JACKFAU-02-570/8

Final Report

Induced Travel Literature Review

Contract No. 68-C7-0051
Work Assignment No. 3-08

Prepared for:
The United States Environmental Protection Agency

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1 INTRODUCTION

This paper reviews the studies of induced demand for travel that have been carried out to date. These studies indicate that induced demand for travel is a real phenomenon and needs to be better accounted for in transportation planning models forecasting levels of congestion and air quality and land use impacts. The interconnectivity between highways, land use and air quality is increasingly being recognized by local, regional, state and federal agencies. However, research indicates that current models fail to recognize the complexity of this interconnection and often underestimate expected levels of congestion and air pollution.

As researchers, policymakers, public officials and the public-at-large struggle to understand the relationship between transportation development, land use, and quality of life changes for the affected areas, induced travel demand emerges as one of the most contentious issues. Understanding what the research says about this phenomenon is critical to making the best possible transportation infrastructure investments.

2   INDUCED DEMAND DEFINED

Noland and Lem (2001) define induced demand for travel to be any increase in vehicle miles traveled (VMT) attributable to any transportation project that increases capacity. For the purpose of this review, this definition will be used.

Basic economic theory can be used to explain the concept of induced demand. For any good, there are short- and long-run supply and demand curves; the point at which these curves intersect is the point of consumption. In this case, the good is travel; supply is the amount of roadway and demand is for use of these roads. The demand for motor vehicle travel is determined by a number of factors. Like any other good, the cost of these factors is reflected in a price. The price of travel includes the capital cost of a vehicle, vehicle maintenance, fuel and time. The time cost is considered to be the most significant factor related to induced travel (Noland, forthcoming).

Any increase in the supply of roadway reduces the time cost of travel, all else being equal. This, conceptually, makes sense: adding an additional lane to a highway reduces congestion and allows travelers to reach their destinations more quickly. As more users take advantage of this supply and the system becomes more congested, however, the price (or travel time) for each user increases until it plateaus at an equilibrium point between supply and demand. In the case of public mass transportation systems, a different supply curve applies due to "economies of scale". This means that as more users take advantage of the public transit systems there is a *reduction* in cost (or travel time) because the system becomes more viable and services can be run more frequently.

In terms of the basic supply and demand graph, a roadway addition or improvement shifts the upward-sloping supply curve outwards, or to the right, seen in Figure 1 as the shift from S_1 to S_2. The original point of consumption, or equilibrium point, was Q_0. After the addition of new roadway, the point of consumption is Q_1. The new supply can provide more of the good at a lower cost. Given the same short-run demand curve (D_1), a greater quantity will be demanded (Q_1). The long-run demand curve seen in Figure 1 (D_{LR}) has a more gradual slope. Over time, the short-run demand curve shifts outward to the point where the D_{LR} and S_2 intersect.
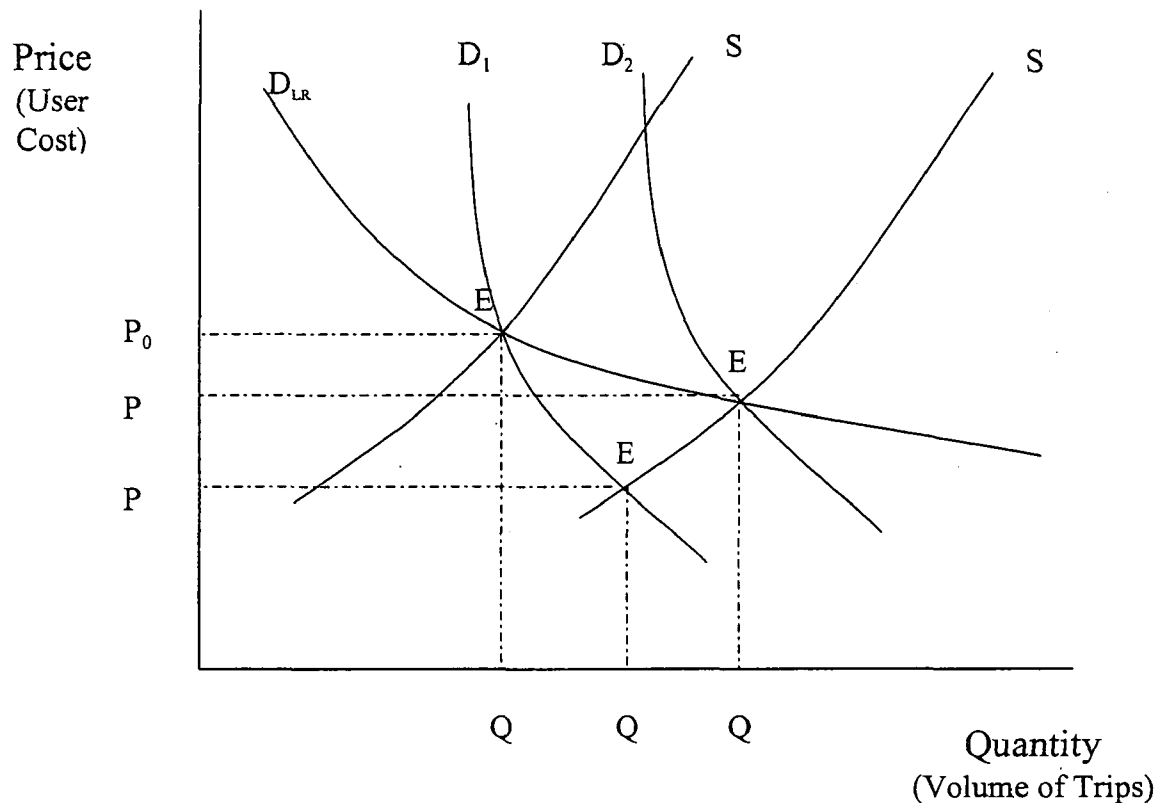
Figure 1: Demand for trip-making in relation to cost (Lee 1999) and effect of capacity improvement

This model assumes no increase in demand spurred by a number of exogenous factors as is the case in the real world. Exogenous factors are independent of the transportation system itself and include population growth, increased incomes, increased vehicle ownership, increased numbers of women in the workplace and other demographic characteristics. These factors lead to an even greater demand for travel. In modeling projected demand on a particular facility, it is extremely difficult to tease out the exogenous factors to measure the exact magnitude of induced demand. That is to say, of the increased quantity of demand for travel over time, it is difficult to calculate how much of that increase is a direct result of construction of the transportation facility itself and NOT of any other of the aforementioned exogenous factors. Determining the magnitude of induced demand and accounting for it in projection models remains the challenge to transportation planning experts.

3   WHAT INFLUENCES DEMAND FOR TRAVEL?

For every action, there is a reaction. People change their behavior in response to reduced travel costs. Behavioral changes occur on two levels: short- and long-term. Many short-term changes in and of themselves do not yield additional VMT directly, but can yield increased VMT in the long-term. Demand for travel is a derived demand, meaning it stems from other economic activity and thus is assumed fixed in the short-run (Lee et al., 1998). Simply stated, economists assume people do not travel for the sake of traveling but in order to achieve some other objective.

Both short- and long-term individual behavioral and developmental changes drive the demand for travel. In the short-term, which can be defined as the period during which households' residential locations and the spatial distribution of economic activity remain fixed (Pickrell, 2001), a transportation development that leads to reduced travel costs can encourage individuals to make longer trips, or provide a disincentive for individuals to combine trips they had combined before. In the long-term, transportation development often encourages land and other infrastructure development. Transportation projects that make historically un- or underdeveloped areas more accessible reduce travel costs and make the area a viable site for economic/urban development. Subsequently, two things can happen: (1) individuals relocate to these more suburban areas and (2) businesses move to the new suburbs as suburban executive parks are developed. Both these activities have the potential to lead to longer commute distances and decreased mass transit use (due to the absence of major mass transit systems in suburban areas, particularly newly developed suburban areas). Further, normal daily activities, such as shopping, often require motor vehicle use because these newly developed areas are usually served by "big box" retail developments, accessible almost exclusively by private motor vehicle.

So despite the increased transportation system's capacity, traffic often returns to the level of congestion it was before the transportation improvement. Downs (1992) developed a theory of "triple convergence" to explain the difficulty of removing peak-hour congestion from highways in the short-term. Hills (1996) and Litman (forthcoming) point to these same behavioral changes. These experts contend that individuals respond to capacity improvement immediately in three ways that contribute to continued congestion: (1) changing the time of their departure in switching from non-peak to peak hour travel; (2) switching travel routes to take advantage of added capacity on the improved roadway; and (3) switching from alternative transportation modes to private vehicle transit. Individuals may also shift their destination entirely. For example, instead of shopping at the local hardware store, an individual might now find it cost-effective to drive further to shop at a national chain store. While a traveler may not increase individual VMT by adjusting departure times or selecting a different travel route, the changed behavior will likely have secondary effects that will lead to increased VMT in the aggregate. The off-peak traveler that switches to peak travel time reduces congestion during off-peak travel times. This may induce other travelers to make new trips during the off-peak period since the travel cost during this time is now less. The same is true in the second scenario where an individual switches routes. That is, the original route of the individual who shifted routes is now less congested, reducing the travel cost for others and inducing additional trips along the original route.

Table 1: Short Term Behavioral Changes that Promote Continued Traffic on Improved Transportation Facilities

Rescheduled Trips	Adjusting departure times in response to facility improvement, spreading or contracting peak hour travel on the facility.
Changed Routes	Diverting from previous route to improved facility.
Mode Shift	Switching to new modes of transport because of improved facility (in this context, refers to shifts from public or alternative transit modes to private passenger vehicle).
Destination Shift	Altering destination because of facility improvement.

4   THE ISSUE: WHAT'S AT STAKE?

Federal, state and local governments spend billions each year on transportation improvements (Dowling & Colman, 1998) with objectives that include reducing congestion, facilitating economic growth, and improving air quality and travel safety. These objectives are not always achieved, since models are failing to accurately project the true impact of a transportation infrastructure project. This is in part due to the inability of models to accurately account for induced demand.

The 1990 Clean Air Act Amendments (CAAA) indirectly mandate that metropolitan planning organizations' (MPO) and state Department of Transportations' (DOT) account for the effects of induced demand in analyses of transportation projects. Agencies must develop a State Implementation Plan (SIP), which includes forecasting future emissions, to meet CAAA requirements. If a state or metropolitan area is out of attainment, CAAA prohibits use of Federal transportation funds for transportation projects that worsen air quality (Dowling & Colman, 1998). This presents MPOs and states with the challenge of forecasting the level of reduced emissions achieved in part through highway expansion that reduces driver speed variations (stop-and-go driving) and the level of additional emissions stemming from induced demand and other endogenous and exogenous factors leading to continued or worsened congestion.

The travel demand forecasting models used to meet the CAAA mandate are becoming increasingly sophisticated yet leave much to be desired in terms of accurate estimates. Recent studies find that forecasts of highway capacity and projections made on travel on a particular transportation facility underestimate the level of usage the facility actually sees once developed (see, for example, SACTRA, 1994).

The issue at hand is no longer whether induced demand exists, as recent studies (see, for example, Fulton et al, 1999; Hansen & Huang, 1997; SACTRA, 1994) find that it does. The issue now is determining its magnitude and methods of accounting for the phenomenon in practice. The projected benefits of a project – reduced travel times, improved air quality – can be tempered by induced demand (Noland & Cowart, 1999). Many highway projects are justified by estimates of congestion reduction (Rodier et al, 2001). If induced demand is not appropriately factored into the analysis, then the benefits of the project may be overstated and the benefits of alternatives to highway expansion, such as auto pricing and mass transit, may be underestimated (Rodier et al., 2001). The problem is that it is still unclear what the "appropriate" factor is for incorporating the effects of induced demand into travel forecasting models. The next section reviews the most recent research on this issue.

5   THE EMPIRICAL EVIDENCE

Research on induced demand has been conducted for decades. Historic research has focused on establishing the existence of induced demand; contemporary research focuses on the magnitude of this real phenomenon. A pivotal point in the history of this research was the United Kingdom release of the Standing Advisory Committee on Trunk Road Assessment's (SACTRA) report, *Trunk Roads and The Generation of Traffic* (1994). This report highlighted the weaknesses of then-current forecasting procedures, reviewing traffic in specific corridors that had capacity increased. The review showed that traffic grew at an unexpectedly high rate. The SACTRA postulated that this growth was not due entirely to exogenous factors such as increased income or GDP and concluded that induced travel is a "real phenomenon" and can affect the economic evaluation of a transportation project. That is, induced demand for travel matters. A number of studies in the United States also demonstrate that induced travel is real and that current forecasting models do not accurately account for it (see for example, Rodier et al., 2001).

The Transportation Research Board reported in 1995 that most modeling procedures do not adequately capture induced travel effects. Hansen et al. (1993) and Hansen & Huang (1997), among others, have used econometric techniques to demonstrate the statistical significance of the induced demand phenomenon and to quantify its magnitude. These and other studies yield a range of values for the short- and long-term effects of induced demand for travel as it relates to increased roadway capacity, measured in terms of elasticity of demand.

Economists use the term "elasticity of demand" to refer to the percentage change in quantity demanded for a good divided by the percentage change in price. For example, an elasticity of demand of .2 means that for a 1% decrease in price, there is a .2% increase in quantity demanded. If the short-run demand elasticity for travel is zero, or inelastic, then traffic volumes are unresponsive to changes in price and the demand curve is vertical. Even if the cost of travel changes, individuals will not change their behavior in response to the price change. In general, short-run demand elasticity for travel is less elastic than the long-run demand elasticity. This makes sense as individuals can do more to change their behavior over the long-run and thus have a greater impact on the total quantity demanded than they can in the short run. For example, if gas prices increase significantly, individuals cannot respond immediately in as drastic a way as they can in the long run as they still need to drive to do the things they did before the price increase. In the long-run, however, they may make behavioral changes, such as switch to public transportation, move to a location closer to work, or purchase a more fuel-efficient vehicle, to lower their fuel consumption.

A universal value for short- and long-run elasticities will be difficult to establish because of the individual characteristics (e.g. income, comprehensiveness of mass transit systems) of a given area. Further, the studies done to date have used different methodologies and data sources, and examined different time periods and area scales (county, metro area, state) so that the extrapolation of a single elasticity factor for travel demand is seemingly impossible. However, a general range of values has emerged from studies. This range can be useful for forecasting

models where analysts can perform sensitivity analysis demonstrating how sensitive the net benefit of a project is to manipulation of the induced travel factor.

The following are studies finding that increased capacity leads to increased traffic:

Table 2: Elasticities of Travel Demand with respect to Lane-Miles of Roadway

Study	Scale	Elasticities	
		Short-run	Long-run
Cervero and Hansen, 2000	County	0.6	
Fulton, Meszler, Noland and Thomas, 2000	County	0.1-0.4	0.5-0.8
Hansen and Huang , 1997	County	0.3-0.7	0.6-0.7
Rodier et al., 2001	Metropolitan Area	0.8	1.1
Noland and Cowart, 2000	Metropolitan Area	0.6-0.8	0.8-1.0
Hansen and Huang, 1997	Metropolitan Area	0.5-0.9	0.9
Johnston and Ceerla, 1996	Metropolitan Area		0.6-0.9
Noland, 2001	State	0.3-0.6	0.7-1.0

All these studies find that induced travel demand plays a significant role. Provide additional roadway and people will alter the behavior and drive more. In particular, people respond by changing their preferences, and thus development patterns. Boarnet and Chalermpong found in a study of an Orange County toll road network that "new highways change the geographic pattern of accessibility, that those changes are reflected in [increased] home sales prices, and thus that it is reasonable to conclude that new highways will also create changes in development patterns" (2000). These changes in development patterns influence induced traffic.

While there are limitations to the conclusions that can be definitively drawn from any one study because of the limitations of the datasets used for each study, the cumulative assessment of studies in this area suggest one thing: the impact of induced demand is considerable and can be seen through a number of measures.

An intensive review of the relevant literature in the United Kingdom and United States (Noland & Lem, 2002) concludes that the theory of induced travel "can certainly not be refuted and is largely confirmed." Noland (2001) estimates that 28% of annualized growth of VMT is due to induced travel. Heanue (1998) determines that between 6-22% of VMT growth is due to capacity additions. The question now is how to incorporate this body of knowledge into practice.

6   NEXT STEPS FOR ACCOUNTING FOR INDUCED TRAVEL DEMAND IN FORECAST MODELS

The studies cited in the last section offer direction for future action. It seems that several points should be kept in mind:

- Regardless of the scale of the project (county, metropolitan area, state), project evaluation must consider induced demand. Forecasting models must include some measure of transportation infrastructure capacity as a determining factor in estimating VMT growth.

- The long-run impact of induced demand is greater than the short-run. Constructing models that incorporate the "lag effect" of travel demand is necessary.

The U.S. Department of Transportation has only recently incorporated induced travel demand in its forecasting model, the Highway Economic Requirements System model (1999). Previously, demand relationships were assumed to be entirely exogenous, unaffected by infrastructure improvement. In its current form, it simulates changes in the demand for travel in response to shifts in the condition and capacity of individual sections. The model uses a short-run (five-year period) travel demand elasticity of 1.0 and a long-run elasticity of 1.6 with respect to total user costs. The model no longer treats each section in isolation; rather it is intended to simulate equilibrium effects in the network.

Rodier et al. examined the potential importance of land use and induced travel effects in the Sacramento, California region using the integrated land use and transportation model, MEPLAN (2001). The model simulates a future base case scenario (low-build) and a beltway scenario for 25- and 50-year horizons. Rodier et al. constructed scenarios to represent methods of operating travel demands models to capture induced travel effects. The study found that when land use effects, and land use and trip distribution effects were not represented, there were large errors in the estimation of increased VMT and emissions. These errors were so large that they changed the rank ordering of the scenarios based on their net benefits. This study demonstrates the significance of incorporating induced travel effects into regional travel demand models as the Sacramento MEPLAN model does (and many other models do not, see for example, Rodier & Johnston, 2000) to more accurately estimate the effect of transportation infrastructure expansion and the related environmental costs.

U.S. transportation policy has long been focused on reducing congestion by increasing capacity. The effects of induced demand suggest that this focus will never be successfully achieved (Noland & Cowart, 2000). That induced travel is a real and significant factor, transportation projects appear to be less about reducing traffic congestion as they are about directing the growth of urbanized areas (Noland & Lem, 2002). Increasing capacity should not be considered negatively in light of induced travel effects; there are many benefits to increased capacity including increased access and mobility and the associated potential increase in quality of life. However, transportation planners and policymakers alike must consider these benefits against the

costs of the project, costs that must include induced demand effects in order to account for the secondary effects of induced demand, including changes in land use (Rodier et al, 2001).

Project analysis that values lowered travel costs or improved air quality without accounting for induced travel effects are inadequate in providing for informed decision-making. Fortunately, forecasting and modeling is moving towards a more precise estimation of travel demand thanks to recent research and Federal mandates to conform to CAAA requirements and to review the environmental impact of Federal projects by the Environmental Protection Agency, as mandated by the National Environmental Policy Act (NEPA) of 1970. The Environmental Protection Agency is also working through its regional offices to assist state transportation agencies and MPOs in improving project level analyses to meet Federal environmental statutes. These statutes are encouraging more comprehensive project assessments and proving to be an effective vehicle for improved policy and project selection (Noland & Lem, 2001).

The existing highway finance process may in itself discourage complete quantification of the social costs of highway construction realized through induced demand for travel. Since many projects are financed largely by state and federal funds, local governments can export a large share of a project's cost to the state and federal government, effectively buying local gains with money that comes from other areas. Ideally, the area that benefits from a project would also incur the costs, encouraging a more comprehensive itemization of costs and benefits (Boarnet and Haughwout, 2000). Pickrell also concludes that a primary reason for the underestimation of project costs is the large portion of project funds that come from state and federal sources (1992). Though Pickrell's analysis focused on rail transit projects, the analogous funding system creates the potential for similarly poor highway project assessment (Boarnet and Haughwout, 2000).

7   CONCLUSIONS

The evidence indicates that improved forecasting models that account for the effect of induced demand for travel will provide for the potential to make better policy decisions regarding transportation development and land use. Also, further research on the highway construction funding system ought to be pursued to assess the potential of the current system to encourage the underestimation of project costs.

It is promising that there is a concerted effort to incorporate induced travel effects into transportation forecasting models. As forecasting models continue to be improved and decision makers become increasingly cognizant of the relationship between transportation capacity, behavioral responses and land use patterns, U.S. transportation planning can enter a new era that holds great promise for being more informed and thus more able to improve the general quality of life.

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