VICTORIA Transport Policy INSTITUTE
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www.vtpi.org
Info@vtpi.org
250-508-5150

Generated Traffic and Induced Travel

Implications for Transport Planning

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Todd Litman
Victoria Transport Policy Institute

Abstract

Traffic congestion tends to maintain equilibrium; traffic volumes increase until congestion delays discourage additional peak-period trips. If road capacity expands, peak-period trips increase 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). Generated traffic often fills a significant portion of capacity added to congested urban roads.

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 report defines types of generated traffic, discusses generated traffic impacts, recommends ways to incorporate generated traffic into evaluation, and describes alternatives to roadway capacity expansion.

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Contents

Introduction 2
Defining Generated Traffic and Induced Vehicle Travel 3
Measuring Generated Traffic and Induced Vehicle Travel 6
Modeling Generated Traffic and Induced Travel 11
Induced Travel Costs 13
Land Use Impacts 16
Consumer Surplus Impacts 17
Example 18
Counter Arguments 22
Alternative Transport Improvement Strategies 24
Legal Issues 24
Conclusions 25
References and Information Resources 26

Introduction

Traffic engineers often treat traffic as a liquid that must flow through the road system, but urban traffic often behaves more like a gas that expands to fill available space (Jacobsen 1997). Traffic congestion tends to maintain equilibrium: traffic volumes increase to the point that congestion delays discourage additional peak-period vehicle trips. Expanding congested roads attracts *latent demand*, trips from other routes, times and modes, and encourages longer and more frequent travel. The additional peak-period traffic on a road is called *generated traffic*, which consists in part of *induced vehicle travel*, which refers to absolute increases in vehicle miles travel (VMT) compared with what would otherwise occur (Hills 1996; Schneider 2018).

Generated traffic reflects the "law of demand," which states that reducing a goods' price tends to increase its consumption. Roadway improvements that reduce the user costs (i.e., the price) of driving encourage more vehicle travel. In the short-run generated traffic represents a shift along the demand curve; reduced congestion reduces travel time and vehicle operating costs. Over the long run it 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 (Deakin, et al. 2020).

This is not to ignore roadway expansion benefits. Accurate transport planning and project appraisal considers these three effects of generated traffic and induced vehicle travel:

1. Generated traffic reduces roadway expansion congestion reduction benefits (a *rebound* effect).
2. Induced travel increases many external costs including downstream congestion, crashes, parking costs, pollution and other environmental impacts, which is inefficient and unfair.
3. The additional vehicle traffic provides modest user benefits since it consists of marginal value vehicle-miles that consumers are most willing to forego if their costs slightly increase.

Ignoring these factors distorts planning decisions. As Goodwin (2026) succinctly explains in a recent review, "In a sentence, I confirm that the core problem established by SACTRA over 30 years ago still exists: building extra road capacity to solve congestion from increasing traffic is likely to induce extra road traffic, which receives benefits itself but causes additional delays and environmental costs to others." Other 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…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). Metz (2021) found that, expanding London's M25 motorway increased traffic volumes up to 23% within three years of opening, but contrary to projections, failed to increase traffic speeds, reducing expected economic benefits.

This report 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 and Induced Vehicle Travel

Generated traffic is the additional peak-period vehicle traffic that results from a road improvement, particularly urban roadway expansions. Congested roads cause people to defer lower value trips, change modes and destinations, and forego avoidable trips. It consists of *diverted travel* (shifts in time and route) and *induced travel* (increased total motor vehicle travel). Highway expansion can stimulate sprawl (dispersed, automobile-dependent development), further increasing per capita vehicle travel.

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 it is heavy. "*We can save $10 on that purchase at stores across town but traffic is slow so let's shop nearby.*"

Extensive research indicates that people tend to have fixed travel time budgets, called *Marchetti's constant* (Litman 2021; Marchetti 1994). Most people strive to limit errand trips to 5-15 each way, commute trips to 15-30 minute each way, and total daily personal travel to 60-90 minutes (Ahmed and Stopher 2014; English 2019; Hunter-Batal, et al. 2025), so faster travel tends to increase travel distances rather than save time. For example, roadway improvements that increase traffic speeds 30% are likely to increase affected motorists travel distance about 30% (Krol 2020). Over the short term those motorists gain access – they can reach more destinations within their travel time budgets – but over the long run these benefits often decline due to more vehicle traffic and sprawl which reduces proximity and increases external costs.

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.

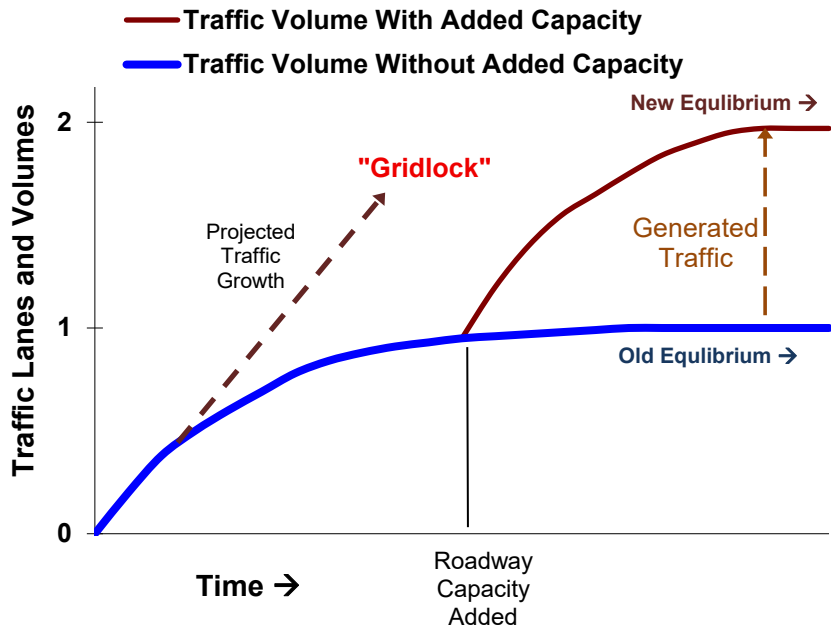
Latent demand: Additional trips that would be made if travel conditions improved (less congested, higher design speeds, lower vehicle costs or tolls).

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

Traffic congestion tends to maintain equilibrium: it increases to the point that delays discourage additional peak-period vehicle trips. If congested roads are expanded, motorists will make additional peak-period trips that they would otherwise forego, driving additional vehicle-miles.

The figure below illustrates this pattern. Traffic volumes grow until congestion causes some travellers to shift time, mode or destination, reducing traffic growth until roadways reach equilibrium, indicated by the curve becoming horizontal. Demand projections made during the growth period will predict severe congestion ("gridlock"), ignoring congestion's traffic suppression effects. If fears of extreme congestion result in roadway expansions, traffic will again grow, creating a self-fulfilling prophecy.

Figure 1 **How Road Capacity Expansion Generates Traffic**



When roads are uncongested traffic grows, but this declines as congestion develops, reaching self-limiting equilibrium (indicated by the blue curve becoming horizontal). If capacity increases, traffic grows again 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."

Table 1 categorizes various types of generated traffic. In the short term it mainly 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. This can reduce overall network efficiency, called *Braess's Paradox* (Youn, Jeong and Gastner 2008). Highway planners are primarily concerned with the traffic generated *on the expanded road segment*, since that affects the project's congestion reduction benefits. A broader perspective also considers changes in *total vehicle travel* (induced travel) that affect total benefits and costs.

Highway capacity expansion can also induce additional vehicle travel on adjacent roads by increasing automobile dependency and sprawl (Byun, Park and Jang 2017). Anciaes, Cheng and Watkins (2025) comment, "an increase in road capacity will have the short-term effect of increasing road travel speeds, leading to more and longer trips and switching of modes and routes. However, in the long term this will influence households' residence location patterns, as it increases the radius of potential commuting areas. More households will choose to live farther away from their workplace as they can access it within an acceptable travel time by private car. However, the result of more households travelling for longer distances is an increase in road traffic volumes. This will occur up to a point where the available road capacity is insufficient to accommodate all users, which means that the road will become congested again."

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 – faster traffic 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 reduces transit service, more traffic degrades walking and bicycling conditions, and vehicle ownership increases.	Induced vehicle trip	Long term	More 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	More 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 time, route, destination and mode.
- *Third order.* Land use changes. More dispersed, automobile-oriented development.
- *Fourth order*. Increased automobile dependency. Wider roads with faster traffic degrade walking and bicycling conditions, less efficient bus service and reduced demand reduces transit service quality (called the *Downs-Thomson paradox*), and non-auto modes become stigmatized.

These impacts can also occur in reverse: reducing urban roadway capacity often reduces total vehicle travel (CNU 2011; Goodwin 2002; ITDP 2012; ITF 2021), sometimes called *traffic evaporation* (EC 2004). More efficient and alternative fueled vehicles can also induce vehicle travel by reducing the per-mile financial costs of driving, called a *rebound effect* (Jägerbrand, et al. 2014; Ojeda-Diaz, et al. 2025).

Measuring Generated Traffic and Induced Vehicle Travel

Numerous studies using various analysis methods and data sets have quantified generated traffic and induced travel impacts (Deakin, et al. 2020; Goodwin 2026; WSP 2018):

- The study, *Road Capacity as a Fundamental Determinant of Vehicle Travel* (Millard-Ball and Rosen 2025) analyzed how road supply affects traffic speeds, accessibility, pedestrian connectivity, land development, transit service feasibility, plus residential and employment location decisions. It found that population and road supply affects total vehicle travel more than income and fuel prices, and since per capita vehicle travel peaked early in the Twenty First Century, road capacity is replacing income as the dominant factor affecting VMT.

- In a comprehensive global study Bain and Cimon (2025) found that road toll price elasticities have a median value of -0.21 with a range of -0.14 to -0.32, with values that increase over time, with the value of trips and the size of price increases, and decline with incomes and the quality of substitutes (other roads or high quality public transit).

- Mamkhezri and Khezri (2024) used 2000 to 2019 US state-level data to evaluate factors that affect vehicle miles travel (VMT). They found that fuel price and efficiency changes directly affect a state's VMT and have spillover effects in neighboring states. The direct price elasticity is estimated at −0.257, with a positive spillover impact of 0.036, yielding a total elasticity of −0.221. Induced travel exhibits a larger indirect effect than a direct effect, resulting in an overall impact of 0.276. Direct and total income elasticities are 0.194 and 0.146, respectively, while direct and total fuel economy rebound effects are 0.546 and 0.496, respectively. The number of licensed drivers, registered vehicles and urbanization also affect state vehicle travel.

- Using sophisticated statistical analysis of traffic flow in 24 global cities, Anupriya, Bansal and Graham (2023) found that increasing roadway capacity does not substantially increase average travel speeds, and by increasing total vehicle travel can increase overall traffic disbenefits.

- Analyses of 545 European cities indicates that urban highway expansion tends to increase vehicle traffic (Garcia-López, Pasidis, and Viladecans-Marsal 2020). They found that each 1% increase in highway lane-kilometers typically increases total vehicle kilometers 1.2%. It found significantly less congestion in cities with road pricing and high-quality rail transit. A 1% increase in lane kilometers increases congestion by 1.9% in cities without tolls but only 0.3% in cities with tolls and 1% more railroad kilometers decreases congestion 0.6% in a city without subways and 1.3% in a city where the majority of the railroad network consists of subways.

- *The Congestion Con: How More Lanes and More Money Equals More Traffic* (TfA 2020) analyzed how roadway expansions affected congestion in the 100 largest U.S. urbanized areas. Between 1993 and 2017 governments spent more than $500 billion on highway projects but congestion grew far more than population, and regions that expanded roads the most had more congestion growth than those that expanded less. The authors concluded that this resulted from generated traffic which filled the added capacity and increased per capita vehicle travel and sprawl.

- Metz (2021) found that, expanding London's M25 motorway increased traffic volumes up to 23% within three years of opening, but contrary to projections, failed to increase traffic speeds, reducing expected economic benefits.

- Rahmana, Bakerb and Rahmanc (2020) found that Dhaka, Bangladesh intersection flyovers typically provide a one-minute time savings, which increased vehicle trips by 35%.

- Detailed analysis by Hymel (2019) found that U.S. vehicle miles traveled increase in proportion with lane-mileage, and capacity expansion congestion relief generally vanishes within five years.

- The National Center for Sustainable Transportation's Induced Travel Calculator (NCST 2019) estimates the incremental vehicle travel induced by increasing general-purpose or high-occupancy-vehicle (HOV) lane miles. Although calibrated for California's urbanized counties, but the methodology is transferable to other geographic areas.

- *A Statistical Model of Regional Traffic Congestion in the United States* (Marshall 2016) used real-time traffic data to analyze factors that affected congestion in 74 U.S. urban regions. It found that more arterial capacity reduces congestion but more freeway capacity is not. It found that congestion increases with incomes so economic productivity increases population and incomes which increase congestion. It concludes that freeway expansions do not reduce congestion.

- Graham, McCoy and Stephens (2014) quantify roadway capacity expansion effects on aggregate urban traffic volume and density in U.S. cities using a mixed model propensity score estimator which accounts for confounding unobserved characteristics. They found that a 10% increase in lane miles increases average VMT 9% beyond 'natural growth.' They conclude that even major urban highway expansions can provide little or no long-term congestion reductions.

- A review by Handy and Boarnet (2014) found that *short-run* highway expansion elasticities generally range from 0.3 to 0.6, and *long-run* effects typically range from 0.6 to just over 1.0, meaning that each 10% increase in road capacity increases traffic volumes by 3-6% within two years, and 6-10% after about five years. They found that more recent studies using more sophisticated methodologies tend to find higher elasticities. They conclude that expanding congested urban highways is unlikely to reduce long run congestion or associated GHGs.

- Duranton and Turner (2008) found that in U.S. urban regions, vehicle travel increases proportionately to highway capacity due to four effects: increased driving by current residents, an inflow of new residents, and more transport intensive production activity. They conclude that, without congestion pricing, increasing road or public transit supply is unlikely to relieve congestion, and current roadway supply exceeds optimums.

- Cervero (2003) used data on freeway capacity, traffic volumes, demographic and geographic factors in California between 1980 and 1994. He estimated a 0.64 long-term elasticity of VMT with respect to traffic speed, meaning that a 10% speed increases VMT 6.4%, about a quarter of which results from land use changes (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.

- Noland (2001) and (Noland and Lem 2002) used time-series travel data for various roadway types to evaluate induced travel. They found an elasticity of vehicle travel with respect to lane miles of 0.5 in the short run, and 0.8 in the long run. 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.

- Leading U.K. transport 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), so increasing travel speeds 20% increases traffic volumes 10% in the short term and 20% over the long term. It estimated the following 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.

- Noland and 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.

- Tennøy, Tønnesen and Gundersen (2019) found that Norwegian highway expansions provide only short-term congestion relief, and by increasing sprawled development, increase total traffic growth. They find that road authorities generally overlooked these effects.

- Yao and Morikawa (2005) analyzed the travel induced by high speed rail 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 Melbourne, Australia freeway traffic speeds did not increase as predicted following 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 1966-2004 U.S. state-level cross-sectional time series data to evaluate how income, fuel price, road supply and traffic congestion affect vehicle miles travel (VMT). They find the elasticity of VMT with respect to statewide road density 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); 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 vehicle use with respect to congestion is -0.045 (a 10% increase in total regional congestion reduces regional VMT 0.45% over the long run), but this increases with income, assumedly because the opportunity cost of time increases with wealth. Their analysis indicates that long-run travel elasticities are typically 3.4–9.4 times short-run elasticities.

- The *Handbook of Transportation Engineering* finds that urban highway capacity expansion often fails to significantly increase travel speeds due to latent demand (Kockelman 2010). They conclude that the long-run elasticities of VMT with respect to roadspace is generally 0.5 to 1.0 after controlling for population growth and income, with values of almost 1.0, suggesting that new roadspace is totally filled by generated traffic where congestion is relatively severe.

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

- A meta-analysis by Schiffer, Steinvorth and Milam (2005) reached the following conclusions:
  - *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.
  - *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.
  - *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.
  - *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, many models overlook time-of-day shifts, and static traffic assignment algorithms may not account for queuing impacts on route shifts; all underestimating generated traffic.

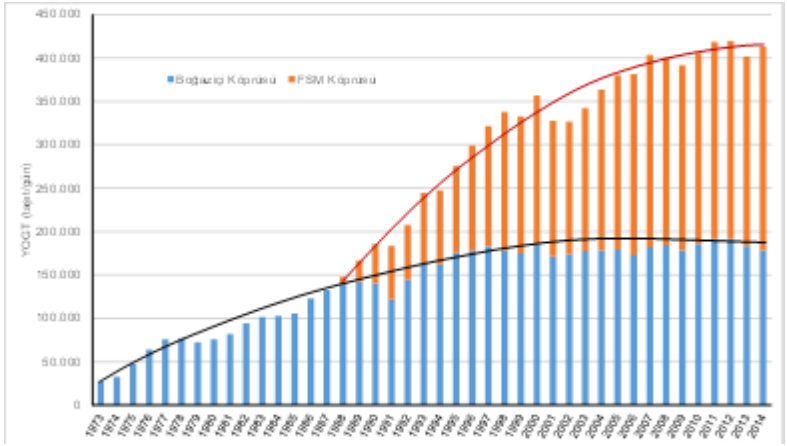
- Cervero and Hanson (2000) found the elasticity of VMT with respect to lane-miles to be 0.56, and an elasticity of lane-miles with respect to VMT of 0.33, indicating that roadway capacity expansion results in part from anticipated traffic growth.

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

- Özuysal and Tanyel (2008) found the elasticity of travel per vehicle relative to Turkish state highway supply is 2.0 for private vehicles and 3.5 for commercial vehicles over 3-5 year periods.

- Analysis by Professor Ismail Sahin of Turkey's Yildiz Technical University shows that after new bridges were built in Istanbul, traffic volumes increased, representing induced vehicle trips, resulting in a new, higher level of congestion equilibrium.

Figure 2 **Istanbul Bridge Traffic Volumes** (Ismail Sahin 2015)



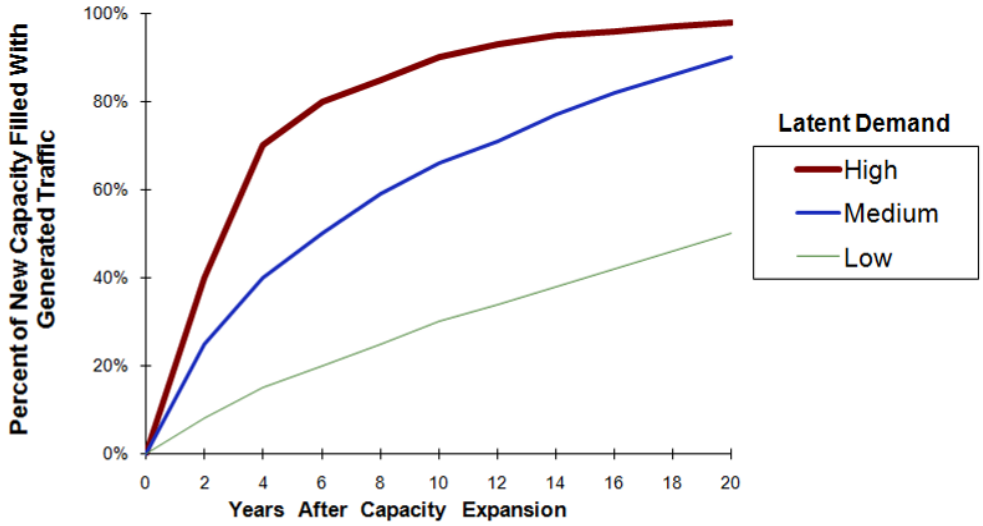
This graph shows Average Annual Daily Trips (AADTs) on Bosporus Bridge (blue bars) opened in 1973 and Fatih Sultan Mehmet (FSM) Bridge (orange bars) opened in 1988. This shows the tendency of traffic volumes to fill the new capacity and then reach equilibrium as congestion becomes self-limiting.

Expanding uncongested roads generates little 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 expansions. Increased capacity on highly congested roads often generates considerable traffic. 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.

Generated traffic usually accumulates over several years. 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 (Goodwin 1998; Handy and Boarnet 2014). The following figure shows typical generated traffic growth based on various studies. The next section describes techniques for modeling these impacts.

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)

Gridlock?
People sometimes warn of roadway *gridlock* without some recommended action, 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 can increase this risk by adding more traffic to surface streets where gridlock occurs.

Modeling Generated Traffic and Induced Travel

Traffic and transportation models are used to predict future travel activity and the effects of system changes such as roadway expansions, transit service improvements and price changes. All current models can predict route and mode shifts, and some can predict changes in trip frequency, scheduling and destination, but few can accurately predict long-term effects caused by changes in land use development patterns (Fehr & Peers 2025; Næss, Nicolaisen and Strand 2012). As a result, current models overestimate highway expansion costs and underestimate long-term induced vehicle travel, and associated costs, including downstream traffic and parking congestion, crashes and emissions (Deakin, et al. 2020; Goodin 2026). The report, *Induced Vehicle Travel Impact Analysis* (Milam 2025) describes methods for more accurate modelling of roadway capacity project traffic impacts. The article, "Is Induced Travel Covered in Transportation Engineering Textbooks? Not Very Well" (Ralph and White 2026) found that current textbooks tend to overlook or underestimate induced travel impacts, and give little attention to demand management solutions.

A study, *Climate Emissions Analysis: Metro's Indirect Impact on Greenhouse Gas Emissions* (METRO 2022) found that in Los Angeles the additional vehicle travel induced by planned freeway expansions more than offset the emission reductions provided by public transit and active transport improvements. Volker, Lee, and Handy (2020) examined the evaluation methods used in five recent highway project. They found that conventional analyses frequently fail to account for induced travel effects, which exaggerated their benefits and underestimated their environmental costs. The authors used this information to develop the National Center for Sustainable Transportation's **Induced Travel Calculator**, which estimates the incremental vehicle travel induced by adding general-purpose or high-occupancy-vehicle (HOV) lane miles to roadways. The Rocky Mountain Institute used this methodology to develop the **SHIFT Calculator** which predicts induced vehicle travel and emissions from capacity expansions of large roadways for U.S. urban regions.

Ramsey (2005) found that a suburban highway expansion project's net benefits declined 50% if the project caused just 2% of the regional population to move from urban to suburban locations. Similarly, Næss, Nicolaisen and Strand (2012) found that ignoring some induced traffic effects significantly affected the estimated value of a proposed Copenhagen, Denmark highway expansion. When induced travel was considered the results show lower travel time savings and more adverse environmental impacts, resulting in significantly lower benefit-cost ratio. They conclude that, "By exaggerating the economic benefits of road capacity increase and underestimating its negative effects, omission of induced traffic can result in over-allocation 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 construction and induced vehicle travel emission quickly exceed any emission reductions from less congestion.

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 transportation demand management alternatives such as road pricing, transit improvements and commute trip reduction programs. 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.

Short Cut Methods of Incorporating Induced Demand
Based on comments 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

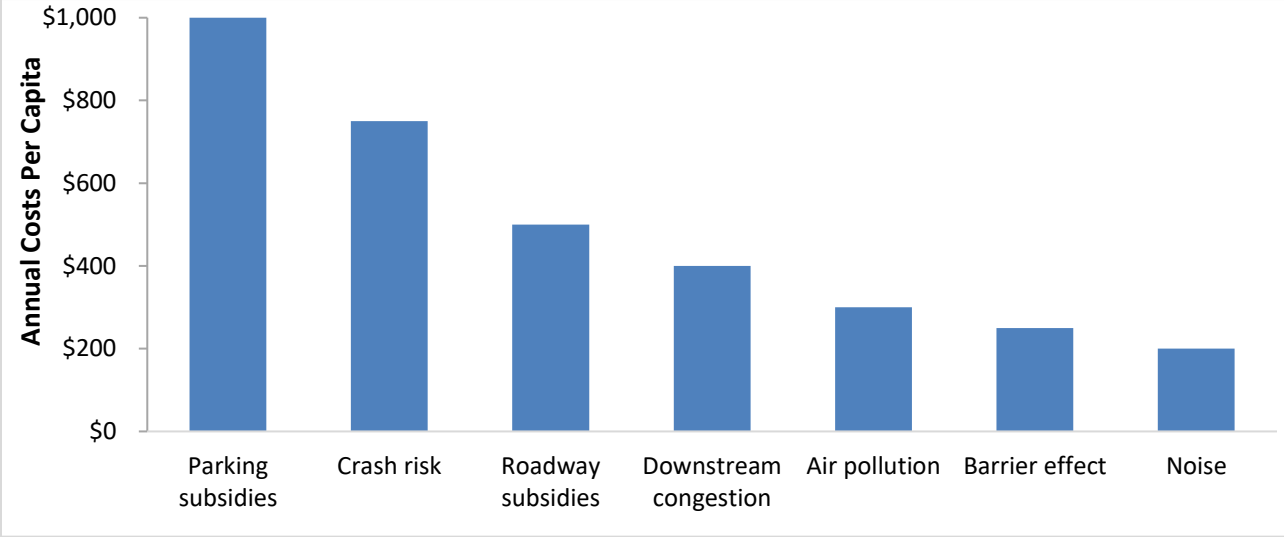
- Direct application of a 'capacity elasticity,' i.e. percent change in vehicle miles resulting from a 1% change in highway capacity, for which lane miles is sometimes used as a proxy, the elasticity in that case usually coming out at about -0.1. This will tend to underestimate the effect if the capacity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

Care is needed if the basic model has cost-sensitive distribution and mode split, as this will already account 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 increased trip generation. Although time-shifting is not induced traffic, it has similar effects on congestion reduction benefits 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.

Induced Travel Costs

Induced vehicle travel can increase many costs, particularly if it occurs under urban-peak conditions. For example, since a typical freeway lane can accommodate about 2,200 vehicles per hour, adding a lane on a highway connecting a suburb with a city center typically induces 3,000 to 6,000 urban-peak vehicle trips which increases various external costs: more parking problems and subsidy needs, additional crash risk imposed on other travellers, roadway costs not borne by user fees, more congestion on surface streets, noise and air pollution, and increased barrier effect (delay and risk imposed on pedestrians).

Figure 4 **Induced Urban Traffic External Costs** (CE Delft 2019; Litman 2026)



Induced travel increases external costs, particularly additional urban-peak vehicle trips.

Any incremental external costs of generated traffic should be included in project evaluations, "incremental" meaning the difference between what occurs with and without the project. 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.

The following table compares costs of different types of generated traffic. 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. 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 (Ewing and Hamidi 2014).

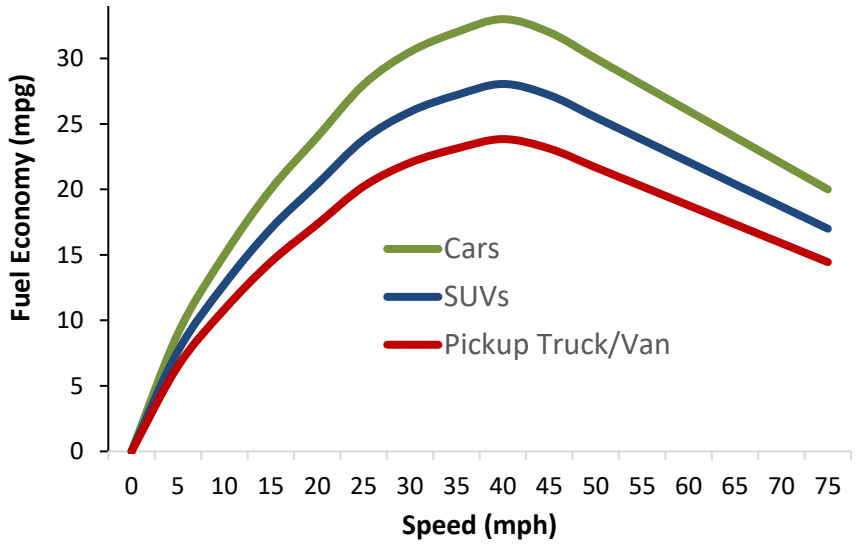
Table 2 **Cost Impacts of Roadway Capacity Expansion**

Costs Reduced	Costs Increased		
	Diverted Trips	**Longer Trips**	**Induced Trips**
• Travel Time • Vehicle Operating Costs • Per-mile crash rates if implemented with roadway design improvements, but these are often offset if traffic speeds increase. • Per-mile pollution emissions (these are usually offset by high traffic speeds and induced vehicle travel).	• Downstream congestion	• Downstream congestion • Road facilities • Traffic services • Per-capita crash rates • Pollution emissions • Noise • Resource externalities • Land use impacts • Barrier effect	• Downstream congestion • Roadway costs • Parking costs and subsidies • Traffic services • Per-capita crash rates • Pollution emissions • Noise • Resource externalities • Barrier effect • Sprawl-related costs • Transit efficiency • Vehicle costs

Roadway expansions tends to reduce some costs but increases others.

Highway expansion advocates sometimes claim that by reducing traffic congestion, such projects will reduce air pollution emissions, but research indicates that this is generally untrue (Noland and Quddus 2006). Per-mile emission rates are generally lowest at 20-50 miles per hour, as indicated in the following figure. Reducing extreme congestion (LOS E or F), so traffic speeds rise above 30 mph may reduce emission rates, but reducing mild congestion (LOS C or D), so traffic speeds increase above 50 mph are likely to increase emission rates, and if roadway expansions induce additional vehicle travel they are likely to increase total emissions.

Figure 5 **Fuel Economy Versus Speed** (USDOE 2025)



Although fuel economy varies depending on vehicle design and driving conditions, mileage usually decreases at speeds above 50 mph, particularly for light trucks, SUVS and vans due to their poor aerodynamics.

As a result, moderate congestion (LOS B-D) that reduces speeds from higher speeds to 30-50 mph usually reduces fuel consumption and emissions.

the short run, but these impacts are generally small and more than offset over the long run by more high-speed driving and induced vehicle travel. In contrast, other congestion reduction strategies, such as improving resource-efficient modes, TDM incentives, efficient transport pricing and Smart Growth policies can provide much greater emission reductions (Litman 2019). 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."

The following table 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 3 **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.

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 (Deakin, et al. 2020; 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 planning decisions affect land use development patterns. Different types of transportation improvements tend to cause different types of land use development patters: highway improvements tend to encourage lower-density, automobile-oriented urban-fringe development while transit improvements tend to encourage compact, multi-modal infill, although the exact types of impacts vary depending on specific conditions and the type of transportation improvements implemented (Rodier, et al. 2001; Nilsen, Stigen and Stevik 2024;).

Some researchers claim that investing in road construction does not lead to the sprawl (Hartgen 2003), although the evidence indicates otherwise. Even in relatively slow-growth regions with modest congestion problems, highway expansions increase suburban development by 15-25%. These effects are likely to be much greater in large cities with significant congestion, 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.

The following table summarizes benefits of Smart Growth policies that create compact, multimodal communities.

Table 4 **Smart Growth Benefits** (Ewing and Hamidi 2014; Litman 2016)

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.

The benefits of increased mobility are often capitalized into land values. For example, a highway improvement can increase urban periphery real estate prices. Because these land value gains are economic transfers (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 resource savings) since that would double count benefits.

Consumer Surplus Impacts

Induced vehicle travel must benefit users or they would not drive the additional miles, but these benefits tend to be modest because the additional travel consists of marginal-value vehicle-miles that users are most willing to forego if their costs increase. Economists call user benefits *consumer surplus*, and value it using the *Rule of Half* which states that consumer surplus changes are worth half the price change times the change in consumption. For example, if a 10¢ per vehicle-mile price reduction causes motorists to drive 1,000 more annual miles, the net change in consumer surplus is calculated at 10¢ x ½ x 1,000 = $50. Consumer surplus analysis allows planners to provide more realistic estimates of roadway improvement benefits.

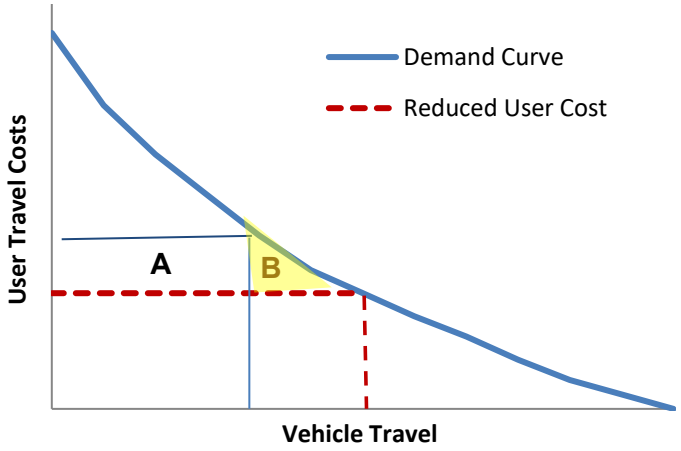
Explanation of the "Rule of Half"
When consumers change their travel in response to a financial incentive, the net consumer surplus averages half of their price change. Let me illustrate.

Let's say that purchasing an electric car reduces your vehicle operating costs from 20¢ to 10¢ per mile, which causes you to drive 1,000 more annual vehicle-miles. You must value the added vehicle-miles between 0¢ and 10¢ because you would not drive vehicle-miles you consider worth less than 0¢ and you would already drive miles worth more than 10¢. We can therefore assume that the average value is the mid-point, 5¢. The added vehicle travel is therefore valued at 5¢ times 1,000 miles or $50. Conversely, a 10¢ per mile price *increase* that causes you to drive 1,000 fewer annual miles is a $50 consumer surplus loss.

Some people complicate this analysis by trying to value each change in consumer travel time, convenience and vehicle operating costs, but that is unnecessary. All that is needed to value consumer surplus changes is change in price, either positive or negative, and resulting change in consumption. This incorporates all the complex trade-offs that consumers make between money, time, convenience and the value off mobility.

This is illustrated in the following figure by the fact that B is a triangle rather than a rectangle.

Figure 6 **Vehicle Travel Demand Curve Illustrating the Rule-of-Half**



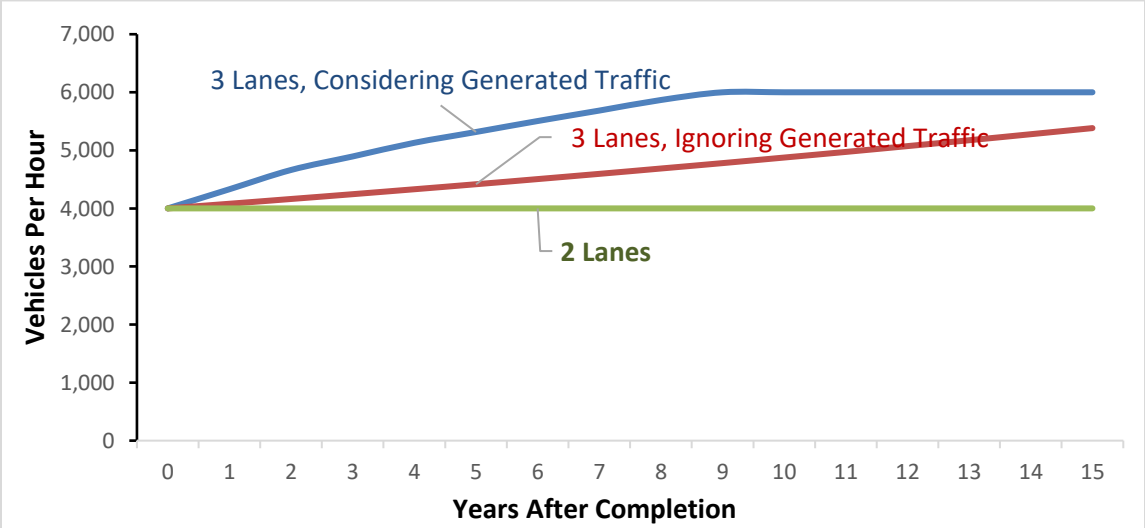
Reduced user costs (downward shift on Y axis) increases vehicle travel (rightward shift on X axis). Rectangle A shows savings to existing trips. Triangle B shows generated travel benefits.

Example

Project evaluations should incorporate generated traffic effects including consumer surplus and external costs (Wang, Zhong and Hunt 2019). Ignoring these tends to exaggerate the benefits of highway capacity expansion and undervalue alternatives such as transit improvements and pricing reforms (Romilly 2004).

For example, a four-lane, 10-kilometer highway connects a city with nearby suburbs. The highway is congested 1,000 annual hours in each direction. Regional travel demand is predicated to grow 2% annually. 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. The figure below 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.

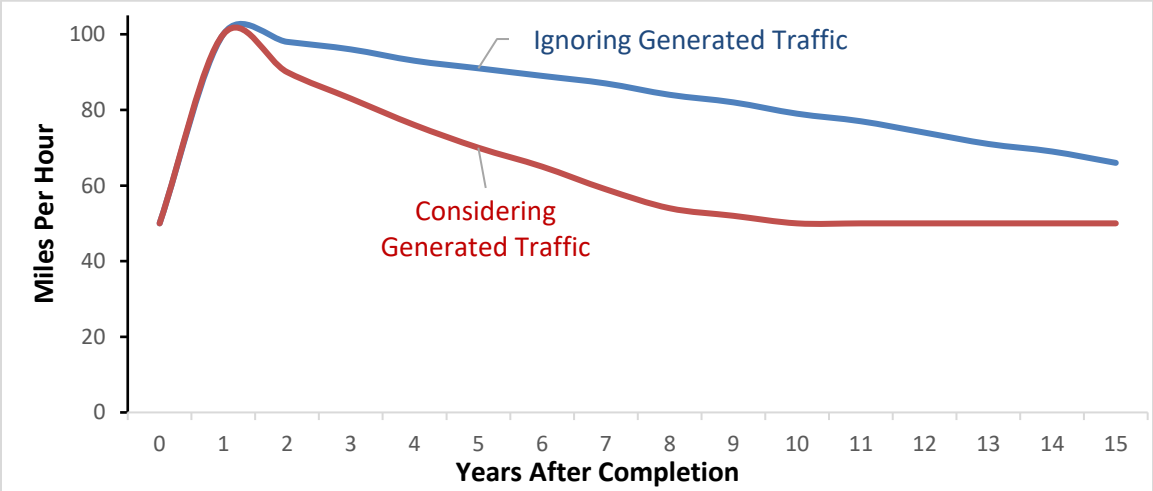
Figure 7 **Projected Traffic**



If generated traffic is ignored the model predicts that traffic volumes will grow at 2% per year regardless of traffic conditions. If generated traffic is considered the model predicts high initial growth which eventually declines when the road reaches capacity and becomes congested. (Based on the "Moderate Latent Demand" curve from Figure 4)

The model divides generated traffic into diverted trips (changes in trip time, route and mode) and induced travel (more and longer trips), using the assumption that the first year's generated traffic is diverted trips and later generated traffic are induced vehicle 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 below.

Figure 8 **Projected 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.

The following three cases are analyzed 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. The table below summarizes this analysis.

Table 5 **Analysis of Three Cases**

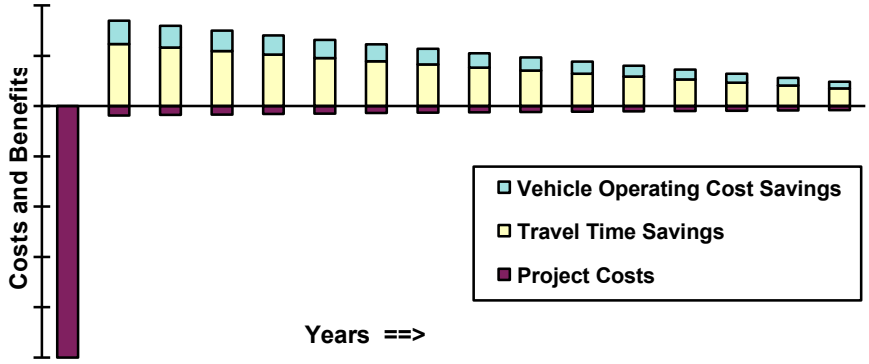
Data Input	Most Favorable	Medium	Least Favorable
Generated Traffic Growth Rate (from Figure 3)	L	M	H
Discount Rate	6%	6%	6%
Maximum Peak Vehicles Per Lane	2,200	2,000	1,800
Before Average Traffic Speed (km/hr)	40	50	60
After Average Traffic Speed (km/hr)	110	100	90
Value of Peak-Period Travel Time (per 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.

The figure below 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.

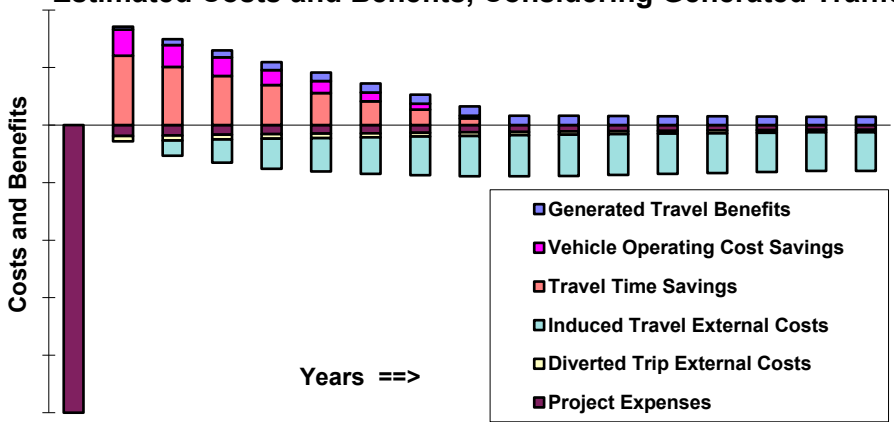
Figure 9 **Estimated Costs and Benefits, Ignoring Generated Traffic**



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.

The figure below 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 10 **Estimated Costs and Benefits, Considering Generated Traffic**

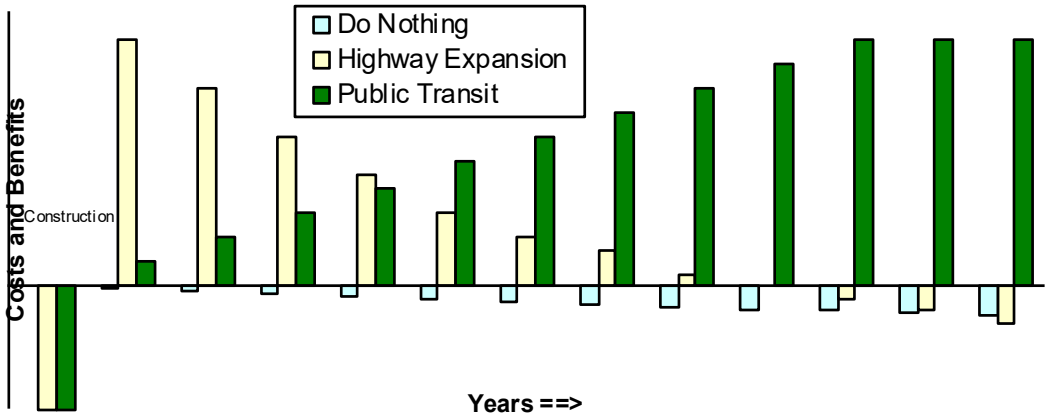


This figure illustrates benefits and costs when generated traffic is considered, using medium assumptions. Benefits are bars above the baseline, costs are bars below the baseline. It includes consumer benefits and external costs associated with generated traffic. Travel time and vehicle operating cost 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 shows how generated traffic can significantly affect project assessment. Ignoring generated traffic exaggerates highway expansion benefits by overestimating congestion reductions and ignoring induced vehicle travel incremental external costs. This tends to undervalue alternatives such as space-efficient mode improvements, TDM incentives and "do nothing" options.

To illustrate this the following graph 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 11 **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 claim 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 population, employment and income growth (Heanue 1998; Burt and Hoover 2006), that increasing roadway capacity does reduce congestion (TRIP 1999; Bayliss 2008), and although new highways generate traffic, they still provide net benefits (Polzin 2022).

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.

Professor Michael Manville's 2024 report, *Induced Travel Estimation Revisited* critically examines the assumptions and methods used to evaluate the induced VMT caused by HOV and HOT lanes in California, including the use of a 1.0 elasticity of lane-miles to VMT, the treatment of VMT as a cost, and the assumption that increased vehicle travel reduces travel by other modes.

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. 2020). 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. 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 no reduction in long-term congestion. They conclude that other types of transportation system improvements could provide greater economic development benefits.

Alternative Transport Improvement Strategies

Generated traffic significantly reduces roadway capacity expansion benefits, making other congestion reduction solutions relatively more cost effective and beneficial. The article, *Spreading the Gospel of Induced Demand* (Klein, et al. 2022) argues that the general public misunderstands induced travel impacts and so tends to overestimate highway expansion benefits and underestimate the benefits of alternative congestion solutions.

Considering generated traffic tends to increase the estimated value of improvements to alternative modes (particularly grade-separated ridesharing and public transit services), transportation systems management, efficient road pricing, and transportation demand management strategies that result in more efficient use of existing roadway capacity. Although these strategies may not necessarily eliminate traffic congestion individually, an integrated package can significantly reduce congestion delays compared with what would otherwise occur, usually with less costs and greater total benefits 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 space-efficient modes such as public transit, ridesharing, bicycling and walking.
- 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

Some new laws and regulations, such as California Senate Bill 743 (S.B. 743), prohibit the use of vehicle level of service (LOS) and similar measures as the sole basis for evaluating transportation improvement options; instead, policies and project are evaluated based on their ability to reduce vehicle miles traveled (VMT). This will require consideration of induced travel effects in analysis of roadway projects.

In 2020, the California Department of Transportation established specific requirements for evaluating and mitigating the induced travel impacts of roadway expansion projects (Sundquist 2020), based on an extensive expert review (Caltrans 2020a). This analysis is based on lane-miles-to-induced-VMT elasticities, as specified in the *Transportation Analysis Framework: Induced Travel Analysis* report (Caltrans 2020b), and estimated by the National Center for Sustainable Transportation's *Induced Travel Calculator* (NCST 2019).

Conclusions

Urban traffic congestion tends to maintain equilibrium. Congestion increases until delays discourage 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 it increasingly consists of induced travel that increases total vehicle-miles. This has several implications for transport planning:

- Predictions based on extrapolating past traffic growth into the future without considering congestion's ability to be self-limiting will exaggerate future congestion severity.
- Ignoring generated traffic overestimates the congestion reduction benefits of roadway expansions and underestimates the benefits of alternative solutions.
- Induced travel increases many costs. Over the long term it tends to increase automobile dependency and sprawl.
- Induced vehicle travel user benefits are relatively small since they consist of marginal value trips, and 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.

Roadway expansions do provide benefits. However, ignoring generated traffic results in inaccurate forecasts of impacts and benefits. Road projects considered cost effective and beneficial by conventional analysis may actually provide little long-term user benefit harm society overall due to induced travel external costs. Other strategies may be better overall. Highway expansion projects should include features to minimize undesirable effects such as increased downstream congestion, barrier effects and sprawl.

Framing the Congestion Question

If you ask people, *"Do you think that traffic congestion is a serious problem?"* they usually 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 road improvements. This is how transport choices are generally framed.

But if you present more realistic options 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 vehicle traffic, or should we implement other types of transportation improvements that provide more diverse and durable benefits?"* the preference for road building is likely to decline.

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