Title

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A REVIEW OF THE REPRESENTATION OF INDUCED HIGHWAY TRAVEL IN CURRENT TRAVEL AND LAND USE MODELS

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ABSTRACT

A considerable body of research on induced travel has emerged over the last several decades, and induced travel has been acknowledged by the U.S. Transportation Research Board and Environmental Protection Agency. This has brought renewed attention to the representation of induced travel in regional land use and travel demand models. A number of case studies (Sacramento, CA, Chittenden, VT, and Salt Lake City, UT) have assessed the ability of existing travel and land use models to represent the induced travel effects of new highway capacity (or elasticity of VMT with respect to lane miles and travel time). In addition, these studies have conducted sensitivity tests, by turning on and off model components, to isolate the relative contribution with respect to the models' representation of induced travel. The results indicate that when travel times are fed back to a land use model and/or the trip distribution step, then (1) models can represent induced travel within the range documented in the empirical literature and (2) the effect of new highway capacity on land use and trip distribution can significantly contribute to the model's representation of induced travel. If induced travel is not represented in travel and land use models, then the need for, and the benefit of, a highway project will tend to be overstated (e.g., 16% to 236% of vehicle hours traveled), and negative environmental effects will be understated (e.g., 72% to 192% of NOx vehicle emissions).

INTRODUCTION

A considerable body of research on induced travel has emerged over the last several decades. As a result of this research, induced travel has been acknowledged by the Transportation Research Board (*1*) and the U.S. Environmental Protection Agency (*2*). This has brought renewed attention to the ability of regional land use and travel demand models to represent the effects of induced travel. The representation of induced travel in current models may have important implications with respect to compliance with the U.S. Clear Air Act Amendments (CAAA) and the U.S. National Environmental Policy Act (NEPA).

The CAAA mandate the conformity of state air quality plans and transportation plans to meet national ambient air quality standards. Non-attainment regions use travel demand models to demonstrate that aggregate emission levels in their transportation improvement plans are not greater than the motor vehicle emissions budget in the approved state implementation plans. If regional travel demand models do not account for the effect of induced travel, vehicle miles traveled (VMT) and emissions may be underestimated in transportation plans that include highway capacity expansions. If the requirements of the CAAA are not met, penalties can be imposed, including the loss of federal funds for transportation projects, the imposition of stricter requirements, and possible litigation.

NEPA requires Environmental Impact Statements for federal projects to provide information about the environmental effects of the project and alternatives to decision-makers and the public. Many highway projects are still justified primarily by estimates of congestion reduction. However, if a regional travel demand model does not account for the effects of induced travel, then congestion reduction from the highway project may be overestimated, and congestion reduction from alternatives (e.g., auto pricing and transit) may be underestimated. In addition, analysis of the secondary impacts of highway projects (e.g., changes in land use) is also required. If a regional travel demand model does not capture induced effects, then it cannot assess secondary effects.

Most travel demand models account for mode and route shifts associated with induced travel, but many do not account for other induced travel effects such as changes in land use, trip generation (or number of trips), and trip distribution (or destination choice). All of these behavioral responses can alter a travel model's estimate of VMT. It is generally acknowledged that changes in mode choice and route choice are components of induced demand; however, the importance of land use, trip generation, and destination choice effects has been a source of controversy (*3*).

Within the past few years, a number of case studies in different regions of the U.S. have been conducted to assess how existing travel and land use models can capture the induced travel effects of new highway capacity in Sacramento (CA), Chittenden (VT), and Salt Lake City (UT) (*4-9*). In these studies, current land use and modeling tools are used to evaluate their ability to represent induced travel (or elasticity of VMT with respect to lane miles and travel time) by simulating scenarios with and without the highway alternative. In addition, sensitivity tests are conducted, by turning on and off model components, in order to isolate the relative contribution of the different induced travel effects represented in the model (i.e., land development, activity allocation, trip generation, trip distribution, mode choice, and traffic assignment).

BACKGROUND ON INDUCED TRAVEL

Induced travel is most generally defined as any increase in travel resulting from an improvement in the transportation system. In the context of the analysis of highway projects, the improvement in the transportation system would be an increase in the supply of highway capacity, an increase in auto travel speeds, and a reduction in auto travel times. These improvements effectively reduce that time cost of auto travel and thus increase the demand for auto travel.

Induced travel effects evolve over time. In the short term, reduced travel time costs from new highway capacity affect changes in departure time, route, and mode choice. Near-term responses to lower travel time costs include changes in destination choices, frequency of trip-making, and vehicle ownership. Longer-term responses include changes in the location choice of households and employment activities.

A considerable body of research on induced travel has emerged over the last several decades (*10-19*). Research has been conducted to verify the induced travel mechanism and to gauge the magnitude of its effect. The methodological difficulties encountered in this research have included data quality, suitability of analytical techniques, and isolation of causality. It is important to note that such difficulties are shared by almost all areas of social science research. On balance, however, the weight of the evidence of the research tends to confirm the existence of induced travel. As a result of this research, induced travel has been acknowledged by the Transportation Research Board (*1*) and the U.S. Environmental Protection Agency (*2*).

In the literature, the magnitude of the induced travel effect is most commonly represented by two elasticity measures:

1. Elasticity of VMT with respect to roadway lane miles. This is typically the change in VMT divided by the change in lane miles resulting from the highway project. The empirical literature finds a short-term elasticity that ranges from 0.1 to 0.7 and the long term elasticity that ranges from 0.3 to 1.0 (*10*-*19*). For example, if the elasticity of lane miles with respect to VMT is 1.0, then a 10% increase in highway lane miles would produce a 10% increase in VMT.

2. Elasticity of VMT with respect to travel time. This is typically the change in VMT divided by the change in travel times resulting from the highway project. The empirical literature finds a short-term elasticity that ranges from -0.3 to -0.5 and the long term elasticity that ranges from -0.4 to -11.0 (*10*-*19*). For example, if the elasticity of travel times with respect to VMT is -1.0, then a 10% reduction in travel times would produce a 10% increase in VMT.

MODELS

For each case study, the model's induced travel components and variables are described in Table 1. In the Sacramento region, tests are conducted on the integrated land use and transportation model, the Sacramento MEPLAN model, (*20*-*25*) and regional travel demand model, the SACMET model (*26*). In the Chittenden case study, tests are conducted on their regional travel demand model link to a land allocation model. In the Salt Lake City study, tests are conducted on the regional travel demand model. These models all iterate or "feed back" modal travel times and/or costs among their sub-models until convergence (or consistent model input and output of travel time and/or cost) values are achieved. All of the models in the case studies are official metropolitan planning organization (MPO) models, with the exception of the Sacramento MEPLAN model. This model was developed as part of a model comparison project at the University of California at Davis (*25*). However, an updated version of the Sacramento MEPLAN model has now been adopted by the MPO for use with the SACMET model.

TABLE 1. Induced travel components and variables in the case study models.

INDUCED TRAVEL MODEL COMPONENTS	SACRAMENTO (CA)		CHITTENDEN (VT)	SALT LAKE CITY (UT)
	MEPLAN	SACMET		
Land Development (acres of land developed)	Modal travel time & cost			
Activity Allocation (where urban activities locate)	Modal travel time & cost		Modal travel time & cost	
Trip Distribution (origin and destination of trip)	Modal travel time & cost	Modal travel time & cost for work trips; auto times for others	Modal travel time & cost	Auto travel time & cost
Mode Choice (mode use in trip)	Modal travel time & cost	Modal travel time & costs	Modal travel time & cost	Modal travel time & costs
Traffic Assignment (route/road taken for trip)	Modal travel time & cost	Auto travel times	Modal travel time & cost	Auto travel times

Shaded areas indicate absence of model components.

SCENARIOS

Sensitivity tests are developed to assess the contribution of each model step to the model's total representation of induced travel in the network scenarios. This is accomplished by turning on and off different model steps. An illustration of the sensitivity tests is provided in Table 2. The first sensitivity test A is simulated with the full model to represent all induced travel effects. Each subsequent sensitivity test (B to D) drops an addition sub-model component by holding it constant from the no-build scenario. For example, sensitivity test B holds land uses constant from the no-build scenario and simulates only the trip distribution, mode choice, and traffic assignment induced travel effects of the highway scenario.

TABLE 2. An example of induced travel sensitivity tests for highway scenario.

INDUCED TRAVEL MODEL COMPONENTS	TEST A	TEST B	TEST C	TEST D
Land Use		No-build land uses	No-build land uses	No-build land uses
Trip Distribution			No-build trip tables	No-build trip tables
Mode Choice				No-build mode choice
Traffic Assignment				

Shaded areas indicate model components held constant from the no-build.

RESULTS

The results of the simulation tests with the Sacramento integrated land use and transportation (MEPLAN) model (*4*) indicated that change in land use patterns from the new highway capacity over a twenty-year time horizon accounted for half of predicted induced travel and that the change in trip origin-destination patterns (or trip distribution component) accounted for the other half. Overall, the model's long-term representation of induced travel (elasticity of VMT with respect to lane miles) for new highway projects was 0.8. This figure is consistent with the high end of the empirical range in the literature (as described above). The percentage underestimation of the travel and emission effects from the highway to the no-build with and without full model feedback would be 102% for VMT and 192% for NOx emissions. See Table 3 below.

TABLE 3. Long-term induced travel sensitivity test results with the case study models.

HIGHWAY ALTERNATIVES	**SACRAMENTO (CA)**		**CHITTENDEN (VT)**	**SALT LAKE CITY (UT)**
	MEPLAN	**SACMET**		
ELASTICITY OF VMT	0.8 (lane miles)	0.23 (lane miles) -0.41 (travel time)	0.76 (lane miles) -0.66 (travel time)	0.78 (lane miles)
SUBMODEL ELASTICITY CONTRIBUTION				
Land Development	25% (lane miles)			
Activity Allocation	25% (lane miles)		-1% (lane miles) 2% (travel time)	
Trip Distribution	50% (lane miles)	113% (lane miles) 112% (travel time)	71% (lane miles) 76% (travel time)	53% (lane miles)
Mode Choice	0% (lane miles)	-4% (lane miles) -17% (travel time)	-1% (lane miles) 0% (travel time)	-1% (lane miles)
Traffic Assignment	0% (lane miles)	-9% (lane miles) 5% (travel time)	32% (lane miles) 23% (travel time)	47% (lane miles)
PERCENTAGE UNDER-ESTIMATE: NO FEED BACK				
Vehicle Miles Traveled (VMT)	102%	94%	70%	85%
Vehicles Hours Traveled (VHT)		16%	236%	
NOx emissions	192%	72%		

Shaded areas indicate an absence of results.

Similar simulation tests were conducted with the region's travel demand model (SACMET), which does not include a land use component (*5*). These results indicated that, for a twenty year time horizon, the model predicted an elasticity of VMT with respect to land miles of 0.23 and an elasticity of VMT with respect to travel time of -0.41. These figures are consistent with the very low end of the empirical elasticity range described above. In addition, the sensitivity tests indicated that the change in origin-destination trip patterns from the highway projects (enabled by full feedback to trip distribution) accounted for almost all of the model's representation of induced travel. The negative results for mode choice and traffic assignment suggest that this model would forecast a reduction in VMT relative to the no-build without full feedback. The percentage underestimation of the travel and emission effects from the highway to the no-build with and without full model feedback would be 94% for VMT, 16% for vehicle hours of travel (VHT), and 192% for NOx emissions.

Another approach was taken to access the Sacramento travel demand model's prediction of induced travel (*6, 7*). This study used a historical forecasting validation technique to estimate actual induced travel in the region over a ten-year period (elasticity of VMT with respect to lane miles was found to be 0.22). This result was compared to the model's prediction of induced travel (elasticity of 0.14). Thus, the model tended to underestimate induced travel by 36% over a ten-year time horizon.

The results of the Chittendon County (VT) case study (*8*) indicate that the trip distribution component accounted for almost 75% and that the traffic assignment component accounted for almost 25% of the model's representation of induced travel. The elasticity of VMT with respect to lane miles was 0.76 and with respect to travel time was -0.66. The land use effect in this scenario was negligible. Over the twenty-five-year time horizon, additional roadway miles are projected to be only about one tenth of the growth in households and employment. As a result, the congestion effect (due to population growth) on the networks tends to swamp any increase in capacity. However, even without significant land use effects, the percentage underestimation of the travel effects from the highway to the no-build with and without full model feedback would be 70% for VMT and 236% for VHT.

The Salt Lake City's (UT) case study (*9*) indicates that the changes in trip distribution and traffic assignment from the new highway project each accounted for about 50% of the model's prediction of induced travel. The elasticity of VMT with respect to lane miles for the highway alternative was 0.78. The percentage underestimation of the travel from the highway to the no-build with and without full model feedback would be 85% for VMT.

SUMMARY AND CONCLUSIONS

Induced travel in the context of highway capacity expansion projects refers to the reduction in the time cost of travel and the resulting in increase in travel demand. The existence of induced travel has been acknowledged by the scientific research community.

In the empirical literature, the elasticity of VMT with respect to lane miles, the most common measure of induced travel in the literature, ranges from 0.3 to 1.0 in the long-run. Thus, if a highway project increases the total lane miles in the region by 10%, then VMT in the region may be increased by 3.0% to 10%.

The body of literature on the ability of existing travel and land use models to represent induced travel indicates that when travel times are fed back to a land use model and/or the trip distribution step, then (1) models can represent induced travel within the range documented in the empirical literature and (2) the effect of new highway capacity on land use and trip distribution significantly contributes to the models' representation of induced travel. If induced travel is not represented in travel and land use models, then the need for, and the benefit of, the project will be overstated (e.g., 16% to 236% of VHT), and negative environmental effects will be understated (e.g., 72% to 192% of NOx emissions).

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