Generated Traffic and Induced Travel
Implications for Transport Planning
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Abstract

Traffic congestion tends to maintain equilibrium. Congestion reaches a point at which it constrains further growth in peak-period trips. If road capacity increases, the number of peak-period trips also increases until congestion again limits further traffic growth. The additional travel is called "generated traffic." Generated traffic consists of diverted traffic (trips shifted in time, route and destination), and induced vehicle travel (shifts from other modes, longer trips and new vehicle trips). Research indicates that generated traffic often fills a significant portion of capacity added to congested urban road.

Generated traffic has three implications for transport planning. First, it reduces the congestion reduction benefits of road capacity expansion. Second, it increases many external costs. Third, it provides relatively small user benefits because it consists of vehicle travel that consumers are most willing to forego when their costs increase. It is important to account for these factors in analysis. This paper defines types of generated traffic, discusses generated traffic impacts, recommends ways to incorporate generated traffic into evaluation, and describes alternatives to roadway capacity expansion.
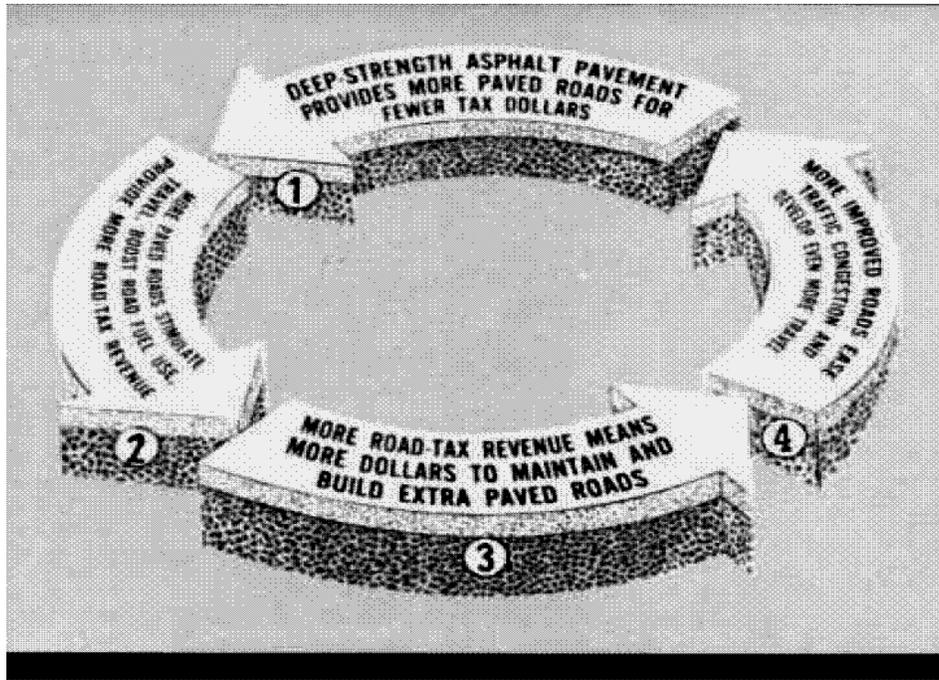
Contents

Roads beget roads: From the cover of *Asphalt Bulletin*, April 1966.

*This illustration from **Asphalt Bulletin** magazine shows how roadway expansion tends to stimulate automobile travel and the need for more roads.*

Introduction

Traffic engineers often compare traffic to a fluid, assuming that a certain volume must flow through the road system. But urban traffic may be more comparable to a gas that expands to fill available space (Jacobsen 1997). Road improvements that reduce travel costs attract trips from other routes, times and modes, and encourage longer and more frequent travel. This is called *generated traffic*, referring to additional vehicle traffic on a particular road. This consists in part of *induced travel*, which refers to increased total vehicle miles travel (VMT) compared with what would otherwise occur (Hills 1996).

Generated traffic reflects the economic "law of demand," which states that consumption of a good increases as its price declines. Roadway improvements that alleviate congestion reduce the generalized cost of driving (i.e., the price), which encourages more vehicle use. Put another way, most urban roads have *latent travel demand*, additional peak-period vehicle trips that will occur if congestion is relieved. In the short-run generated traffic represents a shift along the demand curve; reduced congestion makes driving cheaper per mile or kilometer in terms of travel time and vehicle operating costs. Over the long run induced travel represents an outward shift in the demand curve as transport systems and land use patterns become more automobile dependent, so people must drive more to maintain a given level of accessibility to goods, services and activities (Lee 1999).

This is not to suggest that increasing road capacity provides no benefits, but generated traffic affects the nature of these benefits. It means that road capacity expansion benefits consist more of increased peak-period mobility and less of reduced traffic congestion. Accurate transport planning and project appraisal must consider these three impacts:

1. Generated traffic reduces the predicted congestion reduction benefits of road capacity expansion.

2. Induced travel imposes costs, including downstream congestion, accidents, parking costs, pollution, and other environmental impacts.

3. The additional travel that is generated provides relatively modest user benefits, since it consists of marginal value trips (travel that consumers are most willing to forego).

Ignoring these factors distorts planning decisions. Experts conclude, "*…the economic value of a scheme can be overestimated by the omission of even a small amount of induced traffic. We consider this matter of profound importance to the value-for-money assessment of the road programme*" (SACTRA 1994). "*…quite small absolute changes in traffic volumes have a significant impact on the benefit measures. Of course, the proportional effect on scheme Net Present Value will be greater still*" (Mackie, 1996) and "*The induced travel effects of changes in land use and trip distribution may be critical to accurate evaluation of transit and highway alternatives*" (Johnston, et al. 2001)

This paper describes how generated traffic can be incorporated into transport planning. It defines different types of generated traffic, discusses their impacts, and describes ways to incorporate generated traffic into transport modeling and planning, and provides information on strategies for using existing roadway capacity more efficiently.

Defining Generated Traffic

Generated traffic is the additional vehicle travel that results from a road improvement, particularly expansion of congested urban roadways. Congested roads cause people to defer trips that are not urgent, choose alternative destinations and modes, and forego avoidable trips. Generated traffic consists of *diverted travel* (shifts in time and route) and *induced travel* (increased total motor vehicle travel). In some situations, highway expansion stimulates sprawl (automobile-dependent, urban fringe land use patterns), further increasing per capita vehicle travel. If some residents would otherwise choose less sprawled housing locations, their additional per capita vehicle travel can be considered to be induced by the roadway capacity expansion.

Below are examples of decisions that generate traffic:

- Consumers choose closer destinations when roads are congested and further destinations when traffic flows more freely. "*I want to try the new downtown restaurant but traffic is a mess now. Let's just pick up something at the local deli.*" This also affects long-term decisions. "*We're looking for a house within 40-minute commute time of downtown. With the new highway open, we'll considering anything as far as Midvalley.*"

- Travelers shift modes to avoid driving in congestion. "*The post office is only five blocks away and with congestion so bad this time of day, I may as well walk there.*"

- Longer trips may seem cost effective when congestion is light but not when congestion is heavy. "*We'd save $5 on that purchase at the Wal-Mart across town, but it's not worth fighting traffic so let's shop nearby.*"

Travel time budget research indicates that increased travel speeds often results in more mobility rather than saving time. People tend to average about 75 minutes of daily travel time regardless of transport conditions (Levinson and Kumar 1995; Lawton 2001). National data indicate that as freeway travel increases, average commute trip distances and speeds increase, but trip time stays about constant (Levinson and Kumar 1997). As a result, traffic congestion tends to maintain a self-limiting equilibrium: once congestion becomes a problem it discourages further growth in peak-period travel. Road expansion that reduces congestion in the short term attracts additional peak-period trips until congestion once again reaches a level that limits further growth. It may therefore be incorrect to claim that congestion reductions save travel time.

Definitions

Generated Traffic: Additional peak-period vehicle trips on a particular roadway that occur when capacity is increased. This may consist of shifts in travel time, route, mode, destination and frequency.

Induced travel: An increase in total vehicle mileage due to roadway improvements that increase vehicle trip frequency and distance, but exclude travel shifted from other times and routes.

Latent demand: Additional trips that would be made if travel conditions improved (less congested, higher design speeds, lower vehicle costs or tolls).

Triple Convergence: Increased peak-period vehicle traffic volumes that result when roadway capacity increases, due to shifts from other routes, times and modes.

Figure 1 illustrates this pattern. Traffic volumes grow until congestion develops, then the growth rate declines and achieves equilibrium, indicated by the curve becoming horizontal. A demand projection made during this growth period will indicate that more capacity is needed, ignoring the tendency of traffic volumes to eventually level off. If additional lanes are added there will be another period of traffic growth as predicted.

Figure 1   **How Road Capacity Expansion Generates Traffic**
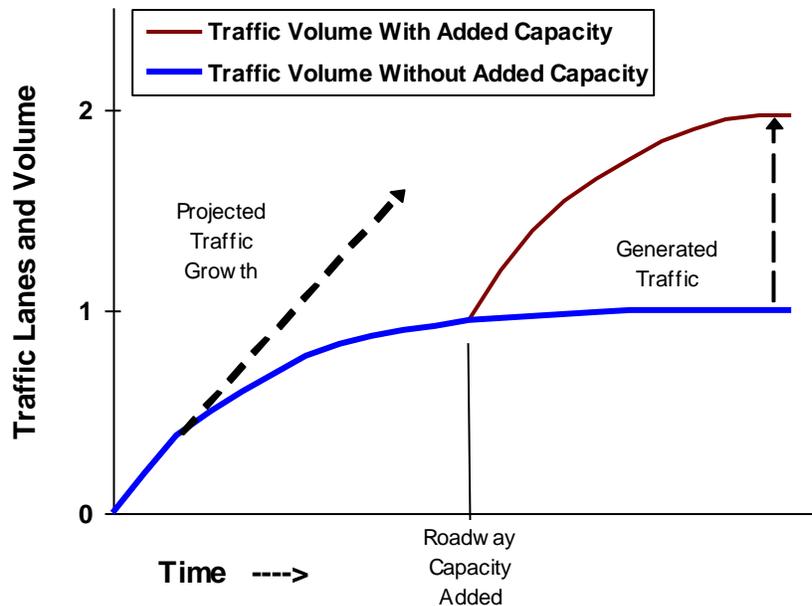
Traffic grows when roads are uncongested, but the growth rate declines as congestion develops, reaching a self-limiting equilibrium (indicated by the curve becoming horizontal). If capacity increases, traffic grows until it reaches a new equilibrium. This additional peak-period vehicle travel is called "generated traffic." The portion that consists of absolute increases in vehicle travel (as opposed to shifts in time and route) is called "induced travel."

Generated traffic can be considered from two perspectives. Project planners are primarily concerned with the traffic generated *on the expanded road segment*, since this affects the project's congestion reduction benefits. Others may be concerned with changes in *total vehicle travel* (induced travel) which affects overall benefits and costs. Table 1 describes

various types of generated traffic. In the short term, most generated traffic consists of trips diverted from other routes, times and modes, called *Triple Convergence* (Downs 1992). Over the long term an increasing portion is induced travel. In some situations, adding roadway capacity can reduce the network's overall efficiency, a phenomena called *Braess's Paradox* (Youn, Jeong and Gastner 2008).

Highway capacity expansion can induce additional vehicle travel on adjacent roads (Hansen, et al. 1993) by stimulating more dispersed, automobile-dependent development. Although these indirect impacts are difficult to quantify they are potentially large and should be considered in transport planning (Louis Berger & Assoc. 1998).

Table 1   **Types of Generated Traffic**

Type of Generated Traffic	Category	Time Frame	Travel Impacts	Cost Impacts
Shorter Route Improved road allows drivers to use more direct route.	Diverted trip	Short term	Small reduction	Reduction
Longer Route Improved road attracts traffic from more direct routes.	Diverted trip	Short term	Small increase	Slight increase
Time Change Reduced peak period congestion reduces the need to defer trips to off-peak periods.	Diverted trip.	Short term	None	Slight increase
Mode Shift; Existing Travel Choices Improved traffic flow makes driving relatively more attractive than other modes.	Induced vehicle trip	Short term	Increased driving	Moderate to large increase
Mode Shift; Changes in Travel Choice Less demand leads to reduced rail and bus service, less suitable conditions for walking and cycling, and more automobile ownership.	Induced vehicle trip	Long term	Increased driving, reduced alternatives	Large increase, reduced equity
Destination Change; Existing Land Use Reduced travel costs allow drivers to choose farther destinations. No change in land use patterns.	Longer trip	Short term	Increase	Moderate to large increase
Destination Change; Land Use Changes Improved access allows land use changes, especially urban fringe development.	Longer trip	Long term	More driving and auto dependency	Moderate to large increase, equity costs
New Trip; No Land Use Changes Improved travel time allows driving to substitute for non-travel activities.	Induced trip	Short term	Increase	Large increase
Automobile Dependency Synergetic effects of increased automobile oriented land use and transportation system.	Induced trip	Long term	Increased driving, fewer alternatives	Large increase, reduced equity

Some types of generated traffic represent diverted trips (trips shifted from other times or routes)
while others increase total vehicle travel, reduce travel choices, and affect land use patterns.

What constitutes *short-* and *long-term* impacts can vary. Some short term effects, such as mode shifts, may accumulate over several years, and some long term effects, such as changes in development patterns, can begin almost immediately after a project is announced if market conditions are suitable. Roadway expansion impacts tend to include:

- *First order.* Reduced congestion delay, increased traffic speeds.

- *Second order.* Changes in travel time, route, destination and mode to take advantage of the increased speeds.

- *Third order.* Land use changes. More dispersed, automobile-oriented development.

- *Fourth order.* Overall increase in automobile dependency. Degraded walking and cycling conditions (due to wider roads and increased traffic volumes), reduced public transit service quality (due to reduced demand and associated scale economies, sometimes called the *Downs-Thomson paradox*), and social stigma associated with alternative modes (Noland and Hanson 2013, p. 75).

Such impacts can also occur in reverse: if urban roadway capacity is reduced a portion of previous vehicle traffic may disappear altogether (Cairns, Hass-Klau and Goodwin 1998; Cervero 2006; CNU 2011; ITDP 2012; Miller 2006) which is sometimes called *traffic evaporation* (EC 2004).

Measuring Generated Traffic

Several studies using various analysis methods have quantified generated traffic and induced travel impacts (Noland and Hanson 2013). Their findings are summarized below:

- Cervero (2003a & b) used data on freeway capacity expansion, traffic volumes, demographic and geographic factors from California between 1980 and 1994. He estimated the long-term elasticity of VMT with respect to traffic speed to be 0.64, meaning that a 10% increase in speed results in a 6.4% increase in VMT, and that about a quarter of this results from changes in land use (e.g., additional urban fringe development). He estimated that about 80% of additional roadway capacity is filled with additional peak-period travel, about half of which (39%) can be considered the direct result of the added capacity.

- Duranton and Turner (2008) investigate the relationship between interstate highway lane-kilometers and highway vehicle-kilometers travelled (VKT) in US cities. They found that VKT increases proportionately to highways and identify three important sources for this extra vehicle travel: increased driving by current residents, an inflow of new residents, and more transport intensive production activity. They find aggregate city-level VKT demand to be elastic and so conclude that, without congestion pricing, increasing road or public transit supply is unlikely to relieve congestion, and current roadway supply exceeds the optimum.

- Time-series travel data for various roadway types indicates an elasticity of vehicle travel with respect to lane miles of 0.5 in the short run, and 0.8 in the long run (Noland 2001). This means that half of increased roadway capacity is filled with added travel within about 5 years, and that 80% of the increased roadway capacity will be filled eventually. Urban roads, which tend to be most congested, had higher elasticity values than rural roads, as would be expected due to the greater congestion and latent demand in urban areas.

- The medium-term elasticity of highway traffic with respect to California state highway capacity was measured to be 0.6-0.7 at the county level and 0.9 at the municipal level (Hansen and Huang 1997). This means that 60-90% of increased road capacity is filled with new traffic within five years. Total vehicle travel increased 1% for every 2-3% increase in highway lane miles. The researcher concludes, "it appears that adding road capacity does little to decrease congestion because of the substantial induced traffic" (Hansen 1995). Mokhtarian, et al (2002) applied a different statistical technique (matched-pairs) to the same data and found no significant induced travel effect, but that technique does not account for additional traffic on other roads or control for other factors that may affect vehicle travel.

- Leading U.K. transportation economists concludes that the elasticity of travel volume with respect to travel time is -0.5 in the short term and -1.0 over the long term (SACTRA 1994). This means that reducing travel time on a roadway by 20% typically increases traffic volumes by 10% in the short term and 20% over the long term.

- The following are elasticity values for vehicle travel with respect to travel time: urban roads, short-term -0.27, long term –0.57; rural roads, short term –0.67, long term –1.33 (Goodwin 1996). These values are used in the FHWA's SMITE software program described below.

- A Transportation Research Board report based finds consistent evidence of generated traffic, particularly with respect to travel time savings (Cohen 1995).

- National Highway Institute concludes that the elasticity of highway travel with respect to users' generalized cost (travel time and financial expenses) is typically -0.5 (NHI 1995).

- Analysis of traffic conditions in 70 metropolitan areas finds that regions which invested heavily in road capacity expansion fared no better in reducing congestion than those that spent far less (STPP 1998). The researchers estimate that road capacity investments of thousands of dollars annually per household would be needed achieve congestion reductions.

- Noland and Mohammed A. Quddus (2006) found that increases in road space or traffic signal control systems that smooth traffic flow tend to induce additional vehicle traffic which quickly diminish any initial emission reduction benefits.

- Cross-sectional time-series analysis of traffic growth in the U.S. Mid-Atlantic region found an average elasticities of VMT with respect to lane miles to be 0.2 to 0.6 (Noland and Lem 2002).

- The USDOT Highway Economic Requirements System (HERS) investment analysis model uses a travel demand elasticity factor of –0.8 for the short term, and –1.0 for the long term, meaning that if users' generalized costs (travel time and vehicle expenses) decrease by 10%, travel is predicted to increase 8% within 5 years, and an additional 2% within 20 years (Lee, Klein and Camus 1998; FHWA 2000).

- Cervero and Hanson (2000) found the elasticity of VMT with respect to lane-miles to be 0.56, and an elasticity of lane-miles with respect to VMT of 0.33, indicating that roadway capacity expansion results in part from anticipated traffic growth.

- A comprehensive study of the impacts of urban design factors on U.S. vehicle travel found that a 10% increase in urban road density (lane-miles per square mile) increases per capita annual VMT by 0.7% (Barr 2000).

- In a study of eight new urban highways in Texas over several years, Holder and Stover (1972) found evidence of induced travel at six locations, estimated to represent 5-12% of total corridor volume, representing from a quarter to two-thirds of traffic on the facility. Henk (1989) performed similar analysis at 34 sites and found similar results.

- Modeling analysis indicates that adding an urban beltway can increase regional VMT by 0.8-1.1% for each 1.0% increase in lane capacity (Rodier, et al. 2001).

Table 2   Portion of New Capacity Absorbed by Induced Traffic

Author	Short-term	Long-term (3+ years)
SACTRA		50 - 100%
Goodwin	28%	57%
Johnson and Ceerla		60 - 90%
Hansen and Huang		90%
Fulton, et al.	10 - 40%	50 - 80%
Marshall		76 - 85%
Noland	20 - 50%	70 - 100%

- Yao and Morikawa (2005) develop a model of induced demand resulting from high speed rail service improvements between major Japanese cities. They calculate elasticities of induced

travel (trips and VMT) with respect to fares, travel time, access time and service frequency for business and nonbusiness travel.

- Odgers (2009) found that traffic speeds on Melbourne, Australia freeways did not decline as predicted following new urban highway construction, apparently due to induced traffic. He concludes that, "major road infrastructure initiatives and the consequent economic investments have not yet delivered a net economic benefit to either Melbourne's motorists or the Victorian community."

- Burt and Hoover (2006) found that each 1% increase in road lane-kilometres per driving-age person increases per capita light truck travel 0.49% and car travel 0.27%, although they report that these relationships are not statistically significant, falling just outside the 80% confidence interval for cars and the 90% confidence interval for light trucks.

- Hymel, Small and Van Dender (2010) used U.S. state-level cross-sectional time series data for 1966 through 2004 to evaluate the effects of various factors including incomes, fuel price, road supply and traffic congestion on vehicle travel. They find the elasticity of vehicle travel with respect to statewide road density (based on 2004 vehicle ownership rates and incomes) is 0.019 in the short run and 0.093 in the long run (a 10% increase in total lane-miles per square mile increases state vehicle mileage by 0.19% in the short run and 0.93% in the long run), and with respect to total road miles is 0.037 in the short run and 0.186 in the long run (a 10% increase in lane-miles causes state VMT to increase 0.37% in the short run and 1.86% over the long run), and the elasticity of vehicle use with respect to congestion is -0.045 (a 10% increase in total regional congestion reduces regional mileage 0.45% over the long run), but this increases with income, assumedly because the opportunity cost of time increases with wealth, and so is estimated to be 0.078 at 2004 income levels (a 10% increase in total regional congestion reduces regional mileage by 0.78% over the long run). Their analysis indicates that long-run travel elasticities are typically 3.4–9.4 times the short-run elasticities.

- The *Handbook of Transportation Engineering* urban highway capacity expansion often fails to significantly increase travel times and speeds due to latent demand (Kockelman 2010). A review of published literature indicates long-run elasticities of demand for roadspace (vehicle miles traveled) are generally 0.5 to 1.0 after controlling for population growth and income, with values of almost 1.0 (suggesting that new roadspace is almost precisely filled by generated traffic where congestion is relatively severe.

- Schiffer, Steinvorth and Milam (2005) perform a meta-analysis of induced travel studies to identify short- and long-term elasticities of VMT with respect to changes in traffic lane-miles and other variables, as summarized in Figure 2. They predicted the amount of VMT induced by regional highway expansion in the Wasatch Front (Salt Lake City region). They reached the following general conclusions concerning induced travel:

  o *Induced travel effects exist* – The elasticity of VMT with respect to added lane-miles or reductions in travel time is generally greater than zero and the effects increase over time.

  o *Short-term induced travel effects are smaller than long-term effects* – As measured by the increase in VMT with respect to an increase in lane-miles, short-term effects have an elasticity range from near zero to about 0.40, while long-term elasticities range from about 0.50 to 1.00. This means that a 10% increase in lane-miles can cause up to a 4% increase in VMT in the short term and a 10% increase in the long term.

  o *Induced travel effects for constructing new roadways versus widening existing roadways were not definitive* – The research did not include any examples that isolated the effects of

constructing new roadways versus widening existing roadways. However, somewhat higher elasticities where found when "new roadways and widenings" were considered together compared to "widenings only." This finding is based on a limited number of studies and indicates that more research is necessary to isolate these differences.

o *Induced travel effects generally decrease with the size of the unit of study* – Larger effects are measured for single facilities while smaller effects are measured for regions and subareas. This is mainly due to diverted trips (drivers changing routes) causing more of the change on a single facility, whereas, at the regional level, diverted trips between routes within the region are not considered induced travel unless the trips become longer as a result.

o *Traditional four-step travel demand models do not fully address induced travel or induced growth* – Land use allocation methods overlook accessibility effects, trip generation often fails to account for latent trips (potential trips constrained by congestion), many models overlook time-of-day shifts, and static traffic assignment algorithms may not account for queuing impacts on route shifts. Errors tend to be greatest when there is more or users are more responsive to travel costs. These weaknesses are due to the static nature of four-step models that carry base-year behavior parameters into future years when congestion tends to increase. For example, the percent of daily trips that occur during a peak hour does not change from the base year to future years, although the portion of trips that occur during peak hours tends to decline as congestion increases. Failing to capture this effect ignores the potential trip suppression effects of congestion.

Figure 2 **VMT With Respect to Road Capacity** (Schiffer, Steinvorth and Milam 2005)
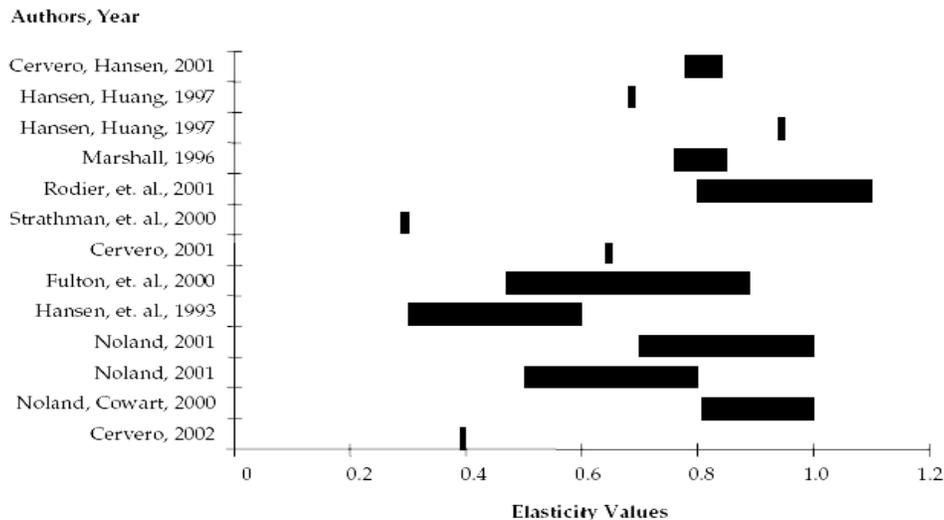
This figure summarizes long term vehicle travel elasticities with respect to roadway capacity.

• Melo, Graham and Canavan (2012) found a positive relationship between urban highway expansion and vehicle travel in the U.S. between 1982 and 2009.

The amount of traffic generated by a road project varies depending on conditions. It is not capacity expansion itself that generates travel, it is the reduction in congestion delays and therefore per-mile travel costs. Expanding uncongested roads will generate no traffic, although paving a dirt road or significantly raising roadway design speeds may induce more vehicle travel. In general, the more congested a road, the more traffic is generated by capacity expansion. Increased capacity on highly congested roads often generates

considerable traffic (Marshall 2000). Older studies of the elasticity of VMT growth with respect to increased roadway lane-miles performed during the early years of highway building (during the 1950s through 1970s) have little relevance for evaluating current urban highway capacity expansion. In developed countries, where most highway expansion now occurs on congested links, such projects are likely to generate considerable amounts of traffic, providing only temporary congestion reduction benefits.

> **Gridlock?**
> People sometimes warn that roads will soon reach *gridlock* unless some recommended action is taken, such as roadway expansion. Such claims are usually exaggerated because they ignore traffic congestion's tendency toward equilibrium. Gridlock is a specific condition that occurs when backups in a street network block intersections, stopping traffic flow. Gridlock can be avoided with proper intersection design and traffic law enforcement. Increasing regional highway capacity tends to increase this risk by adding more traffic to surface streets where gridlock occurs.

Generated traffic usually accumulates over several years (Goodwin 1998). Under typical urban conditions, more than half of added capacity is filled within five years of project completion by additional vehicle trips that would not otherwise occur, with continued but slower growth in later years. Figure 3 shows typical generated traffic growth indicated by various studies. Techniques for modeling these impacts into account are described in the next section (Dargay and Goodwin 1995).

Figure 3   Elasticity of Traffic Volume With Respect to Road Capacity
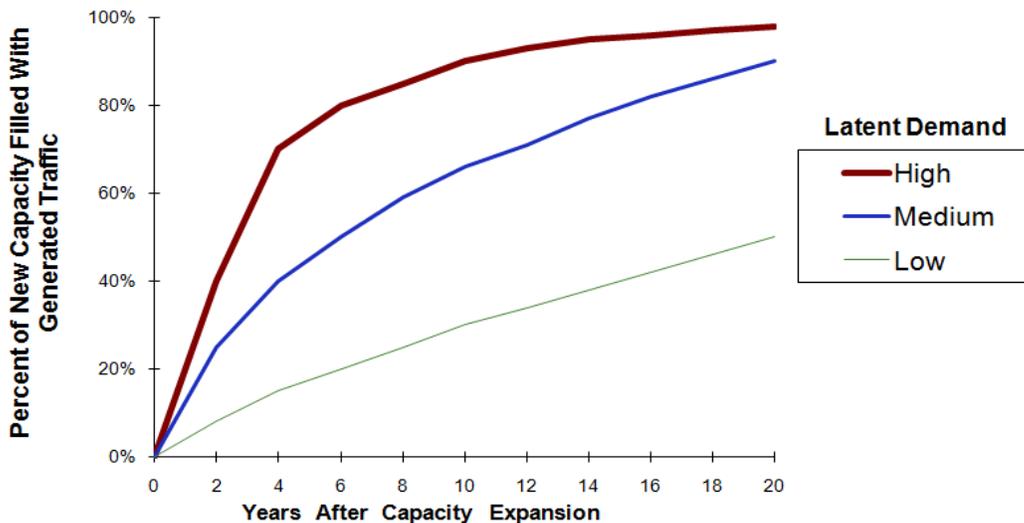
This illustrates traffic growth on a road after its capacity increases. About half of added capacity is typically filled with new traffic within a decade of construction. (Based on cited studies)

Modeling Generated Traffic

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. This recognizes that congestion diverts traffic to other routes, times and modes, and reduces trip length and frequency, while reduced congestion has the opposite effects. Because of non-linear speed flow relationships, and typically small net differences between large costs and large benefits, a small amount of induced traffic can have a disproportionately large effect on the cost effectiveness of a roadway project.

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 (Beimborn, Kennedy and Schaefer 1996; Ramsey 2005; Næss, Nicolaisen and Strand 2012). For example, they do not recognize that highway capacity expansion encourages more automobile-dependent urban fringe development. As a result, current models recognize diverted traffic but do not account for most forms of long term induced vehicle travel, and thus underestimate the amount of traffic likely to be generated when congested roads are expanded.

In one exercise, Ramsey (2005) found that the net benefits of a suburban highway capacity expansion project declined by 50% if the project caused 60,000 residents (about 2% of the regional population) to move from urban to suburban locations, thereby increasing traffic congestion on that roadway link. In a case study of a proposed roadway expansion project in Copenhagen, Denmark, Næss, Nicolaisen and Strand (2012) found that ignoring a portion of induced traffic effects significantly affected cost-benefit results: results show lower travel time savings, more adverse environmental impacts and a considerably lower benefit-cost ratio when induced traffic is partly accounted for than when it is ignored. They conclude that, "By exaggerating the economic benefits of road capacity increase and underestimating its negative effects, omission of induced traffic can result in overallocation of public money on road construction and correspondingly less focus on other ways of dealing with congestion and environmental problems in urban areas."

Analysis of urban highway expansion impacts on total emissions by Williams-Derry (2007) indicates that emissions from construction and additional vehicle traffic quickly exceed any emission reductions from reduced congestion delays.

Transportation modelers have developed techniques for incorporating full feedback (Harvey and Deakin 1993; SACTRA 1994; Loudon, Parameswaran and Gardner 1997; Schiffer, Steinvorth and Milam 2005). This recognizes that expanding the capacity of congested roads increases the number and length of trips in a corridor (DeCorla-Souza and Cohen 1999). Henk (1989) used analysis of vehicle traffic growth rates at 34 urban highways in Texas to develop a model which predicts the amount of latent demand, and therefore future traffic volumes from highway capacity expansion, taking into account the type of facility, the Volume/Capacity ratio, and local population densities. Even more accurate are integrated models that incorporate interrelationships between transport and

land use patterns (Rodier, et al. 2001). Federal clean air rules require that these techniques be used in metropolitan transportation models to evaluate the effects transport system changes have on vehicle emissions, but many metropolitan planning organizations have yet to comply, and few models used in medium and small cities have full feedback.

Full feedback is necessary to accurately predict future traffic congestion and traffic speeds, and the incremental costs and benefits of alternative projects and policy options. Models without full feedback tend to overestimate future congestion problems and overestimate the benefits of roadway capacity expansion. In one example, modeling a congested road network without feedback underestimated traffic speeds by more than 20% and overestimated total vehicle travel by more than 10% compared with modeling with feedback (Comsis 1996). Models that fail to consider generated traffic were found to overvalue roadway capacity expansion benefits by 50% or more (Williams and Yamashita 1992). Another study found that the ranking of preferred projects changed significantly when feedback is incorporated into project assessment (Johnston and Ceerla 1996). Ignoring generated traffic tends to skew planning decisions toward highway projects and away from No Build and mobility management alternatives such as road pricing, transit improvements and commute trip reduction programs (Boarnet 1995).

UK Department For Transport's *Transport Analysis Guidance* (DfT 2007), includes a section on *Variable Demand Modelling* (www.dft.gov.uk/webtag/documents/expert/unit3.10.1.php) which describes methods for incorporating induced travel demand into project appraisal.

The FHWA *Spreadsheet Model for Induced Travel Estimation* (SMITE) was developed to predict the amount of traffic induced by road improvements and the effects on consumer welfare and vehicle emissions (DeCorla-Souza 2000). It is a relatively easy way to incorporate generated traffic impacts into road project assessments. Another approach involves integrated transport/ land use models (such as TRANUS and MEPLAN) that track transport benefits through their land value impacts (Abraham 1998).

Short Cut Methods of Incorporating Induced Demand
Based on comments in the *Transportation Model Improvement Program* listserve (TMIP-L@listserv.tamu.edu) by Phil Goodwin, 2001.

The easiest way to incorporate induced demand into conventional traffic models is to apply an overall demand elasticity to forecasted changes in travel speed, calculated either:

- Elasticities applied to generalized costs (travel time and financial costs) using a price elasticity (about -0.3 for equilibrium, less for short term), with monetized travel time costs. The time elasticity is generally about -0.5 to -0.8 or so, though this is highly dependent on context. Where to apply it depends on the model used. With a fixed trip matrix altered only by reassignment, apply elasticities to each separate cell, or the row and column totals, or the overall control total - depending on how short the short cut has to be. Or add a separate test at the end.

  or

- Direct application of a 'capacity elasticity,' i.e. percent change in vehicle miles resulting from a 1% change in highway capacity, for which lane miles is sometimes used as a proxy, the elasticity in that case usually coming out at about -0.1. This will tend to underestimate the effect if the capacity increase is concentrating on bottlenecks.

Care is needed if the basic model has cost-sensitive distribution and mode split, as this will already make allowance for some induced traffic. Induced traffic consists of several types of travel changes that make vehicle miles "with" a scheme different from "without," including re-assignment to longer routes and some increased trip generation. Allowance for time-shifting, which is not induced traffic at all, is equally important because it has similar effects on calculation of benefits of reducing congestion, and is often a large response. Ideally you iterate on speed and allow for the effect from retiming of journeys, and separate the various behavioural responses which make up induced traffic. These short cuts are subject to bias, but less than the bias introduced by assuming zero induced traffic.

Land Use Impacts

An important issue related to generated and induced travel is the degree to which roadway improvements affect land use patterns, and in particular, whether highway capacity expansion stimulates lower-density, urban fringe development (i.e., urban sprawl), and the costs to society that result (Louis Berger & Assoc. 1998; USEPA 2001; ICF Consulting 2005). Land use changes are one category of induced travel. Such changes take a relatively long time to occur, and are influenced by additional factors, but they are durable effects with a variety of economic, social and environmental impacts.

Urban economists have long realized that transportation can have a major impact on land use development patterns, and in many situations improved accessibility can stimulate development location and type. Different types of transportation improvements tend to cause different types of land use development patters: highway improvements tend to encourage lower-density, automobile-oriented development at the urban fringe, while transit improvements tend to encourage higher-density, multi-modal, urban redevelopment, although the exact types of impacts vary depending on specific conditions and the type of transportation improvements implemented (Rodier, Abraham, Johnston and Hunt 2001; Boarnet and Chalermpong 2002; Litman 2002).

Some researchers claim that investing in road construction does not lead to the sprawl (Sen, et al. 1999; Hartgen 2003a and 2003b), although the evidence indicates otherwise. Even in relatively slow-growth regions with modest congestion problems, highway capacity expansion increases suburban development by 15-25%. These effects are likely to be much greater in large cities with significant congestion problems, where peak-period traffic congestion limits commute trip distances, and increased roadway capacity would significantly improve automobile access to urban fringe locations. This is particularly true if the alternative is to implement Smart Growth development policies and improved walking, cycling and transit transportation ("Smart Growth, VTPI 2006).

There has been considerable debate over the benefits and costs of sprawl and Smart Growth (Burchell, et al. 1998; Litman 2002). Table 2 summarizes some benefits that tend to result from reduced sprawl.

Table 2   **Smart Growth Benefits** ("Smart Growth, VTPI 2006)

Economic	Social	Environmental
Reduced development and public service costs. Consumer transportation cost savings. Economies of agglomeration. More efficient transportation.	Improved transportation choice, particularly for nondrivers. Improved housing choices. Community cohesion.	Greenspace and wildlife habitat preservation. Reduced air pollution. Reduce resource consumption. Reduced water pollution. Reduced "heat island" effect.

Costs of Induced Travel

Driving imposes a variety of costs, including many that are external, that is, not borne directly by users (Murphy and Delucchi 1998). Table 3 illustrates one estimate of the magnitude of these costs. Other studies show similar costs, with average values of 10-30¢ per vehicle-kilometer, and more under urban-peak conditions (Litman 2003).

Table 3   **Motor Vehicle Indirect and External Costs** (Delucchi 1996)

Cost Item	Examples	Vehicle-Year	Vehicle-Mile
Bundled private sector costs	Parking funded by businesses	$337-1,181	2.7-9.4 cents
Public infrastructure and services	Public roads, parking funded by local governments	$662-1,099	5.3-8.8 cents
Monetary externalities	External crash damages to vehicles, medical expenses, congestion.	$423-780	3.4-6.2 cents
Nonmonetary externalities	Environmental damages, crash pain.	$1,305-3,145	10.4-25.2 cents
Totals		*$2,727-6,205*	*22-50 cents*

This table summarizes an estimate of motor vehicle indirect and external costs. (US 1991 Dollars)

Any incremental external costs of generated traffic should be included in project evaluations, "incremental" meaning the difference between the external costs of the generated travel and the external costs of alternative activities (NHI 1995). For diverted traffic this is the difference in external costs between the two trips. For induced travel this is the difference in external costs between the trip and any non-travel activity it replaces, which tends to be large since driving has greater external costs than most other common activities. Most generated traffic occurs under urban-peak travel conditions, when motor vehicle external costs are greatest, so incremental external costs tend to be high.

Incremental external costs depend on road system conditions and the type of generated traffic. Generated traffic often increases downstream congestion (for example, increasing capacity on a highway can add congestion on surface streets, particularly near on- and off-ramps). In some conditions adding capacity actually increases congestion by concentrating traffic on a few links in the network and by reducing travel alternatives, such as public transit (Arnott and Small 1994). Air emission and accident rates per vehicle-mile may decline if traffic flows more freely, but these benefits decline over time and are usually offset as generated traffic leads to renewed congestion and increased vehicle travel (TRB 1995; Shefer and Rietvald 1997; Cassady, Dutzik and Figdor 2004).

Table 4 compares how different types of generated traffic affect costs. All types reduce user travel time and vehicle costs. Diverted trips have minimal incremental costs. Longer trips have moderate incremental costs. Shifts from public transit to driving may also have moderate incremental costs, since transit service has significant externalities but also experiences economies of scale and positive land use impacts that are lost if demand declines ("Social Benefits of Public Transit," VTPI 2001). Induced trips have the largest incremental costs, since they increase virtually all external costs. Longer and induced vehicle trips can lead to more automobile dependent transportation and land use over the long term. These costs are difficult to quantify but are probably significant (Newman and Kenworthy 1998; Burchell, et al 1998).

Table 4   **Cost Impacts of Roadway Capacity Expansion**

Costs Reduced	Costs Increased		
	Diverted Trips	*Longer Trips*	*Induced Trips*
Travel Time Vehicle Operating Costs Per-mile crash rates (if implemented in conjunction with roadway design improvements, but these are often offset if traffic speeds increase). Per-mile pollution emissions (if congestion declines, but these may be offset if traffic speeds increase).	Downstream congestion	Downstream congestion Road facilities Traffic services Per-capita crash rates Pollution emissions Noise Resource externalities Land use impacts Barrier effect	Downstream congestion Road facilities Parking facilities Traffic services Per-capita crash rates Pollution emissions Noise Resource externalities Land use impacts Barrier effect Transit efficiency Equity Vehicle ownership costs

Increased roadway capacity tends to reduce two costs, but increases others.

The incremental external costs of road capacity expansion tend to increase over time as the total amount of generated traffic grows and an increasing portion consists of induced motor vehicle travel and trips.

Table 5 proposes default estimates of the incremental external costs of different types of generated traffic. These values can be adjusted to reflect specific conditions and analysis needs.

Table 5   **Estimated Incremental External Costs of Generated Traffic**

Type	Description	Cost Per Mile
Time and route shift	Trips shifted from off-peak to peak, or from another route.	5 cents
Transit-to-Auto mode shift, and longer trips	Trips shifted from transit to driving alone, and increased automobile trip lengths.	15 cents
Induced vehicle trip	Additional motor vehicle trip, including travel shifted from walking, cycling and ridesharing.	30 cents.

This table indicates the estimated incremental costs of different types of generated traffic.

There is considerable discussion of the emission impacts of roadway expansion (TRB 1995). Although expanding highly congested roadways may reduce emission rates per vehicle-kilometer, expanding moderately congested roads may increase traffic speeds to levels (more than 80 kms/hr) that increase emission rates, and by inducing total vehicle travel tends to increase total emissions, particularly over the long run. According to a study by the Norwegian Centre for Transport Research (TØI 2009):

> "Road construction, largely speaking, increases greenhouse gas emissions, mainly because an improved quality of the road network will increase the speed level, not the least in the interval where the marginal effect of speed on emissions is large (above 80km/hr). Emissions also rise due to increased volumes of traffic (each person traveling further and more often) and because the modal split changes in favor of the private car, at the expense of public transport and bicycling."

Table 6 summarizes roadway improvement emission impacts, including effects on emission rates per vehicle mile, increases in total vehicle mileage, and emissions from road construction and maintenance activities.

*Table 6*   **Roadway Expansion Greenhouse Gas Emission Impacts** (TØI 2009)

	General Estimates	Large Cities	Small Cities	Intercity Travel
Emission reductions per vehicle-kilometer due to improved and expanded roads.		Short term reductions. Stable or some increase over the long-term.	Depends on situation, ranging from no change to large increases.	Depends on situation. Emissions may decline or increase.
Increased vehicle mileage (induced vehicle travel), short term (under five years)	A 10% reduction in travel time increases traffic 3-5%	Significant emission growth	Moderate emission growth	Moderate emission growth
Increased vehicle mileage (induced travel), long term (more than five years)	A 10% reduction in travel time increases traffic 5-10%	Significant emission growth	Moderate emission growth	Moderate emission growth
Road construction and improvement activity	12 tonnes of CO_2 equivalent for 2-lane roads and 21 tonnes for 4-lane roads.	Road construction emissions are relatively modest compared with traffic emissions.		
Roadway operation and maintenance activity	33 tonnes of CO_2 equivalent for 2-lane roads and 52 tonnes for 4-lane roads.	Road operation and maintenance emissions are relatively modest compared with traffic emissions.		

This table summarizes roadway improvement emission impacts according to research by the Norwegian Centre for Transport Research.

Calculating Consumer Benefits

Generated traffic represents increased mobility, which provides consumer benefits. However, these benefits tend to be modest because generated traffic consists of marginal value trips, the trips that people are most willing to forego (Small 1998). To calculate these benefits economists use the *Rule of Half*, which states that the benefits of additional travel are worth half the per-trip saving to existing travelers, as illustrated in Figure 4 by the fact that B is a triangle rather than a rectangle (AASHTO 1977; Litman 2001a).

Figure 4   **Vehicle Travel Demand Curve Illustrating the Rule-of-Half**
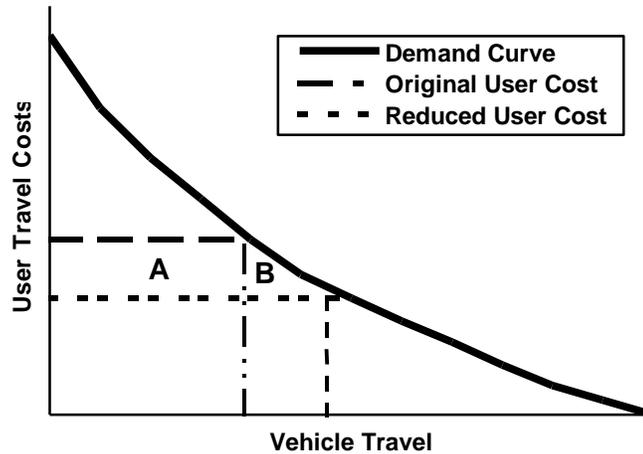
Reduced user costs (downward shift on Y axis) increases vehicle travel (rightward shift on X axis). Rectangle A shows savings to existing trips. Triangle B shows generated travel benefits.

Because induced travel provides relatively small user benefits, and imposes external costs such as downstream congestion, parking costs, accident risk imposed on other road users, pollution emissions, sprawl and other environmental costs, the ratio of benefits to costs, and therefore total net benefits of travel, tend to decline as more travel is induced.

Failing to account for the full impacts of generated and induced travel tends to exaggerate the benefits of highway capacity expansion and undervalue alternatives such as transit improvements and pricing reforms (Romilly 2004). Some newer project evaluation models, such as the FHWA's SMITE and STEAM sketch plan programs, incorporate generated traffic effects including the Rule of Half and some externalities (FHWA 1997; FHWA 1998; DeCorla-Souza and Cohen 1998).

The benefits of increased mobility are often capitalized into land values. For example, a highway improvement can increase urban periphery real estate prices, or a highway offramp can increase nearby commercial land values (Moore and Thorsnes 1994). Because this increase in land values is an economic transfer (land sellers gain at the expense of land buyers), it is inappropriate to add increased real estate values and transport benefits, such as travel time savings (which represent true resource savings). This would double count benefits.

Example

A four-lane, 10-kilometer highway connects a city with nearby suburbs. The highway is congested 1,000 hours per year in each direction. Regional travel demand is predicated to grow at 2% per year. A proposal is made to expand the highway to six lanes, costing $25 million in capital expenses and adding $1 million in annual highway operating expenses.

Figure 5 illustrates predicted traffic volumes. Without the project peak-hour traffic is limited to 4,000 vehicles in each direction, the maximum capacity of the two-lane highway. If generated traffic is ignored the model predicts that traffic volumes will grow at a steady 2% per year if the project is implemented. If generated traffic is considered the model predicts faster growth, including the basic 2% growth plus additional growth due to generated traffic, until volumes levels off at 6,000 vehicles per hour, the maximum capacity of three lanes.

***Figure 5*** **Projected Traffic**
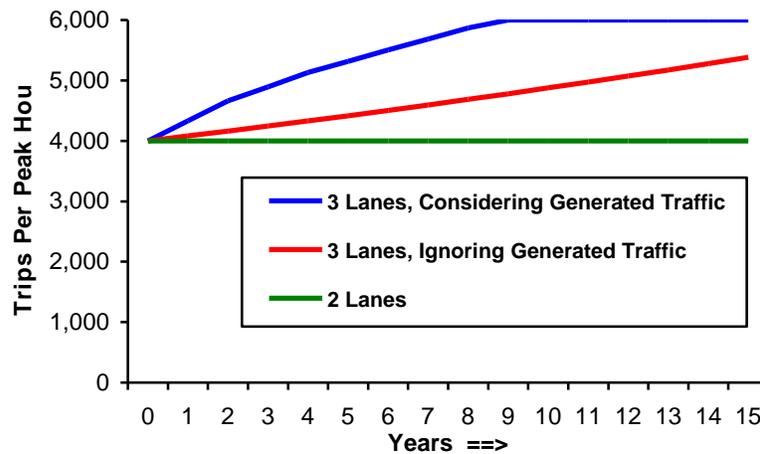
If generated traffic is ignored the model predicts that traffic volumes will grow at a steady 2% per year if the project is implemented. If generated traffic is considered the model predicts a higher initial growth rate, which eventually declines when the road once again reaches capacity and becomes congested. (Based on the "Moderate Latent Demand" curve from Figure 3)

The model divides generated traffic into diverted trips (changes in trip time, route and mode) and induced travel (increased trips and trip length), using the assumption that the first year's generated traffic represents diverted trips and later generated traffic represents induced travel. This simplification appears reasonable since diverted trips tend to occur in the short-term, while induced travel is associated with longer-term changes in consumer behavior and land use patterns.

Roadway volume to capacity ratios are used to calculate peak-period traffic speeds, which are then used to calculate travel time and vehicle operating cost savings. Congestion reduction benefits are predicted to be significantly greater if generated traffic is ignored, as illustrated in Figure 6.

Figure 6   **Projected Average Traffic Speeds**
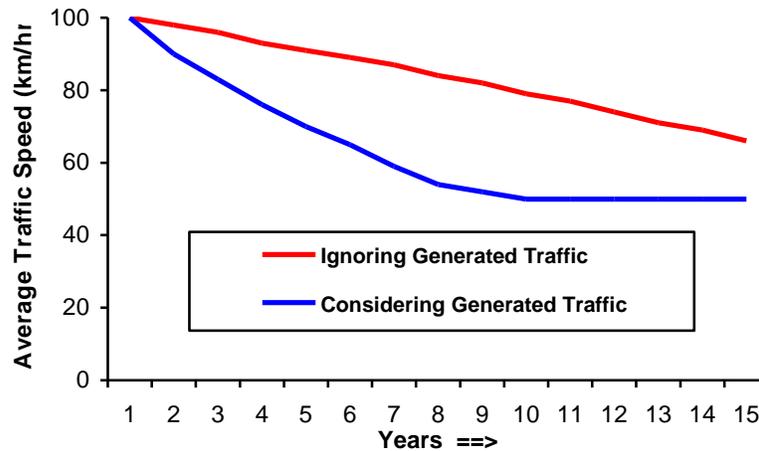
Ignoring generated traffic exaggerates future traffic speeds and congestion reduction benefits.

Incremental external costs are assumed to average 10¢ per vehicle-km for diverted trips (shifts in time, route and mode) and 30¢ per vehicle-km for induced travel (longer and increased trips). User benefits of generated traffic are calculated using the Rule-of-Half.

Three cases where considered for sensitivity analysis. *Most Favorable* uses assumptions most favorable to the project, *Medium* uses values considered most likely, and *Least Favorable* uses values least favorable to the project. Table 7 summarizes the analysis.

Table 7   **Analysis of Three Cases**

Data Input	Most Favorable	Medium	Least Favorable
Generated Traffic Growth Rate (from Figure 3)	L	M	H
Discount Rate	6%	6%	6%
Maximum Peak Vehicles Per Lane	2,200	2,000	1,800
Before Average Traffic Speed (km/hr)	40	50	60
After Average Traffic Speed (km/hr)	110	100	90
Value of Peak-Period Travel Time (per veh-hr)	$12.00	$8.00	$6.00
Vehicle Operating Costs (per km)	$0.15	$0.12	$0.10
Annual Lane Hours at Capacity Each Direction	1,200	1,000	800
Diverted Trip External Costs (per km)	$0.00	$0.10	$0.15
Induced Travel External Costs (per km)	$0.20	$0.30	$0.50
Net Present Value (millions)			
NPV Without Consideration of Generated Traffic	*$204.8*	*$45.2*	*-$9.8*
NPV With Consideration of Generated Traffic	*$124.5*	*-$32.1*	*-$95.7*
Difference	*-$80.3*	*-$77.3*	*-$85.8*
Benefit/Cost Ratio			
Without Generated Traffic	*6.90*	*2.30*	*0.72*
With Generated Traffic	*3.37*	*0.59*	*0.11*

This table summarizes the assumptions used in this analysis.

The most favorable assumptions result in a positive B/C even when generated traffic is considered. The medium assumptions result in a positive B/C if generated traffic is ignored but a negative NPV if generated traffic is considered. The least favorable assumptions result in a negative B/C even when generated traffic is ignored. In each case, considering generated traffic has significant impacts on the results.

Figure 7 illustrates project benefits and costs based on "Medium" assumptions, ignoring generated traffic. This results in a positive NPV of $45.2 million, implying that the project is economically worthwhile.
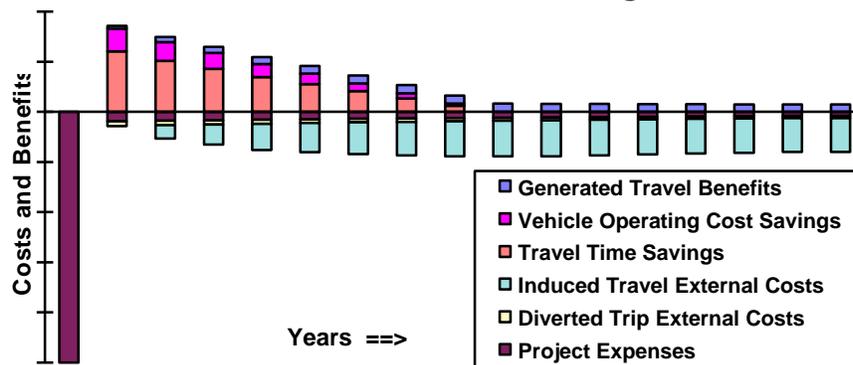
Figure 7   **Estimated Costs and Benefits, Ignoring Generated Traffic**
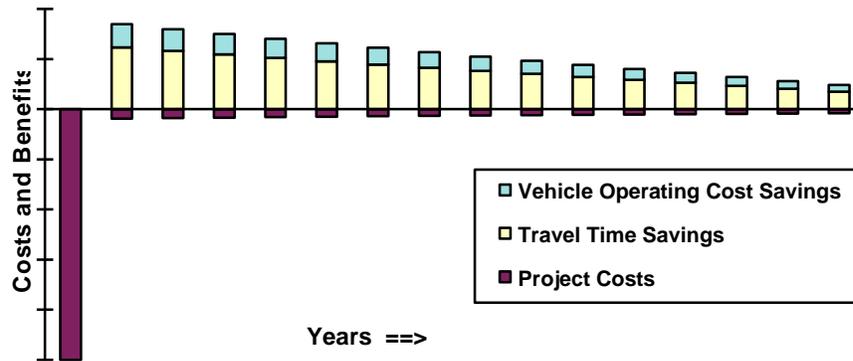
This figure illustrates annual benefits and costs when generated traffic is ignored, using "Medium" assumptions. Benefits are bars above the baseline, costs are bars below the baseline. Project expenses are the only cost category.

Figure 8 illustrates project evaluation when generated traffic is considered. Congestion reduction benefits decline, and additional external costs and consumer benefits are included. The NPV is −$32.1 million, indicating the project is not worthwhile.

Figure 8   **Estimated Costs and Benefits, Considering Generated Traffic**


This figure illustrates benefits and costs when generated traffic is considered, using medium assumptions. Benefits are bars above the baseline, costs are bars below the baseline. It includes consumer benefits and external costs associated with generated traffic. Travel time and vehicle operating cost savings end after about 10 years, when traffic volumes per lane return to pre-project levels, resulting in no congestion reduction benefits after that time.

This analysis indicates how generated traffic can have significant impacts on project assessment. Ignoring generated traffic exaggerates the benefits of highway capacity expansion by overestimating congestion reduction benefits and ignoring incremental external costs from generated traffic. This tends to undervalue alternatives such as road pricing, TDM programs, other modes, and "do nothing" options.

For example, Figure 9 compares three possible responses to congestion on a corridor with increasing traffic demand. Do nothing causes traffic congestion costs to increase over time. Expanding general traffic lanes imposes large initial costs due to construction delays, but provides large short-term congestion reduction benefits. However, these decline over time, due to induced traffic, and the additional vehicle travel imposes additional external costs including downstream congestion, increased parking demand, accident risk and pollution emissions. Building grade-separated public transit (either a bus lane or rail line) also imposes short-run congestion delays, and the congestion reduction benefits are relatively small in the short term but increase over time as transit ridership grows, networks expand, and development becomes more transit-oriented.

***Figure 9*   Road Widening Versus Transit Congestion Impacts**
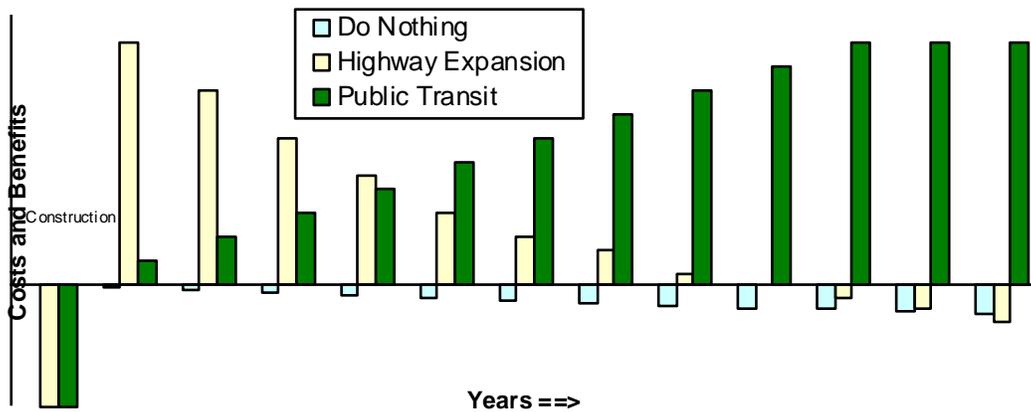
A Do Nothing causes congestion costs to increase in the future. Highway expansion imposes short term construction delays, then large congestion reduction benefits, but these decline over time due to generated traffic. Grade-separated public transit provides smaller benefits in the short-term but these increase over time as public transit ridership grows.

Counter Arguments

"Widening roads to ease congestion is like trying to cure obesity by loosening your belt" Roy Kienitz, executive director of the Surface Transportation Policy Project

"Increasing highway capacity is equivalent to giving bigger shoes to growing children" Robert Dunphy of the Urban Land Institute

Some highway expansion advocates argue that generated traffic has minor implications for transport planning decisions. They argue that increased highway capacity contributes little to overall growth in vehicle travel compared with other factors such as increased population, employment and income (Heanue 1998; Sen 1998; Burt and Hoover 2006), that although new highways generate traffic, they still provide net economic benefits (ULI 1989), and that increasing roadway capacity does reduce congestion (TRIP 1999; Bayliss 2008).

These arguments ignore critical issues, and are often based on outdated data and inaccurate analysis. Overall travel trends indicate little about the cost effectiveness of particular policies and projects. For example, studies which indicate that, in the past, increased lane-miles caused minimal growth in vehicle travel (Burt and Hoover 2006), provide little guidance for future planning, since, in the past, much of the added highway lane-miles occurred on uncongested rural highways while most future highway expansion occurs on congested urban highways. Strategies that encourage more efficient use of existing capacity, such as commute trip reduction programs and road pricing, may provide greater social benefits, particularly considering all costs (Goodwin 1997).

Highway expansion advocates generally ignore or severely understate generated traffic and induced travel impacts. For example, Cox and Pisarski (2004) use a model that accounts for diverted traffic (trips shifted in time or route) but ignores shifts in mode, destination and trip frequency. Hartgen and Fields (2006) assume that generated traffic would fill just 15% of added roadway capacity, based on generated traffic rates during the 1960s and 1970s, which is unrealistically low when extremely congested roads are expanded. They ignore the incremental costs that result from induced vehicle travel, such as increased downstream traffic congestion, road and parking costs, accidents and pollution emissions. They claim that roadway capacity expansion reduces fuel consumption, pollution emissions and accidents, because they measure impacts per vehicle-mile and ignore increased vehicle miles. As a result they significantly exaggerate roadway expansion benefits and understate total costs.

Debates over generated traffic and its implications often reflect ideological perspectives concerning whether automobile travel (and therefore road capacity expansion) is "good" or "bad". To an economist, such arguments are silly. Some automobile travel provides large net benefits (high user value, poor alternatives, low external costs), and some provides negative net benefits (low user value, good alternatives, and large external costs). The efficient solution to congestion is to use pricing or other incentives to test consumers' willingness to pay for road space and capacity expansion.

If consumers only demand roadway improvements when they are shielded from the true costs, such projects are likely to be economically inefficient. Only if users are willing to pay the full incremental costs their vehicle use imposes can society be sure that increased road capacity and the additional vehicle travel that results provides net benefits. Travel demand predictions based on underpriced roads overestimate the economically optimal level of roadway investments and capacity expansion. Increasing capacity in such cases is more equivalent to loosening a belt than giving a growing child larger shoes (see quotes above), since the additional vehicle travel is a luxury and economically inefficient.

Some highway advocates suggest there are equity reasons to subsidize roadway capacity expansion, to allow lower-income households access to more desirable locations, but most benefits from increased roadway capacity are captured by middle- and upper-income households (Deakin, et al. 1996). Improving travel choices for non-drivers tends to have greater equity benefits than subsidizing additional highway capacity since physically and economically disadvantaged people often rely on alternative modes.

Although highway projects are often justified for the sake of economic development, highway capacity expansion now provides little net economic benefit (Boarnet 1997). An expert review concluded, "The available evidence does not support arguments that new transport investment in general has a major impact on economic growth in a country with an already well-developed infrastructure" (SACTRA 1997). Melo, Graham and Canavan (2012) found a positive relationship between U.S. urban highway expansion and economic output between 1982 and 2009, but conclude that other types of transportation system improvements could provide greater net benefits.

Alternative Transport Improvement Strategies

Since roadway capacity expansion provides smaller net benefits than is often recognized, due to the effects of generated traffic, other solutions to transportation problems may provide relatively more benefits. A "No Build" option may become more attractive since peak-period traffic volumes will simply level off without additional capacity. This can explain, for example, why urban commute travel times are virtually unchanged despite increases in traffic congestion, and why urban regions that have made major investments in highway capacity expansion have not experienced significant reductions in traffic congestion (Gordon and Richardson 1994; STPP 1998).

Consideration of generated traffic gives more value to transportation systems management and transportation demand management strategies that result in more efficient use of existing roadway capacity. These strategies cannot individually solve all transportation problems, but a package of them can, often with less costs and greater overall benefit than highway capacity expansion. Below are examples (VTPI 2001):

- Congestion pricing can provide travelers with an incentive to reduce their peak period trips and use travel alternatives, such as ridesharing and non-motorized transport.

- Commute trip reduction programs can provide a framework for encouraging commuters to drive less and rely more on travel alternatives.

- Land use management can increase access by bringing closer common destinations.

- Pedestrian and cycle improvements can increase mobility and access, and support other modes such as public transit (since transit users also depend on walking and cycling).

- Public transit service that offers door-to-door travel times and user costs that are competitive with driving can attract travelers from a parallel highway, limiting the magnitude of traffic congestion on that corridor.

Legal Issues

Environmental groups successfully sued the Illinois transportation agencies for failing to consider land use impacts and generated traffic in the Environmental Impact Statement (EIS) for I-355, a proposed highway extension outside the city of Chicago (Sierra Club 1997). The federal court concluded that the EIS was based on the "implausible" assumption that population in the rural areas would grow by the same amount with and without the tollroad, even though project was promoted as a way to stimulate growth. The court concluded that this circular reasoning afflicted the document's core findings. The judge required the agencies to prepare studies identifying the amount of development the tollroad would cause, and compare this with alternatives. The Court's order states:

> Plaintiffs' argument is persuasive. Highways create demand for travel and expansion by their very existence…Environmental laws are not arbitrary hoops through which government agencies must jump. The environmental regulations at issue in this case are designed to ensure that the public and government agencies are well informed about the environmental consequences of proposed actions. The environmental impact statements in this case fail in several significant respects to serve this purpose. (ELCP)

In 2008 the California Attorney General recognized that regional transportation plans must consider induced travel impacts when evaluating the climate change impacts of individual projects to meet California Environmental Quality Act (CEQA) requirements (Brown 2008). CEQA requires that "[e]ach public agency shall mitigate or avoid the significant effects on the environment of projects that it carries out or approves whenever it is feasible to do so." The state Attorney General recognizes that transportation planning decisions, such as highway expansion projects, can have significant emission impacts due to induced vehicle travel.

Conclusions

Urban traffic congestion tends to maintain equilibrium. Congestion reaches a point at which it discourages additional peak-period trips. Increasing road capacity allows more vehicle travel to occur. In the short term this consists primarily of generated traffic: vehicle travel diverted from other times, modes, routes and destinations. Over the long run an increasing portion consists of induced vehicle travel, resulting in a total increase in regional VMT. This has several implications for transport planning:

- Ignoring generated traffic underestimates the magnitude of future traffic congestion problems, overestimates the congestion reduction benefits of increasing roadway capacity, and underestimates the benefits of alternative solutions to transportation problems.

- Induced travel increases many external costs. Over the long term it helps create more automobile dependent transportation systems and land use patterns.

- The mobility benefits of generated traffic are relatively small since they consist of marginal value trips. Much of the benefits are often capitalized into land values.

Ignoring generated traffic results in self-fulfilling *predict and provide* planning: Planners extrapolate traffic growth rates to predict that congestion will reach *gridlock* unless capacity expands. Adding capacity generates traffic, which leads to renewed congestion with higher traffic volumes, and more automobile oriented transport and land use patterns. This cycle continues until road capacity expansion costs become unacceptable.

The amount of traffic generated depends on specific conditions. Expanding highly congested roads with considerable latent demand tends to generate significant amounts of traffic, providing only temporary congestion reductions.

Generated traffic does not mean that roadway expansion provides no benefits and should never be implemented. However, ignoring generated traffic results in inaccurate forecasts of impacts and benefits. Road projects considered cost effective by conventional analysis may actually provide little long-term benefit to motorists and make society overall worse off due to generated traffic. Other strategies may be better overall. Another implication is that highway capacity expansion projects should incorporate strategies to avoid increasing external costs, such as more stringent vehicle emission regulations to avoid increasing pollution and land use regulations to limit sprawl.

Framing the Congestion Question

If you ask people, *"Do you think that traffic congestion is a serious problem?"* they frequently answer yes. If you ask, *"Would you rather solve congestion problems by improving roads or by using alternatives such as congestion tolls and other TDM strategies?"* a smaller majority would probably choose the road improvement option. This is how transport choices are generally framed.

But if you present the choices more realistically by asking, *"Would you rather spend a lot of money to increase road capacity to achieve moderate and temporary congestion reductions and bear higher future costs from increased motor vehicle traffic, or implement other types of transportation improvements?"* the preference for road building might disappear.

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