Transportation Analysis Framework

First Edition

Evaluating Transportation Impacts of State Highway System Projects

California Department of Transportation
Sacramento, California
September 2020

ACKNOWLEDGEMENTS

The *Transportation Analysis Framework* (TAF) and *Transportation Analysis Under CEQA* (TAC) were prepared by the California Department of Transportation working with State Administration partners and Stakeholders from the public, private and non-profit sectors. Contributors within the Department included staff and management from the Headquarters Divisions of Environmental Analysis, Transportation Planning, Traffic Operations, and Legal, as well as from the Director's Office Sustainability Team. The Headquarters team benefitted from input provided by the Caltrans Executive Team as well as by staff and management from Caltrans districts.

The documents are the products of a collaboration among State government partners. Throughout the development of the documents, the Caltrans team worked closely with technical and policy experts from the Governor's Office of Policy and Research and the California Air Resources Board.

A list of the individuals who contributed to the preparation of the TAF and TAC is included at the end of this document. We are grateful for the time and effort that they generously gave to develop and document the Department's new approach to analyzing and evaluating transportation impacts of projects on the State Highway System.

LETTER FROM THE DIRECTOR

To Caltrans staff, partners, and stakeholders,

I am pleased to issue the enclosed guidance document: *Transportation Analysis Framework* (TAF) as part of the California Department of Transportation's (Caltrans) continuing commitment to implement the California Environmental Quality Act (CEQA) in alignment with State goals and policies. The TAF, and its companion document, *Transportation Impacts Analysis under CEQA for Projects on the State Highway System* (TAC) provides Caltrans policy along with guidance for implementing Senate Bill (SB) 743 (Steinberg, 2013) codified at Public Resources Code section 21099.

The new processes being implemented through Caltrans' environmental program are a key part of Caltrans' increasingly important work to confront the challenge of climate change and build more livable communities. Caltrans is actively implementing strategies to reduce emission of greenhouse gases, including initiatives to use clean fuels and vehicles, and to reduce waste. Perhaps most importantly, we are rethinking the way we invest so people can drive less.

Reducing total driving, or Vehicle Miles Traveled, is the focus of the TAF, TAC and the associated changes to transportation impact analysis under CEQA for projects on the State Highway System. In plain terms, the more we drive our cars, the more damage we cause to the environment and our health—and the less time we spend with our families and communities. A Vehicle Miles Traveled-based approach supports transportation projects that create more travel choices, such as new rail lines, improved bus service, trails, paths, and safer streets for walking and bicycling. As these modes of transportation grow, we can reduce the dependence and burden on our already congested highway system.

Thank you to our partners and stakeholders, as well as to Caltrans staff, whose contributions have helped to shape this document. I look forward to your continued partnership as we make the changes needed to meet California's goals for climate, air quality, and public health. It's an exciting time to continue our commitment to provide more transportation options to Californians and reduce our dependence on driving.

Sincerely,

Toks Omishakin
Director

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FOREWORD

The *Transportation Analysis Framework* (TAF) and *Transportation Analysis under CEQA* (TAC) guide CEQA transportation impact analysis for projects on the State Highway System (SHS). The California Department of Transportation (Caltrans) has prepared these documents to guide implementation of Senate Bill (SB) 743 (Steinberg, 2013). The TAF and TAC establish Caltrans guidance on how to analyze induced travel associated with transportation projects and how to determine impact significance under CEQA, respectively. These documents guide transportation impact analysis for projects on the SHS only. The non-capacity-increasing maintenance projects like re-paving and filling potholes are unaffected, as are many safety improvements, including traffic calming measures to slow traffic, and transportation projects that create facilities for pedestrians and cyclists and transit projects.

In response to a high level of interest in the guidance from Caltrans' transportation partners, climate and environmental advocates and others, Caltrans has hosted a total of 130 meetings with stakeholders and provided a 60-day informal feedback period on the draft documents. Statewide outreach events included two external webinars attended by over 850 participants, and three external technical roundtables attended by more than 150 participants. These Caltrans events were supplemented by OPR's webinar and Office Hours outreach which reached over 3,500 participants. Additionally, Caltrans met regularly through the guidance development process with key stakeholders including the Self-help Counties Coalition, the ClimatePlan coalition, and the Rural Counties Task Force.

Caltrans received feedback on the drafts from 37 agencies including counties, cities, and MPOs as well as from consultants, advocates, coalitions and other State agencies. Throughout the process, a small number of controversial issues stood out. To address the difference of opinions around key technical issues, Caltrans convened an expert panel of academics and practitioners through UC Berkeley Tech Transfer. The panel chair presented the group's conclusions to stakeholders at a virtual Technical Roundtable prior to finalizing the group's recommendations. Caltrans and State partners have accepted the panel's recommendations, which are reflected in the guidance documents.

The Caltrans TAF and TAC guidance documents reflect a cultural shift for how Caltrans interprets, analyzes and mitigates transportation impacts. This shift will impact the entire project delivery process and shape the future of California's transportation system. The September 2020 TAF and TAC are the first versions of these materials, and we anticipate future improvement as our understanding and expertise deepens through implementation. Your continuing input and partnership with Caltrans will help further improve the guidance. Your commitment and participation in this ongoing work is appreciated.

1 INTRODUCTION

1.1 OVERVIEW OF GUIDANCE DOCUMENTS

This document, *Transportation Analysis Framework: Evaluating Transportation Impacts of State Highway System Projects (TAF)* is one component of a set of materials prepared by Caltrans to guide the implementation of SB 743 (Steinberg, 2013). The TAF is a companion to the *Transportation Analysis under CEQA (TAC)*, which describes changes to the environmental review process for many projects on the State Highway System (SHS). These changes better align the analysis of transportation impacts with State objectives for greenhouse gas emissions reduction, preservation of the environment, and public health. Practitioners should consult both documents in conducting a transportation analysis.

Additionally, the Governor's Office of Planning and Research (OPR) has prepared a Technical Advisory on *Evaluating Transportation Impacts in CEQA* (OPR 2018) to assist agencies conducting a transportation impact analysis for both land use and transportation projects based on Vehicle Miles Traveled (VMT). Caltrans relied on OPR's recommendations in developing this guidance. Practitioners should consult the OPR Technical Advisory when evaluating transportation impacts of projects on the SHS.

1.2 PURPOSE OF THE TRANSPORTATION ANALYSIS FRAMEWORK

The purpose of this *Transportation Analysis Framework* is to assist Caltrans district staff and others responsible for assessing likely transportation impacts as part of environmental review of proposed projects on the SHS by providing guidance on the preferred approach for analyzing the VMT attributable to proposed projects (induced travel) in various project settings. The TAF and TAC together provide the guidance needed to implement amendments to the 2018 CEQA Guidelines and Caltrans policy for analyzing transportation impacts. The policy states:

Consistent with the language of Section 15064.3 of the CEQA Guidelines, Caltrans concurs that VMT is the most appropriate measure of transportation impacts under CEQA. The determination of significance of a VMT impact will require a supporting induced travel analysis for capacity-increasing transportation projects on the SHS when Caltrans is lead agency or when another entity acts as the lead agency.

Many types of projects will be unaffected by the use of VMT as the metric for determining transportation impacts because they are assumed not to lead to a substantial increase in vehicle travel. See Section 5.1 of the TAC for further detail regarding screening. Note that for transportation projects not on the SHS, per the CEQA Guidelines, local agencies have the discretion to select a different metric for determining transportation impacts.

This Framework focuses on the analysis of transportation impacts only. It is not intended to supersede guidance for analysis under CEQA of other resources (such as air quality or noise) or under the National Environmental Policy Act (NEPA). Those analyses have their own distinct requirements.

The TAF is to be used in conjunction with the guidance provided in the TAC. The flow chart provided in Figure 1 illustrates the steps for transportation impact analysis using the TAC and TAF. As shown, if a project is determined to be of a type that is likely to induce travel, the analyst follows the framework described in the TAF. The TAF framework should be applied to the proposed project and all project alternatives. The results of applying the TAF's analytical framework is intended to provide the substantive information from which significance determinations under CEQA can be made, as further described in the TAC.

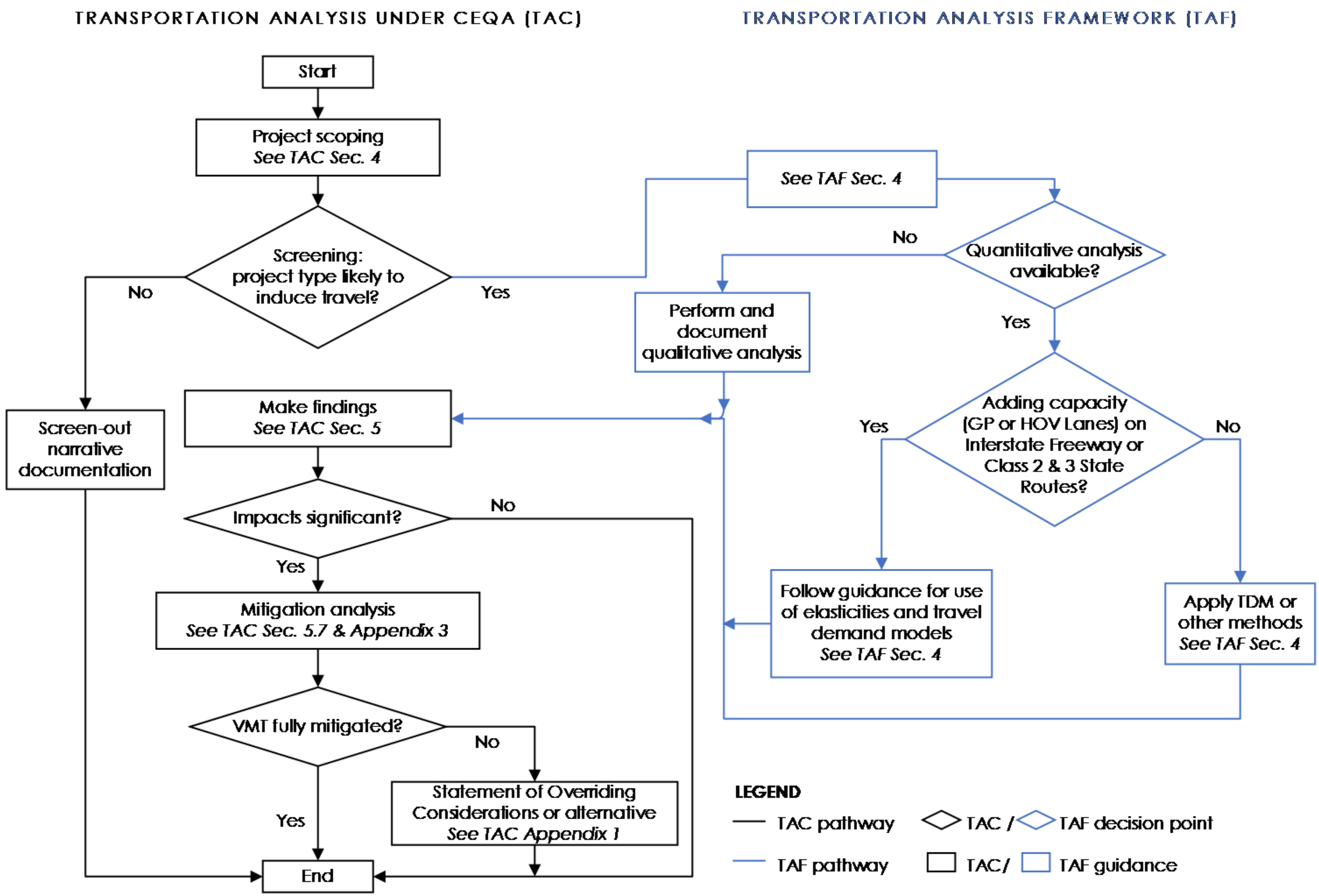

Figure 1. Steps in CEQA Transportation Impact Analysis for SHS Projects

2 FUNDAMENTALS

2.1 Focus of Transportation Impact Analysis

CEQA analysis of transportation impacts of proposed projects on the SHS focuses on the amount of driving attributable to the proposed project, measured as change in VMT. CEQA requires identifying, assessing and disclosing potentially adverse environmental impacts resulting from a project, i.e. impacts that would not occur but for the project. Generally stated, the transportation impact of a roadway project is the overall increase in VMT that is attributable to the project, distinct from any background changes in VMT due to other factors such as population or economic growth. The transportation impact is the difference in VMT with the project and without the project. The difference in VMT may be negative for some projects that reduce VMT; zero for projects which do not affect VMT or positive for those projects which are associated with an increase in VMT. The analysis reflects the phenomenon of induced travel, which is discussed below.

Generally, the project types associated with an increase in the total amount of driving are projects that add passenger vehicle and light duty truck capacity to the SHS. Many project types, including maintenance and rehabilitation projects as well as most safety projects, will be identified as unlikely to induce travel, requiring only screening and a narrative documenting that analysis and conclusion. Such projects are identified through the screening process depicted in Figure 1 and discussed in Section 5 of the TAC. Other types of projects are specifically excluded from transportation impact analysis process. These types of projects typically include pedestrian, bicycle and transit infrastructure projects.

2.2 Induced Travel Definition and Illustration

2.2.1 INDUCED TRAVEL DEFINITION

When transportation system changes effectively reduce the cost of travel to individuals and businesses, there is typically a change in user behavior. Induced travel is the term used to describe this phenomenon, which is illustrated conceptually in Figure 2. The reduction of travel time from T_1 to T_2 ($T_1>T_2$) due to network improvement leads to increased VMT from VMT_1 to VMT_2 ($VMT_1<VMT_2$).The reduced "cost" may be due to reduced travel time as shown in Figure 2, increased reliability, lower price, or some combination of factors.

The induced travel phenomenon manifests itself in multiple ways:

- Longer trips. The ability to travel a long distance in a shorter time increases the attractiveness of destinations that are farther away, increasing trip length and vehicle travel.

- Changes in mode choice. When transportation investments reduce automobile travel time, travelers tend to shift toward automobile use from other modes, increasing vehicle travel.
- Route changes. Faster travel times attract more drivers to the altered route, which can increase or decrease VMT, depending on whether trips are shortened or lengthened.
- Newly generated trips. Shorter travel times can induce additional trips, which increases vehicle travel. For example, an individual who previously telecommuted or shopped online might choose to accomplish those tasks with car trips as they become quicker and less stressful.
- Location and land use changes. In choosing where to live or where to locate or expand a business, households and investors take travel costs into account. In choosing where to allow development, local governments take available capacity into account, as do investors in new development. Over the long term, changes associated with these decisions lead to further changes in the other aspects of travel (routes, modes, destinations, number of trips made) as people adjust to the choices available at the new location.

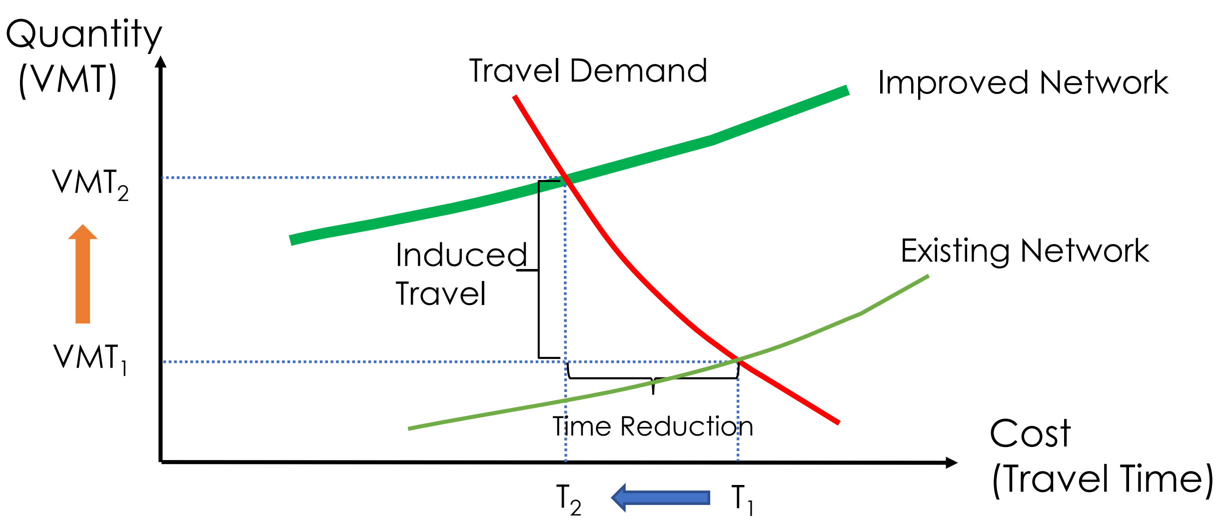

Figure 2. An Illustration of Induced Travel due to Reduced Travel Time

A variety of road project types can create the conditions where induced travel can occur (Noland and Lem, 2002). Importantly, induced travel is not limited to increased travel on the facility that has been changed. Trip-making in a wider area will be affected because of the various types of change described above. As illustrated conceptually in Figure 3a, a new connection across a natural barrier, a river in this case, may not only see increased travel between the points that directly benefit from the new connection (Town A and Town B); but may also alter travel patterns in a wider area. In the longer term, the nearby areas may see new development that would not have occurred in the absence of the increased transportation network capacity. In Figure 3b, the bypass will not only divert traffic away from the town center but may in the longer term generate development along the new connection and alter the travel pattern of the entire area. For example, town center stores may give way to big box stores along the new connection, stimulating additional driving.

(a) (b)

Figure 3. Connectivity and Induced Travel - Conceptual Sketches

As noted above, the changes in travel are not limited to the specific project and its environs, nor do they necessarily appear immediately; some of these changes are seen in the short term and in the project corridor, while others occur over a wider area (potentially, the commute shed and beyond) and play out over a time frame of many years. Some academic studies of the induced travel effect quantify both "short run" and "long run" induced travel effect magnitudes. Generally, "short run" magnitudes measure induced travel that occurs in the first year or two, while "long run" magnitudes measure induced travel that occurs in 5-10 years. The long-run induced travel effect that combines direct impacts with the indirect impacts stimulated by land use change is the full effect of a project. Even roads that simply provide greater access under conditions of no congestion may facilitate development in locations that lead to increased travel.

Additional vehicle travel provides additional mobility benefits to users and may also support expanded access to housing and employment opportunities. However, additional travel also tends to increase negative externality costs. Induced travel will reduce the effectiveness of capacity expansion as a strategy for alleviating traffic congestion and may reduce the benefits of such projects in lowering emissions. Mobility and accessibility increases can still be valuable, but their benefits may be offset partially or entirely by the impacts of added travel.

2.2.2 INDUCED TRAVEL - ILLUSTRATION

With a hypothetical project, Figure 4 illustrates the induced travel effect unfolding over time. The baseline trend, shown in the figure by the line labeled "VMT Without Project", shows the VMT on the network growing over time, perhaps the result of population and/or economic growth. On the other hand, the increase in vehicle travel associated with the increase in network capacity is shown by the line labeled

"VMT With Project". The VMT attributable to the project, or induced travel, is the difference between VMT on the network with the project compared to VMT on the network without the project counted in the horizon year.

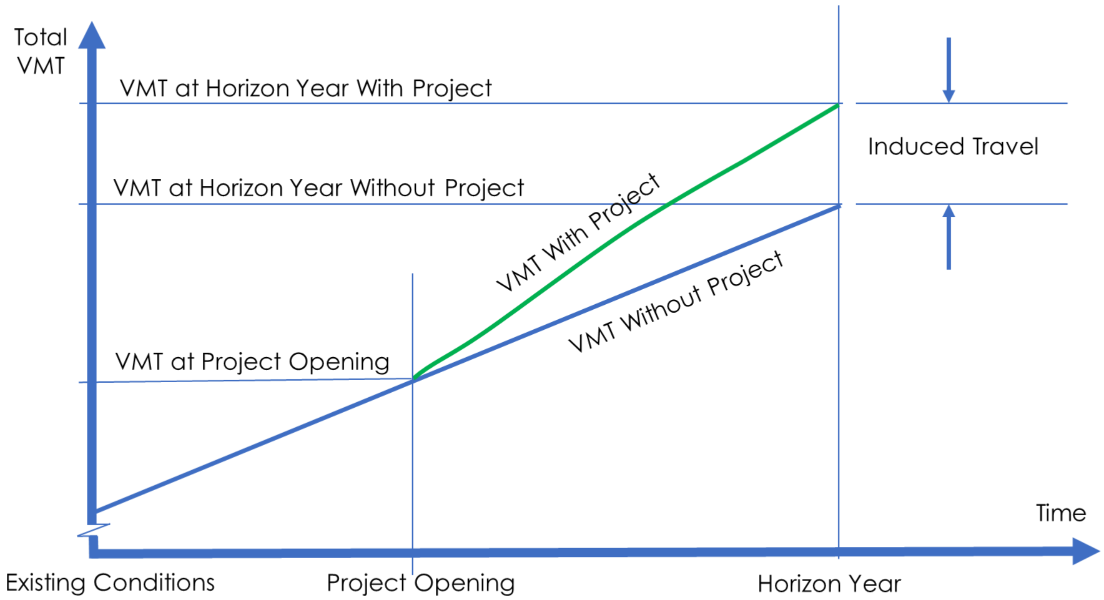

Figure 4. Identification of Induced Travel (VMT Attributable to a Transportation Project)

While the theory behind induced travel is straightforward, empirically estimating this effect has proven to be complicated, as a brief overview of the literature illustrates. The extent to which travel changes occur depends on the elasticity of travel demand, but how to estimate that elasticity and its effects over a network and over time has been debated. The next section of the TAF describes the most common tools for estimating induced travel. Section 4 then provides guidance on selecting the appropriate tools for analysis of specific projects. See, e.g., literature reviews in Cervero, 2002; Noland and Lem, 2002; Duranton and Turner, 2011; Handy and Boarnet 2014a; Handy and Boarnet 2014b; and Milam et al. 2017.

3 TOOLS FOR ESTIMATING INDUCED TRAVEL

3.1 OVERVIEW

Projecting the amount of induced travel attributable to a project is complex. Travel growth associated with overall population and economic growth need to be separated from the likely effects of system investments, and changes can occur over many years and a large area. It is not a simple matter of monitoring traffic on the particular facility and its immediate environs, because some of the travel changes are likely to affect other elements of the overall transportation system. As described above in Section 2, induced travel can result in trips diverted to different routes, trips switched to different modes; longer trips reflecting the choices of farther destinations, and additional trips. In addition, transportation improvements can affect the relative attractiveness of different locations for both housing and commercial development, leading to land development projects that in the longer term can reshape the pattern of activity and trip making in the region. Because of these complexities, studies of induced travel have turned to a variety of models to help identify the key factors affecting VMT.

Methods used to study induced travel include models specifically investigating the effects of transportation investments on induced travel, travel demand models designed for multiple analysis and forecasting tasks and sometimes used to estimate the share of travel that is induced, and case studies of travel growth and its causes in particular corridors and regions. The guidance provided in Section 4 directs CEQA practitioners to select and apply a single method or a combination of methods based on project characteristics and context and the applicability of the available tools. A general discussion of the two primary tools available for estimating induced travel in connection with infrastructure investments is provided below. Elasticity-based methods including the National Center for Sustainable Transportation (NCST) induced travel calculator are discussed in Section 3.2 and use of travel demand models is discussed in Section 3.3.

3.2 ELASTICITY-BASED METHODS

A key approach in representing the induced travel effect is reporting it as an elasticity based on empirical studies of changes in travel associated with past increases in roadway capacity. Mathematically, the elasticity of VMT is the percent increase in VMT associated with a given percent increase in roadway lane miles. Over time, both short-term and longer-term estimates of the elasticity of VMT with respect to highway improvements (most commonly measured in lane miles) have been produced for different types of facilities and for different geographic scales, with increasingly sophisticated methods controlling for the overall effects of growth and other factors also affecting VMT.

The NCST at the University of California at Davis has developed an online tool, the NCST induced travel calculator, that uses elasticities to estimate induced travel associated with the addition of new general purpose (GP) or high occupancy vehicle (HOV) lanes on the SHS. Guidance for the use of the NCST induced travel calculator, (referred to here as "the NCST Calculator" or "the Calculator"), is provided in Section 4. This Section describes strengths and limitations of the Calculator to provide users with a deeper understanding of this tool.

The NCST Calculator incorporates elasticities of VMT with respect to capacity increases, drawing on the best available peer-reviewed papers on the topic; other recent high-quality studies have reported similar elasticities to those used in the Calculator (NCST 2019a; NCST 2019b; and Panel Report 2020). The cited studies control for other factors that could confound the estimates. The use of these elasticities in the estimation of induced travel is reasonable. However, analysts need to be aware that they are long-term average elasticities for the particular highway types and contexts studied. Some project-to-project variation is to be expected. Recognizing this, the guidance in Section 4 advises using the Calculator's results to benchmark results from other methods, and it also provides analysts with an opportunity to document why particular projects can be reasonably expected to result in changes that vary more substantially from the Calculator's results.

The panel of academics and practitioners that advised the team developing this guidance concluded that:

- The peer-reviewed studies the Calculator has chosen to rely upon are widely considered to be the best available, and other recent studies have found similar elasticities, adding credence to those used by the Calculator;
- The standard errors for the models estimating the elasticities are reported in the papers and are at acceptable levels;
- The elasticities extracted from the studies account for the full set of possible impacts and distinguish infrastructure-induced VMT impacts from other factors that could be driving observed changes (e.g., general growth in population and economic activity);
- Since the elasticities in the calculator are based on traffic count and lane mileage data and are derived from econometric analyses that use advanced methods to control for possible confounding variables, they are a strong indicator of likely regional average, long-run responses (Panel Report 2020).

The Calculator elasticities are long-term elasticities. Some studies such as Cervero and Hansen (2002) also produce short-term elasticities, either by looking at a short time frame or by omitting factors that tend to appear over the longer term, such as land use changes. ("Short term" in this context means under five years and can be as little as a year or two; "long term" can be 10 years into the future.) While the studies in the literature use differing time frames, there is no clear conclusion to be drawn from the literature regarding how fast the changes occur. Highly congested areas are likely to have considerable unsatisfied demand for travel; and therefore, the response to new capacity may be rapid. Areas at the urban fringe have also been found to generate high levels of induced traffic, more likely to manifest over time, as new facilities alter development opportunities, business and housing locations, and users' overall travel patterns.

3.2.1 SENSITIVITY TO DIFFERENT PROJECT TYPES

Any project that adds capacity to the SHS has the potential for generating additional travel. However, the studies used to construct the NCST Calculator are limited to only GP and HOV lane facilities; and thus, the Calculator is applicable for assessing induced travel of GP and HOV lane addition only and not for special purpose lanes such as high-occupancy toll (HOT)/ managed lanes or truck lanes. The Calculator treats GP and HOV lanes identically.

Because there is a lack of a strong evidence base for estimating the induced travel effects of HOT lanes and other types of priced lanes, the NCST Calculator cannot be used for priced lanes such as HOT lanes. This limitation is reflected in the guidance provided in Section 4. Adding a lane restricted to a special purpose, such as a toll lane, freight or transit lane, may induce travel by particular users. It may also make capacity available in the GP lanes, in turn inducing traffic into the GP lanes. It can be complex to determine how much capacity is added by a managed lane, as its capacity is related to design, operating rules, and driver choices. Features including the number, location and design of entry and exit points can make a difference in facility performance and use. Operating hours, occupancy requirements, toll levels for HOT lanes, enforcement/violation rates may also influence impact on VMT.

HOT lanes, whereby single occupancy vehicles (SOVs) can legally use the HOV lane for a toll, are particularly complex. They are relatively new and therefore have not been studied extensively, though HOT lanes have been used in California and several other states and generated case studies (e.g., in Texas and Minnesota) as well as scenario-based analyses.

Like an HOV lane, a new HOT lane may attract vehicles from GP lanes due to their travel time benefit. However, the toll option is likely to lead to more complex travel behaviors than would an HOV lane. SOVs may move from GP lanes to the HOT lane, attracting new trips and longer trips formerly deterred by congestion, and inducing mode shift such as HOVs to SOVs.

3.2.2 SENSITIVITY TO PROJECT CONTEXT

Many practitioners raise concerns about the NCST Calculator's apparent lack of sensitivity to project context. For example, questions have been asked about whether the studies that underlie the Calculator match the background conditions where projects are being proposed - particularly non-metropolitan planning organization (MPO) counties, smaller MPOs, and rural areas of larger MPOs. Considerations include land use patterns and densities, modal choices and route options. In fact, similar concerns apply to the Travel Demand Models (TDMs), too. The aggregate data and estimated coefficients used in the TDMs reflect heavily the more urbanized, populous, modally diverse portions of the modeled region.

Whether the metropolitan statistical area (MSA) or urban county data apply to the more rural areas of a given county will depend on how integrated the area in question is to the broader urban economy. The MSA designation assumes that they are indeed integrated through commute patterns, which are a significant indicator of interconnectedness. Therefore, the Calculator is applicable throughout MSA areas. However, the Calculator is not applicable to rural counties. It will be used for projecting induced travel for GP and HOV lane projects in MSA counties as shown in Table 2. Section 4.4 provides an opportunity for analysts to describe cases where specific conditions make the induced travel effects of a project likely to be substantially different from the estimate derived from the Calculator.

As noted earlier, available studies do not offer a definitive answer about whether outlying areas are more or less likely to experience induced travel resulting from capacity increases. Several such studies suggest that the elasticity of demand may be higher in the outlying areas partly because of the relative percent increase in capacity, and partly because of the potential for location and land use shifts and increased travel to and from other parts of the metropolitan region (Panel Report 2020). Case examples also show that rural areas and areas with limited congestion can still experience induced travel resulting from new capacity because the new capacity improves travel times/ reduces costs and creates new patterns of accessibility and new location and land use opportunities. Available studies such as Duranton and Turner (2011) also indicate that accounting for transit services at the levels of service and geographic scales of availability experienced in most US contexts do not significantly alter the induced travel estimates.

3.2.3 SENSITIVITY TO DIFFERENT REGIONS

The NCST Calculator uses a constant elasticity across a county or an MSA. However, it accounts for variation in the travel-inducing strength between counties and regions by using the base year level of VMT as an input. Counties and regions that start with more traffic (higher existing VMT per lane mile) experience more induced travel for a given lane-mile addition. For example, a county or region that has twice the existing traffic per lane mile would see twice the amount of induced travel per lane mile added.

3.3 TRAVEL DEMAND MODELS

3.3.1 OVERVIEW

Travel models are often called Travel Demand Models (TDMs), though they also include models of transport supply. TDMs are widely used in California and throughout the United States as transportation system analysis and forecasting tools. Among their many applications, the travel models are used to measure network performance and identify deficiencies, to forecast future levels of service under anticipated levels of growth and change, and to generate the traffic data and projections needed for air pollution emissions estimates.

TDMs vary considerably in their specifications. Some MPOs and a few counties and cities in California have developed advanced activity-based models; many others use trip-based models. Some are run as part of an integrated land use-transportation modelling process while others handle current and future land use as a separate analysis step and use the results as inputs to the travel models. Models also vary in the extent to which they cover such issues as trip scheduling, time-of-day of travel, transit service characteristics (e.g., bus vs. rail), nonmotorized modes, and freight movements. Highway networks usually cover major collector and higher-level roads, but some models also include local roads.

TDMs vary also in their ability to estimate induced travel associated with highway investments. Some models can estimate induced travel reasonably well and some others cannot. For example, some model systems do not have the capability to account for changes in origin-destination patterns, increases in trip rates, and changes in location and land use resulting from transportation investments. In addition, models are not always applied in a way that fully uses their capabilities.

Many improvements have been made to travel models over the last two decades, but there remains considerable variation in the level of detail and the sophistication of the models in use in California and elsewhere. Depending on the specifics of model specification, estimation, and application, travel models may provide a reasonable estimate of induced travel, or they may under- or over-estimate induced travel. As Volker et al. (2020) reported, induced travel estimates set forth in some published environmental documents are well below those estimated by empirical studies, and underestimation is a concern. The likely reasons for such differences include:

- Land use changes and associated travel are a significant component of induced travel, but some transportation planning models treat land use as exogenous and some further assume it is fixed (i.e., land use is not altered as a result of transportation system changes.)
- Some travel models, either in specification or in application, do not include a mechanism to feedback network travel times and travel costs to land use mode choice, destination choice, and trip frequency modeling elements (Marshall 2018)
- Price and income are sometimes treated in limited ways; and therefore, important impacts on travel choice are not well represented in the models
- Reliability is often not represented by the travel model even though it can be important to the traveler: a small reduction in travel time can be accompanied by a large reduction in travel standard deviation, providing a meaningful improvement in reliability.
- Network levels of detail may be insufficient to reflect traffic conditions, available route and mode choices.
- Boundary cutoffs may mean that a portion of travel outside the model's boundaries is not well represented in model analyses, though it may be impacted by system changes.
- Models are not always run to traffic assignment equilibrium where network congestion is minimized.

- Models are often calibrated to observed data such that the alternative-specific constants take a large (outsized) importance in the choice models, rendering them less sensitive to time and cost.
- Finally, models may not have been thoroughly validated over a period of time in which travel times and costs have changed (such that it should be possible to see if the models would have predicted such changes.) (Panel Report, 2020)

A review of the capabilities of available travel demand models and their applications is therefore in order before relying solely on their outputs as a basis for evaluating induced travel impacts of projects on the SHS. The checklist in Section 4.5 provides specific guidance for evaluating whether a travel demand model is appropriate for use in estimating induced travel.

3.3.2 SOURCES FOR MODELING IMPROVEMENT GUIDANCE

Recent reports from the National Cooperative Highway Research Program (Erhardt et al. 2019) provide additional guidance on evaluating errors in models and could be valuable sources of advice. Guidance on modeling has been produced by State of California agencies, including the California Transportation Commission, the Governor's Office of Planning and Research, and the California Air Resources Board.

The Federal Highway Administration (FHWA) has also produced extensive advice on modeling, especially through its Travel Model Improvement Program (TMIP). The FHWA-HEP-10-042 report prepared by Cambridge Systematics, Inc. (2010) discussed the best practices on how to calibrate/adjust and validate/test TDMs, checking them for reasonableness. Note that checking the model can reveal underlying problems that need to be corrected; e.g., if VMT per household is unreasonably high or low, it would be advisable to make sure data errors were not introduced. Data from the US Census and travel surveys such as the National Household Travel Survey (NHTS) (https://nhts.ornl.gov/) provides useful comparisons. (NHTS data covers trip modes, lengths, and purposes, and all areas of the country, urban and rural.)

The TMIP advises that to be useful, tests of reaction to change must be done through applications of the model in full production mode. However, this is not always done in practice. Also, many models are validated on a reserved set of base year data; it would be useful to further validate predictive capabilities against a future year when such data are available.

4 GUIDANCE TO PRACTITIONERS

4.1 APPLICABILITY OF GUIDANCE

The TAF should be consulted when a transportation project on the SHS could lead to a measurable and substantial increase in vehicle travel. The OPR Technical Advisory states that these projects would "…generally include… Addition of through lanes on existing or new highways, including general purpose lanes, HOV lanes, peak period lanes, auxiliary lanes, or lanes through grade-separated interchanges" (OPR 2018). Refer to Section 5.1 of the TAC for the project screening process and the list of project types that would not likely lead to a substantial or measurable increase in vehicle travel, and therefore generally should not require an induced travel analysis.

4.2 SELECTING THE ANALYSIS APPROACH

4.2.1 OVERVIEW

Section 5.1 of the TAC guides the analyst through the process of screening a project on the SHS to determine whether a VMT significance determination is necessary. This process applies to both the project and project alternatives being considered. Such a determination requires analysis of induced travel impacts using one of the analysis approaches described in this section of the TAF.

Following a decision that induced travel analysis is needed, the analyst must select the analysis approach based on project location, facility type, and available tools as described in the following sections. The selection process applies equally to project alternatives under consideration. In a typical document, multiple alternatives will be described and analyzed. Analysis of induced travel may be necessary for each alternative, requiring selection and application of appropriate methods for each.

This guidance provides analysts with the basis for identifying the best available analysis approach for the project and alternatives. Table 1 guides the selection of preferred analysis approaches based on project location, project and facility type, and applicability of tools.

1. **Applicability of tools.** Section 4.3 provides a general discussion of the tools for estimating induced travel. In cases where the NCST Calculator can be directly used, it should either be used exclusively or used to benchmark results from a TDM. Where the NCST Calculator is not applicable and a TDM is suitable for use, a TDM should be used. The TDM should be assessed as adequate for assessing induced travel based on the checklist presented as Table 4 or should

undergo modifications in order to remedy identified deficiencies. Section 4.4 and 4.5 provide additional detail.

2. **Project location.** Whether the project is in an MSA or a rural county will influence the approach selected, since the NCST Calculator is not applicable in non-MSA counties. For projects in rural counties, the best available method should be selected by analysts and reasons for selecting the method should be documented. This would preferably be a TDM or other quantitative method. A qualitative assessment will be acceptable if it takes into account the potential for capacity additions to induce travel as a result of changes in travel behavior in response to reduced travel cost, improved reliability, or long-term land use change likely to be associated with the project.

3. **Project and Facility Type.** Only projects adding general purpose or HOV lanes can use the NCST Calculator directly. The Calculator's applicability varies by facility type as shown in Table 1.

4.2.2 GUIDANCE FOR SELECTING ANALYSIS APPROACH

Table 1 provides a selection matrix to be used in identifying the preferred VMT assessment method(s) based on location and project type. The application of the NCST Calculator and the TDM is described in Section 4.3 and 4.4, respectively. Table 1 applies only to the forecasting of induced travel associated with projects on the SHS for CEQA analysis. Depending on the method selected, other methods and tools may be necessary to forecast total VMT in the horizon year for other CEQA impact analysis and for NEPA analysis when applicable. Consult with Caltrans Division of Environmental Analysis (DEA) for details.

4.3 APPLICATION OF THE NCST CALCULATOR

The NCST Calculator can be applied to mainline general-purpose lane additions and mainline HOV lane additions on Class 1 facilities (Interstate freeways) and Class 2 and 3 facilities (Other Freeways, Expressways, and Other Principal Arterial state routes) as defined by the FHWA. See Appendix A for facility class definitions. Of the 58 counties in California, the Calculator can be applied directly in 37 counties that belong to MSAs but not in the remaining 21 non-MSA rural counties. See Table 2 for a list of the 37 MSA counties, and Table 3 for a list of the 21 non-MSA rural counties.

For a Class 1 facility, the NCST Calculator must be applied at the MSA level; while for Class 2 and 3 types of facilities, the Calculator must be applied at the county level. This is because the NCST Calculator was based on studies that examined only those geographies. As shown in Table 2, the Calculator applies to all Class 1, 2, and 3 facilities in 23 MSA counties. In 14 MSA counties the Calculator applies to Class 2 and

3 facilities only because either there are no Class 1 facilities in the county, or the Class 1 facility mileage is less than one mile in the county.

Table 1. Selection Matrix for Preferred Induced Travel Assessment Method for Projects on the SHS[1]

Project Type / Project Location	GP or HOV Lane Addition to Interstate Freeway	GP or HOV Lane Addition to Class 2 & 3 State Routes	Other VMT Inducing Projects and Alternatives
County in MSA with Class I Facility	Apply the NCST Calculator by MSA and/or TDM[2] benchmarked with NCST Calculator.	Apply the NCST Calculator by county and/or TDM[2] benchmarked with NCST Calculator.	Apply TDM[2] or other quantitative methods
Other MSA County	Apply TDM[2] or other quantitative methods		
Rural County	Apply TDM[2] or other quantitative methods		

[1]If preferred methods are not available, qualitative assessment is acceptable as shown in Figure 5.
[2]TDMs must be checked for applicability as described in Sections 4.4 and 4.5.

Freeway ramps and minor arterials or collector-distributor roads associated with a freeway fall outside the scope of application for the NCST Calculator. The VMT inducing effects for ramp, minor arterial, and collector-distributor road capacity projects should be evaluated as "Other VMT Inducing Projects" in Table 1.

The NCST Calculator allows users to directly assess the likely average increase in VMT resulting from induced travel associated with the planned addition of GP or HOV lane miles. The Calculator output represents the increase on area-wide facilities, not solely on the facility that the project would alter. It uses 2016 lane-mile and VMT data from Caltrans databases (and therefore applies only to California, as currently presented) together with long-term elasticities taken from the literature, specifically the Duranton and Turner (2011) nationwide estimate for Interstate facilities (which the Calculator rounds to 1.0) and the Cervero and Hansen (2002) California county-level estimate for class 2 and 3 facilities (0.75 as implemented in the Calculator). The user specifies the category of facility and lane miles being added and the county or Metropolitan Statistical Area (MSA) of application; the Calculator is only applied to counties for which there are data and for which the studies are applicable (Tables 2 and 3 indicate the Calculator's applicability to California counties).

While use of the online Calculator is the recommended approach to applying the elasticity-based method, the method may also be applied manually by the analyst.

A standard formula for estimating project induced VMT is embedded in the Calculator:

Project-Induced VMT = %∆ Lane Miles x Existing VMT x Elasticity

where,
%∆ Lane Miles = The increase of lane miles expressed as a percentage of the total lane miles in the study area. This must be a positive number.

Table 2. The 37 MSA Counties where the NCST Calculator Applies

23 MSA Counties: The NCST Calculator Applies to Class 1, 2, and 3 Facilities		
Alameda	Merced	San Joaquin
Contra Costa	Orange	San Mateo
Fresno	Placer	Santa Clara
Imperial	Riverside	Shasta
Kern	Sacramento	Solano
Kings	San Bernardino	Stanislaus
Los Angeles	San Diego	Yolo
Marin	San Francisco	
14 MSA Counties: The NCST Calculator Applies to Class 2 and 3 Facilities only		
Butte	San Benito	Sutter
El Dorado	San Luis Obispo	Tulare
Madera	Santa Barbara	Ventura
Monterey	Santa Cruz	Yuba
Napa	Sonoma	

Table 3. The 21 Rural Counties where the NCST Calculator does not Apply

Alpine	Inyo	Nevada
Amador	Lake	Plumas
Calaveras	Lassen	Sierra
Colusa	Mariposa	Siskiyou
Del Norte	Mendocino	Tehama
Glenn	Modoc	Trinity
Humboldt	Mono	Tuolumne

Additional details on application of the Calculator are available online at https://ncst.ucdavis.edu/research-product/induced-travel-calculator and also discussed in Appendix A.

As described above, the NCST Calculator uses empirical data to establish elasticities that reflect the likely change in travel volumes associated with a change in roadway capacity. The Calculator's output reflects an average areawide change, not simply the change in volumes on the facility itself. The NCST Calculator reports long-run induced travel results for the horizon year. Estimates for intermittent years can be determined with linear interpolation. The NCST Calculator does not distinguish between GP and HOV lanes, so the tool cannot be used to assess any potential difference in induced travel between those two project types.

The NCST tool may in some cases be used to provide a valuable point of reference in a quantitative assessment of the impacts of project types other than GP and HOV lanes. For example, while the NCST calculator does not apply directly to HOT lanes, in the absence of a travel demand model capable of projecting induced travel based on the checklist assessment, the NCST Calculator may supply a useful data point for consideration in the analysis of a HOT lane project.

4.4 Application of Travel Demand Models

As shown in Table 1, TDMs will be used to assess induced travel in the following two situations:

1. Applied in combination with the NCST Calculator as discussed below;
2. Applied alone when the NCST Calculator is not applicable.

Where a travel model is used, often the regional travel model will be the most appropriate scale to capture the entire area over which induced VMT is observed. However, as discussed above, some TDMs lack key elements for assessing induced travel. For example, some model systems do not have the capability to account for changes in origin-destination patterns, increases in trip generation rates, and changes in location and land use resulting from transportation investments. In addition, models are not always applied in a way that fully exercises these capabilities. Analysts should document the models, the calibration steps taken, reasonableness tests performed, and validation tests against later year conditions. Documentation should indicate both verification that the model has the capacity to reflect travel behavior accurately, and that it is run correctly, in order to assess induced travel.

When a travel model is used to assess induced travel, the following steps must be followed:

1. Assess the travel model and off-model processes using the checklist provided in Section 4.5.

2. If the NCST Calculator can be applied to the project, and the travel model passes the checks, apply both methods.
   a) Use the TDM results, if within 20 percent of the value provided by the NCST Calculator.
   b) If travel demand model results differ from that of the Calculator by more than 20 percent, use the Calculator's results exclusively, or use the TDM results and provide specific quantitative evidence explaining this variation. The evidence may include reference to quality academic studies, or analysis of specific project features or context justifying that the project's induced travel could be substantially higher or lower than the average value indicated by the NCST Calculator.

3. If the NCST Calculator cannot be applied to the project, and the travel model passes the checks, then apply travel models only.

4. If the NCST Calculator cannot be applied to the project, and the travel model does not pass all the checks, then:
   a) Disclose and document the areas of deficiency and make improvements to the model to address those issues. If that is not possible in the timeframe of the project analysis, use other options below.
   b) Apply off-model approaches using the best available information or tools to compensate for TDM's deficiencies, making approximations as needed where more precise data or information are not available.
   c) Where a quantitative assessment cannot be reasonably undertaken, a qualitative assessment may be undertaken (see Section 4.6).

When both the NCST Calculator and TDMs are used as guided by Table 1, a detailed method selection flow chart is provided in Figure 5 to further facilitate the process of selecting an analysis approach.

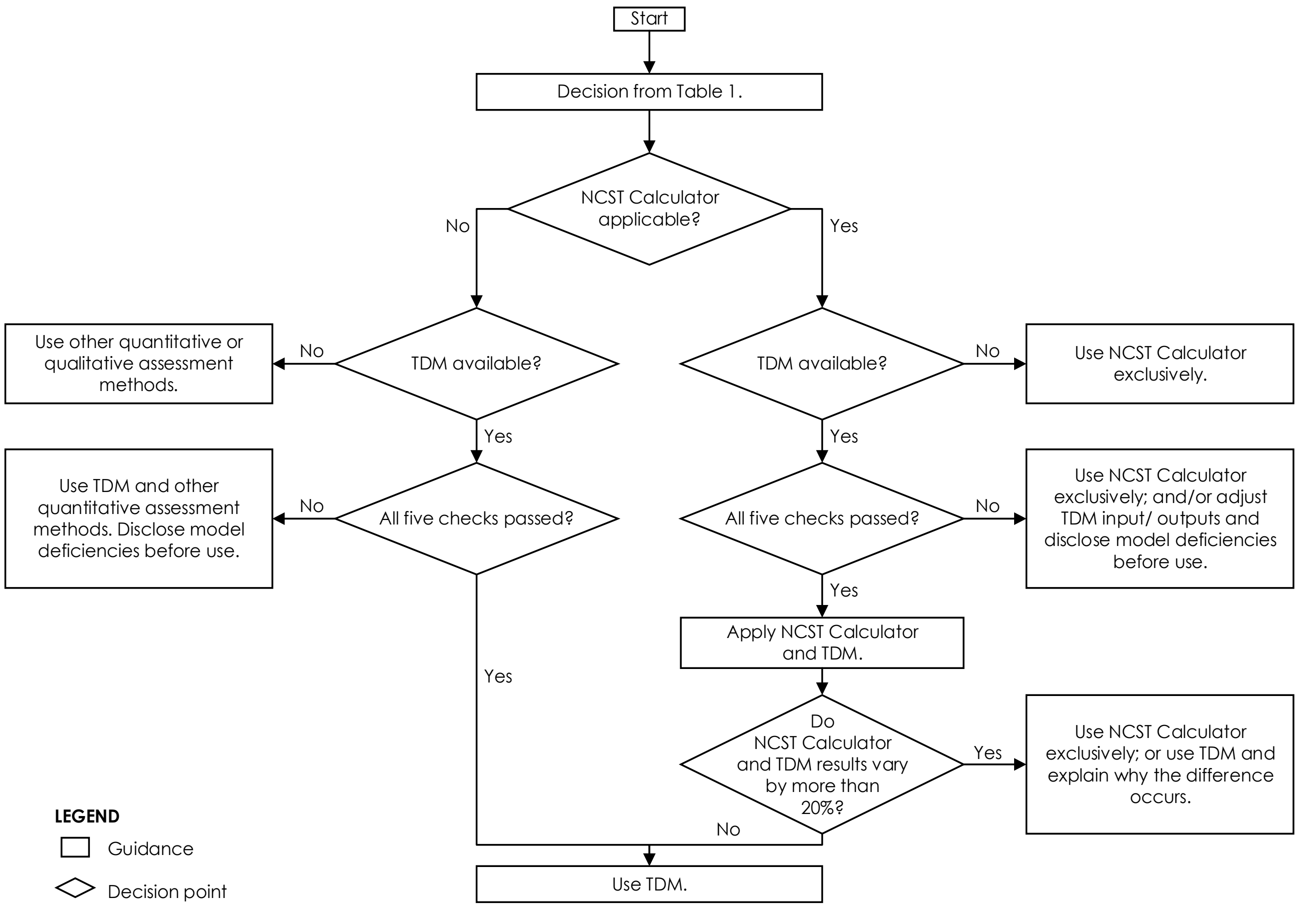

Figure 5. A detailed assessment method selection flow chart.

4.5 THE CHECKLIST FOR EVALUATING MODEL ADEQUACY

The checklist in Table 4 specifies model capabilities required for induced travel assessment. The checklist focuses on both modeling mechanisms and modeling practices. The purpose is to ensure induced travel modeling mechanisms are built in, and established modeling practices are followed in implementing a TDM for induced travel modeling. There are five checks in total. In general, a model should pass all five checks before the analyst concludes that the TDM is appropriate for making projections of induced travel. As noted elsewhere, assessments made using models that do not satisfy all checks should include disclosure of deficiencies, documenting ways in which the deficiencies may affect results.

Table 4. A Checklist for Evaluating Adequacy of Travel Demand Models for Estimating Induced Travel

Check 1. Land use response to network changes[1]. Check the box if the answer to the question is "yes". "Check 1" passes if either box 1a or 1b is checked.	
1a ☐	Is the model's specification of future land use sensitive to travel time and cost, i.e., varying across modeling scenarios to simulate the land use response to network changes?
1b ☐	If future year land use is exogenous to the modeling process, are land use assumptions determined via a Delphi method (Linstone and Turoff eds., 1975; Rand Corp, 1969; Cavalli-Sforza and Ortolano, 1984; and Melander 2018) or through examination of outcomes under a range of modeling scenarios, including both build and no build alternatives?
[1] Any TDM used to assess induced travel must be paired, or iterated, with an approach for predicting changes in land use caused by the project. OPR's Technical Advisory (*Appendix 2, Induced Travel Mechanisms, Research, and Additional Assessment Approaches*, p. 34) lists options for incorporating land use effects in a travel model-based assessment.	
Check 2. Sensitivity of trip-making behavior to network travel times and travel costs[2]. Check the box if the answer to the question is "yes". "Check 2" passes when box 2a, 2b, and 2c are all checked.	
2a ☐	Do changes in network travel times and travel costs by mode (e.g. vehicle operating costs, tolls, parking costs, transit fares, etc.) influence mode choice, destination choice (including workplace location), route choice, and trip frequency?
2b ☐	Are the network travel times and costs fed back into the mode choice, destination choice, route choice, and trip frequency models so that travel times and costs are roughly consistent with the "converged" travel times and costs from traffic assignment?
2c ☐	Does the modeling reflect the heterogeneity and complexity of travelers' responses to time and cost changes relevant to the examined project?

Table 4. A Checklist for Evaluating Adequacy of Travel Demand Models for Estimating Induced Travel (cont'd)

[2]. If the trip generation sub-model is not sensitive to travel time, then the analyst will need to provide for a manual intervention in the trip generation stage of the model to adjust the trip generation rates in the model for off-line computed induced travel effects of the project, its alternatives, and potential mitigation measures. The analyst can employ activity based travel model parameters that are available from a similar region to manually estimate off-model the effects of the project, its alternatives, and potential mitigation measures on trip generation with and without the project for the desired forecast years (with the land use linkage described above activated) and noting the predicted percentage change in trip generation by purpose predicted by the activity based TDM parameters. These percentages, which will vary by project alternative, may then be applied to the output of the trip generation stage of the trip-based model.	
Check 3. Sufficiency of detail and coverage of modelled roadway and transit networks[3]. Check the box if the answer to the question is "yes". "Check 3" passes if both box 3a and 3b are checked.	
3a ☐	Are the roadway and transit networks provided in sufficient detail and coverage to reflect the full set of route and mode choices available to the traveler?
3b ☐	If the project would lead to induced travel extending beyond the model's boundary, has the model been modified to incorporate the larger geography, or has an off-model assessment captured the additional travel generated?
[3]. In cases where the project would lead to induced travel that extends beyond the model's boundary, the model should either be modified to incorporate that geography (e.g. by adding "halo zones") or an off model assessment should be made to capture the additional travel (e.g. where that travel is destined for a population center outside the model area, multiply gateway volumes by distance from the gateway to that population center). For sufficiency of geographical coverage, the analyst should use select link analysis to check whether links that run up to the model's edge show increased volumes as a result of the project. If they do, VMT increases likely continue outside the model's boundary. Where that is the case, one of three approaches can be used to capture that VMT. First, "halo zones" can be added to capture the additional VMT within the model. Second, a reasonable assumption can be made about length of the missing portion of the trip (e.g. use the distance to next major jobs or population center, if trips are likely allocated there), and that distance can be multiplied by the volume. Third, a model with greater coverage, such as the California Statewide Travel Demand Model (CSTDM), can be used.	

Table 4. A Checklist for Evaluating Adequacy of Travel Demand Models for Estimating Induced Travel (cont'd)

<table>
<tr><td colspan="2">For temporal coverage, the analyst should examine the peaking of traffic flows in the area served by the project to determine the needed temporal coverage of the model (weekday peak hours, peak periods, daily, weekends and holidays, recreational seasons, full year), and then check to ensure the model assesses those time periods.</td></tr>
<tr><td colspan="2">Check 4. Network assignment processes[4]. Check the box if the answer to the question is "yes". "Check 4" passes if box 4a is checked.</td></tr>
<tr><td>4a ☐</td><td>Is the modeling guidance published by FHWA (Cambridge Systematics, 2008, 2010) followed, in order to provide a sufficient level of convergence in network assignment such that the differences in outcomes between modeling scenarios can be reliably attributed to the differences in scenario definitions rather than the network assignment process itself?</td></tr>
<tr><td colspan="2">[4]. For static roadway assignment, a relative gap between model runs of 0.001 is a good safe harbor.</td></tr>
<tr><td colspan="2">Check 5. Model Calibration and Validation[5]. Check the box if the answer to the question is "yes". "Check 5" passes if box 5a is checked.</td></tr>
<tr><td>5a ☐</td><td>Has the model been validated across points in time and changes in travel time and cost in order to confirm that it is appropriately sensitive to changes in these factors?</td></tr>
<tr><td colspan="2">[5]. In order to preserve sensitivities, alternative specific constants shall not deviate substantially in overall magnitude relative to the other variables unless the resulting sensitivity is validated based on observed data.</td></tr>
</table>

4.6 Qualitative Assessment Approach

The CEQA Guidelines 15144 specify, "Drafting an EIR or preparing a Negative Declaration necessarily involves some degree of forecasting. While foreseeing the unforeseeable is not possible, an agency must use its best efforts to find out and disclose all that it reasonably can." Specifically addressing transportation impact analysis, CEQA 15064.3 states, "…if existing models or methods are not available to estimate the VMT for the particular project being considered, a lead agency may analyze the project's vehicle miles traveled qualitatively. For many projects, a qualitative analysis of construction traffic may be appropriate." When neither the NCST Calculator nor an appropriate TDM is available, modeling improvement cannot practically be accomplished, and no other quantitative assessment approach can be identified, a qualitative assessment approach may be appropriate.

When a project type is identified from the screen-out list contained in Section 5.1 of the TAC, a simple narrative will generally suffice in terms of induced travel assessment.

4.7 DOCUMENTATION

Documenting the factual and analytic basis for the decisions made throughout the project development process is critical to explaining how those decisions were made. The mandate to document facts and analysis used in reaching a conclusion applies to both the decisions made in analyzing a proposed project for whether a VMT analysis is required and if so, the technical level details as to how it was performed. These requirements apply to CEQA alternatives as well as to the proposed project.

Documentation of each fact relied upon, each inference derived from established facts and the logical approach taken to reach a conclusion are necessary so others, including a court if the matter is litigated, can follow the analytical path taken by the practitioner. The requirement to adequately document the analytical path applies whether the practitioner is a Caltrans staff member, a partner agency staff member or a consultant retained to prepare the analysis.

4.7.1 CALTRANS UNIFORM FILING SYSTEM

Caltrans has established a formal "Uniform Filing System" which must be the framework for documenting the facts, inferences and conclusions reached when reviewing a project's potential impacts. Taken together, the Uniform Filing System's components form the "Administrative Record" for the project. Training for how to apply the Uniform Filing System, and the creation and maintenance of the Administrative Record, is available through the Division of Environmental Analysis. See, e.g., http://etp.dot.ca.gov/env/files/admin-record/presentation_html5.html for additional background. Note that for those projects where NEPA compliance is required, similar procedures for records retention are required. See, e.g., https://dot.ca.gov/programs/environmental-analysis/standard-environmental-reference-ser/volume-1-guidance-for-compliance/ch-38-nepa-assignment#files.

Caltrans, like many other entities, has enterprise-level policies relating to the automatic deletion of emails after a certain amount of time elapses. While those policies generally apply, in order to assure retention of the records which document the analytical path taken in performing an analysis, relevant emails and any attachments should be retained in the project file, either in electronic format or by printing and saving to the project's paper file.

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APPENDIX A. THE NCST INDUCED TRAVEL CALCULATOR

SCOPE OF NCST INDUCED TRAVEL CALCULATOR

The technical documentation for the NCST Induced Travel Calculator states that (see https://ncst.ucdavis.edu/research-product/induced-travel-calculator *accessed August 11,* 2020):

- The calculator is limited to use for capacity expansions. It cannot be used to estimate VMT effects of capacity reductions or lane type conversions.
- The calculator is limited to use for additions of general-purpose and high occupancy vehicle (HOV) lanes.
    - It should not be used for additions of toll lanes or high occupancy-toll (HOT) lanes.
    - Hundreds of both general-purpose and HOV lane mile additions were included in the two studies used to derive the elasticities for the Calculator (Duranton & Turner, 2011); (Cervero & Hansen, 2002). By contrast few toll and high-occupancy toll (HOT) lanes were added before the end of the data collection periods for the two studies. The studies' estimated elasticities therefore might not reflect toll and HOT lanes. This Calculator should not be used to estimate the induced travel impacts of toll and HOT lanes.
- The calculator produces long-run estimates of induced VMT, the additional annual VMT that could be expected 5 to 10 years after facility installation.
- All estimates account for the possibility that some of the increased VMT on the expanded facility is traffic diverted from other types of roads in the network. In general, the studies show that "…capacity expansion leads to a net increase in VMT, not simply a shifting of VMT from one road to another" (Handy & Boarnet, Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions Policy Brief, 2014)
- The Calculator currently uses 2016 lane mileage and VMT data from the Highway Performance Monitoring System (HPMS), including both passenger and heavy-duty vehicle data. The data will be updated periodically as new data become available.
- Knowledge of local conditions can help contextualize the calculator's estimates.

FHWA FUNCTIONAL CLASSIFICATION SYSTEM

The FHWA functional classification system used in the UC Davis NCST Induced Travel Calculator is defined in an FHWA memorandum (https://www.fhwa.dot.gov/policy/ohpi/hpms/fchguidance.cfm):

Functional Class 1 = Interstate
Functional Class 2 = Other Freeways and Expressways

Functional Class 3 = Other Principal Arterial

A variety of roadway facilities in California are represented within these functional classifications and in the corresponding Caltrans HPMS data, including but not limited to: State Highway System (SHS), local roadways, Department of Defense roads, State Parks roads, and U.S. Forest Service roads.

Note that according to the technical documentation for the NCST Induced Travel Calculator, functional classes 1, 2, and 3 are within the scope of the NCST Calculator if they are state highways.

CONCEPTS

Handy and Boarnet (2014a, 2014b) define "induced travel" as an "increase in vehicle miles traveled (VMT) attributable to increases in capacity." Handy and Boarnet (2014a, 2014b) then state:

> *"Increased highway capacity can lead to increased VMT in the short run in several ways: if people shift from other modes to driving, if drivers make longer trips (by choosing longer routes and/or more distant destinations), or if drivers make more frequent trips. Longer-term effects may also occur if households and businesses move to more distant locations or if development patterns become more dispersed in response to the capacity increase. Capacity expansion can lead to increases in commercial traffic as well as passenger travel."*

Handy and Boarnet (2014a, 2014b) also state:

> *"The induced-travel impact of capacity expansion is generally measured with respect to the change in VMT that results from an increase in lane miles, determined by the length of a road segment and its number of lanes (e.g. a two mile segment of a four-lane highway equates to eight lane miles). Effect sizes are usually presented as the ratio (elasticity) of the percent change in VMT associated with a one percent change in lane miles."*

According to a survey of the literature by Handy and Boarnet (2014a, 2014b), "Elasticity estimates of the short-run effect of increased highway capacity range from 0.3 to 0.6. Estimates of the long-run effect of increased highway capacity are considerably higher, mostly falling in the range from 0.6 to just over 1.0.

RESEARCH BASIS

Handy and Boarnet (2014a, 2014b) provide some of the technical background for six of the studies they included in their policy brief. Key characteristics shared by many of the research studies upon which the elasticity estimates are based are:

- They measure changes in regional, county, or statewide VMT and lane-miles of road in most cases only on freeways. Some focused on state-owned highways. One used sample from the US DOT Highway Statistics database for all road types in that database.

- Data on changes in capacity and traffic volumes for non-freeways, minor roads and arterials was not available to the researchers in most cases, so they could not account for diversion effects, where traffic shifts to and from minor roads and arterials in the region to the freeways. The background documentation for the NCST Calculator states that Duranton estimated this unmeasured diversion effect to be between zero and 10% (which would have no effect or would reduce the reported elasticity).
- The long-term time frames considered varied from 14 years to 22 years.
- Researchers fitted log-linear regression models with lane-miles as one of various explanatory factors for observed changes in regional or county VMT.
- They all included changes in population as one of the explanatory factors but varied in what additional variables impacting VMT were included. Some included income, some employment density, some fuel cost. The additional explanatory factors usually lowered the elasticity with respect to lane-miles.
- They used different approaches to control for demand driven capacity construction, called "simultaneity bias."
- Three of the studies used only California data. Three used data from around the United States.

APPENDIX B. PANELIST BIOGRAPHICAL SKETCHES

As mentioned in the Foreword of this document, in Spring 2020 Caltrans convened an expert panel of academics and practitioners through the University of California Berkeley Tech Transfer in order to provide recommendations on key issues associated with analysis of induced travel impacts. The panel was charged with making recommendations on how to estimate travel "attributable to the project", best tools to use, reasons for differences in estimates from various tools, and ways to resolve or reconcile differences if they occur. The panel also provided advice on "next steps", including the need for further guidance and additional research. A short biography of each of the eight panelists is presented here.

Elizabeth Deakin (Panel Chair) is Professor Emerita of City and Regional Planning and Urban Design at UC Berkeley and an affiliated faculty member of the Energy and Resources Group. She previously was Director of the UC Transportation Center (1999-2008) and co-director of the Global Metropolitan Studies Center (2004-2009). She also served as vice-chair and then chair of the UC Berkeley Academic Senate (2013-2015).

Deakin's research and teaching focus on transportation and land use policy, the environmental impacts of transportation, and equity in transportation, and she has published over 300 journal articles, conference papers, book chapters, and research reports. Since her retirement she has continued to carry out research projects and mentor students and has co-edited a book on international experiences with high speed rail and edited a book on transportation, land use, and environmental planning.

She has been appointed to several government posts including city and county commissions and state advisory boards in California. She has testified on transportation legislation before the US Senate Public Works Committee, the House Technology and Infrastructure Committee and the House Science Committee, as well as before California Senate and Assembly committees and city councils.

She was the co-creator of several transportation-land use plans that won prizes from APA and AIA and has received awards for best paper (TRB energy committee) and best reviewer for a journal (ASCE).

Fred Dock is the former Director of Transportation for the City of Pasadena, California. During his tenure and under his direction, Pasadena pioneered the use of VMT and multi-modal transportation performance metrics and developed a Complete Streets Framework that focused on achieving the City's goals for safety and sustainability. Now retired from the City, he advises on transportation policy and practice with emphasis in urban transportation issues and performance measures.

Prior to joining the City of Pasadena, Mr. Dock consulted for engineering and planning firms in northern and southern California, Chicago, and Minneapolis for 30 years. He directed and prepared a variety of engineering and planning projects ranging from impact analysis to corridor studies to regional plans. He was one of the principal investigators for the University of Minnesota's research on Transportation and Regional Growth. His work in operations included advanced traffic control systems and simulation modeling of complex traffic networks.

He led a nationwide initiative on urban street design that developed a context-based framework for street design and resulted in the publication of *Designing Walkable Urban Thoroughfares* (ITE, 2010). That work is the basis for the modified system of functional classification in the 7th Edition of the AASHTO Green Book. His work with transit-oriented development is nationally recognized by the Transportation Research Board for both policy and practice and by the Urban Land Institute, for which he authored *Developing Around Transit* (ULI, 2005) with other nationally recognized individuals.

Mr. Dock has received various awards, including the 2015 Dale Prize for Excellence in Urban and Regional Planning when the theme was *Streets for Everyone: Advancing Active Transportation*. Mr. Dock earned both bachelor's and master's degrees in civil engineering from the University of California at Berkeley. He is currently a registered Civil Engineer and Traffic Engineer in California, a PTOE and an AICP. He was previously registered as a Professional Engineer in the states of Illinois, Michigan, and Montana.

Gordon Garry is currently mostly retired after a professional career of 40 years. He keeps an active role professionally through various projects with government agencies and NGOs.

From 1990 to 2017 he was a senior staff member at the Sacramento Area Council of Governments. Mr. Garry developed and managed an increasing array of data, forecasting, and scenario programs to support the agency's transportation, air quality, land use planning, and climate change efforts. Mr. Garry was responsible for modeling projections and analyses in these areas that meet local, state, and Federal planning requirements. Also, while at SACOG he worked with a number of regional agencies across California and the country to develop and implement these technical tools in support better decision making for public agencies.

Prior to joining SACOG he worked at the City of Santa Rosa CA, SRF Consulting in Minneapolis, and the South Dakota Department of Transportation. Mr. Garry received his B.S. in Economics at South Dakota State University and his Master's in City and Regional Planning at the Harvard Kennedy School of Government.

Susan Handy is a Professor in the Department of Environmental Science and Policy and the Director of the National Center for Sustainable Transportation at the University of California, Davis. She is internationally known for her research on the relationships between transportation and land use, particularly the impact of neighborhood design on travel behavior. Her current work focuses on bicycling as a mode of transportation and on strategies for reducing automobile dependence.

Dr. Handy holds a B.S.E. in Civil Engineering from Princeton University, an M.S. in Civil Engineering from Stanford University, and a Ph.D. in City and Regional Planning from the University of California at Berkeley.

Michael McNally is Professor of Civil and Environmental Engineering and of Urban Planning and Public Policy, and a Faculty Associate of the Institute of Transportation Studies at the University of California, Irvine. He received his Ph.D. in Engineering in 1986 from UC Irvine and was with the School of Urban and Regional Planning and the Department of Civil Engineering at USC prior to joining the faculty at UCI in 1987. Research interests focus on the study of complex travel behavior, investigations of interrelationships between transportation and land use, and the development of new technologies and modeling methodologies which reflect and support these research areas.

Among various research awards, he received a Presidential Young Investigator Award from the National Science Foundation. He has served as Principal Investigator on a variety of funded projects, including research and development relating to: operational models of activity-based travel forecasting, web-based self-administered travel surveys, GPS-based, wireless in-vehicle data collection systems, information technology for shared-use station car programs, multi-jurisdictional corridor decision support systems with integrated traffic microsimulation models, the role of information on traveler behavior, and the evaluation of advanced traffic management and control technologies.

Elizabeth Sall is a Principal at UrbanLabs LLC a mission-driven urban science and research firm. Ms. Sall specializes in the intersection of policy with data and technology especially as it relates to travel behavior and multi-modal transportation network management. She is currently serving as the Mobility Data Team lead for the California Integrated Travel Project at CalSTA/Caltrans and is the technical lead on several travel model development projects.

Ms. Sall has served in numerous capacities as a consultant and through appointed volunteer positions with the Transportation Research Board (TRB) and Zephyr Foundation for Improved Travel Analysis. She has served as a task lead for the recently published NCHRP Report 934 *Travel Forecasting Accuracy Assessment Research* and is serving on the panel for NCHRP 08-121 *Accessibility Measures in Practice: Guidance for Agencies*. In the past, she has served as the chair for SHRP2 C46 *Resource on Advanced Integrated Models and Implementation Strategy*, on the panel for NCHRP Report 775 *Applying GPS Data to Understand Travel Behavior*, and as a researcher for NCHRP Report 716 *Travel Demand Forecasting: Parameters and Techniques.* Ms. Sall is currently serving the TRB as a member of Committee on Travel Demand Forecasting and the Transportation Research Record Advisory Board and has served in the past on the following committees: Planning Applications, Travel Forecasting Resource, Metropolitan Policy and Practices, and the Task Force on Bring Activity-Based Models to Practice. She has served on seven of the past eight organizing committees for the TRB Innovations in Travel Modeling Conference series and six of the past TRB Planning Applications Conferences including as conference chair and technical track leads. Outside TRB, she is the co-founder and workforce development lead for the Zephyr Foundation for Improved Travel Analysis, a former leader of the Washington DC Chapter of ITE, and frequent collaborator and presenter with NACTO, MobilityData IO, and a variety of Universities. Ms. Sall serves frequently on Peer Review Panels facilitated by the Travel Model Improvement Program and a variety of other expert panels for both research and policy.

As the former Deputy Director for Technology, Data and Analysis of the San Francisco County Transportation Authority Ms. Sall was responsible for developing, maintaining, and applying an Activity-Based Travel Demand Model that served as the basis for local long-range planning documents, FTA New- and Small-Starts submissions, the environment review process, and various land use and transportation studies. Ms. Sall began her career as a consultant working on a variety of projects ranging from project-level forecasting and travel impact analysis to urban and rural long-range transportation plans and neighborhood planning studies. She has Civil Engineering degrees from North Carolina State University (B.S.) and the University of Texas at Austin (M.S.).

Alex Skabardonis is an internationally recognized expert in traffic flow theory and models, traffic management and control systems, design, operation and analysis of transportation facilities, intelligent transportation systems (ITS), energy and environmental impacts of transportation. He is a Professor at the University of California, Berkeley, and program Leader at California PATH, a statewide ITS research center. He has worked extensively in the development and application of models and techniques for traffic control, performance analysis of highway facilities and applications of advanced technologies to transportation. He has served as Principal Researcher for 85 extramurally funded contracts and grants totaling over $30M and has published over 350 papers and technical reports. He is co-developer of the California Freeway Performance Measurement System (PeMS) and the Berkeley Highway Laboratory that produced the NGSIM vehicle trajectories database used by transportation researchers worldwide.

Dr. Skabardonis teaches graduate courses on transportation modeling and analysis, traffic operations and intelligent transportation. He has advised and supported more than 120 graduate students toward their MS and PhD degrees at UC Berkeley. He also developed and taught workshops on traffic management, control systems and traffic simulation models attended by more than 500 transportation professionals. He holds an undergraduate degree in Civil Engineering from the Technical University of Athens and master's and PhD degrees in CE from Southampton University in the United Kingdom.

Joan Walker conducts research on behavioral modeling, with an expertise in discrete choice analysis and travel behavior. She works to improve the models that are used for transportation planning, policy, and operations. Professor Walker joined UC Berkeley in 2008 as faculty in the Department of Civil and Environmental Engineering and a member of the interdisciplinary Global Metropolitan Studies (GMS) initiative. She received her Bachelor's degree in Civil Engineering from UC Berkeley and her Master's and PhD degrees in Civil and Environmental Engineering from Massachusetts Institute of Technology. Prior to joining UC Berkeley, she was Director of Demand Modeling at Caliper Corporation and an Assistant Professor of Geography and Environment at Boston University. She is a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE) – the highest honor bestowed by the U.S. government on scientists and engineers beginning their independent careers. She served for six years as the Chair of the Committee on Transportation Demand Forecasting (ADB40) for the Transportation Research Board of the National Academies. She is an instigator and founding stakeholder of The Zephyr Foundation, which aims to advance rigorous transportation and land use decision-making for the public good and was awarded its Leadership Award in 2020. She has served as Acting Director of UC Berkeley's Institute of Transportation Studies (ITS).

APPENDIX C. GLOSSARY OF ACRONYMS AND TERMS

Caltrans	California Department of Transportation
CEQA	California Environmental Quality Act
CSTDM	California Statewide Travel Demand Model
DOT	Department of Transportation
EIR	Environmental Impact Report (State)
EIS	Environmental Impact Statement (federal)
FHWA	Federal Highway Administration
GHG	Greenhouse Gas
GP	General Purpose lane
HCM	Highway Capacity Manual
HOT	High Occupancy Toll lane
HOV	High Occupancy Vehicle lane
HPMS	Highway Performance Monitoring System database hosted by Federal Highway Administration and maintained by Caltrans Division of Research, Innovation, and System Information
IS	Initial Study
MPO	Metropolitan Planning Organization
MTP	Metropolitan Transportation Plan or Metropolitan Transportation Program
MSA	Metropolitan Statistical Area
NCST	National Center for Sustainable Transportation, University of California, Davis
ND	Negative Declaration
NEPA	National Environmental Policy Act
OPR	Governor's Office of Planning and Research
PA&ED	Project Approval and Environmental Document
PDT	Project Development Team
PEAR	Preliminary Environmental Analysis Report
PRC	California Public Resources Code
SB	Senate Bill
SHS	State Highway System
SOV	Single Occupancy Vehicle
TA	Office of Planning and Research Technical Advisory on Evaluating Transportation Impacts in CEQA (2018)
TAC	*Transportation Analysis under CEQA* (Caltrans guidance document for implementing SB 743)
TAF	*Transportation Analysis Framework* (Caltrans guidance document for implementing SB 743)
TBM	Trip-Based Model
TDM	Travel Demand Model

TMIP	Travel Model Improvement Program
VMT	Vehicle Miles Traveled
Elasticity	Elasticity is a measure of a variable's sensitivity to a change in another variable. In economics, elasticity is the measurement of the percentage change of one economic variable in response to a change in another. In transportation forecasting, an example is elasticity of travel demand, which can be expressed as the percent change in regional VMT divided by the percent change in regional lane-miles of state highways.
Induced Travel	Induced travel (or the VMT attributable to a transportation capacity increase) is the increased amount of vehicle travel on the transportation network that is caused by travel behavior changes associated with decreased cost of travel due to improved travel times, improved reliability, or reduced price of travel. Over the short run, travel behavior changes including longer trips, more trips, mode shift, and route shift all tend to occur as a result of a highway capacity increase. Over the long run, these effects intensify (e.g. as people shift job or residential location to benefit from the infrastructure), and also land use development may become more dispersed, adding additional vehicle travel; for these reasons, long run induced travel is generally greater than short run induced travel.
Latent Demand	Latent demand is the travel that would occur on the transportation network if travel times (or costs) were reduced. Much like any public utility (e.g. electricity or water), consumers will use more of it when its cost or impedance of use is reduced or made free. Note that unless the current price of travel is zero (instantaneous travel at will at no cost), there is always latent demand.
Metropolitan Statistical Area	A U.S. metropolitan statistical area (MSA) is a geographical region with a relatively high population density at its core and close economic ties throughout the area, as defined by the U.S. Office of Management and Budget and used by the Census Bureau and other federal government agencies for statistical purposes.
Transit	Transit generally includes all forms of shared common carrier passenger ground transportation in moderate to high capacity vehicles ranging from dial-a-ride vans to buses, trolleys, light rail, commuter rail, and intercity rail transportation.
Travel Demand Model	A travel demand model is any relatively complex computerized set of procedures for predicting future trip making as a function of land use, demographics, travel costs, the road system, and the transit system. These models may cover an entire metropolitan area, a single city or county, or the entire State..

Trip-Based Model	Trip-based travel models use the individual person trip as the fundamental unit of analysis. Trip-based models are often referred to as "4-step" models because they split the trip making decision process into 4 discrete steps: trip generation by time of day, destination choice, mode choice, and route choice (traffic assignment).
Trucks	Trucks are a subtype of the heavy vehicles category which includes trucks, intercity buses, and recreational vehicles. This Framework follows the Highway Capacity Manual definition of what constitutes a heavy vehicle: "A vehicle with more than four wheels touching the pavement during normal operation." This is consistent with the Caltrans Traffic Census definition of a truck: "The two-axle (truck) class includes 1-1/2-ton trucks with dual rear tires and excludes pickups and vans with only four tires."
Vehicle Miles Traveled	The number of miles traveled by motor vehicles on roadways in a given area over a given time period. VMT may be subdivided for reporting and analysis purposes into single occupant passenger vehicles (SOVs), high occupancy vehicles (HOV's), buses, trains, light duty trucks, and heavy-duty trucks. For example, an air quality analysis may require daily VMT by vehicle class and average speed or vehicle operating mode (idle, acceleration, cruise, deceleration, etc.). For a CEQA compliant transportation impact analysis, automobile VMT (cars and light trucks) may be evaluated.
VMT Attributable to a Project	In the context of a CEQA analysis, the VMT attributable to a transportation project, or induced travel, is the difference in passenger VMT between the with project and without project alternatives. VMT attributable to a project is equivalent to induced travel in this context.

APPENDIX D. ACKNOWLEDGEMENTS

TECHNICAL ROUNDTABLE

Made up of over 35 practitioners and stakeholders, the following participants met three times to provide detailed technical input for the development of the guidance documents:

- Saravana Suthanthira, Alameda County Transportation Commission
- Maura Twomey, Association of Monterey Bay Area of Governments
- Liza Zorn, Bay Area Metropolitan Transportation Commission
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