously suppressed" trips, longer trips, or trips that switch to vehicle travel (Cervero 2003). Duranton and Turner (2011) expand Cervero's investigation and find that the principle of triple convergence applies even beyond highways to "a broad class of major urban roads."

The built environment has implications for travel behavior beyond the effects of roadway expansion. Ewing and Cervero identified in their 2010 paper more than 200 studies of travel and the built environment that have been published mostly since 2001. Ewing and Cervero (2010) synthesize the results of more than 50 of these studies to quantify the effects of residential density, land use mix, street connectivity, accessibility, and transit service (all given a creative alias starting with "D", thus creating the "Ds" variables) on VMT, walking, and transit use. A qualitative summary of their findings is shown in Table 2, indicating that higher levels of population density, land use mix, et cetera are associated with lower levels of VMT and higher levels of walking and transit use. Stevens (2017) performs a similar synthesis on nearly 40 studies of VMT and the built environment published since 1996 and found similar associations as Ewing and Cervero (2010). However, both of these syntheses are cross sectional; they can show associations between built environment characteristics and travel behavior, but they do not prove causality between *changes* in travel behavior as a result of changes to the built environment. Handy, Cao, and Mokhtarian (2005), though, directly examined changes travel behavior in a quasi-longitudinal analysis of built environment changes and driving. Handy et al. (2005) show that there is in fact a causal relationship between these factors, not just correlation, even when accounted for attitudinal factors and self-selection in housing location. These relationships imply that changes to the built environment – engendered by policy and land development patterns – can indeed affect change in VMT.

Table 2: Average Association of Built Environment Variables on Travel Behavior

	VMT	Walking	Transit Use
Population Density	–	+	+
Employment Density	0	+	+
Land Use Mix	–	++	++
Intersection Density	– –	+++	+++
Accessibility	– – –	++	
Distance to Transit	–	++	+++

Adapted from Ewing & Cervero (2010)

A related branch of travel behavior research aims to quantify factors that affect active travel, including walking and bicycling. The causal links and feedbacks in Figure 2 hold for the relationships between transportation policies, land development patterns, and active travel; of course, the policies and land use patterns that augment active travel are different from those that induce VMT.

In addition to land use, transportation infrastructure is a built environment factor that has been shown to affect levels of active travel. Pucher and Buehler (2012) analyzed factors that affect bicycling across 90 US cities and show that "cities with a greater supply of bike lanes and paths have higher bike commute levels – even after controlling for other factors that may affect cycling levels." Dill and Carr (2003) found that existing bicycle infrastructure and public investment in bicycle infrastructure (state spending per capita) were significant predictors of bicycle commuting across 50 US cities. Handy (1996), analyzing four neighborhoods in depth, found that "higher accessibility, in terms of short distances as well as qualitative factors that may lead to higher perceived levels of accessibility" (e.g. urban design) were associated with more utilitarian walking trips.

2.4. Modeling Travel as a Function of the Built Environment

Relationships between land development patterns, transportation networks, and travel patterns like those discussed above provide the basis for travel demand modeling. These relationships can be described with methods and models of varying complexity, ranging from more basic sketch modeling to complex simulation and discrete choice methods (Handy 1996). These methods and models also vary in their ability to accurately capture the causal relationships between travel behavior and the built environment.

Transportation planners and practitioners rely on these travel demand models (e.g. activity-based, the traditional four-step model) to evaluate the performance of land use and transportation plans and investments. Indeed, SB 375 directs MPOs to use regional travel demand models to evaluate alternatives during development of their sustainable communities strategies (California Transportation Commission 2017).

In light of SB 743 and project-level VMT analysis in CEQA, robust travel demand models that capture built environment characteristics would seem ideal for evaluating the effects of new land use developments on travel behavior. Unfortunately this is not quite the case: "travel demand forecasting models were never meant to estimate the travel impacts of neighborhood-scale projects or developments" because "their resolution tends to be too gross to pick up fine-grained design and land-use-mix features" (Cervero 2006). Even travel models with high resolution are problematic, as they require multiple runs of a single project to reduce the inherent randomness of forecasted travel introduced by the models' stochasticity (Castiglione et al 2003, Bradley et al 2002).

This creates need for neighborhood- and project-scale modeling approaches. Cervero (2006) defines two main approaches for "first cut sketch-planning tools." Post-processing is one approach, which "tweaks" outputs from travel demand models using elasticities to capture relationships not accounted for in the travel model (in some cases, built environment characteristics). Direct modeling – "stand-alone models to directly estimate travel for neighborhoods" – is the other approach (Cervero 2006). Sketch-planning tools, Cervero claims, "may do a better job of picking up some of the nuanced relationships between smart growth and travel demand than even enhanced large-scale models." Furthermore, many sketch-planning tools can be run quickly and economically compared to regional travel demand models, which require substantial staff and consultant resources (Cervero 2006).

A wide and growing range of sketch-planning models are available to estimate VMT associated with land use change (see Table 3). Several of these are California-specific, and some have supplanted others. We discuss this subset of these models (shown in Table 4) in depth.

Table 3: Available Sketch VMT Estimation Models

Model	Developer
Adjusting ITE Trip Generation for an Urban Context	Clifton, Currans, & Muhs (2015)
California Emissions Estimator Model (CalEEMod)	California Air Pollution Control Officers Association (CAPCOA)
California Smart Growth Trip Generation Adjustment Tool	Handy, Shafizadeh, & Schneider (2013)
Envision Tomorrow	Fregonese Associates
GreenTrip Connect	Center for Neighborhood Technology
MXD	Fehr & Peers
Sketch7	Fehr & Peers, UC Davis ULTRANS, Sacramento Area Council of Governments
Urban Emissions Model (URBEMIS)	California Air Resources Board
Urban Footprint	Calthorpe Analytics
VMT+	Fehr & Peers
VMT Impact Tool	Salon (2014)

Table 4: VMT Estimation Models selected for Davis Case Studies			
Method	**Adjusts**	**Methodology**	**Applicability**
CalEEMod (2016)	Trip Generation VMT	Direct Model	• Residential, commercial, retail, industrial, recreational, educational • Any context area in California
California Smart Growth Trip Generation Adjustment Tool	Trip Generation	Direct Model	• Mid- to high-density residential, office, restaurant, coffee shop, retail • "Smart growth" project location*
GreenTrip Connect	VMT	Direct Model	• Residential • Any context area in California
MXD	Trip Generation	Direct Model	• Residential, retail, office, industrial, commercial, educational, other • Any context area
Sketch7	VMT	Post-Process	• Mixed use, residential, retail, office, industrial, public, civic, medical, educational, military, airport • Any context area in Sacramento region (currently)

* Case study projects do not meet this criterion

Perhaps the simplest way to estimate VMT is to multiply the number of trips generated by a project by the length of those trips. For example, we can consider a simple situation illustrated in Figure 4, where activities are each three miles away (i.e. the length of arrows are each three miles). Two residents of a new household drive to work together (trip 1). One person drops off the other and proceeds on to their workplace alone (trip 2). This person stops by the grocery store (trip 3) on their way home (trip 4), while Person 1 takes transit home. The household generates four vehicle trips on this average weekday, each trip is three miles, thus the household generates an average of 12 VMT per day. If there are two residents in this household, each has an average household VMT per capita of 6 VMT per day.

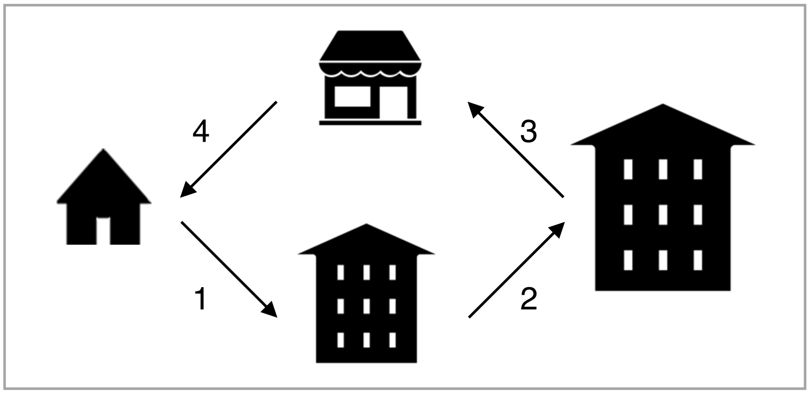

Figure 4: Hypothetical Weekday Travel

In the US, the Institute of Transportation Engineers' *Trip Generation Manual* (ITE 2012) has been the authority for trip generation estimates (Clifton et al 2013). Planners use ITE trip generation rates in LOS analysis, as do some VMT estimation methods to estimate the number of trips a project generates. However, ITE trip generation data have widely-known and self-identified limitations. Data collection focused on "single-use, vehicle-oriented trip rates in suburban sites" (Clifton et al 2015); if a project "is located in a downtown setting, served by significant public transport… the site is not consistent with ITE data" (Institute of Transportation Engineers 2004). Several studies have identified the extent to which ITE trip rates overestimate trip generation for projects in urban settings (e.g. Arrington and Cervero 2008, Shafizadeh et al. 2012) and some suggest methods for adjusting ITE trip rates to better reflect observed travel in urban areas (e.g. Clifton et al. 2013, Clifton et al. 2015, Currans et al. 2015, Schneider et al. 2015). Some sketch VMT estimation models use this type of research to adjust the trip generation rates, trip lengths, or both to account for various characteristics of the project and its surroundings (e.g. MXD, California Smart Growth Trip Generation Adjustment Tool). Others use the post-processing method described by Cervero (2006) to adjust baseline travel behavior data from travel demand models (e.g. Sketch7).

Three of the VMT estimation models in Table 4 adjust ITE trip generation rates to account for a number of factors: trips internal to the project (for instance, when one makes several stops within a mixed-use development), trips that would have passed by the project anyway and thus are not all "new" VMT. The California Emissions Estimation Model (CalEEMod) uses this approach to estimate VMT. CalEEMod also includes adjustments of overall project VMT based on characteristics of the project and the built environment surrounding the project (e.g. housing and employment density, distance to transit, distance to the central business district, et cetera) (CAPCOA 2013). The California Smart Growth Trip Generation Tool (Handy et al. 2013) and the Mixed-Use Trip Generation Model (MXD) (Walters et al. 2013) use statistical relationships (linear regressions) to adjust ITE trip generation rates based on characteristics of the project and the project surroundings. Both methods primarily adjust trip generation, but the estimated number of trips can be multiplied by appropriate trip lengths to find VMT.

Two of the VMT estimation methods in Table 4 use statistical models to draw relationships directly between VMT and project characteristics, characteristics of the built environment surrounding the project, and demographics. GreenTrip Connect is based on a statistical relationship (also a linear regression) between VMT and demographics, household income, regional context, and location efficiency (Newmark & Haas 2016, Newmark et al 2015). Sketch7 adjusts household VMT using elasticities related to the built environment. It is based on Ewing and Cervero's 2010 meta-analysis of "Ds" variables, thus it estimates the relationship between travel behavior (VMT, walking, transit use) and housing and employment density, land use mix, street design, accessibility, and transit accessibility.

3. Research Questions & Methods

The implications of the shift from VMT to LOS for California's foundational environmental policy are uncertain. How do projects perform when evaluated under each metric? How do the impacts highlighted by each metric differ? What mitigation strategies does each metric suggest? And do those mitigation strategies lead to outcomes that the community desires?

To answer these questions, we evaluate the transportation impacts and corresponding mitigation measures using both LOS and VMT metrics for three land development projects in Davis, California. Each project is summarized in Table 5 and located in Figure 5. We first inventory and analyze the "significant" LOS impacts and their required mitigations as documented in the projects' draft environmental impacts reports (EIRs). We then estimate the VMT generated by each project using the VMT estimation models in Table 4. Finally, we analyze each project with the VMT-based streamlining and significance thresholds proposed in the SB 743 technical advisory and consider possible mitigations.

Table 5: Case Study Projects			
	The Cannery	**Nishi Gateway**	**2nd Street Crossing**
Acres	100	47	19
Land Uses	336 units single-family 314 units multi-family 78 ksf retail 157 ksf commercial 5.5 ksf community center 4.7 acres park	650 units multi-family 325 ksf research/office	173 ksf retail (including Target)
Prior Land Use	Agricultural Processing	Agriculture	Undeveloped
Adjacent Land Uses	Residential Commercial Agricultural	Central Business District Residential University Commercial Interstate & Railroad	Residential Commercial Agricultural Interstate & Railroad
Transit within ¼ Mile	7 bus lines	10 bus lines Passenger rail (Amtrak)	7 bus lines
Distance to Downtown	1.5 miles	0.5 mile	3.5 miles
Affordable Housing	120 units	None	Not Applicable

ksf = thousand square feet

3.1. Case Study Projects

The Cannery is a 100-acre grayfield development adjacent to the northern-most residential neighborhoods in Davis, California. The site was previously a Hunt-Wesson tomato cannery and is surrounded on two sides by actively farmed agricultural land. It is a predominantly residential mixed-use development with multiple housing densities and 240,000 square feet of retail, research and development, and/or commercial land use potential. It proposes approximately 600 dwelling units – 120 of which are affordable housing units – and employment between 600 and 850 jobs.

The Nishi Gateway project is proposed on the southern edge of historic downtown Davis, adjacent to the University of California and north of Interstate 80. It is a 50-acre mixed-use development with 325,000 square feet of research and development, approximately 900 units of multi-family residential, 20,000 square feet of retail, and 13.1 acres of surface parking. It is unique for a project of this scale to be infill development within a quarter-mile of a historic downtown, university, and passenger rail station.

The 2nd Street Crossing project is a commercial development on the edge of Davis city limits and was the first "big box" retail store in Davis. The site is 19 acres consisting of 173,000 square feet of retail, including a Target Store, and 15 acres of surface parking. It is surrounded by newer, suburban-style development, Interstate 80, industrial offices, and actively-farmed agricultural land.

Figure 5: Map of Case Study Projects and Key Intersections

3.2. LOS Impacts & Mitigations

To compare LOS- and VMT-based transportation impacts, we inventory and analyze the impacts and mitigations identified using LOS in the projects' EIRs. We identify impacts as being LOS-related or not, as local jurisdictions can choose to measure transportation impacts other than impacts on traffic and with metrics other than LOS. For example, transportation analyses usually include impacts to emergency access, and the City of Davis chose to analyze the VMT impacts of the Nishi Gateway.

Across the three projects, LOS-based impacts are the most common among significant and potentially significant impacts identified in the EIRs. The significance of an impact is determined by comparing it to a specified threshold for that type of impact. The setting of thresholds and the comparison of estimated impacts to these thresholds is thus a critical component of CEQA analyses.

Impacts that are found to be significant or potentially significant require mitigation measures "which would substantially lessen the significant environmental effects of such projects" as feasible (PRC §21002). We inventory mitigation measures for LOS-based impacts. The impacts identified and mitigation measures implemented under CEQA not only have implications for the contentiousness of the environmental review process and cost of development; they have implications for the built environment, community design, and likely the incentives and disincentives that underpin the types and location of development.

3.3. Project VMT Estimates

To estimate VMT, we use the same land use assumptions that were used in the transportation chapters of the projects' respective EIRs (§ 3.14 of the Cannery Park Draft EIR, § 4.14 of the Nishi Gateway Project Draft EIR, and § 3.4 of the Second Street Crossing [Target Store] Project Draft

EIR), rather than the land use assumptions described in the Project Description or elsewhere. The mix of land uses within the Cannery are described several ways throughout the EIR and includes various types of residential units (e.g. lofts, studios), food market stands, and research and development space. The land uses in the transportation chapter – and those we use to estimate VMT – are single-family residential, apartments, retail, office, and community center.

For analysis of case study projects, we initially identified all sketch VMT estimation methods that are available for California (see Table 3). A panel of 20 consultants, MPO and state agency staff, and academic researchers with expertise in travel demand modeling gave input about the methods' unique attributes, computational abilities, and practical considerations. With their input, we selected five VMT estimation methods to use in this study (Table 4).

We use EIR land use assumptions in each VMT estimation model, as possible. GreenTrip Connect only estimates residential VMT, thus we use it to estimate VMT from the residential components of the Cannery and Nishi Gateway. We did not use GreenTrip Connect on 2nd Street Crossing, because the project is exclusively retail, nor did we use it on the office components of the Cannery and Nishi. Sketch7's land uses use the same categories as the MPO's regional transportation plan, rather than ITE land use categories that are used by CalEEMod, MXD, and often the projects' EIRs. When land use categories were not the same as those listed in the EIR's transportation chapter, we use the closest available land use. For example, 2nd Street Crossing includes the ITE categories "free-standing discount store" and "shopping center" in its EIR; we categorize it as "community/neighborhood retail" in Sketch7.

3.4. VMT-Based CEQA Analysis

We analyze the location of each project in relation to SB 743's "screening" thresholds: small projects, high-quality transit stations, "low-VMT" areas, and locally-serving retail. We use information from transit districts to identify high-quality transit areas. We use data from the California Statewide Travel Demand Model (CSTDM) to determine regional average VMT per person and per employee, and to determine average VMT of each TAZ (Caltrans 2014). GreenTrip Connect and Sketch7 have VMT data built into them that could ostensibly be used to identify low-VMT TAZs, though the data are not currently extractable from either tool.

We then analyze project-specific VMT for the project components that do not meet the screening criteria. We analyze each component (residential, employment, retail) in each available VMT estimation model and compare results to relevant thresholds. We use the residential, employment, and retail thresholds recommended in the SB 743 technical advisory: 85 percent of regional household VMT per capita, 85 percent of regional commute VMT per employee, and locally serving retail, respectively. By comparing project-specific VMT to its appropriate threshold, we make significance presumptions for each project.

4. Findings

In our analysis, the two performance metrics lead to very different conclusions about significant transportation impacts that result from even three case study projects. The differences in significant impacts also point to different substantially mitigations strategies. We summarize and compare these differences by project.

4.1. The Cannery

LOS Impacts & Mitigations

The EIR for the Cannery identifies six impacts to transportation, three of which are LOS-related. One LOS-related impact is identified as "significant" and one as "potentially significant" without mitigation. The three impacts not related to LOS are "less than significant". The Cannery's LOS-related impacts and mitigations are summarized in Table 6.

Table 6: Cannery LOS-Related Impacts and Mitigations

Impact & Significance	Mitigation Measures
3.14-1. Project implementation would result in a significant [LOS] impact at the unsignalized Covell Boulevard/Oak Tree Plaza Driveway Intersection. **Significant without mitigation. Significant and unavoidable after mitigation.**	1A Prohibit outbound left-turns 1B Construct refuge island in median of Covell Boulevard to enable outbound left turns to merge more easily 1C Install traffic signal at Covell & Oak Tree Plaza Driveway 1D Install traffic signal at Covell & L Street. Operate traffic signals to create more gaps in traffic for outbound left-turns from Oak Tree Plaza 1E Modify permitted turn movements into driveway serving Oak Tree Plaza 1F Accept LOS F
3.14-2. Under cumulative conditions, project implementation would worsen already unacceptable levels of service at study intersections. **Potentially significant without mitigation. Less than significant after mitigation.**	Contribute fair share funding to cover proportionate cost of the following intersection improvements: • Install traffic signal and dedicated left-turn pocket at 8th & J Streets • Install traffic signal and reconfigure lanes at Pole Line Road & Picasso Avenue • Install traffic signal and reconfigure lanes at Pole Line Road & Moore Boulevard • Install traffic signal and reconfigure lanes at Covell Boulevard & L Street, and add a dedicated right-turn lane. Add second left-turn lane if Covell Village (future project) developed as Light Industrial
3.14-6. Construction traffic may cause significant intersection impacts. **Less than significant.**	No mitigation required.

The Cannery's most significant LOS impact is at an intersection with the driveway of a nearby shopping center. Measures to mitigate decreased LOS include restricting automobile turning movements, construction of a median island for two-stage left-hand turns, and installation of two traffic signals. Regardless, LOS impacts to this intersection remain significant and unavoidable after mitigation. Cumulative LOS impacts from the Cannery and other planned projects are potentially significant; however, the installation of four traffic signals and lane reconfigurations mitigate the cumulative LOS impacts to less than significant.

VMT Analysis

We analyze the Cannery with all four sketch VMT estimation methods using the land use and context area assumptions in Table 7. Each method defines and estimates VMT differently, thus VMT estimates for the Cannery vary by 200 percent (Table 8). GreenTrip Connect and Sketch7 estimate only VMT generated from the residential components of the Cannery, which partially explains the fraction of VMT estimated by GreenTrip Connect and Sketch7 when compared to CalEEMod. But, we also see that GreenTrip Connect and Sketch7 estimate lower household VMT per capita than CalEEMod, indicating that the latter method indeed estimates more VMT per unit.

GreenTrip Connect and Sketch7 both compare household VMT estimates to a regional average household VMT, allowing analysts to compare project-generated VMT to a baseline. Both methods estimate that households in the Cannery generate VMT below the regional average: GreenTrip Connect estimates the Cannery's household VMT per capita as 86 percent of the regional average; Sketch7 estimates household VMT per capita as 94 percent of the regional average, and a 6 percent increase in VMT in the half-mile radius project "context area" (Table 5). Neither CalEEMod nor MXD provide regional baselines to compare project VMT.

Table 7: Inputs for the Cannery				
	CalEEMod	**GreenTrip Connect**	**MXD**	**Sketch7**
Land Uses	• Apartments: 314 DUs • Single Family: 336 DUs • City Park: 4.7 acres • Community Center: 5.5 ac • General Office: 157.3 ksf • Retail: 78.67 ksf	• Total DUs: 650 – Studios: 45 – 1 BR: 325 – 2 BR: 176 – 3+ BR: 104 • Parking: 1,100 spaces	• Single Family: 336 DUs • Multi Family: 314 DUs • General Retail: 78.7 ksf • Non-Medical Office: 157 ksf • Trips from other land uses: – Comm. Center Daily: 8,083 – Comm. Center AM: 490 – Comm. Center PM: 655	• Low-Density Res: 336 DUs • High-Density Res: 314 DUs • Public/Quasi-Public: 5.5 acre • Comm./Neighb'd Office: 4 acres, 500 non-retail jobs • Comm./Neighb'd Retail: 2 acres, 200 retail jobs
Context Inputs	• Setting: Suburban Center • Res. Density: 9.5 DU/acre • Increases Diversity • Distance to CBD: 2 miles • Distance to Transit: ¼ mile • Affordable Housing: 20% • Intersection Density: 85/sqmi	• Affordable Housing: – 20 very low-income – 90 low-income • No parking charge, no provision of transit passes, bike/car share membership	• Developed Area: 98.4 acres • Number of Intersections: 13 • Transit Within or Adjacent to Site • Site not in CBD • Employment within (jobs): – 1 mile: 4,357 – 30 min. transit trip: 115,364 • Avg. Vehicles Owned/Unit: 1.66 • Avg. Household Size: 2.71	• Transit Service: Moderate • Street Pattern: Moderate • Demographics – Average number 55 and older – Households near median income
Trip Rates (trips per unit per day)	• Single Family: 12.82 (default) • Apartments: 5.96 (default) • City Park: 3.40 (default) • Comm. Center: 22.88 (default) • General Office: 17.50 (default) • Retail: 54.40 (default)	N/A	• Single Family: 9.57 (default) • Multi Family: 6.65 (default) • General Retail: 42.94 (default) • Non-Med. Office: 11.01 (default)	N/A
Trip Lengths (miles, from CSTDM)	• Home-Work: 9.59 • Home-Shop: 4.78 • Home-Other: 3.53 • Commercial-Customer: 4.78 • Commercial-Worker: 11.59 • Commercial-NonWork: 6.85	N/A	• Region – Home-Work: 12.05 – Home-Other: 6.04 – Not Home-Based: 6.66 • TAZ – Home-Work: 9.59 – Home-Other: 3.53 – Not Home-Based: 4.78	N/A

DU = dwelling unit; ksf = 1000 square feet; CBD = central business district; TAZ = transportation analysis zone

Table 8: VMT Estimates for the Cannery				
	CalEEMod	**GreenTrip Connect**[1]	**MXD**[2]	**Sketch7**[1]
VMT per Day (Raw Estimate)	67,339	21,912	56,990	29,448
Daily HH VMT per Capita (Standardized)	17.2	12.4	–	18.2
Daily Office VMT per Employee (Standardized)	22.4	–	–	–
Regional Average Household VMT per Capita	–	14.4	–	19.3
Percent Change in Context Area VMT	–	–	–	+6%

[1] Estimates only household VMT
[2] MXD does not report household VMT separately
HH = household

VMT-Based CEQA Analysis

Table 9 summarizes the VMT-based screening thresholds applicable to the Cannery, using data from the 2010 run of the CSTDM. The TAZ in which the Cannery is currently located is based on its previous agricultural and industrial use as a canning facility. Its TAZ covers unincorporated county that is nearly entirely active agriculture and stretches north to Woodland's city boundary. Upon build-out, the Cannery will operate similarly to the Davis neighborhoods that are immediately adjacent and almost certainly be incorporated into its adjacent TAZ. Thus we use TAZ averages for TAZ immediately to the west of the Cannery for screening analysis.

Per the screening thresholds, the residential and retail components would be presumed to have "less than significant" impacts on VMT and would thus require no further analysis. The office component cannot be presumed to have less than significant VMT impacts, so we estimate VMT from the Cannery's offices. Table 10 shows office-generated VMT estimates and compares it to 85 percent of regional average commute VMT per capita, which is the technical advisory's recommended threshold.

Table 9: VMT Screening Thresholds for the Cannery			
	Threshold	**Cannery**	**Significance Presumption**
Near Transit	Within ½ mile of rail or frequent bus service	Not Near Transit	Not LTS
Low-VMT Residential Area – Household VMT per Capita	11.2[1]	9.9[2]	Less than Significant
Low-VMT Office Area – Commute VMT per Employee	12.4[1]	15.2[2]	Not LTS – Further analysis required
Retail	Locally-Serving	Locally-Serving	Less than Significant

[1] 85% of regional average from 2010 CSTDM data
[2] TAZ average from 2010 CSTDM Data
LTS = less than significant

Table 10: Commute VMT per Employee from Office Component of Cannery			
	Threshold	**Cannery**	**Significant Presumption**
CalEEMod	12.4[1]	22.4	Significant without Mitigation
GreenTrip Connect	–	–	–
MXD	12.4[1]	–	–
Sketch7	–	–	–

[1] 85% of regional average commute VMT per employee from 2010 CSTDM data

Analysis of the Cannery's office-generated VMT shows that it may be presumed to have significant VMT impacts. Like significant LOS impacts, VMT impacts can be mitigated to lessen the severity of impacts. Some characteristics inherent to the Cannery's office component – like adding jobs to a housing-rich community (thus increasing the jobs-housing balance) – could reduce commute VMT. The Cannery's office-generated VMT would require a 45 percent reduction to fall below the threshold – an aggressive VMT reduction – so it is likely that the office VMT impacts would be presumed to be "significant and unavoidable" after mitigation, as were the LOS impacts at the intersection of Covell Boulevard and the Oak Tree Plaza driveway.

4.2. Nishi Gateway

LOS Impacts & Mitigations

The EIR for the Nishi Gateway identifies ten transportation impacts; five are LOS-related. Of the five LOS-related impacts, three are identified as significant without mitigation, and two are significant and unavoidable after mitigation. Of the five impacts unrelated to LOS, one is significant, three are potentially significant, and one is less than significant. The LOS-related impacts and associated mitigation measures are summarized in Table 11.

Two of the LOS impacts from the Nishi Gateway are significant and unavoidable, even after mitigation. These impacts increase vehicle delay at surrounding local intersections and at the Interstate 80-Richards Boulevard interchange. The EIR identifies substantial and costly mitigation measures for these impacts, notably the realignment of and widening of roadways at the Interstate 80 interchange that serves downtown Davis. Mitigation also includes the construction of a protected bicycle facility over Interstate 80 to connect south Davis to downtown.

In addition to LOS, the Nishi Gateway voluntarily used VMT as a transportation metric in its EIR. It identified a potentially significant VMT impact because "the project would increase local and regional vehicle miles traveled as a result of people driving to and from the project site on a daily basis" (Nishi Gateway Project Draft EIR § 4.14). Mitigation measures such as the creation and monitoring of a transportation demand management program, development of bicycle infrastructure and incentives, and provision of on-site workforce housing reduce the VMT impacts to less than significant.

Table 11: Nishi Gateway LOS-Related Impacts & Mitigations	
Impact & Significance	**Mitigation Measures**
4.14-1. The addition of project-related traffic would increase delay at local intersections outside freeway interchange areas. **Significant without mitigation. Significant and unavoidable after mitigation.**	4.14-1 Project applicant shall fund the design and construction of modifications to the single-lane roundabout at the intersection of Old Davis & La Rue Road. Modifications shall consist of constructing a right-turn bypass lane from southbound La Rue to westbound Old Davis Road.
4.14-2. The additional of project-related traffic would increase delay at local intersections within the Richards Boulevard Freeway Interchange Areas. **Significant without mitigation. Significant and unavoidable after mitigation.**	4.14-2 Conduct focused traffic assessment, or provide fair share contribution to roadway and intersection widening within the Richards Boulevard interchange area: • Widen south leg of Richards Boulevard to add second northbound left turn lane • Widen north leg of Richards Boulevard to add second southbound through/turn lane (widening of south leg may require some widening of the approach to the underpass) • Widen west leg of West Olive Drive to provide two westbound lanes and three eastbound lanes (left turn lane, through/right lane, right turn lane) • Place barriers in median to restrict driveway access between West Olive Drive and I-80 westbound ramps • Realign I-80 westbound ramps to eliminate the two loop ramps to provide a diamond ramp configuration and install traffic signal. Provide left turn lane and two right turn lanes on westbound off-ramp, two through lanes and right turn lane on southbound approach • Widen I-80 eastbound off-ramp to provide second left turn lane • Construct a separated cycle track on west side of Richards Boulevard from West Olive Drive to Research Park Drive.
4.14-3. Implementation of project would not contribute substantial traffic volumes to freeway segments in the area such that LOS of the freeway segments would be considered unacceptable. **Less than significant.**	No mitigation required.
4.14-4. While the project would increase daily trips to and from the project site, the project would not result in substantial increase in local residential street volumes. **Less than significant.**	No mitigation required.
4.14-7. During construction of the project, construction activities and temporary construction vehicle traffic would increase traffic congestion in the area. **Significant without mitigation. Less than significant with mitigation.**	4.14-7 Project applicant shall prepare a detailed Construction Traffic Control Plan.

VMT Analysis

We analyze the Nishi Gateway with all four sketch methods using the land use and context assumptions in Table 12. The project-level VMT estimates vary by nearly 100 percent for the Nishi Gateway, where CalEEMod estimates project VMT nearly double that estimated by GreenTrip Connect (Table 13).

We again compare the project-generated VMT to regional averages calculated by the respective sketch method. GreenTrip Connect and Sketch7 estimate that the households in the Nishi Gateway would generate 76 and 71 percent of the regional average household VMT per capita, respectively (Table 13). Sketch7 further estimates that the Nishi Gateway would decrease VMT in its half-mile context area by 2 percent.

Table 12: Inputs for Nishi Gateway

	CalEEMod	GreenTrip Connect	MXD	Sketch7
Land Uses	• Apartments Mid-Rise: 298 DUs • Apartments High-Rise: 637 DUs • Research & Development: 325 ksf	• Total DUs: 935 – Studios: 65 – 1 BR: 468 – 2 BR: 252 – 3+ BR: 150 • Parking: 1,107 spaces	• Multi Family: 637 DUs • High-Rise Condo: 298 DUs • Non-Medical Office: 325 ksf	• High-Density Res: 935 DUs • Comm./Neighb'd Office: 7.5 acres, 200 retail & 600 non-retail jobs
Context Inputs	• Setting: Suburban Center • Res. Density: 95 DU/acre • Increases Diversity • Distance to CBD: 0.5 miles • Distance to Transit: ¼ mile • Intersection Density: 40/sqmi	• Affordable Housing: None • $65/month charge for parking • Subsidized transit pass (80% of $150/month pass) • 1 carshare membership/driver • 2 bikeshare memberships/unit	• Developed Area: 46.9 acres • Number of Intersections: 3 • Transit Within or Adjacent to Site • Site in CBD or TOD • Employment within (jobs): – 1 mile: 5,344 – 30 min. transit trip: 115,364 • Avg. Vehicles Owned/Unit: 1.66 • Avg. Household Size: 2.0	• Transit Service: High • Street Pattern: Moderate • Demographics – Fewer people 55 and older – Households near median income
Trip Rates (trips per unit per day)	• Apartments Mid-Rise: 6.15 (default) • Apartments High-Rise: 4.32 (default) • Research & Development: 8.11 (default)	N/A	• Multi Family: 6.65 (default) • High-rise Condo: 4.18 (default) • Non-Med. Office: 11.01 (default)	N/A
Trip Lengths (miles, from CSTDM)	• Home-Work: 9.31 • Home-Shop: 4.51 • Home-Other: 3.67 • Commercial-Customer: 4.51 • Commercial-Worker: 13.19 • Commercial-NonWork: 7.04	N/A	• Region – Home-Work: 12.05 – Home-Other: 6.04 – Not Home-Based: 6.66 • TAZ – Home-Work: 9.31 – Home-Other: 3.67 – Not Home-Based: 4.51	N/A

DU = dwelling unit; ksf = 1000 square feet; CBD = central business district; TOD = transit-oriented development; TAZ = transportation analysis zone

Table 13: VMT Estimates for Nishi Gateway				
	CalEEMod	**GreenTrip Connect**[1]	**MXD**[2]	**Sketch7**[1]
VMT per Day (Raw Estimate)	39,437	20,424	42,392	26,200
Daily HH VMT per Capita (Standardized)	13.0	10.92	–	13.67
Daily Office VMT per Employee (Standardized	20.6	–	–	–
Regional Average Household VMT per Capita	–	14.4	–	19.3
Percent Change in Context Area VMT	–	–	–	-2%

[1] Estimates only household VMT
[2] MXD does not report household VMT separately
HH = household

VMT-Based CEQA Analysis

VMT impacts for Nishi Gateway are unique because, unlike the Cannery, the Nishi Gateway is within a half-mile radius of the Davis Amtrak station. This proximity qualifies the project as "near transit" and it can be presumed to generate less than significant VMT, requiring no further VMT analysis nor mitigation.

Table 14: VMT Screening Thresholds for Nishi Gateway			
	Threshold	**Nishi Gateway**	**Significance Presumption**
Near Transit	Within ½ mile of rail or frequent bus service	Near Transit	Less than Significant – No Further Analysis Required
Low-VMT Residential Area – Household VMT per Capita	11.2[1]	8.4[2]	Less than Significant
Low-VMT Office Area – Commute VMT per Employee	12.4[1]	15.7[2]	Not Less than Significant
Retail	Locally-Serving	None	N/A

[1] 85% of regional average from 2010 CSTDM data
[2] TAZ average from 2010 CSTDM Data

A finding that the Nishi Gateway causes a less-than-significant VMT impact is substantially different than the significant and unavoidable impacts identified in the EIR's LOS analysis. The significant

LOS impacts triggered extensive mitigation to improve traffic operations and decrease delay around the interstate highway. A high-density mixed-use project within the urban boundary (i.e. the Nishi Gateway) is the type of project California's climate policies attempt to promote, but costly mitigation measures like interchange reconfiguration hinder the state's efforts. For one thing, the costly mitigation measures may make the project financially infeasible in this location, potentially pushing development to areas with less traffic but also less potential for other modes. If the mitigation measures are implemented, they are likely to accommodate more traffic flow leading to an increase in VMT.

4.3. 2nd Street Crossing

LOS Impacts & Mitigations

The EIR for 2nd Street Crossing identifies ten transportation impacts; eight of them are LOS-related. Five of the eight LOS-based impacts are significant. One non-LOS-based impact (impacts to parking) is identified as significant. Table 15 summarizes the LOS-related impacts and mitigations.

All eight LOS impacts caused by 2nd Street Crossing are mitigated to be less than significant. Mitigation measures include installation and timing of one traffic signal (and potentially three more), reconfiguration and addition of automobile lanes, restriction of automobile movements, and installation of crosswalks and bicycle parking.

Table 15: 2nd Street Crossing LOS-Related Impacts & Mitigations	
Impact & Significance	**Mitigation Measures**
4.3-1. Impacts related to increases in traffic as a result of the proposed project on 2nd Street/Faraday Avenue. **Significant without mitigation. Less than significant with mitigation.**	4.3-1 Applicant shall fully fund the design and installation of a traffic signal at 2nd Street/Faraday Avenue. The intersection should have the following lane configuration: • Eastbound 2nd Street: One left-turn pocket; two through lanes • Westbound 2nd Street: One left turn pocket, one through lane; one right turn lane • Project Driveway: One left-turn lane, one shared through/right lane • Additional design features should include crosswalks; future transit stops should be located west of the intersection to avoid queueing that would back up in intersection.
4.3-2. Mace Boulevard Overcrossing **Less than significant.**	No mitigation required.
4.3-3. Impacts regarding the provision of efficient site access and circulation. **Significant without mitigation. Less than significant with mitigation.**	4.3-3 The following elements shall be incorporated into the site plan: • Add center strip and outbound Stop and Right-Turn Only signs to the northernmost driveway • Add center stripe and outbound Stop and Right-Turn Only signs to driveway south of northernmost driveway • At primary project driveway, stripe outbound portion of the driveway to provide separate left-turn and shared through/right lanes. Inbound portion should be striped for separate shared through/left and right-turn lanes. At internal intersection of the primary driveway and the primary north-south aisle, provide Stop signs on the northbound, southbound, and eastbound approaches. • At southernmost driveway on 2nd Street, provide center stripe, outbound Stop and Right-Turn Only signs. Median opening will be closed at this location. • Large Target delivery truck access routes should be defined in accordance with Figure 4.3-17. • Provide bicycle parking spaces near Target store and near each of the other four buildings
4.3-5. Impacts to traffic flow from construction traffic associated with grading and development of project site. **Significant without mitigation. Less than significant with mitigation.**	4.3-5 Project applicant shall prepare a Construction Traffic Management Plan.
4.3-7. Cumulative impacts regarding the deterioration of LOS of the 2nd Street/Mace Boulevard intersection. **Significant without mitigation. Less than significant with mitigation.**	4.3-7 Prior to occupancy, applicant shall either (a) pay for a traffic operations analysis to support the development of a new optimized signal timing plan for 2nd Street/Mace Boulevard to restore LOS E, or (b) pay for the design and construction of a second northbound left turn lane to better accommodate the northbound left turn volume, and re-time the signal, to provide LOS D conditions in the Cumulative With Project case.

4.3-8. Cumulative impacts regarding the LOS at the intersections of 2nd Street/Cantrill Drive, 2nd Street/Peña Drive, and 2nd Street/Cousteau Place. **Significant without mitigation. Less than significant with mitigation.**	4.3-8 The City of Davis shall monitor the intersections of 2nd Street/Cantrill, 2nd Street/Peña, and 2nd Street/Cousteau to determine when and if signals should be installed based on a full warrant analysis. The City shall require a fair share payment of the cost of new signals from the applicant.
4.3-9. Impacts to Remainder Access Road. **Less than significant.**	No mitigation required.
4.3-10. Cumulative freeway mainline and ramp impacts. **Less than significant.**	No mitigation required.

VMT Analysis

We analyze 2nd Street Crossing with three of the four sketch methods using the land use and context assumptions in Table 16. GreenTrip Connect estimates household VMT, thus it cannot be used on non-residential projects. Sketch7 can be used on many types of projects, though its estimates report household VMT and the project's effect on household VMT within a half-mile radius, rather than project-generated VMT per se.

Table 17 shows the usefulness of a VMT metric beyond a trip-rate-times-length estimate. The rate-times-length estimate can provide insight about the multi-modal accessibility and location efficiency of a project, particularly when a project is residential (Lee et al. 2017), but non-residential development like 2nd Street Crossing is likely to redistribute existing VMT rather than generate new VMT (Lovejoy et al. 2013). The 50,000 VMT calculated by CalEEMod estimates the vehicle travel that will start and end at the project parcel, whereas the 7 percent increase in VMT estimated by Sketch7 shows the changes in surrounding travel patterns that result from 2nd Street Crossing. The raw project-level VMT estimate requires multiple scenarios to understand how a project and project location performs; the net effect on VMT indicates how a project will interact with the community's existing built environment.

Interestingly, an empirical study of 2nd Street Crossing's effect on VMT shows the opposite of Sketch7's estimated increase. A before-and-after study of 2nd Street Crossing found that overall shopping VMT of survey respondents decreased by 20 percent after the project opened for business (Lovejoy et al. 2013). Shoppers primarily re-routed trips from the similar shopping centers in Woodland and Sacramento (10 and 15 miles to the north and east, respectively) to the new, closer Target in Davis.

Table 16: Inputs for 2nd Street Crossing

	CalEEMod	GreenTrip Connect	MXD	Sketch7
Land Uses	• Free-Standing Discount Store: 137 ksf • Shopping Center: 46 ksf	N/A	• General Retail: 183 ksf	• Comm./Neighborhood Retail: 5 acres, 280 retail jobs
Context Inputs	• Setting: Suburban Center • Distance to CBD: 3 miles • Distance to Transit: 0.1 mile	N/A	• Developed Area: 19.1 acres • Number of Intersections: 1 • Transit Within or Adjacent to Site • Site not in CBD or TOD • Employment within (jobs): – 1 mile: 1,823 – 30 min. transit trip: 34,564 • Avg. Vehicles Owned/Unit: 2.66 • Avg. Household Size: 2.7	• Transit Service: Moderate • Street Pattern: Low • Demographics – Average number of people 55 and older – Households near median income
Trip Rates (trips per unit per day)	• Free-Standing Discount Store: 56.0 (default) • Shopping Center: 55.0 (default)	N/A	• General Retail: 42.94	N/A
Trip Lengths (miles, from CSTDM)	• Home-Work: 11.04 • Home-Shop: 6.63 • Home-Other: 5.24 • Commercial-Customer: 6.63 • Commercial-Worker: 13.05 • Commercial-NonWork: 8.52	N/A	• Region – Home-Work: 12.05 – Home-Other: 6.04 – Not Home-Based: 6.66 • TAZ – Home-Work: 11.04 – Home-Other: 5.24 – Not Home-Based: 6.63	N/A

DU = dwelling unit; ksf = 1000 square feet; CBD = central business district; TOD = transit-oriented development; TAZ = transportation analysis zone

Table 17: VMT Estimates for 2nd Street Crossing				
	CalEEMod	GreenTrip Connect[1]	MXD[2]	Sketch7[1]
VMT per Day (Raw Estimate)	51,866	–	60,502	–
Percent Change in Context Area VMT	–	–	–	+7%

[1] Estimates only household VMT
[2] MXD does not report household VMT separately
HH = household

VMT-Based CEQA Analysis

Two of the four VMT screening thresholds are applicable to the exclusively-retail 2nd Street Crossing. The project is not located "near transit," though it is considered locally-serving retail in the project's EIR. The retail opportunities planned for 2nd Street Crossing (primarily Target) duplicate those in several nearby communities. Its development would presumably shorten shopping trips, reducing VMT, and would thus have less than significant VMT impacts (Table 18). Indeed, this concept is supported by the before-and-after study performed by Lovejoy et al (2013). Because the retail project is locally-serving, no further VMT analysis and no mitigation would be required. This would relieve 2nd Street Crossing of installing up to four traffic signals required to mitigate LOS impacts.

Table 18: VMT Screening Thresholds for 2nd Street Crossing			
	Threshold	**2nd Street Crossing**	**Significance Presumption**
Near Transit	Within ½ mile of rail or frequent bus service	Not Near Transit	Not Less than Significant
Low-VMT Residential Area – Household VMT per Capita	11.2[1]	11.8[1]	N/A
Low-VMT Office Area – Commute VMT per Employee	12.4[1]	16.0[1]	N/A
Retail	Locally-Serving	Locally-Serving	Less than Significant – No further analysis required

[1] Regional and TAZ averages from 2010 CSTDM Data

5. Discussion

There are many implications of quantifying VMT rather than LOS in project-level evaluation and CEQA review. Practically, our analysis shows that the available VMT quantification models have notable strengths and weaknesses. Some methods are simpler to implement "off-the-shelf" than others, such as GreenTrip Connect and CalEEMod. Others – namely Sketch7, and CalEEMod to run well – require baseline land use and VMT data, but can be run efficiently once those data are acquired. Some methods allow customization of inputs to reflect project contexts – CalEEMod's trip rates and trip lengths, for example – which can increase precision but also bias, as well as burden, on the analyst. However, simply using VMT quantification methods "off-the-shelf" with default values is unlikely to produce robust and defensible VMT estimates.

For the purposes of CEQA review, an important consideration regarding the use of VMT estimation models is the ability to compare its results to a baseline. Baselines – average VMT per capita, average VMT per household, et cetera – are critical for the formation of significance thresholds in CEQA review, and thus the determination of "significant" impacts. However, not all VMT estimation methods produce results that can be easily compared to a baseline. A baseline is ideally created from the same data and modeling method as the project-specific VMT estimate to ensure an "apples-to-apples" comparison between a chosen threshold and a measured impact. However, sketch-level models are explicitly created for project-level VMT assessment, rather than for calculating city- or region-wide averages. For example, analysts can fine the average VMT for single-family homes in a given geography by multiplying the single-family trip generation rate by the average trip length in a model like CalEEMod or MXD. However, the housing stock in a geography is likely a mixture of single-family, apartments, duplexes, townhomes, et cetera. The average VMT per household would reflect a weighted average of this mixture, though calculating a weighted average for a city or region with a tool built for project-level assessment pushes the analytical limits of sketch models.

A Per-Unit Transportation System

The ability to standardize VMT outputs is critical for use of project-level VMT in decision-making. Only a subset of models produce VMT estimates that are easily standardized (e.g. VMT per household or per employee) simply because of how the VMT estimates are reported. This is particularly the case for mixed-use projects, like the Cannery and Nishi Gateway, where a single project includes several different land uses (housing, employment, retail, et cetera). The output from some models (e.g. MXD) reports a singular project-level VMT without specifying the amount of VMT generated by each land use. If we simply divide total project VMT by the number of people or households, we overestimate household VMT by the amount of driving generated by the employment and retail uses. We thus cannot determine from models like MXD how the travel patterns of residents and employees in mixed-use developments would compare to average residents and employees in the region. However, a simple line-item report of total VMT by land use would allow us to calculate VMT per household (and per capita or employee) and would solve this limitation.

Transportation efficiency – measured by VMT per unit (household, capita, employee, et cetera) – more closely aligns with state policies like AB 32 and SB 375 than an aggregate project-specific VMT does. AB 32 and SB 375 set increasingly stringent targets for statewide VMT *per capita*, while acknowledging that *total* statewide VMT will actually increase as the state's population grows. To implement California's state and regional VMT targets, the project-by-project CEQA process would demonstrate that the residents and employees of new developments generate less per capita VMT than their counterparts in existing homes and offices. Put simply, new residential and office projects are not expected to reduce total VMT in a community or region. Rather, new projects are expected to generate less VMT per person than the status quo by the efficiency of their location and design.

However, this topic is ripe for future research. A new residential development may, in fact, be occupied by some residents moving from higher VMT areas in the region, rather than from outside the region, in which case regional VMT would in fact decline. Study of travel behavior before and after moving to a new home (like those in the Cannery and Nishi) would allow for better understanding of the net effects of new land use developments.

Whose VMT?

The question and complexity of "whose VMT" is also important. Sketch methods are generally designed to estimate the project-specific ingress and egress of VMT, rather than projects' overall effect on VMT in the community or region. In the case of retail projects like 2nd Street Crossing, the new retail opportunity ostensibly redistributes existing household VMT rather than generating entirely new trips. However, VMT estimates from most sketch models are blind to the redistributive effect of new retail opportunities in the community; they output a VMT value based on traditional ITE trip generation rates used in LOS analysis to measure localized vehicle volumes. By this accounting the retail VMT is estimated as new VMT and would theoretically be counted twice – once as part of household VMT and again for the retail project. It engenders an important research question as to the appropriate ways to allocate VMT to land use projects, industries, and even jurisdictions.

The illustration presented in Chapter 2.3, slightly modified in Figure 6 below, shows a simple version of this accounting dilemma. In the first land use scenario (Figure 6a), we can allocate the 12 VMT (4 trips × 3 miles per trip) entirely to the household, as we did when we estimated the VMT from the residential components of the Cannery and Nishi Gateway. When analyzing retail, most sketch models allocate to the grocery store the 3 VMT generated by the trip from the workplace (trip 3 in Figure 6a), and aggregate VMT from all customers that visit the store on an average day. This accounting difference becomes more apparent when we add another retail opportunity to the land use mix. The new grocery store in Figure 6b could be credited for reducing total VMT from 12 miles per day to 10.25 miles per day (3 miles + 3 miles + 4.25 miles = 10.25), like Sketch7's calculation of net change in VMT. If allocated traditionally, its VMT allocation would be 2.125 miles (trip 3 in Figure 6b), aggregated with the trip lengths of all other customers on an average day. If we allocate VMT to the household the hypothetical household is responsible for the 10.25 VMT.

How VMT is allocated has implications for policy and GHG emissions. It creates incentive and disincentive for certain development types and locations via policies like SB 743 and SB 375. For example, locally-serving retail within an urbanized area is incentivized over more "attractive" regional retail projects when its system-wide VMT effects are accounted, rather than accounting via the ingress and egress approach. Allocating VMT entirely to households may create disincentive for residential projects compared to employment and retail projects, particularly between jurisdictions.

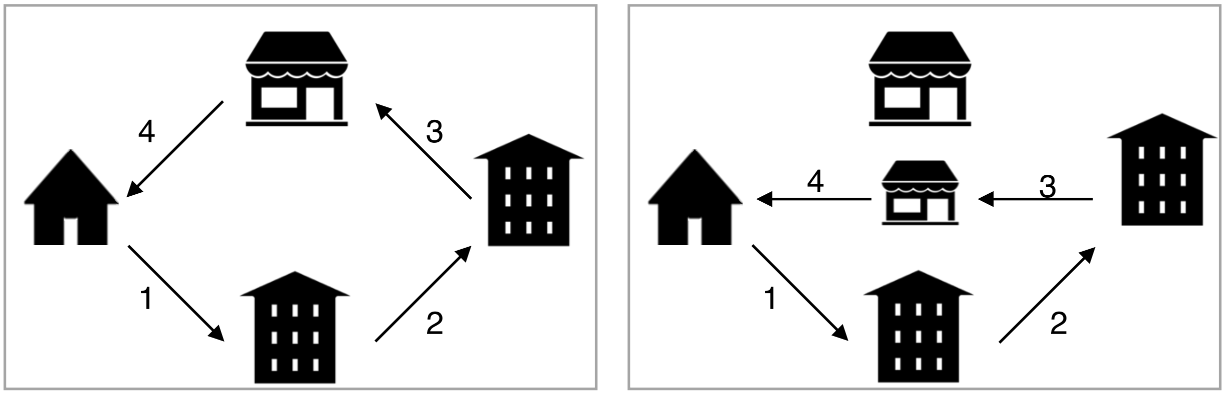

Figure 6: (a) Scenario 1, (b) Scenario 2, with change to land development pattern

Sketch7 partially overcomes the allocation limitation by directly estimating the net change in VMT from projects, though the half-mile radius reference geography limits its ability to capture even changes in intra-city travel. Future sketch models would ideally increase this reference geography to better capture the system-wide transportation effects, which are the crux of policies aiming to reduce VMT and transportation-related GHG emissions.

At a larger scale, this question of VMT allocation involves jurisdictional and analytical boundaries. For example, a resident in the Cannery may drive out of Davis city limits or the metropolitan region to destinations at Lake Tahoe or in wine country. The framework of SB 743 (and many other VMT mitigation polices) implies that development is responsible for the VMT it generates, thus the Davis-to-Tahoe VMT could be allocated to the origin (i.e. household), the destination, or some blend of both. A more complex example is a highway expansion project somewhere between Davis and Lake Tahoe would induce more travel, but the origin and destination would be responsible for the increased VMT if we allocate only to land use developments. How this VMT is allocated – which development and jurisdiction "owns" which VMT – is a policy question that has land use development implications and merits future research.

Validation

Analytically, we see from three case studies that the available VMT quantification methods estimate a wide range of project-generated VMT. These VMT estimation methods have not been validated with surveys or data, so we cannot say which is most accurate. Lovejoy et al.'s before-and-after study provides the rare empirical data to validate the analysis of 2nd Street Crossing; without similar studies of various types of projects in different contexts, we cannot say which of these methods is most accurate.

One of the challenges in switching to VMT metrics is that practitioners are in unchartered territory as to which methods are most accurate and legally defensible for estimating project-level VMT for CEQA analysis. Many decades of practice and litigation have contributed to the development of widely accepted methods to conduct LOS analysis for CEQA; this is not yet the case for analyzing project-level VMT. As we see from only three case studies, VMT estimates vary by as much as 200% for a given project.

The Right Direction?

Comparing the project-level VMT estimates to the VMT-based CEQA analyses, we see a pattern between the magnitude of project VMT and the significance of the projects' presumed transportation impacts. The relative impacts from the Cannery versus the Nishi Gateway are most notable. Households in the Cannery drive an estimated 13 to 30 percent more than households in the Nishi Gateway, though both projects generate household VMT below the regional average. Further, Sketch7 estimates that the Cannery would increase surrounding-area VMT by 6 percent; the Nishi Gateway would decrease VMT by 2 percent. The VMT analysis à la the SB 743 technical advisory indicates that the Cannery generates potentially significant VMT impacts from its office component, whereas the Nishi Gateway is presumed to have less than significant VMT impacts because of its proximity to transit. The technical advisory circumvents the shortfalls of the existing VMT quantification methods when it comes to estimating VMT from retail projects. The technical advisory instead cites the empirical findings of Lovejoy et al. (2013) and we can presume that 2nd Street Crossing causes less than significant VMT impacts. Further research across more projects would be necessary to establish the association between project VMT and significant VMT impacts, but in these three case studies SB 743's technical advisory indeed streamlines the lower-VMT developments.

Replacing LOS with VMT within the CEQA process also has implications for the built environment. In the short-term, we see from just three case studies that projects near transit and in low-VMT areas will benefit from a more streamlined CEQA process and fewer costly mitigation measures aimed at maintaining automobile flow rate. Streamlining and facilitating transit-oriented, low-VMT development corresponds with California's policy goals to reduce transportation GHG emissions via coordinated land use and transportation planning.

This is perhaps best illustrated by the case of the Nishi Gateway. The elimination of a costly, capacity-adding mitigation measure for a mixed-use infill project has quantifiable benefits. It streamlines the planning process and eases the financial burden of a project that adds housing to a housing-poor community. Rather than saddling infill development with the costs of easing auto congestion onto the Interstate – an externality of systemic undersupply of housing near employment – or locating employment opportunity away from its workforce, this policy shift creates a less burdensome CEQA process for a project that brings housing to employment-rich, highly-bikeable downtown core. This change is significant for creating more efficient land development patterns that provide a range of transportation options.

Mitigation for projects farther than a half-mile from transit and in high-VMT areas will also certainly change. Mitigating VMT impacts will require increasing accessibility and decreasing automobile demand, whereas mitigation of automobile delay has largely focused on optimizing traffic operations and increasing automobile capacity at specific intersections or roadway links (see Figure 7). For example, all three case study projects required traffic signal timing and additional turn lanes as mitigation under the LOS approach. But, some LOS mitigation strategies focused on decreasing automobile demand, exemplified by the bicycle and pedestrian facilities required at 2^{nd} Street Crossing. With a shift to VMT instead of LOS, we will likely see mitigations addressing travel distance to a variety of destinations (i.e. accessibility) in addition to mitigations addressing automobile demand (i.e. number of auto trips). For example, we may see projects mix land uses (add housing to, say, an office or retail project) to increase accessibility, in addition to or instead of traditional travel demand strategies like installing bicycle facilities.

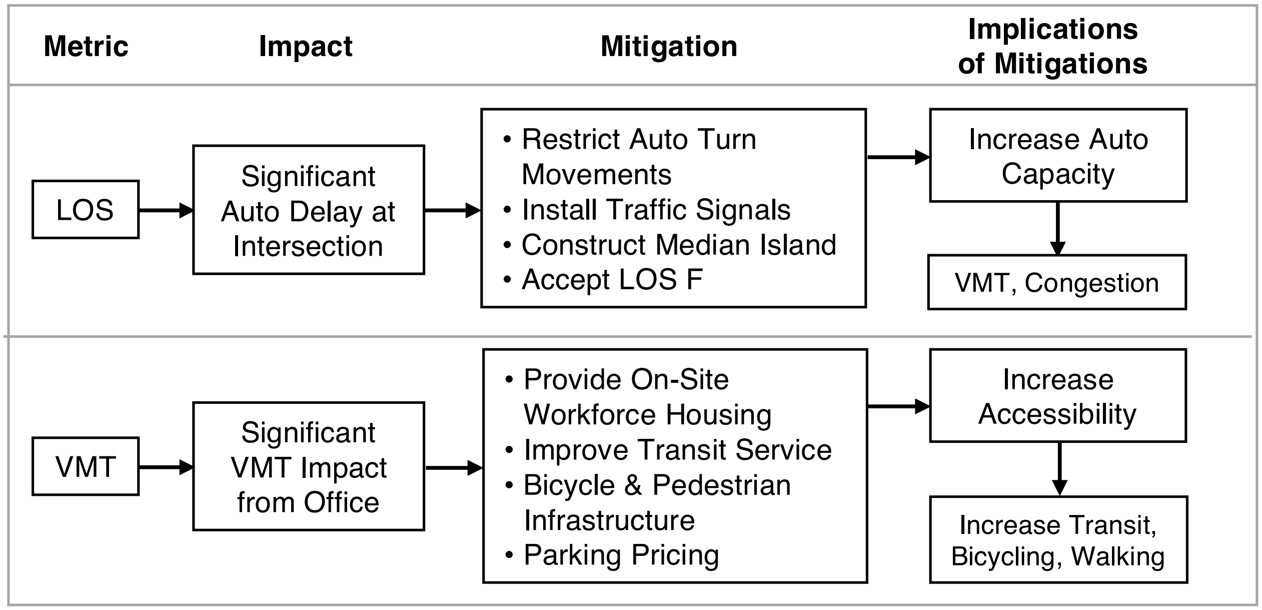

Figure 7: Comparison of Mitigations for the Cannery in Davis

In fact, the Nishi Gateway EIR includes several mitigations to address the VMT impacts it identifies (per voluntary city policy, as Nishi Gateway went through CEQA review prior to SB 743). VMT mitigations for Nishi Gateway include bicycle and pedestrian infrastructure, transit infrastructure and incentives, parking pricing strategies, as well as the provision of on-site housing to employees of the commercial component of the project. These strategies not only decrease VMT (CARB 2017), they can also improve congestion by decreasing the vehicle volumes that are loaded onto roadways. One of the many co-benefits of VMT reduction is that it "alleviates congestion in the specific locations where net vehicle travel is curtailed" (Fang & Volker 2017), whereas traditional congestion mitigations facilitate vehicle speeds and volumes through roadway capacity increases. The VMT induced by increased capacity ultimately causes congestion to rebound to pre-existing levels over the long term, negating the intent and short-term benefit of congestion relief (Downs 2004, Duranton and Turner 2011). Figure 8 illustrates the interaction between LOS, mitigation, measures, and induced travel.

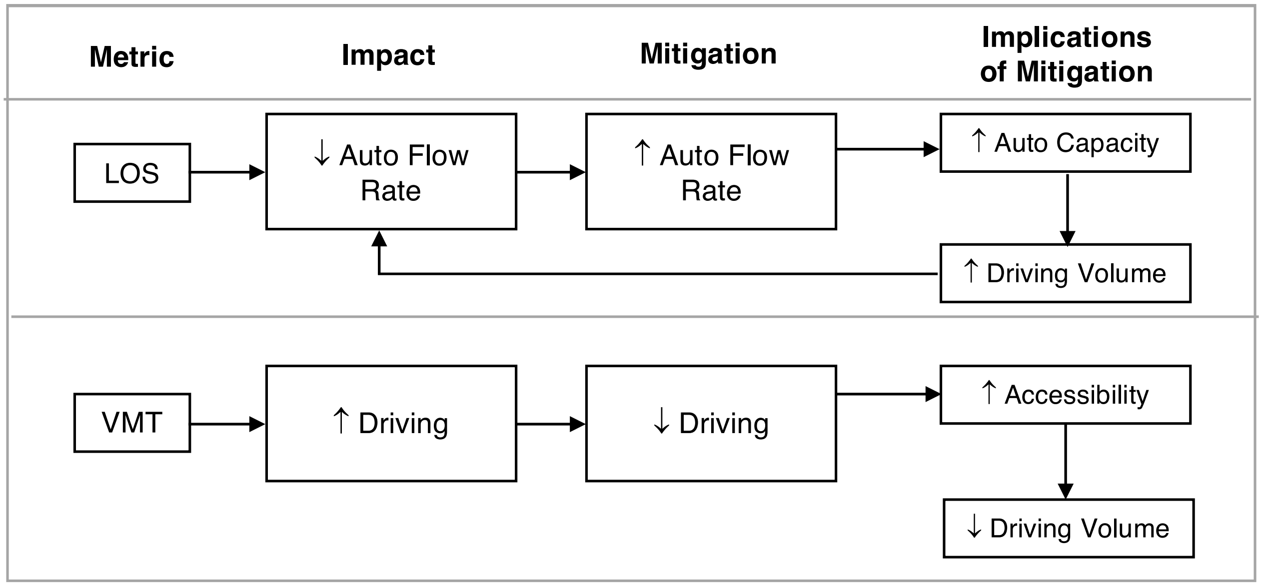

Figure 8: Impacts, Mitigations, and Travel Behavior – LOS versus VMT

CEQA and the Art of Mitigation Measures

A comparison of mitigation measures under these two metrics raises a fundamental question about what type of built environments communities want, and how they use the CEQA process to achieve them. Does Davis want more traffic signals and turn lanes? Will replacing LOS with VMT in CEQA facilitate – or make it more challenging – for communities to finance and construct the built environment they desire? General plans tell us the aspirations of the community, and the City of Davis has visions for its built environment that include (City of Davis 2007):

- Foster a safe, sustainable, healthy, diverse, and stimulating environment for all in the community.
- Become a community where the impacts of traffic, noise, pollution, crime, and litter are minimized.

- Maintain Davis as a cohesive, compact, university-oriented city surrounded by and containing farmland, greenbelts, natural habitats, and natural resources.
- Reflect Davis' small town character in urban design that contributes to and enhances livability and social interaction.
- Maintain a strong, vital, pedestrian-oriented and dynamic downtown area
- Encourage carefully-planned, sensitively-designed infill and new development to a scale in keeping with the existing city character.
- Encourage a clean, quiet, safe, and attractive transportation system that harmonizes with the city's neighborhoods and enhances quality of life.
- Promote alternative transportation modes such as bicycling, walking, public transit, and telecommuting.

In many cases across these three projects, the goals of the General Plan are inconsistent with the built environment created by mitigating vehicle delay. The significant automobile delay that the Cannery causes at the intersection of the Oak Tree Plaza, for example, triggers the restriction of automobile turn movements, installation of traffic signals, construction of a median island, and the City Council accepting LOS F at this location (see Figure 7). These measures attempt to maintain a certain vehicle flow rate around a community grocery store. This is perhaps in line with the goal of "minimizing traffic," but not in line with "encouraging a clean, quiet, safe, and attractive transportation system that harmonizes with the city's neighborhoods," nor does it "promote alternative transportation modes."

When we evaluate transportation impacts with VMT metrics, the Cannery causes significant impacts from the employees commuting to its offices. Potential VMT mitigations include the provision of on-site workforce housing (as was required of the Nishi Gateway), improvements to transit service, installation of active transportation infrastructure, and parking pricing. Each metric likely results in significant and unavoidable transportation impacts, but the alterations to the built environment are drastically different. The VMT-related mitigations align closely with the General Plan's goals for the community – a "cohesive" and "compact" city, "enhance livability and social interaction" – whereas the capacity-increasing mitigations to combat vehicle delay hamper them, and still result in auto delay (given that one LOS mitigation is to accept LOS F).

In the longer-term, policy makers should watch for changes in the types and locations of developments that are proposed. This change in performance metric changes the incentives and disincentives to develop certain types of projects in certain areas. Where LOS analysis has favored projects and locations that can maintain "driver comfort and convenience" per the *Highway Capacity Manual*, VMT analysis incentivizes projects and locations that decrease driving. We would presumably see dense urban areas with well-mixed land uses and high-quality transit – areas with inherently high vehicle delay but often low VMT – become more attractive to developers as they prompt fewer transportation impacts and requisite mitigations.

6. Conclusions

Our analysis is one of the first academic comparisons of the use of LOS and VMT metrics in transportation impact assessment under the California Environmental Quality Act. Analysis of impacts and thresholds is important for understanding the short- and long-run incentives for different types and location of development. As SB 743 is implemented across California, and the concept is perhaps adopted elsewhere, longitudinal research will show how the use of VMT as a performance metric influences long-term planning and incentivizes certain types of development decisions, and ultimately the types of communities that are built.

For the shorter-term, we show the influence that each metric has on communities via impact mitigations. Our analysis of LOS mitigation shows how the CEQA process per se impacts the built environment, often in ways that increase vehicle capacity and thus VMT (Figures 7 & 8). Over time, the VMT induced by mitigating LOS with capacity increases will cause further vehicle delay and trigger more LOS impacts. Breaking the congestion-capacity-repeat cycle requires addressing the demand for travel, which is inextricably linked with the accessibility provided by land development patterns (Figure 8).

We further show that under its current framework of SB 743, expensive capacity-increasing mitigation measures aimed at easing automobile congestion may be supplanted by streamlining for projects that reduce travel demand by design and location. Projects sited in urban cores near transit will enjoy an expeditious transportation impact analysis, as well as fewer mitigations to finance.

Finally, we show that the vehicle capacity constructed to mitigate LOS may contravene the goals and aspirations of many communities in California and the state's goals for GHG reductions. Further investigation of LOS mitigations across a larger sample of projects and jurisdictions would shed light on the extent of vehicle capacity that has been built in the name of CEQA.

Acknowledgements

This study was funded in part by a grant from the National Center for Sustainable Transportation (NCST), supported by USDOT through the University Transportation Centers program and the California Department of Conservation through the Strategic Growth Council's Sustainable Communities Planning Grants and Incentives Program (SCPGIP). The author would like to thank the NCST, USDOT, and the Strategic Growth Council for their support of university-based research in transportation, and especially for the funding provided in support of this project.

The author is incredibly grateful to Professors Susan Handy, Lisa Aultman-Hall, and Alissa Kendall for their excellent advising and inspiration. Jamey Volker also deserves many thanks for his extensive expertise of and collaborative deliberation over CEQA and NEPA.

References

Cervero, R. 2006. Alternative approaches to modeling the travel-demand impacts of smart growth. *Journal of the American Planning Association*, *72*(3): 285-295.

Cervero, R. and G.B. Arrington. 2008. Vehicle trip reduction impacts of transit-oriented housing. *Journal of Public Transportation*, 11(3).

Bradley, M., J. Bowman, B. Griesenbeck. 2002. SACSIM: An applied activity-based model system with fine-level spatial and temporal resolution. *Journal of Choice Modeling,* 3(1): 5-31.

Buehler, R. & J. Pucher. 2012. Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. *Transportation,* 39: 409.

California Air Pollution Control Officers Association (CAPCOA). (2013) California Emissions Estimator Model (CalEEMod). http://www.caleemod.com

California Air Resources Board. 2017. Senate Bill 375 – Research on Impacts of Transportation and Land Use-Related Policies. arb.ca.gov/cc/sb375/policies/policies.htm

[dataset] California Department of Transportation (Caltrans) Office of Multi-Modal Planning. 2014. California Statewide Travel Demand Model 2.0. dot.ca.gov/hq/tpp/offices/omsp/VMT_Analysis_2015_11_19.xlsx

California Code of Regulations, Title 14 Natural Resources, Division 6 Resources Agency, Chapter 3 Guidelines for Implementation of the California Environmental Quality Act (§ 15000 - §15387). https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I95DAAA70D48811DEBC02831C6D6C108E&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)

California Public Resources Code, Division 13: Environmental Quality (§ 21000 - §21189.57). https://leginfo.legislature.ca.gov/faces/codes_displayexpandedbranch.xhtml?tocCode=PRC&division=13.&title=&part=&chapter=&article=

California Transportation Commission. 2017. Regional Transportation Plan Guidelines for Metropolitan Organizations. www.dot.ca.gov/hq/tpp/offices/orip/rtp/docs/2017RTPGuidelinesforMPOs.pdf

Castiglione, J., J. Freedman, and M. Bradley. 2003. Systematic investigation of variability due to random simulation error in an activity-based microsimulation forecasting model. *Transportation Research Record: Journal of the Transportation Research Board*, 1831: 76-88.

Cervero, R. 2003. Road Expansion, Urban Growth, and Induce Travel: A Path Analysis. *Journal of the American Planning Association*, 69:2, 145-163.

City of Davis. 2006. Draft Environmental Impact Report – Second Street Crossing (Target Store) Project. community-development.cityofdavis.org/Media/Default/Documents/PDF/CDD/Planning/Special-Projects/Target-Store/Environmental-Review/Environmental-Impact-Report/04d-Transportation-and-Circulation.pdf

City of Davis. 2013. Draft Environmental Impact Report – Cannery Park. cityofdavis.org/city-hall/community-development-and-sustainability/development-projects/the-cannery/environmental-review

City of Davis. 2007. City of Davis General Plan – Amended 2007. cityofdavis.org/city-hall/community-development-and-sustainability/planning-and-zoning/general-plan

City of Davis. 2015. Nishi Gateway Project – Draft Environmental Impact Report. http://cityofdavis.org/city-hall/community-development-and-sustainability/development-projects/nishi-and-downtown-university-gateway-district/environmental-review

City of Oakland Planning Commission. 2016. Modification of CEQA Thresholds of Significance Guidelines. Staff Report for September 21, 2016 hearing. www2.oaklandnet.com/government/o/PBN/OurOrganization/PlanningZoning/o/Commissions/OAK062917

City of Orange v. Valenti. 1974. 37 Cal. App. 3rd 240.

Clifton, K and K. Currans. 2016. A Sustainable Multimodal Planning Framework for Transportation Impact Analysis. In 96th Annual Meeting of the Transportation Research Board (No. 17-03991).

Clifton, K., K. Currans, and C. Muhs. 2013. Evolving ITE Trip Generation Handbook: Proposal for Collecting Multimodal, Multicontext, Establishment-Level Data. *Transportation Research Record: Journal of the Transportation Research Board*, (2344): 107-117.

Clifton, K., K. Currans, K.M. and C. Muhs. 2015. Adjusting ITE's Trip Generation Handbook for urban context. *The Journal of Transport and Land Use,* 8(1): 5-29.

Currans, K. and K. Clifton. 2015. Using household travel surveys to adjust ITE trip generation rates. *Journal of Transport and Land Use*, 8(1): 85-119.

DeRobertis, M., J. Eells, J. Kott, & R. Lee. 2014. Changing the paradigm of traffic impact studies: How typical traffic studies inhibit sustainable transportation. *Institute of Transportation Engineers. ITE Journal, 84*(5): 30-35.

Dill, J. and T. Carr. 2003. Bicycle commuting and facilities in major US cities: if you build them, commuters will use them. *Transportation Research Record: Journal of the Transportation Research Board*, (1828), pp.116-123.

Downs, Anthony. 2004. Why Traffic Congestion is Here to Stay … and Will Get Worse. *Access Magazine*, 25, 19-25.

Duranton, G., and M. Turner. 2011. The Fundamental Law of Road Congestion: Evidence from US Cities. *American Economic Review 101: 2616-2652*

Ewing, R. & R. Cervero. 2010. Travel and the Built Environment. *Journal of the American Planning Association*, 76:3, 265-294.

Fang, K. & J. Volker. 2017. Cutting Greenhouse Gas Emissions is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled. National Center for Sustainable Transportation. ncst.ucdavis.edu/wp-content/uploads/2017/03/NCST-White-Paper-VMT-CoBenefits-White-Paper-LP_EB.pdf

Federal Highway Administration. 1987. Technical Advisory 6640.8A: GUIDANCE FOR PREPARING AND PROCESSING ENVIRONMENTAL AND SECTION 4(F) DOCUMENTS. environment.fhwa.dot.gov/projdev/impTA6640.asp#back

Fulton, W. and P. Shigley. *Guide to California Planning*. 3rd Edition. Point Arena: Solano Press Books. 2005.

Fulton, W. and P. Shigley. *Guide to California Planning*. 4th Edition. Point Arena: Solano Press Books. 2012.

Governor's Office of Planning and Research. 2016. Revised Proposal on Updates to the CEQA Guidelines on Evaluating Transportation Impacts in CEQA: Implementing Senate Bill 743 (Steinberg, 2013). opr.ca.gov/docs/Revised_VMT_CEQA_Guidelines_Proposal_January_20_2016.pdf

Handy, S. 1996. Methodologies for Exploring the Link Between Urban Form and Travel Behavior. *Transportation Research Part D*. 1(2): 151-166.

Handy, S. 1996. Understanding the Link Between Urban Form and Nonwork Travel Behavior. *Journal of Planning Education and Research* 15(3): 183-198.

Handy, S. 2005. Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us? International Regional Science Review 28(2): 146–167.

Handy, S. & M. Boarnet. 2014. Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions. California Air Resources Board Technical Background Document. arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_bkgd.pdf

Handy, S., X. Cao, and P. Mokhtarian. 2005. Correlation or Causality between the Built Environment and Travel Behavior? Evidence from Northern California. *Transportation Research Part D,* 10: 427-444.

Handy, S. and K. Clifton. 2001. Local shopping as a strategy for reducing automobile travel. *Transportation*, *28*(4): 317-346.

Handy, S., K. Shafizadeh, and R. Schneider. 2013. Final Report: California Smart-Growth Trip Estimation Study. University of California, Davis for the California Department of Transportation. downloads.ice.ucdavis.edu/ultrans/smartgrowthtripgen/Final_Report.pdf

Highway Research Board of the Division of Engineering and Industrial Research. 1965. *Highway Capacity Manual 1965*. National Academy of Sciences – National Research Council, Washington, DC.

Highway Research Board of the Division of Engineering and Industrial Research. 2000. *Highway Capacity Manual 2000*. National Academy of Sciences – National Research Council, Washington, DC.

Institution of Transportation Engineers (ITE). 2012. *Trip Generation Handbook, 9th Edition*. Institute of Transportation Engineers.

Jaffe, E. "Transit Projects Are About to Get Much, Much Easier in California." *CityLab*. July 8, 2014. http://www.citylab.com/commute/2014/07/transit-projects-are-about-to-get-much-much-easier-in-california/374049/

Lee, A., K. Fang, and S. Handy. 2017. Evaluation of Sketch-Level Vehicle Miles Traveled Quantification Tools. National Center for Sustainable Transportation. ncst.ucdavis.edu/wp-content/uploads/2017/06/NCST-SGC_Handy-VMT-Quant_Final-Report-AUGUST-2017.pdf

Lovejoy, K., G.C. Sciara, D. Salon, S. Handy, & P. Mokhtarian. 2013. Measuring the impacts of local land-use policies on vehicles miles of travel: The case of the first big-box store in Davis, California. *The Journal of Transport and Land Use*, 6(1), 25-39.

Newmark, G. L., & P. M. Haas. 2016. Does the Vehicle-Miles Traveled Associated with Location Efficiency Vary by Income Group? In Transportation Research Board 95th Annual Meeting (No. 16-4242).

Newmark, G., P. Haas, J. Pappas, M. Schwartz, A. Kenyon, and M.O. Unit. 2015. Income, Location Efficiency, and VMT: Affordable Housing as a Climate Strategy. Center for Neighborhood Technology Working Paper, Produced for the California Housing Partnership.

Oregon Department of Transportation. 2013. Oregon Statewide Transportation Strategy: A 2050 Vision for Greenhouse Gas Emissions Reduction, Volume 1. oregon.gov/ODOT/Planning/Documents/Oregon_Statewide_Transportation_Strategy.pdf

Pasadena Department of Transportation. 2015. Transportation Impact Analysis Current Practice & Guidelines. ww5.cityofpasadena.net/transportation/wp-content/uploads/sites/6/2015/12/Current-Practice-and-Guidelines.pdf

Roess, R. P. 1984. Level of service concepts: development, philosophies, and implications. *Transportation Research Record: Journal of the Transportation Research Board*, (971), 1-6.

Rothman, L.D. 2011. CEQA Turns Forty: The More Things Change, the More They Remain the Same. *Environmental Law News*, Vol. 20, No. 1, Winter.

San Francisco Planning Department. 2016. Executive Summary: Resolution Modifying Transportation Impact Analysis. commissions.sfplanning.org/cpcpackets/Align-CPC%20exec%20summary_20160303_Final.pdf

Senate Bill No. 743. California State Senate. 2013-2014. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB743

Shafizadeh, K., R. Lee, D. Niemeier, T. Parker, S. & Handy. 2012. Evaluation of operation and accuracy of available smart growth trip generation methodologies for use in California. *Transportation Research Record: Journal of the Transportation Research Board*, (2307), 120-131.

Schneider, R.J., K. Shafizadeh, and S.L. Handy. 2015. Method to adjust Institute of Transportation Engineers vehicle trip-generation estimates in smart-growth areas. *Journal of Transport and Land Use*, *8*(1): 69-83.

State of Washington 60th Legislature 2008 Regular Session. 2008. Engrossed Second Substitute House Bill 2815. lawfilesext.leg.wa.gov/biennium/2007-08/Pdf/Bills/House%20Passed%20Legislature/2815-S2.PL.pdf

Virginia Department of Transportation (VDOT). 2015. HB2 Implementation Policy Guide. vasmartscale.org/documents/hb2policyguide_8-1-2015.pdf

Walker, J. and M. Ben-Akiva. 2002. Generalized Random Utility Model. *Mathematical Social Sciences,* 43(3): 303-343.

Walters, J., B. Bochner, and R. Ewing. 2013. Getting Trip Generation Right: Eliminating the Bias Against Mixed-Use Development. American Planning Association. asap.fehrandpeers.com/wp-content/uploads/2016/03/APA_PAS_May2013_GettingTripGenRight-2.pdf

Zhao, Y., & Kockelman, K. M. 2002. The propagation of uncertainty through travel demand models: an exploratory analysis. *The Annals of Regional Science*, 36(1): 145-163.