Closing the Induced Vehicle Travel Gap Between Research and Practice

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Several studies have rigorously documented the induced travel effect, in which added highway capacity leads to added vehicle travel. Despite the evidence, transportation planning practice does not fully account for this phenomenon, with the result that estimates of the potential congestion-reducing benefits of added highway capacity may be overstated and estimates of potential environmental impacts understated. In 2015, the California Department of Transportation (Caltrans) sponsored a review of applicable induced vehicle travel research that could inform transportation analysis guidance in response to new laws in California such as Senate Bill 743 (S.B. 743), which prohibits the use of vehicle level of service (LOS) and similar measures as the sole basis for determining significant transportation impacts under the California Environmental Quality Act. Instead, vehicle miles traveled was selected to replace LOS under S.B. 743, and along with the new metric there will be a requirement to account for induced travel effects in analysis of roadway capacity expansion projects. The Caltrans review revealed an inconsistent lexicon in academic research and among practitioners, questions about research applicability, limitations in the sensitivity of travel forecasting models, and confusion about the appropriate use of induced vehicle travel elasticities from research. This paper summarizes the Caltrans review and shares the findings to advance understanding of induced vehicle travel effects and suggest steps for additional research.

"If you build it, they will come." This adaptation of the famous line from the 1989 movie "Field of Dreams" has been invoked in countless contexts. In the transportation context, it summarizes what happens when new highway lanes are built: more cars come. Several studies have documented this phenomenon (*1*), that is, the induced travel effect or, more specifically, the induced vehicle travel effect. However, despite the evidence, transportation planning practice does not fully account for the phenomenon, with the result that estimates of the potential congestion-reducing benefits of added highway capacity may be overstated and estimates of potential environmental impacts understated.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2653, 2017, pp. 10–16.
http://dx.doi.org/10.3141/2653-02

In 2015, the California Department of Transportation (Caltrans) sponsored a review of research on the induced travel effect to inform transportation analysis guid ance in response to new laws in California, such as Senate Bill 743. This bill prohibited the use of vehicle level of service (LOS) and similar measures as the sole basis for determining significant transportation impacts under the California Environmental Quality Act. Instead, vehicle miles traveled (VMT) was chosen to replace LOS under Senate Bill 743, and a companion to this new metric is a requirement to account for induced travel effects in analysis of projects that expand roadway capacity.

The Caltrans review found an inconsistent lexicon in academic research and among practitioners, questions about research applicability, limitations in the sensitivity of travel forecasting models, and confusion about the appropriate use of induced vehicle travel elasticities from research. This paper summarizes the review and includes definitions and background, a summary of the evidence for the magnitude of the induced travel effect, new research questions, and a discussion of the sensitivity of travel demand forecasting models to the induced travel effect. The paper concludes with a discussion of overall findings, desired research, and project analysis applications.

DEFINITIONS AND BACKGROUND

What is induced travel and how is it defined? A literature review identified many terms describing induced travel effects. Sorting these terms out will give practitioners a common understanding of the technical definitions. For the purposes of this paper, which focuses on practitioner guidance, the following terms are defined:

- Latent demand is the travel that would occur if the cost were lower (e.g., times were faster), that is, the travel that does not occur because costs are high (e.g., times are slow).
- Induced travel is the additional travel that occurs when the cost is lower (e.g., as a result of a capacity expansion that reduces travel times), that is, the additional travel that is induced by the lower costs that result from capacity expansion.
- Induced vehicle travel is additional vehicle travel that occurs when the cost is lower; this is a subset of all induced travel. For the purposes of this paper, the VMT level is used to measure additional vehicle travel.

Figure 1 shows the influence of roadway capacity expansion on vehicle traffic growth over time for a specific roadway segment.

Without new capacity, traffic growth, especially during peak hours, is constrained. Once capacity is added, traffic growth returns. A portion of the traffic growth is related to latent demand converting to

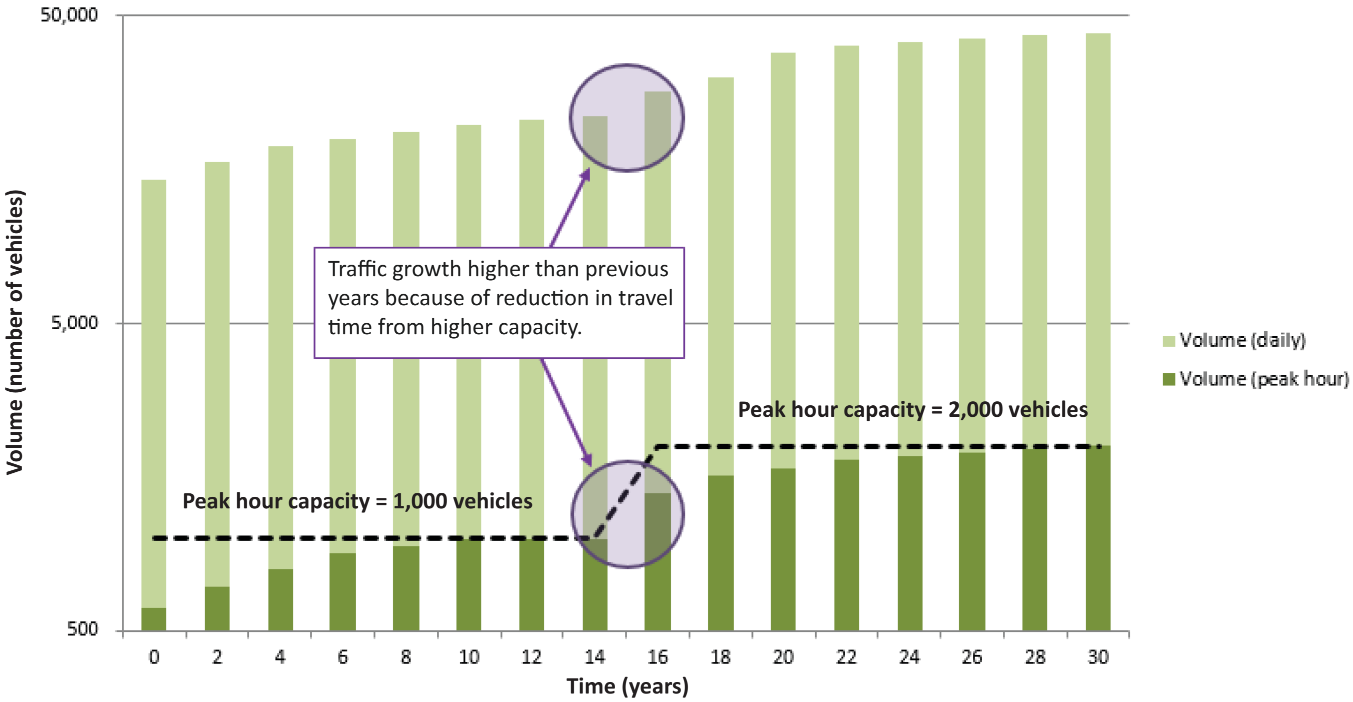

FIGURE 1 Example of induced travel: influence of capacity expansion on vehicle traffic growth.

actual vehicle travel on the network because of travel time improvements associated with the capacity increase. This conversion is the basis of the term "induced." Over the long term, traffic growth will reflect other factors, such as population and employment growth. Induced vehicle travel can include increased personal and commercial driving as a result of new or modified activities, shifts from nonauto modes to driving, and diversions from other roadways, all of which increase the level of VMT.

The induced travel effect occurs in situations in which traffic volumes are near capacity, so that congestion levels are high and travel times are longer than under free-flow conditions. In this situation, traffic growth is naturally constrained, as the long travel times deter travel and some demand for travel goes unmet—this is the latent demand. If new capacity is added and travel times improve, more people are likely to travel on this route—they are able to satisfy their latent demand (*2*). In the long term, traffic growth will reflect population and employment growth, which may be influenced by the added highway capacity.

Induced travel can be explained in terms of supply and demand. An increase in highway capacity represents a shift in the supply curve to the right: for the same volume of traffic, costs are lower (Figure 2). When the supply curve shifts to the right, it intersects the demand curve at a new point, at a higher travel volume than before. This increase is the induced vehicle travel. The greater the increase in supply, the greater the increase in travel volume, all else equal.

For an understanding of how capacity expansion increases the level of VMT, the individual components of how travelers respond to travel time reductions and within what time frames those changes

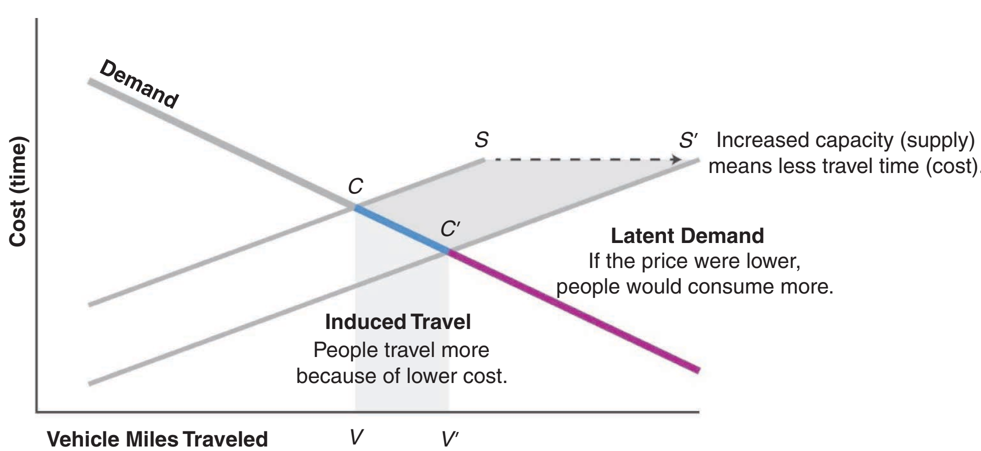

FIGURE 2 Supply and demand relationships for induced travel (C = initial cost; C' = new cost; S = initial supply/capacity; S' = new supply/capacity; V = initial VMT; V' = new VMT).

occur can be broken down. Travel time savings (as well as cost savings and reliability improvement) to a traveler can result in a change of route, change of schedule, change in activities that generate new trips (e.g., including unchaining previous trip tours), change in mode of travel, change to a more distant destination, and change in land development patterns. Of these effects, departure time changes do not represent new trips or new VMT levels but should be considered in transportation analysis because the effect can contribute to higher peak period travel demands. The other factors can affect the amount of VMT generally within the following periods:

- Short-term responses:
  1. New vehicle trips that would otherwise would not be made,
  2. Longer vehicle trips to more distant destinations,
  3. Shifts from other modes to driving, and
  4. Shifts from one driving route to another.
- Longer-term responses:
  5. Changes in land use development patterns (these are often more-dispersed, low-density patterns that are auto dependent) and
  6. Changes in overall growth.

The longer-term responses (Items 5 and 6) are sometimes referred to as induced growth, which leads to induced demand. In addition, Cervero defined induced investment to describe the phenomenon by which the increased vehicle traffic associated with highway investments leads public agencies to invest in projects that expand vehicle capacity (*3*). This phenomenon leads to a feedback loop that makes it difficult to solve congestion through roadway capacity expansion alone.

Despite the evidence supporting induced vehicle travel as a real and measurable effect, transportation planning practitioners have often challenged the concept and have not recognized the limitations of current travel forecasting models to fully account for these effects. Current travel forecasting models fall short when there is the lack of a feedback mechanism to trip generation and land use allocation. Trip generation models are largely static, and land use or socioeconomic forecasts are a fixed input in most model applications. The feedback mechanism would ideally respond to changes in the accessibility and travel time effects associated with capacity expansion projects to avoid downward biases in VMT forecasts, as discussed further below.

One outcome of the inconsistent consideration of induced travel in analysis of capacity expansion projects is legal challenges by interest groups typically opposed to the project (*4*). Often at the core of legal challenges are competing views related to induced vehicle travel in evaluation of the merits or impacts of a transportation capacity expansion project. In several cases, the courts have concluded that induced vehicle travel should be accounted for in environmental impact analysis since induced vehicle travel effects can reduce the benefits of capacity expansion and worsen air quality and greenhouse gas emissions.

Accurate assessment of induced vehicle travel requires a thorough understanding of how travel conditions are influenced by capacity constraints in the network. The change in travel times (and thus costs) caused by the project will influence the travel response. Capacity enhancements tend to have greater effects on induced travel under the following conditions:

- Low average speeds, high delays, and long travel times (often extending across parallel facilities);
- Clear evidence of peak spreading to multiple hours;
- Traffic growth that is lower than population and employment growth (when not a result of smart growth actions);
- Atypically high percentage of nondiscretionary trips (i.e., discretionary trips have been discouraged);
- Low fuel and parking prices (making travel time a higher proportion of total cost); and
- Observed trip routing distorted away from congested areas.

Even without these factors, induced vehicle travel effects may occur. For example, constructing a 65-mph freeway parallel to an existing uncongested 45-mph arterial could cause higher VMT levels from route shifts, travel to more distant destinations, or both. The new freeway route could require a longer travel distance, but the higher speed of the facility would offer a faster travel time and greater access to destinations further away.

Depending on the situation, projects for increasing vehicle capacity may differ in the types of travel they induce as well. In extreme cases, where congestion levels are substantial and alternative travel modes unavailable, induced travel may include work or school trips that tend to have less discretion and therefore the highest value to drivers. In others, where base conditions are not extreme or where modal alternatives exist, the travel response may induce lower-value vehicle trips with less economic benefit.

EVIDENCE FOR THE INDUCED TRAVEL EFFECT

Most research into the induced travel effect focuses on measuring the amount of induced vehicle travel (i.e., changes in VMT levels) with respect to changes in transportation network supply and it is expressed with an elasticity metric. Elasticity is the percentage change in a variable resulting from a percentage change in another variable. For VMT levels with respect to lane-miles, it is defined as the percentage change in total VMT resulting from a percentage change in lane-miles (number of lanes times centerline miles). The evidence has been reviewed in several publications (*2, 5, 6*).

The published research on induced vehicle travel represents a variety of study conditions, methodologies, and results. Studies vary across a range of factors, including terminology, time frame, geographic location and size, means of measuring variables, quality of data, and the type of statistical model used to determine the association between capacity change and change in VMT levels. Two studies differ in notable ways. Cervero used a path analysis to account for the two-way relationship between travel demand and supply (*3*). That study translated the addition of lane-miles into changes in travel speeds, which are the key cause of induced vehicle travel. The study also accounted for induced investment that can occur in response to growing travel over time or to anticipated increases in real estate values conferred by improved access to transportation. A limitation of Cervero's research is that it focused on corridors and did not directly measure the full networkwide effects that are often desirable for environmental impact analysis related to air quality and greenhouse gas emissions.

Duranton and Turner measured induced vehicle travel effects for urbanized areas throughout the United States by using a comprehensive data set based on metropolitan statistical areas (MSAs) (*1*). This study captures networkwide effects and considers induced vehicle travel effects on major urban roads and nonurban Interstates and more carefully distinguishes between induced vehicle travel and sources of traffic growth that may have been independent of the added road supply.

Overall, the elasticity of VMT levels to lane-miles from published research referenced in the review papers ranges from 0.0 to 0.68 for short-term effects and from 0.29 to 1.1 for long-term effects. Duranton and Turner, whose study is the most recent, estimated a long-term elasticity of approximately 1.0 for Interstate highways and major roadways within metropolitan areas (*1*). Two papers measured the elasticity of VMT levels to travel time as −0.3 to −0.5 for short-term effects and −0.4 to −1.0 for long-term effects (*1*). After reviewing the available studies, Handy and Boarnet recommended that an elasticity value close to 1.0 is the best estimate for the long-run effect of highway capacity on VMT levels (*5*). Elasticity values as summarized in Handy and Boarnet are presented in Table 1.

Based on the elasticities for the long-term condition, the congestion-relief effects of added lane-miles diminish over time and can result in higher long-term VMT levels and greater reliance on auto travel. This limited conclusion may not fully consider the two-way relationship between demand and supply. As Cervero notes, "Many induced-demand studies have suffered from methodological problems that, I believe, have distorted their findings" (*7,* p. 22). Cervero mentions that one of the problems is dealing with causality, and he asks, "Are rising traffic volumes caused by more road capacity? Or, might added road capacity be even more strongly caused by historical growth in traffic?" (*7,* p. 22). This question, known as simultaneity bias, was addressed by Cervero in his analysis; he concluded, "To the degree that the path model better captures causal relationships than previous studies, many past elasticity estimates could very well be inflated" (*3,* p. 159).

Other researchers, however, have also controlled for this bias, as explained by Handy and Boarnet (*5*):

> the studies use different approaches to addressing simultaneity bias, the possibility that VMT growth causes capacity expansions at the same time that capacity expansions cause VMT growth. Most common is the use of two-stage least squares regression with instrumental variables (Noland and Cowart 2000; Duranton and Turner 2011). This approach involves "instrumenting" the independent variable of interest (i.e., lane-miles) with an estimator based on exogenous variables that do not directly affect the dependent variable (i.e., VMT). (*5,* Technical Background Document, p. 5)

Even after accounting for the effect that VMT growth has on the construction of new capacity, research studies still found significant influence of capacity expansion on VMT levels (*5, 8*). However, the aggregate nature of the data and research analysis raises other questions about the specific sources of the added VMT. The research studies generally control for the following variables:

- Population growth,
- Changes in income, and
- Other exogenous variables (demographic, auto ownership, etc.).

Most of the research does not explain how much specific sources contribute to added VMT. An exception is the work of Duranton and Turner, who identified the following four potential sources as contributing to the added VMT (*1*):

- Increase in household driving—11% to 46%,
- Increase in commercial driving—18% to 28%,
- Migration (increase in population)—5% to 15%, and
- Diversion of traffic from other routes—0% to 10%.

This information is needed for understanding the potential underestimation of VMT that may occur in travel forecasting models. To capture all these potential sources, models need feedback processes that allow changes in accessibility and travel time to influence personal and commercial driving as well as long-term land use locations. The forecasting models should be able to isolate VMT levels associated with planned population and employment growth versus the induced VMT levels that may arise from not anticipating the full effect of network changes. As to the magnitude of the values, further investigation is warranted as explained below.

How Do Increases in Household Driving Contribute to the Increase in VMT Levels from New Capacity Expansion?

According to the national and California household travel surveys, per-household (and per-person) vehicle trip rates have remained relatively constant over time, so the increase largely would be associated with longer trips. Because the Duranton–Turner research used

TABLE 1 Impact of Capacity Expansion on VMT (*5*)

Study	Study Location (study type)	Study Years	Change in VMT/ Change in Lane-Miles	Time Period
Duranton and Turner (*1*)	United States (MSAs)	1983–2003	1.03	10 years
Cervero (*3*)	California (freeway corridors)	1980–1994	0.10 0.39	Short term Long term
Cervero and Hansen[a]	California (urban counties)	1976–1997	0.59 0.79	Short term (1 year) Intermediate (5 years)
Noland[b]	United States (states—all roadway types)	1984–1996	0.30 to 0.60 0.70 to 1.00	Short term Long term
Noland and Cowart[c]	United States (metro areas—freeways and arterials)	1982–1996	0.28 0.90	Short term Long term
Hansen and Huang (*10*)	California (metro areas—state-owned highways)	1973–1990	0.20 0.60 to 0.70 0.90	Short term Long-term counties Long-term metro areas

[a]Cervero, R., and M. Hansen. Induced Travel Demand and Induced Road Investment: A Simultaneous Equation Analysis. *Journal of Transport Economics and Policy,* Vol. 36, No. 3, 2002, pp. 469–490.
[b]Noland, R. B. Relationships Between Highway Capacity and Induced Vehicle Travel. *Transportation Research Part A,* Vol. 35, No. 1, 2001, pp. 47–72.
[c]Noland, R. B., and W. A. Cowart. Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel. *Transportation,* Vol. 27, 2000, pp. 363–390.

data from 1983 to 2003, when VMT per capita was increasing, the finding may be reasonable but is generally applicable under similar circumstances. As shown in Figure 3, trends in VMT per capita in the past few years have included a mix of declines and increases.

If trip length changes are the main contributor to increased VMT levels from roadway capacity expansion, then enhancements or adjustments to travel forecasting model may require more than a feedback process to trip generation and long-term land use patterns. Further investigation of changes in trip length would be needed to inform trip distribution or destination choice models. Current distribution models are often limited by trip length frequency patterns established in the model's calibration year.

Is Road Supply Expansion Alone Sufficient to Accelerate the Overall Rate of Population and Employment Growth Within an Entire MSA?

Other researchers have suggested that roadway capacity expansion influences the geographic distribution of future population and employment growth within an MSA, but they did not provide evidence that road supply expansion could increase regional population and employment growth. This possibility has implications for forecasting VMT changes at regional scales versus project scales. Duranton and Turner suggested that an increase in MSA population explained between 5% and 15% of the increase in VMT levels from road supply expansion (*1*). This finding suggests that population and employment growth forecasts used in regional transportation plans should not be fixed. Instead, the forecasts would depend on the amount of roadway capacity expansion. Further, the location of capacity expansion projects would influence both the regional and project-scale allocation of population and employment growth.

Does the Use of Aggregate Data Based on Lane-Miles Instead of on Travel Time Changes Skew Elasticity Findings?

Although an increase in lane-miles is a supply change, not all lane-mile changes have the same influence on travel times, which is the key variable for influencing traveler response. Thus, do travel forecasting models provide a better estimate of short-term induced travel effects while elasticities found in research provide a better estimate of long-term effects?

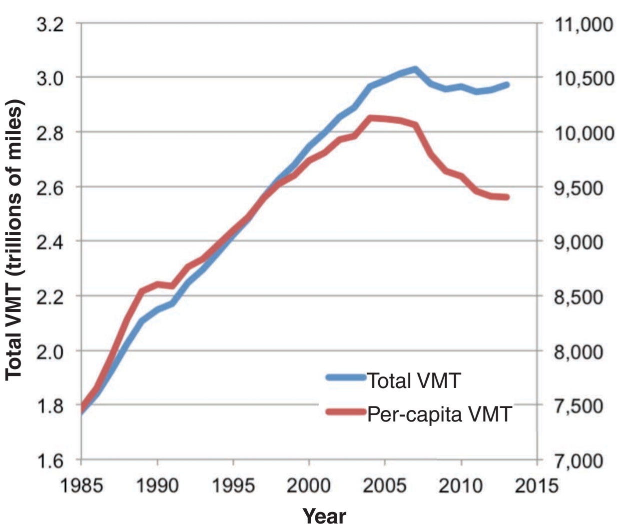

FIGURE 3 VMT trends. (Source: State Smart Transportation Initiative, FHWA, U.S. Census Bureau.)

The elasticity estimates demonstrate that VMT levels increase with lane-miles such that induced travel effects should be captured in transportation analysis when relevant to the technical questions under investigation. However, how best to account for induced vehicle travel effects does not have a single answer, especially considering recent VMT per capita trends and the myriad disruptive technology, demographic, and social trends. Also, almost all the research studies focused on Interstate or major roadways (i.e., arterials), although some differentiated between roadway widenings versus new roadway construction. Thus, little information is available on how the effects of induced vehicle travel may vary across the following roadway project types:

- High-occupancy vehicle lanes,
- High-occupancy toll lanes,
- Tolled lanes,
- Auxiliary lanes,
- Limited-access highways versus arterials, and
- Transportation systems management strategies:
  - Ramp metering and
  - Variable speed limits.

There is a lack of specific studies associated with these project types, but the induced vehicle travel research findings generally would apply to the extent that these project types reduce travel time. However, managed and tolled facilities may be designed to manage demand and could be used to keep VMT levels constant (or possibly reduce VMT levels), which Cervero points out is the key factor influencing travel changes (*3*).

TRAVEL MODEL SENSITIVITY

Schiffer et al. conducted a model sensitivity study in response to the lawsuit over the Legacy Parkway highway project in Salt Lake City, Utah (*6*). The sensitivity study was required as part of the settlement agreement among the Sierra Club, FHWA, FTA, and the Utah Department of Transportation. The study documented the measured change in VMT levels associated with roadway capacity expansion projects and the ability of travel forecasting models to capture induced vehicle travel effects fully. Today's travel forecasting models are not likely to have sufficient capability to predict induced demand and induced vehicle travel effects. Naess et al. noted that, "Although the phenomenon of induced traffic has been theorized for more than 60 years and is now widely accepted among transport researchers, the traffic-generating effects of road capacity expansion are still often neglected in transport modeling" (*9,* p. 291).

This deficiency in travel forecasting models is well understood among researchers and modeling experts and has been emphasized in various modeling literature. Litman said, "To predict generated traffic, transport models must incorporate 'feedback,' which reflects the impacts congestion has on travel behavior, and long-term changes in transport and land use patterns" (*2,* p. 13). He expanded on this statement by referencing other authors and concluded, "Most current traffic models can predict route and mode shifts, and some can predict changes in scheduling and destination, but few adjust trip frequency and most ignore the effects transport decisions have on land use development patterns" (*2,* p. 13).

The limitations of travel forecasting models to fully account for induced vehicle travel effects is a common argument used when forecast validity is questioned. Schiffer et al. addressed this topic and described what components of induced vehicle travel can be expected to be addressed in four-step travel forecasting models (*6*). Most urban area travel forecasting models include features to capture induced vehicle travel effects, but sensitivity testing is often necessary to verify the effectiveness of the features.

To assess sensitivity or accuracy of an individual travel forecasting model, testing should start with the following basic checklist of questions:

1. Newly generated trips. Does the model contain a feedback process by which person-trip generation is influenced by travel time estimates informed by network modifications (i.e., does trip generation vary with the level of roadway congestion)?
2. Longer trips. Does the model contain a feedback process by which trip distribution is influenced by changes in travel time? Is this influence limited by trip length patterns estimated for the calibration year?
3. Modal split. Does the model contain a mode choice process by which modal split is influenced by changes in travel time by mode?
4. Route diversions. Does the model contain a trip assignment process by which route choice is influenced by changes in travel time? This effect may not change the amount of overall travel, but it can be important for accurately forecasting location-specific traffic volumes for use in traffic operations analysis.
5. Time-of-day shifts. Does the model contain a temporal process by which departure time is influenced by changes in travel time? This effect is related to travel changes between time periods, not to the amount of overall travel; however, this effect can be important for accurately forecasting peak period traffic volumes for use in traffic operations analysis.
6. Land use development pattern shifts. Does the model contain a process by which long-term land use patterns are influenced by changes in accessibility and travel time?

In addition to sensitivity tests, questions could address travel time reliability, long-term auto ownership and availability rates (e.g., auto availability has expanded substantially with carsharing, microrentals, and transportation network companies), and public transit quality. All these factors can influence the induced vehicle travel effects and how travel changes in response to network modifications. Another form of testing is backcasts, for evaluating a model's ability to capture long-term effects on VMT levels. If a travel forecasting model can be shown to predict correctly increasing VMT per capita and total VMT for a period when historical growth in VMT levels exceeded population and employment growth, then the model has demonstrated the ability to predict long-term effects.

The most common limitations in current models (both four-step and activity based) is that feedback processes do not exist for long-term land use changes or trip generation when these models are used for project-level applications. Departure times may be fixed according to the use of preset periods representing a 24-h day. Although this does not adversely affect the total amount of travel for the 24-h day, it can influence the demand within individual periods. Trip distribution, mode choice, and trip assignment components of current practice models generally can capture the induced vehicle travel effects associated with Tests 2, 3, and 4 when feedback loops exist, have sufficient sensitivity, and are properly executed. However, model sensitivity testing must be done to verify that these components of the model have been properly specified and calibrated. A model structure may include an appropriate feedback structure, but testing is necessary to verify that the structure has been properly executed in the model environment and that errors have not been introduced in the model coding or data. Verifying that the model responds in the correct direction and magnitude is an important part of this testing. Another important check is the amount of variability or noise exhibited by the model that could distort the traffic and VMT estimates. In a regional context, and for some projects even at a corridor scale, the project impacts on travel could be relatively small, and model insensitivity or oversensitivity could significantly bias the estimate of VMT change relative to the VMT base.

CONCLUSIONS

Elasticity results demonstrate that the addition of lane-miles (especially in urban congested areas) causes increases in VMT levels that often dampen the ability of capacity expansion projects to relieve congestion and thereby generate higher levels of emissions. Handy and Boarnet supported this conclusion, noting that the quality of the evidence linking highway capacity expansion to VMT increases is relatively high (*5*). With long-term induced travel elasticity estimates reaching 1.0, a common conclusion, as stated by Duranton and Turner, is that "the extension [expansion] of most major roads is met with a proportional increase in traffic" (*1*). Their findings distinguished among the various sources of the traffic increase and indicated that the largest contributor to increases in VMT levels was more personal and commercial driving. Other contributors included route shifts and higher levels of population growth.

Research by Hansen and Huang (*10*) that used California-specific data reached similar conclusions about the overall long-term elasticities, although Cervero (*3*) revealed a lower long-term elasticity of about 0.80, of which only 0.39 was attributable to increased driving and growth with use of a methodology that also explained some of the two-way relationships between induced travel and induced growth and investment (*10*). According to Cervero, the path analysis approach, which was based on a long-term data set covering 14 years, revealed the following:

> The path analysis showed that for every 100 percent increase in capacity there'd be an eighty percent increase in travel, reflecting increased travel speeds and land use shifts along improved corridors. However, only around half the increases in speed and growth in building permits was due to the added capacity. Factors like employment and income growth accounted for the other half. Accordingly, the traffic gains that one can attribute to the added capacity is actually around half of eighty percent, or forty percent. (*7,* p. 26)

Other important findings in the research are as follows:

1. The induced vehicle travel effect size depends on the size of the geographic area and the size of the network change. The influence of an individual project is relative to its proportion of the larger network.
2. The induced vehicle travel effect size is influenced by other costs associated with driving, such as parking and fuel prices. When fuel prices are lower, the induced travel effects of expanded capacity tend to be higher as travel time becomes a greater share of travel costs in this situation (*5, 8*).
3. The induced vehicle travel effect is influenced by the starting level of congestion.

Beyond these conclusions, additional research is needed to evaluate further the following topics:

- Replicating the Duranton–Turner research at the metropolitan planning organization or county level (*1*),
- Isolating the specific contributing sources of added VMT (including determining whether new vehicle trips are related to creation of a trip that did not previously occur or the unchaining of a trip),
- Evaluating the effects of induced vehicle travel according to speed or travel time changes instead of lane-miles,
- Evaluating the effects of induced vehicle travel across facility and project types, and
- Evaluating the effects of induced vehicle travel under various levels of congestion and VMT per capita trends.

Although such research would be desirable, the research findings to date provide sufficient evidence that induced vehicle travel effects occur, are measurable, and should be accounted for in transportation analysis when relevant to the technical questions under investigation. Given the strength of the research findings, the next challenge is to connect the research to transportation planning practice and modeling so that effects of highway capacity on VMT levels are accurately captured.

PROJECT ANALYSIS APPLICATIONS

Beyond the research, how to address induced demand and induced vehicle travel in project analysis remains a significant question. Data and modeling limitations must be recognized and accounted for in the analytical process to avoid underestimates of induced travel effects. If a travel forecasting model is found to have limitations related to one or more of the induced vehicle travel components above, corrective actions can compensate for the limitation. Depending on project circumstances, this may be a qualitative or quantitative response. Project circumstances include the type of project, analysis purpose (alternatives analysis, design, or environmental impact analysis), resources, schedule, and controversy. When making a decision about the appropriate method, analysts should be aware of the expectations established in technical guidelines and environmental case law. In general, almost all the effects of induced vehicle travel can be accounted for with advanced travel forecasting models that account for the feedback effects of travel time (or travel cost) savings on travel behavior and long-term land use allocation. Failure to account for the feedback effects will result in underestimation of induced vehicle travel effects. Nevertheless, it is not always possible, feasible, or desirable to apply advanced models fully and appropriately for every transportation analysis.

At a minimum, induced vehicle travel effects should be acknowledged and discussed for capacity expansion projects that will reduce travel times. Acknowledgment should disclose any limitations related to the forecasting that may have not been sensitive to induced vehicle travel effects and how those effects could influence the analysis results. This effort could include a qualitative discussion or even simple elasticity-based estimates of VMT levels derived from the project's lane-mile changes. Disclosures should refer to the research findings on the subject presented above or to the most recent and relevant research available. This recommendation applies to regional and project scale analysis.

Quantification of induced vehicle travel effects becomes particularly important when capacity constraints are severe. The process for quantification will depend on the available travel forecasting models and their sensitivity to induced vehicle travel effects. A first level of quantification would calculate the model-produced elasticity of VMT levels to lane-miles under short-term and long-term conditions. For example, the short-term evaluation could compare the net change in VMT levels divided by the net change in lane-miles between the no-build and build scenarios with the research elasticity estimates of short-term responses such as those produced by Cervero (*3*). If the model fails to capture the full change expected in VMT levels, the VMT forecasts could be adjusted according to the elasticity differences. For long-term conditions, the elasticity values from research studies could be used as a benchmark for comparison. The research analysis controls for variables such as population growth, while travel demand models use population growth as a key variable in forecasting VMT levels. Hence, the travel demand model forecast of VMT levels should be higher than an estimate derived from long-term elasticity values found in the research.

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The Standing Committee on Transportation Planning Applications peer-reviewed this paper.