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Smart Congestion Relief

Comprehensive Analysis Of Traffic Congestion Costs and Congestion Reduction Benefits

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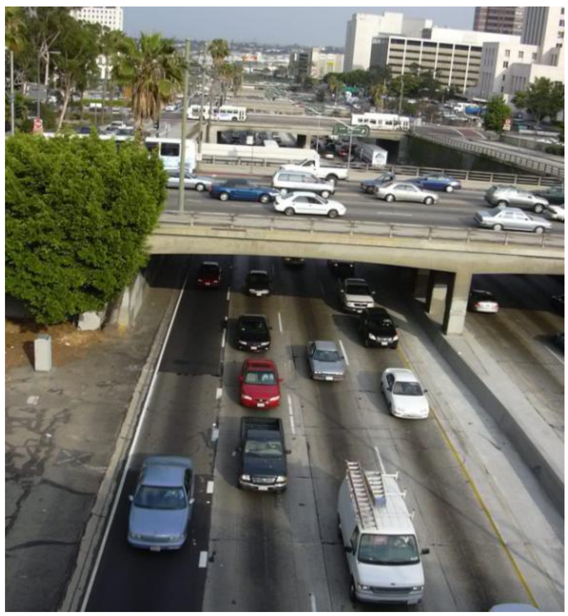

Abstract

This report critically evaluates the methods used to evaluate traffic congestion costs and the benefits of various congestion reduction strategies. It describes various biases in current congestion evaluation practices. It develops a more comprehensive evaluation framework which is applied to four congestion reduction strategies: Roadway expansion, improving alternative modes, pricing reforms, and smart growth land use policies. The results indicate that highway expansion often provides less total benefit than alternative congestion reduction policies. Comprehensive evaluation can identify more efficient and equitable congestion solutions. It is important that decision makers understand the omissions and biases in current evaluation methods.

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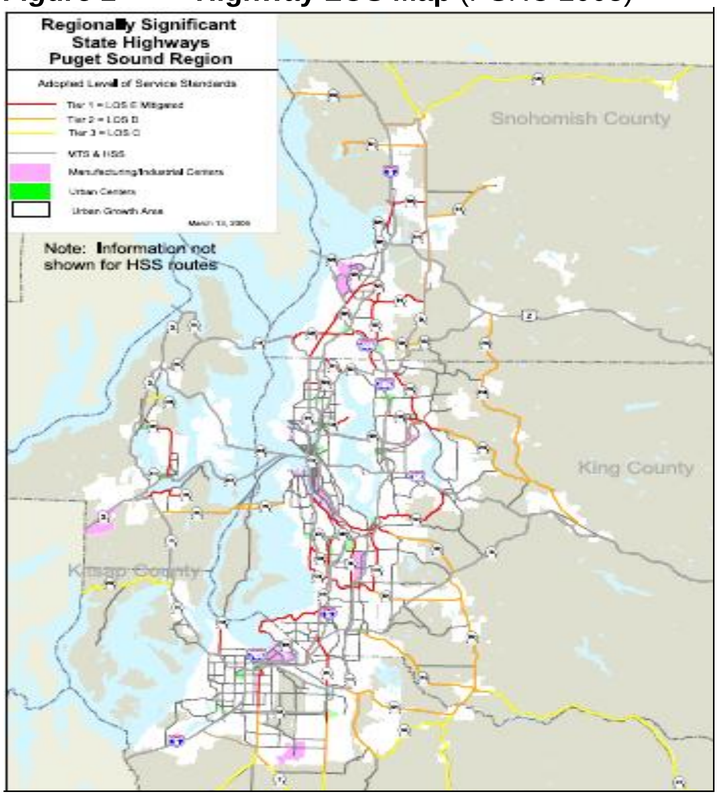
Introduction

Traffic congestion refers to the incremental delay and vehicle operating costs that result from interactions among vehicles, particularly as traffic volumes approach roadway capacity. Conventional transportation planning tends to consider traffic congestion a significant cost and congestion reduction is often a dominant planning objective. How congestion is evaluated can significantly affect planning decisions.

For example, transport system performance is often evaluated based primarily on congestion indicators such as roadway Level of Service (LOS) as illustrated in Figure 1. This assumes that 1) *transportation* means driving; 2) vehicle traffic speed is the main evaluation criteria; 3) congestion reduction is the primary planning objective; and 4) roadway widening is the best solution. It tends to ignore other modes, other impacts, other planning objectives, and other types of transport system improvements. This approach can have unintended consequences.

Figure 1 **Highway LOS Map** (PSRC 2008)



This typical transport planning map indicates the roadways considered to have excessive congestion (LOS D or worse), and therefore in need of improvement.

This type of analysis implies that "transportation" means driving, that traffic delay is the most important transport system performance indicator, and congestion is the greatest transport problem. This tends to steer resources toward roadway expansion over other transport improvement strategies.

Consider another example. Residents of compact, multi-modal urban neighborhoods tend to drive significantly (typically 20-60%) less than residents of automobile-oriented suburban neighborhoods, which reduces regional traffic congestion, accidents and pollution emissions. However, more compact, urban infill development is often opposed on grounds that it increases local traffic congestion, as measured by roadway LOS on nearby roads. In this way, focusing on local traffic congestion can result in planning decisions that increase total regional congestion delays and other transport problems.

Similarly, if congestion is considered a problem at a school or other activity center, a common response is to expand local roadways, which is considered a roadway *improvement*, although wider roads and higher vehicle traffic speeds create a barrier to walking. This can create a self-reinforcing cycle of less walking, more driving, more traffic congestion and wider roads. In this way, considering automobile congestion while ignoring delays to other modes can results in transport planning decisions that favor driving over alternatives.

These examples illustrate how congestion evaluation practices can affect planning decisions. Different assumptions and evaluation methods can result in very different conclusions about the magnitude of congestion costs and the effectiveness of specific congestion reduction strategies. Current methods tend to measure congestion *intensity*, which tends to favor roadway expansion. Evaluation methods that measure congestion impacts *per capita* tend to favor other congestion reduction strategies because they recognize the congestion avoided by shifts to alternative modes and more accessible land use development.

This is not to deny that traffic congestion imposes significant costs and deserves serious consideration in planning, but it is possible to exaggerate congestion costs compared with other transport costs, and to exaggerate roadway expansion benefits compared with other transport system improvements. Current evaluation practices focus on the costs of *insufficient roadway capacity* but lack a comparable vocabulary to describe the costs of *excessive roadway capacity*, *inadequate travel options*, and *underpriced road use*.

Although most modern transport planning *does* recognize other impacts and objectives, congestion continues to dominate. This emphasis occurs, in part, because standard methods exist for measuring congestion impacts, which creates an impression of greater confidence and importance than other impacts. Yet, this confidence is misplaced, as discussed in this report. It is important that decision-makers understand the omissions and biases in current congestion costing methods when they use the results of such analysis.

To the degree that congestion costs and roadway expansion benefits are exaggerated, and alternative transport system improvement undervalued, the transport planning process will fail to implement the most cost effective options. It can create self-fulfilling prophecies with unintended consequences. Congestion reduction efforts often involve choosing between mutually exclusive options: either expand roadways *or* create more compact, multi-modal communities. Such decisions can have diverse economic, social and environmental impacts. This is a timely issue due to changes in transport demands and planning objectives.

This report critically examines congestion evaluation practices. It identifies various omissions and biases in current congestion costing methods and provides guidelines for more comprehensive and objective analysis. It uses a comprehensive framework to evaluate common congestion reduction strategies including roadway expansion, improvements to alternative modes, transport pricing reforms and smart growth land use reforms. Much of this analysis also applies to parking congestion analysis.

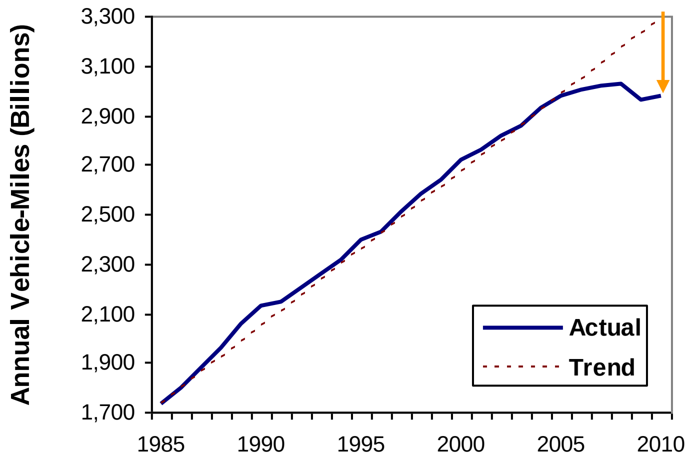
Historical Context

The relative importance of congestion costs and the assumptions and perspectives used to evaluate congestion reduction options are changing due to trends described below.

Changing Travel Demands

Current demographic, geographic and economic trends (aging population, rising fuel prices, increasing urbanization, changing consumer preferences, and increasing health and environmental concerns) are reducing growth in automobile travel demand and increasing demand for alternative modes (walking, cycling, ridesharing and public transit). Since about 2003 vehicle travel stopped growing in the U.S. and most other developed countries (Figure 2), while use of other modes has grown, particularly where public policies are supportive (Litman 2006; Millard-Ball and Schipper 2010).

Figure 2 **U.S. Annual Vehicles Mileage Trends** (USDOT 2010)



US vehicle travel grew steadily during the Twentieth Century, but stopped growing after 2003.

It made sense to invest significant resources in roadway when the basic roadway system was first developed and automobile travel demand was growing rapidly. During that period highway projects provided high economic returns, consumers reaped large benefits, and there is little risk of overbuilding roadway capacity since it would eventually fill. But once the road system matures, so there are high-speed highways connecting regions and a well-developed network of paved local roads, the marginal benefits of incremental roadway expansion tend to decline.

Transport planning and financing practices will need to change in response to reduced growth in vehicle travel demand and congestion problems, and increasing demand for travel by alternative modes. This will require reducing emphasis on congestion problems and roadway expansion and increasing emphasis on other planning objectives and other types of transport system improvements.

Expanding Planning Objectives

The range of objectives considered in the transport planning process is increasing, as summarized in Table 1. This is sometimes called *sustainability* or *comprehensive* planning.

Table 1 **Traditional and Newer Objectives Considered in Transport Planning**

Traditional Objectives	Newer Objectives
Improve mobility (increase traffic speeds)	Reduce parking congestion
Reduce traffic congestion	Reduce fuel consumption
Reduce vehicle operating costs	Reduce climate change emissions
Reduce crash rates	Reduce per capita crash rates
Reduce air pollution rates	Improve mobility options for non-drivers
Minimize environmental damages	Incorporate universal design
Maximize project and service cost efficiency	Improve transport affordability
	Reduce stormwater management impacts and costs
	Support strategic land use objectives (reduce sprawl)
	Improve public fitness and health impacts

Traditional transport planning tends to focus on a limited set of objectives, but over time newer planning objectives have gained importance. Traditional objectives tended to justify roadway expansion but newer objectives tend to justify improvements to alternative modes and smart growth development.

The traditional objectives tended to focus the transport planning process on congestion reduction and roadway expansion solutions. Newer objectives tend to increase consideration of other modes, problems and solutions.

For example, the traditional transport planning process generally describes road widening as a *transportation improvement*, since it increases mobility and reduces vehicle operating costs. However, wider roads and increased vehicle traffic speeds tends to degrade walking and cycling conditions and therefore reduce mobility for non-drivers, increase impervious surface area and therefore stormwater management costs, and by inducing additional vehicle travel and dispersed land use development it tends to increase total fuel consumption and pollution emissions. As a result, newer planning recognizes that road widening provides both benefits and costs. Newer planning therefore requires multi-modal planning, including multi-modal Level of Service indicators, as recently developed by the Transportation Research Board (Dowling et al. 2008).

This expanded set of planning objectives does include traffic congestion reduction and roadway expansion benefits, but it puts them into perspective along with various other objectives and solutions.

Changing Planning Paradigm

Transport planning is experiencing a *paradigm shift* (a fundamental change in the way problems are defined and solutions evaluated) from *traffic-based* to *mobility-based* to *accessibility-based* planning (Litman 2003). *Traffic* refers to vehicle travel. *Mobility* refers to physical movement. *Accessibility* refers to people's ability to reach desired services and activities, which is the ultimate goal of most travel activities, excepting the small portion of travel that has no destination. Vehicle traffic and mobility certainly affect accessibility, but so do other factors including the geographic location of activities, road and path connectivity, and the quality of mobility substitutes such as telecommunications and delivery services. Table 2 compares these different perspectives.

Table 2 **Comparing Transportation Measurements** (Litman 2003)

	Traffic	Mobility	Accessibility
Definition of Transportation	Vehicle travel	Movement of people and goods	Ability to obtain goods, services and activities.
Unit of measure	Vehicle-miles and vehicle-trips	Person-miles, person-trips and ton-miles	Trips, and ability to reach activities and destinations
Modes considered	Automobile and truck	Automobile, truck and transit	All modes
Common performance indicators	Vehicle traffic volumes and speeds, roadway Level of Service, costs per vehicle-mile, parking convenience	Person-trip volumes and speeds, road and transit Level of Service, cost per person-trip, travel convenience	Multi-modal Level of Service, land use accessibility, generalized cost to reach activities.
Assumptions concerning what benefits consumers	Maximum vehicle mileage and speed, convenient parking, low vehicle costs	Maximum personal travel and goods movement	Maximum transport options, convenience, land use accessibility, cost efficiency
Consideration of land use	Favors low-density, urban fringe development	May support some transit-oriented development	Favors compact, mixed, multi-modal development
Favored transport improvement strategies	Increased road and parking capacity, speed and safety	Increased transport system capacity, speeds and safety	Improved mobility, land use accessibility and mobility substitutes

This table compares the three major approaches to measuring transportation.

This has important implications for planning. Planning decisions often involve trade-offs between different impacts and objectives. For example, urban roadway expansion tends to increase vehicle traffic speeds but creates barriers to pedestrian travel and stimulates sprawl, which reduces accessibility by other modes. A land use development pattern that is favorable for automobile access is often unfavorable for access by other modes.

Traffic and mobility-based planning assume that faster modes and longer trips are more important than slower modes and shorter trips. It therefore tends to support planning decisions that favor mobility over accessibility and automobile travel over other modes, resulting in greater per capita investments per automobile user than for users of other modes. Only accessibility-based planning, which measures impacts per capita rather than per vehicle-mile, can identify the most efficient and equitable planning solutions.

Congestion Costing Methods

Various methods are used to quantify congestion impacts, *monetize* (measure in monetary units) congestion costs, and evaluate congestion reduction strategies (Grant-Muller and Laird 2007; "Congestion Costs," Litman 2009). This usually involves the following steps:

1. If available, collect peak and off-peak traffic speeds on roads being analyzed. If such data are unavailable, estimate speeds using volume-to-capacity-ratios (V/C), as summarized in Table 3.

Table 3 **Typical Highway Level-Of-Service (LOS) Ratings**[1]

LOS	Description	Speed (mph)	Flow (veh./hour/lane)	Density (veh./mile)
A	Traffic flows at or above posted speed limit. Motorists have complete mobility between lanes.	Over 60	Under 700	Under 12
B	Slightly congested, with some impingement of maneuverability.	57-60	700-1,100	12-20
C	Ability to pass or change lanes constrained. Posted speeds maintained but roads are close to capacity. This is the target LOS for most urban highways.	54-57	1,100-1,550	20-30
D	Speeds somewhat reduced, vehicle maneuverability limited. Typical urban peak-period highway conditions.	46-54	1,550-1,850	30-42
E	Flow becomes irregular, speeds vary and rarely reach the posted limit. This is considered a system failure.	30-46	1,850-2,000	42-67
F	Flow is forced, with frequent drops in speed to nearly zero mph. Travel time is unpredictable.	Under 30	Unstable	67-Maximum

This table summarizes roadway Level of Service (LOS) ratings, an indicator of congestion intensity.

2. Calculate the speed difference between peak-period and baseline traffic on each roadway link and use these results to calculate network indicators such as Travel Time Rate (TTR) and Travel Time Index (TTI), as summarized in Table 4. For example, a 1.3 TTR indicates that trips which take 20 minutes off-peak take 26 minutes during peak periods. Such analyses often use freeflow traffic speeds as the baseline, although most economists argue that a moderate level of congestion, such as LOS C, is more appropriate, as discussed later.

3. Use vehicle operating cost models to estimate the additional fuel consumption and pollution emissions caused by congested travel. Multiply travel time, additional fuel consumption and emission times unit costs (dollars per hour of travel time, gallon of fuel, and ton of emissions) to calculate monetized congestion costs.

4. Use these estimates to predict the time and total economic savings of specific congestion reduction strategies.

[1] "Level of Service," *Wikipedia*, http://en.wikipedia.org/wiki/Level_of_service.

Table 4 describes various congestion indicators. The right column indicates whether each is comprehensive and considers delays to all forms of travel. Common congestion indicators such as roadway LOS and the Travel Time Index are not comprehensive, they only consider motorists delay and so ignore the congestion avoided when travelers shift to other modes or reduce their total travel distances. Only comprehensive indicators such as per capita congestion delay or average commute travel time reflect overall accessibility.

Table 4 **Roadway Congestion Indicators** ("Congestion Costs" Litman 2009)

Indicator	Description	Comprehensive?
Roadway Level Of Service (LOS)	Intensity of congestion delays on a particular roadway or at an intersection, rated from A (uncongested) to F (most congested).	No
Travel Time Rate	The ratio of peak period to free-flow travel times, considering only reoccurring delays (normal congestion delays).	No
Travel Time Index	The ratio of peak period to free-flow travel times, considering both reoccurring and incident delays (e.g., traffic crashes).	No
Percent Travel Time In Congestion	Portion of peak-period vehicle or person travel that occurs under congested conditions.	No if for vehicles, yes if for people.
Congested Road Miles	Portion of roadway miles that are congested during peak periods.	No
Congested Time	Estimate of how long congested "rush hour" conditions exist	No
Congested Lane Miles	The number of peak-period lane miles of congested travel.	No
Annual Hours Of Delay	Hours of extra travel time due to congestion.	No if for vehicles, yes if for people.
Annual Delay Per Capita	Hours of extra travel time divided by area population.	Yes
Annual Delay Per Road User	Extra travel time hours divided by peak period road users.	No
Excess Fuel Consumption	Total additional fuel consumption due to congestion.	Yes
Fuel Per Capita	Additional fuel consumption divided by area population	Yes
Annual Congestion Costs	Hours of extra travel time multiplied times a travel time value, plus additional fuel costs. This is a monetized value.	Yes
Congestion Cost Per Capita	Additional travel time costs divided by area population	Yes
Congestion Burden Index (CBI)	Travel rate index multiplied by the proportion of commuters subject to congestion by driving to work.	Yes
Avg. Traffic Speed	Average peak-period vehicle travel speeds.	No
Avg. Commute Travel Time	Average commute trip time.	Yes
Avg. Per Capita Travel Time	Average total time devoted to travel.	Yes

This table summarizes various congestion cost indicators. Some only consider impacts on motorists and so are unsuited for evaluating congestion reduction benefits of mode shifts or more accessible land use.

Monetized Congestion Cost Estimates

Various studies monetize congestion costs (Litman 2009; Grant-Muller and Laird 2007):

- Delucchi (1997) estimated that U.S. congestion costs, including incremental delay and fuel costs, totaled $34-146 billion in 1991 ($52-222 billion in 2007 dollars).
- Lee (1982) estimated that U.S. traffic congestion delay costs relative to free flowing traffic totaled the equivalent of about $108 billion in 2002, but the economic losses are a much smaller $12 billion, based on his estimate of what road users would willingly pay for increased traffic speed (cited in Roth 2006).
- Transport Canada research calculated congestion costs (including the value of excess delay, fuel use and greenhouse gas emissions) using various baselines which represent the point at which urban-peak speed reductions are considered unacceptable (TC 2006). For example, a 50% baseline calculates congestion costs for traffic speeds below 50% of freeflow traffic speeds, and a 70% baseline calculates congestion costs below 70% of freeflow. Table 5 summarizes the results.

Table 5 **Congestion Costs In Various Canadian Cities** (iTrans 2006)

Location	50%	60%	70%
Vancouver	$737	$927	$1,087
Edmonton	$96	$116	$135
Calgary	$185	$211	$222
Winnipeg	$121	$169	$216
Hamilton	$20	$33	$48
Toronto	$1,858	$2,474	$3,072
Ottawa-Gatineau	$100	$172	$246
Montréal	$1,179	$1,390	$1,580
Québec City	$73	$104	$138
Total	*$4,370*	*$5,596*	*$6,745*

This analysis estimates congestion costs based on three baseline traffic speeds. A higher baseline speed indicates a higher expectation for urban-peak traffic speeds.

- The Texas Transportation Institute's widely cited *Urban Mobility Study* (TTI 2009) estimates that U.S. traffic congestion imposes about $115 billion annually in additional travel time and vehicle operating costs compared with freeflow travel, assuming $16 per hour of person travel and $106 per hour of truck time.
- Winston and Langer (2004) used their own model to estimate that U.S. congestion costs total $37.5 billion annually (2004 dollars), a third of which consists of freight vehicle delays. They find that highway spending is not a cost effective way to reduce congestion.

These studies illustrate how different analysis assumptions can affect cost estimates. A key factor is the baseline used to calculate incremental delays. Many estimates use free-flowing traffic (LOS A), which is theoretically feasible but generally not economically optimal due to the high costs of urban roadway expansion. Some estimates use moderate congestion (LOS C/D, or 45-55 mph on highways), since that maximizes traffic throughput and fuel efficiency, and probably reflects consumers' willingness-to-pay for faster peak-period travel.

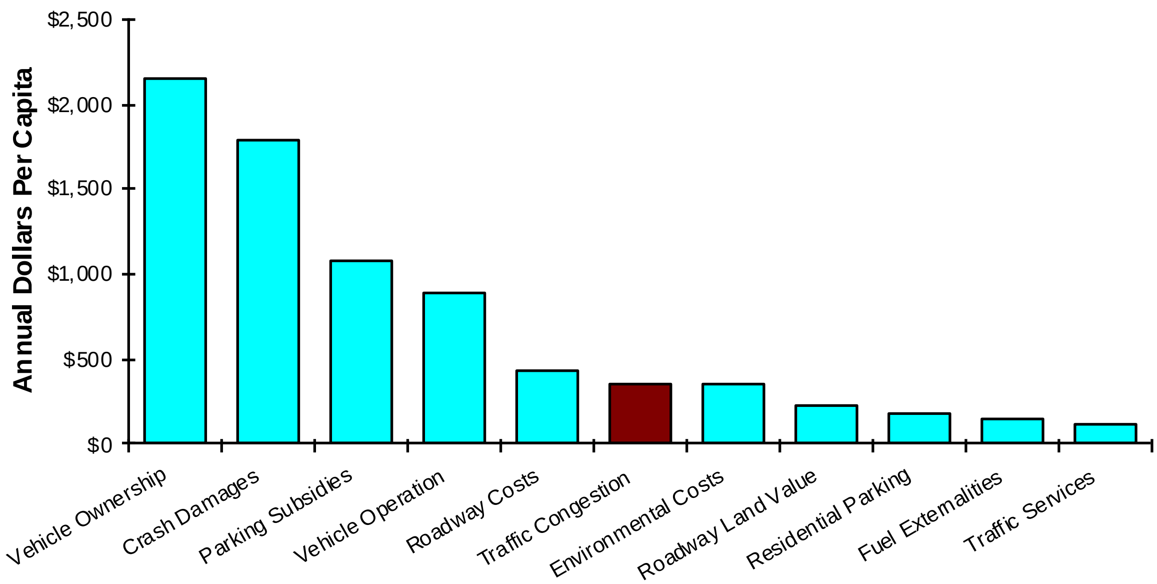
Estimates based on free-flow traffic speeds typically conclude that total U.S. congestion costs exceed $100 billion annually or about $350 per capita, but estimates based on optimal speeds typically conclude that congestion costs total $20-40 billion, or $70-150 per capita.

Figure 3 compares congestion with other transportation costs measured annually per capita. Vehicle expenses average about $4,000, crash damages more than $1,500, parking facilities more than $1,000, and roadway facilities about $400 per year, compared with $350 congestion costs estimated by the Texas Transportation Institute.

These cost estimates are affected by the analysis scope. Only about 20% of total travel occurs under urban-peak conditions, and only a minority of this occurs on significantly congested (LOS D or worse) roads, so only 5-10% of total *driving*, and a smaller portion of total *travel*, occurs under truly congested conditions. The Texas Transportation Institute reports congestion costs *per automobile commuter*, which implies that congestion delays are common and congestion costs are relatively large compared with costs per capita.

This indicates that congestion is a moderate cost overall, larger than some but smaller than others. This means, for example, that it would be economically inefficient to implement a strategy that reduced congestion by 20% if doing so increases total vehicle expenses, crash damages or parking costs by 5%, but a congestion reduction strategy becomes far more cost effective if it provides even modest reductions in these other costs.

Figure 3 **Costs Ranked by Magnitude** (Litman 2009)

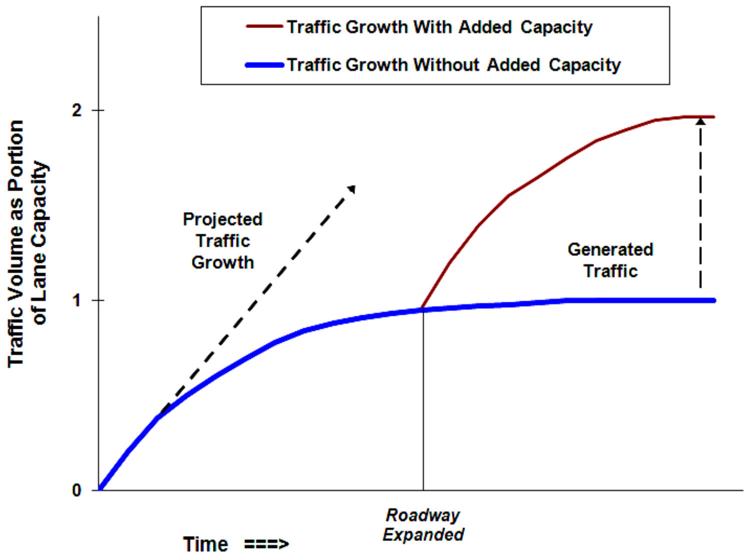


Even using upper-bound estimates, congestion is a moderate cost compared with other transport costs.

Generated Traffic Impacts

One factor that complicates this analysis is that traffic congestion tends to maintain equilibrium: it grows to the point that congestion delays constrain further peak-period vehicle trips, causing travelers to shift to alternative times, routes and mode, and forego lower-value trips (Cervero 2003). For example, when roads are congested you might choose a closer destination or defer a trip until later, but if congestion is reduced you make those peak-period trips. Similarly, when considering a new home or job you might only consider a 10 mile commute if roadways are congested, but up to 30 miles if roads flow freely. Figure 4 illustrates this effect.

Figure 4 **How Road Capacity Expansion Generates Traffic** (Litman 2001)



Traffic grows when roads are uncongested, but growth rates decline as congestion develops, reaching a self-limiting equilibrium (indicated by the curve becoming horizontal). If capacity is added, traffic growth continues until it reaches a new equilibrium. The additional peak-period vehicle travel that results 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."

This has important implications for congestion evaluation. It means that (Litman 2001):

- Congestion seldom gets as severe as predicted by extrapolating past trends. As traffic congestion increases it will discourage further peak-period traffic growth, leading to equilibrium. A do nothing option will not really lead to traffic gridlock (conditions where traffic becomes totally stuck for hours).
- Capacity expansion provides less congestion reduction benefits because the additional travel tends to be filled with *generated traffic* (increased peak-period vehicle travel, including shifts in time and route).
- Capacity expansion causes *induced travel* (increases in total vehicle mileage) which increases external costs including downstream congestion (expanding highway capacity tends to increase surface street traffic congestion), parking costs, accidents, energy consumption, pollution emissions and land use sprawl.
- The additional vehicle travel provides direct user benefits, but these tend to be modest because the additional vehicle travel consists of lower-value mileage that users are most willing to forego if their travel costs marginally increase.

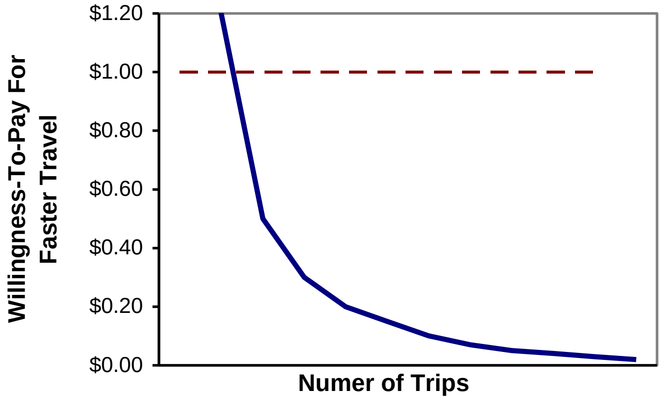
Congestion Costing Criticisms and Reforms

Conventional congestion indicators and costing methods are criticized for being incomplete and biased (Bertini 2005; Cortright 2010; "Congestion Costs" Litman 2009):

- They only measure congestion *intensity* on particular roadways, rather than *total congestion costs*. As a result, they ignore the additional delay and transport costs caused by dispersed development and reduced transport options that increase per capita driving. Indicators such as the TTI imply that congestion declines if uncongested travel increases since congested travel is divided by more total vehicle-miles.
- They only consider impacts on motorists. They overlook the congestion avoided when travelers shift mode (for example, if grade separated bus or rail service allows some travelers to avoid driving on congested driving), and they ignore delays that wider roads and increased traffic imposes on to non-motorized travelers (called the *barrier effect*).
- They estimate delay relative to free flow conditions (LOS A). Economists point out that it would be economically inefficient to build enough roadway capacity to allow free-flow driving under urban-peak conditions. LOS C or D is more realistic.
- They apply relatively high travel time cost values (typically 35-60% of average wage rates for personal travel, and more for business travel). Lower values are often found when motorists' willingness-to-pay is actually tested with congestion tolls.
- They use outdated fuel and emission models that ignore new technologies such as fuel injection and variable valve timing, which exaggerates congestion reduction fuel savings and emission reductions. Although shifts from high to moderate congestion (LOS E/F to C/D) can save energy and reduce emissions, shifts from moderate congestion to free flow (LOS C/D to A/B) can increase costs since vehicles efficiency declines at high speeds.
- They ignore the tendency of traffic congestion to maintain equilibrium (peak period vehicle traffic increases until congestion discourages additional trips) and the *generated travel* (additional peak-period trips) and *induced travel* (absolute increases in total vehicle travel) caused by unpriced roadway expansion. Analysis should account for:
    - The decline in congestion reduction benefits due to generated traffic.
    - Increases in external costs of the increased mileage, including increased accidents, pollution emissions and sprawl due to induced travel.
    - The relatively small direct user benefits from the increased vehicle travel.

- The demand curve for faster vehicle travel typically includes a few high-value trips plus many lower-value trips, as illustrated in Figure 5. Delivery and service vehicles, transit buses, business travelers, and travelers with urgent errands might willingly pay a dollar per-mile to avoid congestion. If all vehicles had such willingness-to-pay, highway widening would be cost effective. However, only a minority of total vehicles are typically engaged in high-value trips, even under urban-peak conditions. Without some sort of rationing system, such as road tolls, the additional road capacity will eventually fill with generated traffic which mostly consists of lower-value trips. This is inefficient, since much of the additional vehicle travel is worth less than the added roadway capacity (for example, society may spend 50¢ per vehicle-mile to accommodate travel that users only value at 10¢ per vehicle-mile.

Figure 5 **Demand Curve for Faster Vehicle Travel**



The demand curve for faster vehicle travel usually includes a minority of higher-value trips that have willingness-to-pay sufficient to justify roadway expansion. In such cases, roadway expansion is inefficient because the additional capacity will fill with lower-value trips that have lower willingness-to-pay for road expansion, causing the higher value trips to again be slowed by congestion.

These omissions and biases tend to favor mobility over accessibility in the planning process. For example, more compact development tends to increase congestion intensity as measured by roadway LOS or the TTI, but tend to increase accessibility and reduce total transport costs by reducing the distance between destinations and improving alternative modes. Similarly, bike and bus lanes can increase congestion intensity but reduce total transport costs.

These omissions and biases can lead to suboptimal decisions. For example, exaggerating congestion costs relative to other impacts or overstating roadway expansion benefits encourages overinvestment in roadway projects and underinvestment in other types of transport improvements. Table 6 summarizes these various congestion costing biases, their impacts, and corrections for more comprehensive and objective congestion costing.

Table 6 **Congestion Costing Biases, Impacts and Corrections**

Type of Bias	Planning Impacts	Corrections
Only measures congestion intensity rather than total congestion costs	Favors roadway expansion over other transport improvements	Measure congestion and other transport costs per capita. Measure overall accessibility.
Only considers impacts on motorists.	Favors driving over other modes. Ignores *barrier effect* impacts on non-motorized travel	Use multi-modal transport system performance indicators
Estimates delay relative to free flow conditions (LOS A)	Results in excessively high estimates of congestion costs.	Use realistic baselines (e.g., LOS C) when calculating congestion costs
Applies relatively high travel time cost values	Favors roadway expansion beyond what is really optimal	Test willingness-to-pay for congestion reductions with road tolls
Uses outdated fuel and emission models that exaggerate fuel savings and emission reductions	Exaggerates roadway expansion economic and environmental benefits	Use more accurate models
Ignores the self-limiting nature of congestion and the additional external costs of induced travel	Exaggerates future congestion problems and roadway expansion benefits	Use advanced models that recognize congestion equilibrium and the full impacts of generated traffic

This table summarizes common congestion costing biases, their impacts on planning decisions, and corrections for more comprehensive and objective congestion costs.

Comprehensive Evaluation of Congestion Reduction Strategies

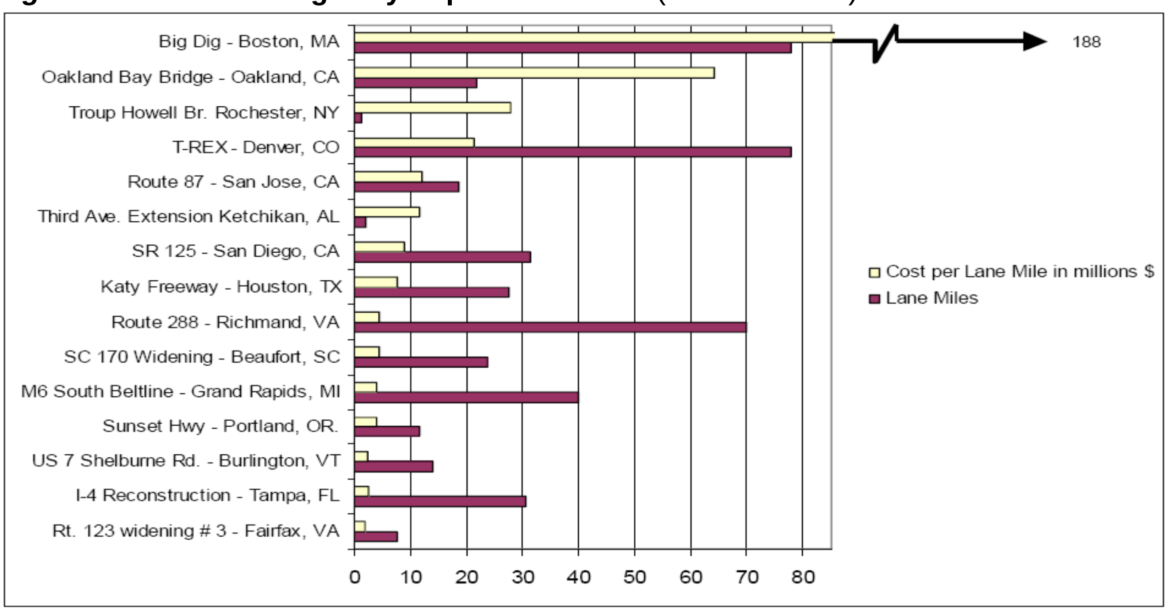
This section uses a comprehensive framework to evaluate various congestion reduction strategies.

Roadway Capacity Expansion

Roadway expansion can include traffic signal synchronization, automated highway technologies, intersection flyovers, grade separation, adding new lanes and building entirely new roadways (roadway expansion projects often include features that provide other benefits, such as increased safety and bike lanes, which are excluded from this analysis). Roadway expansion is generally considered the preferable solution to traffic congestion (AHUA 2004; Cox and Pisarski 2004; Hartgen and Fields 2006). Other approaches, such as improvements to alternative modes and demand management strategies, are generally considered only if roadway expansion is infeasible.

Although some capacity expansion strategies, such as signal synchronization, are relatively inexpensive, most are costly (WSDOT 2005; "Roadway Costs," VTPI 2011). Urban highway capacity expansion projects often costs $10-20 million per lane-mile, including land acquisition, lane pavement and intersection reconstruction costs, as illustrated in Figure 6. This represents an annualized cost of $300,000-700,000 per lane-mile (assuming a 7% interest rate over 20 years). Dividing this by 4,000 to 8,000 additional peak-period vehicles for 250 annual commute days indicates costs of 15-75¢ per additional vehicle-mile of travel, and even more in the built-up areas of large cities.

Figure 6 **Urban Highway Expansion Costs** (WSDOT 2005)



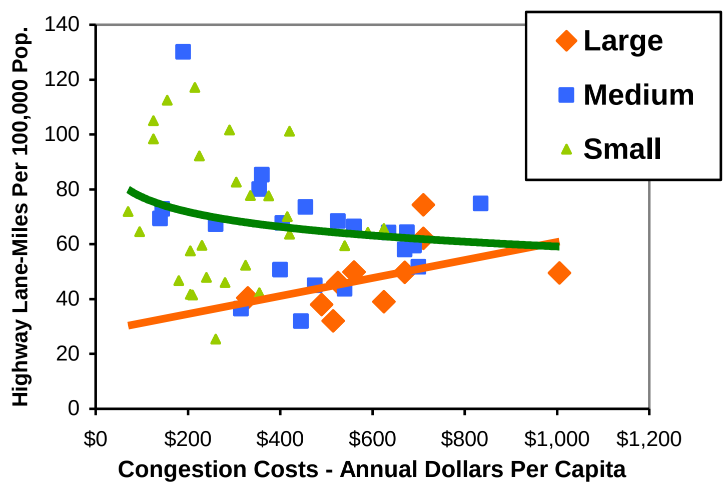
Of 36 highway projects studied by the Washington State Department of Transportation 13 had costs exceeding $10 million per lane-mile. Future projects are likely to have higher unit costs since most jurisdictions have already implemented the cheapest highway projects, and both construction costs and urban land values have increased faster than inflation in recent years.

Road tolls of this magnitude tend to significantly reduce travel demand (Spears, Boarnet and Handy 2010). If given a choice with *value priced* (also called *express*) lanes, a portion of motorists will pay tolls of 20-40¢ per mile to use uncongested toll lanes, but when applied to all road users, tolls of 10-20¢ per vehicle-mile typically reduce travel demand by 20-30% ("Road Pricing," VTPI 2011). Many recent toll road projects have failed to achieve their traffic volumes and revenue projections (Prozzi, et al. 2009).

As a result, few roadway expansion projects can be financed primarily through user fees. Most North American roadway expansion projects are unpriced (no special fees are required for their use), financed primarily through fuel taxes, which motorists pay regardless of how much they drive on congested roadways, and through general taxes that people pay regardless of how much they drive (Subsidy Scope 2009). This indicates that roadway expansion is seldom a cost effective way to reduce congestion: users only want projects if they are subsidized. Economic efficiency requires that congestion pricing (described below) be used to reduce peak-period traffic volumes to optimal levels, and only if revenues can finance expansion would such projects be implemented. However, current transport policies often prohibit or discourage tolling of existing roadways; tolls are generally only applied after projects are completed to repay costs. This is equivalent to medical systems that only treat people when they are ill with no preventive health programs.

Some research indicates that urban regions that increased roadway capacity in proportion to traffic volume growth experienced less congestion growth than regions with less capacity expansion (TTI 2010, p. 15), but most capacity expanding regions are smaller cities with slow growth, and the analysis does not indicate whether such projects are cost effective. Empirical evidence indicates that roadway expansion provides only modest congestion reductions, particularly in large cities. Figure 7 illustrates the relationship between urban highway lane-miles and congestion costs. Considering all cities, congestion declines with highway supply but the relationship is weak (green line): capacity expansion modestly reduces congestion. Among the ten largest cities (orange diamonds) the relationship is negative (orange line): those with more highways tend to have more congestion.

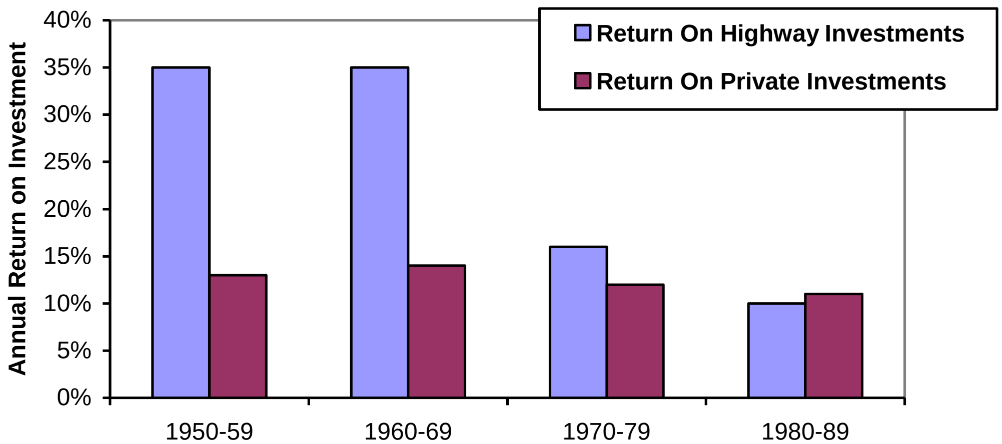
Figure 7 **Congestion Costs Versus Highway Supply** (TTI 2003; FHWA 2002)



This figure illustrates the relationship between highway supply and congestion costs. Overall, increased roadway supply provides a small reduction in per capita congestion costs (green line), but among large cities, congestion increases with road supply (orange line).

Advocates often claim that highway expansion provides large economic benefits, but numerous studies show that economic returns on highway expansion investments are modest and declining (Boarnet and Haughwout 2000; Shirley and Winston 2004). Figure 8 shows how highway investments provided high annual economic returns during the 1950s and 60s, far higher than returns on private capital, but these declined to below that of private capital investments by the 1980s. This is what economic theory predicts, since the most cost-effective investments have already been made, so more recent projects provide less benefit at a higher cost.

Figure 8 **Annual Rate of Return** (Nadri and Mamuneas 1996)



During the 1950s-70s, highway expenditures provided a high return on investment, but this has declined over time as economic theory predicts.

Highway expansion advocates often extrapolate past trends to predict significant growth in vehicle traffic and congestion problems, to the point that roads will reach *gridlock*. Such predictions are generally wrong. As previously discussed, congestion tends to maintain equilibrium: traffic volumes grow until congestion discourages additional peak-period vehicle trips. True gridlock, in which traffic is totally stuck, only occurs under unusual conditions, generally in major activity centers during special events, the risks of which are exacerbated if regional highway expansion increases total traffic there.

Roadway expansion appears even less efficient and equitable if evaluated using a comprehensive framework that accounts for the tendency of wider roads and higher traffic speeds to induce additional vehicle use, stimulate dispersed, automobile-dependent development, and to degrade non-motorized travel conditions and reduce non-automobile accessibility.

Improving Alternative Modes (Especially High Quality Public Transit and HOV)

Alternative modes include walking, cycling, ridesharing, public transit and telework. High quality public transit (relatively convenient, fast, comfortable and affordable) tends to be particularly effective at reducing congestion through the following three mechanisms:

1. High-quality, time-competitive transit tends to attract travelers who would otherwise drive, which reduces congestion on parallel roadways (described in the box below).
2. Rail transit can stimulate transit oriented development (TODs) – compact, mixed-use neighborhoods where residents tend to own fewer vehicle, drive less and rely more on alternative modes than in more automobile-dependent neighborhoods (Arrington and Sloop, 2010; "Transit-Oriented Development" VTPI 2009).
3. High quality transit service can reduce user travel time costs. Even if transit takes more minutes, many travelers consider their cost per minute lower than driving if transit service is comfortable (passengers have a seat, vehicles and stations are clean and safe, etc.) allowing passengers to relax and work ("Travel Time Costs" Litman 2009).

How Transit and HOV Reduces Traffic Congestion
Urban traffic congestion tends to maintain equilibrium. If congestion increases, people change route, destination, travel time and mode to avoid delay, and if it declines they take additional peak-period vehicle trips. Reducing the point of equilibrium is the only way to reduce long-term congestion.

The quality of travel options available affects the point of equilibrium: If alternatives are inferior, motorists will resist shifting mode until congestion becomes severe. If alternatives are attractive, motorists will more readily shift mode, reducing the level of congestion equilibrium. Improving travel options can therefore reduce delay both for travelers who shift modes and those who continue to drive.

To attract discretionary riders (travelers who could drive), transit must be fast, comfortable, convenient and affordable. Grade-separation gives transit a speed advantage over driving. When transit is faster than driving, a portion of motorists shift until the highway reaches a new equilibrium (until congestion declines so transit's time advantage attracts no more motorists). Even small shifts can provide significant congestion reductions. For example, a 5% reduction from 2,000 to 1,900 vehicles per lane will typically increase traffic speeds from 40 to 50 mph and eliminate stop-and-go conditions (Table 3). Congestion does not disappear but is never as bad as would otherwise occur. Several studies have found that faster transit service increases travel speeds on parallel highways (Vuchic 1999; Lewis and Williams 1999).

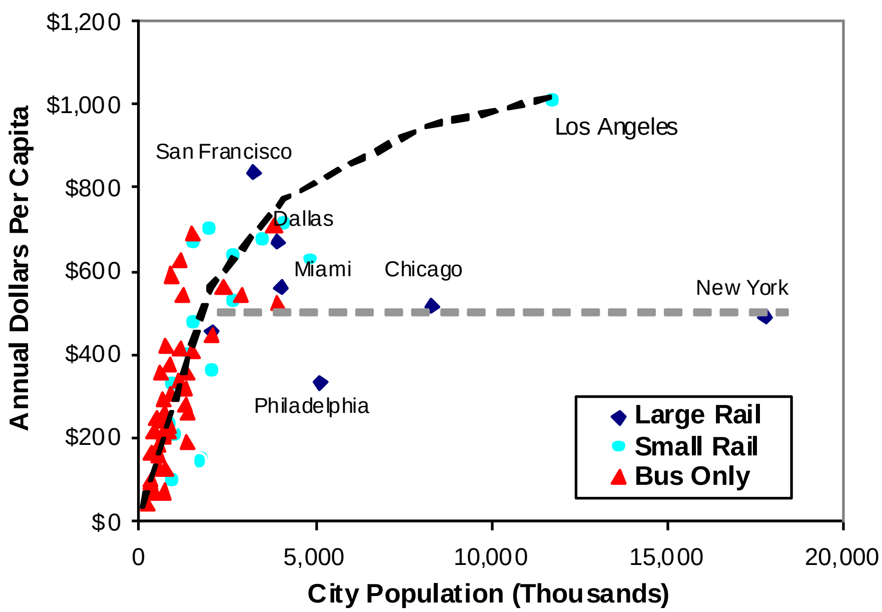
Transit service does not usually eliminate roadway congestion, but it can significantly reduce congestion intensity on parallel roadways and total per capita annual congestion delays. Several studies indicate that per capita congestion costs tend to be lower on corridors and in cities with high quality, grade-separated public transit services. For example, Kim, Park and Sang (2008) found that after the Twin City's Hiawatha LRT line was completed vehicle traffic volumes on that corridor decreased, with particularly large reductions during peak periods, despite growth in regional vehicle traffic. Garrett and Castelazo (2004) also found that congestion growth tend to decline after light rail service begins. Baltimore's congestion index increased an average of 2.8% annually before light rail but only 1.5% annually after. Sacramento's index grew 4.5% annually before light rail but only 2.2% after. St. Louis' index grew of 0.89% before light rail, and 0.86% after.

Winston and Langer (2004) found that motorist and truck congestion delay declines in cities as rail transit mileage expands, but increases as bus transit mileage expands, apparently because buses attract fewer motorists, contribute to congestion, and do little to increase land use accessibility. Aftabuzzaman, Currie and Sarvi (2010) concluded that in Australian cities, high quality public transit provides $0.044 to $1.51 worth of congestion cost reduction (Aus$2008) per marginal transit-vehicle km of travel, with higher values where traffic congestion is particularly intense.

Bhattacharjee and Goetz (2012) found that in Denver, Colorado, traffic volumes grew less on roadways within the new light rail corridors than on comparable roads on corridors that lack rail transit. Between 1992 and 2008, vehicle-miles traveled increased 41% outside the light rail zones but only 31% inside, despite rapid land development in those corridors. Baum-Snow and Kahn (2005) found significantly lower average commute travel times in areas near rail transit than in otherwise comparable locations that lack rail, due to the relatively high travel speeds of grade-separated transit compared with automobile or bus commuting under the same conditions. Nelson, et al (2006) used a regional transport model to estimate transit system benefits, including direct users benefits and the congestion-reduction benefits to motorists, in Washington DC. They found that rail transit generates congestion-reduction benefits that exceed subsidies.

Texas Transportation Institute data indicate that congestion costs tend to increase with city size, but not if cities have large, well-established rail transit systems, as illustrated in Figure 9. As a result, New York and Chicago have far less congestion than Los Angeles.

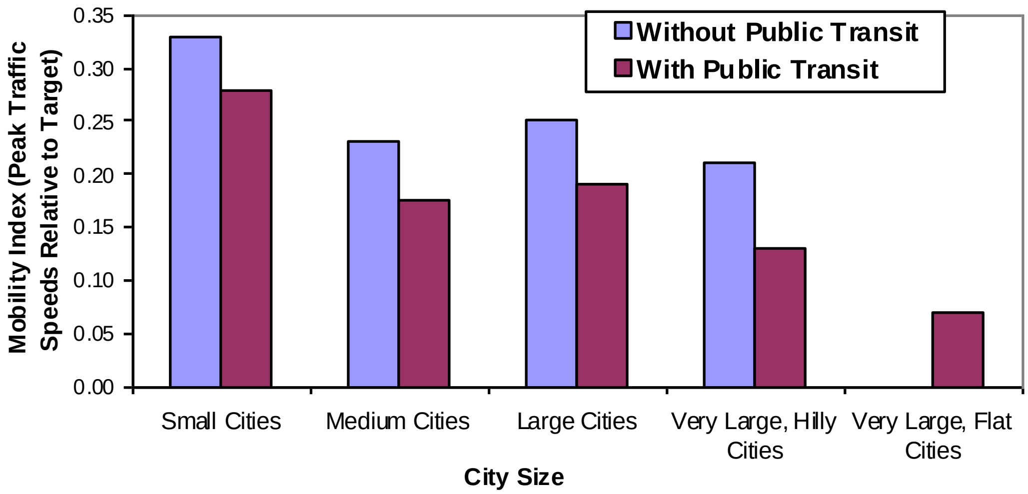
Figure 9 **Congestion Costs** (Litman 2004)



Traffic congestion costs tend to increase with city size, as indicated by the dashed curve, except for cities with large rail transit systems.

Similar patterns are found in developing countries, as summarized in Figure 10, which shows that Indian cities with rail transit systems tend to have a higher Mobility Index (less roadway congestion).

Figure 10 **Traffic Congestion in India** (Wilbur Smith 2008)



Average traffic speeds tend to decline with city size, but are significantly higher for cities with high quality public transit systems.

Another indicator of transit's congestion reduction benefits is the increased traffic delay that occurs when transit service fails due to mechanical failures or strikes. For example, Lo and Hall (2006) found highway traffic speeds declined as much as 20% and rush hour duration increased significantly during the 2003 Los Angeles transit strike, although transit has only a 6.6% regional commute mode share. Speed reductions were particularly large on rail transit corridors.

High quality public transit service and High Occupant Vehicle lanes complement congestion pricing. They tend to reduce the price (road toll, parking fee or fuel price) required to achieve a given reduction in traffic congestion. The *Traffic Choices Study* simulated the effects of congestion pricing in the Puget Sound (Seattle, Washington area) region (PSRC 2008). The study found that commuters' responsiveness to congestion tolls is significantly affected by transit service quality: the elasticity of Home-to-Work vehicle trips was approximately -0.04 (a 10% price increase causes a 0.4% reduction in commute trips), but increased to -0.16 (a 10% price increase causes a 1.6% reduction in commute trips) for workers with the 10% best transit service. Similarly, Guo, et al. (2011) analyzed data from the 2006-2007 Oregon Road User Fee Pilot Program, which charged motorists for driving in congested conditions. They found that households in transit-accessible neighborhoods reduced their peak-hour and overall travel significantly more than comparable households in automobile dependent suburbs, and that congestion pricing increased the value transit-oriented locations, indicating that households see high quality transit as a rational response to higher automobile user costs.

Major transit system expansions generally occur in large and growing urban areas that experience increasing congestion. As a result, simplistic analysis can indicate a positive correlation between transit service and congestion intensity as measured by indicators such as the Travel Time Index (TTI) which only measure motorist delay and ignore congestion avoided by travelers who shift from driving to transit. Some critics exploit this relationship to "prove" that rail transit increases congestion (O'Toole 2004), but such analysis confuse correlation with causation.

Similarly, average transit travel is slower than automobile travel, but average speeds are irrelevant; what matters is travel speeds under specific conditions. Transit service is concentrated on major urban corridors where automobile traffic speeds are low. Under such conditions grade-separated transit and HOVs are often faster than driving. Of course, each trip is unique. Transit is inappropriate for destinations located far from transit routes and trips involving heavy loads. Some travelers prefer driving because they want to smoke or have difficulty walking to transit stations. Some people enjoy driving even in congested conditions. But that does not negate the value of transit and HOV: if quality options are available travelers can select the best one for each trip. This maximizes transport system efficiency (by reducing traffic congestion) and consumer benefits (since it lets travelers choose the optimal option for each trip).

This leaves little doubt that high quality public transit can reduce congestion costs. This does not mean that cities with high quality transit lack congestion. In fact, congestion tends to be particularly intense in these cities, but people in these cities drive fewer peak-period miles and so experience fewer annual hours of congestion delay.

Improvements to other alternative modes (walking, cycling, ridesharing and telework) can also provide congestion reduction benefits. High Occupancy Vehicle (HOV) lanes, which increase carpool, vanpool and bus transit speeds, are likely to attract peak-period travelers away from highways, reducing the point of congestion equilibrium. Improvements to walking and cycling can reduce automobile travel for local trips and help support more compact, accessible land use development.

Transport Pricing Reforms

Various transport pricing reforms are advocated to achieve various planning objectives including revenue generation, congestion reduction, traffic safety, energy conservation and emission reductions. To the degree that automobile travel is currently underpriced, these pricing reforms tend to increase efficiency and equity.

Table 7 **Transport Pricing Reform Impacts**

Pricing Type	Description	Travel Impacts	Congestion Impacts
Congestion pricing	Road user tolls and fees that are significantly higher under congested conditions.	Shifts urban-peak driving to other times, routes, modes and destinations. Reduces urban-peak travel.	Effects are concentrated on congested conditions so it can provide large congestion reductions
Flat road tolls and vehicle travel fees	Tolls and mileage-based vehicle fees intended to generate revenue.	Shifts automobile travel to other modes and destinations. Reduces total vehicle travel.	Effects are dispersed. It tends to provide modest congestion reductions.
Parking pricing	User fees to finance parking facilities. Can also include parking cash out and unbundling.	Shifts driving to other modes and destinations. Reduces total vehicle travel.	Because it is implemented most in dense urban areas, it can provide large congestion reductions.
Higher fuel prices	Increase fuel prices to finance roads and traffic services, and to internalize fuel economic and environmental costs.	Shifts automobile travel to other modes and destinations. Reduces total vehicle travel. Encourages shifts to more fuel-efficient vehicles.	Because effects are dispersed, it tends to provide modest congestion reductions.
Distance-based pricing	Prorate vehicle insurance premiums and registration fees by mileage.	Shifts automobile travel to other modes and destinations. Reduces total vehicle travel.	Effects are potentially large but dispersed, so it tends to provide modest congestion reductions.

This table summarizes major pricing reforms and their travel and congestion reduction impacts.

Congestion pricing is particularly effective at reducing traffic congestion. Performance-based congestion pricing sets fees at the level needed to reduce traffic volumes to optimal levels. Other pricing reforms also tend to reduce traffic congestion, although to a lesser degree since they do not target urban-peak driving.

Congestion pricing is theoretically the most cost-effective way to reduce congestion problems, that is, it can achieve a given congestion reduction at the lowest total cost to motorists. However, such pricing has high implementation costs, since it requires pricing that varies by time, travel route and vehicle type. Other pricing strategies (flat road user fees, higher fuel prices and distance-based pricing) tend to affect a larger portion of total travel and therefore tend to be more effective at achieving other planning objectives such as reducing accidents, energy consumption and pollution emissions. Parking pricing has relatively modest implementation costs (since most cities already have parking meter systems) and tends to be concentrated in urban areas and so tends to be a relatively cost-effective congestion reduction strategy.

Smart Growth Development Policies

Smart growth is a general term for policies that result in more compact, accessible development within existing urban areas. Smart growth is an alternative to dispersed, automobile dependent development outside existing urban areas, often called *sprawl*.

Smart growth policies can include:

- Allowing more compact development with higher densities and taller buildings, and more mixed use, with residential and commercial allowed in the same neighborhoods, blocks and buildings.
- Allowing more diverse housing types, including townhouses, condominiums and apartments, rather than just single-family homes.
- Reduced and more flexible parking requirements, and more efficient parking management, particularly for compact development.
- Support for infill development, including improvements to public services and brownfield reclamation within existing urban areas.
- Location of public facilities (schools, offices, post offices, etc.) in accessible, multi-modal locations.
- Location-based development charges and utility fees that reflect the lower costs or providing public services in more compact, infill locations.
- Urban growth boundaries and other restrictions on urban expansion.
- More multi-modal transport planning, with more emphasis on walking, cycling and high quality public transit.

Smart growth tends to support and is supported by improvements to alternative modes, particularly high quality public transit and transport pricing reforms, and tends to conflict with roadway expansion. Residents of smart growth communities tend to own fewer automobiles, drive less, rely more on alternative modes, and are more responsive to incentives than they would be in more automobile-oriented locations. As a result, smart growth tends to reduce total regional traffic congestion costs. However, because smart growth tends to increase density and therefore trips per land area, it tends to increase local congestion intensity.

Smart growth congestion reduction benefits therefore depend on how it is implemented and measured. If implemented as an integrated program with complementary strategies such as improvements to alternative modes and efficient pricing, and measured based on overall accessibility and per capita congestion delay, smart growth can significantly reduce traffic congestion. However a small smart growth program implemented alone, and measured based on congestion intensity (roadway LOS, average traffic speeds and the Travel Time Index), may seem to increase traffic congestion.

Summary

Table 8 summarizes the four congestion reduction strategies. Roadway expansion can provide short-term congestion reductions, is commonly considered in the planning process, and provides minimal co-benefits (such as small air pollution reductions). Improvements to alternative modes, particularly grade-separated transit and HOVs, can provide significant congestion reductions and numerous co-benefits. Pricing reforms can provide large congestion reductions and numerous co-benefits, but are generally considered politically infeasible and are seldom implemented. Smart growth tends to reduce total regional travel and congestion costs but may increase local congestion intensity, and provides numerous co-benefits, but these tend to be given little weight in conventional transport planning. Smart growth is often promoted as a way to reduce infrastructure costs and pollution emissions, but not congestion-reductions.

Table 8 **Congestion Reduction Strategies**

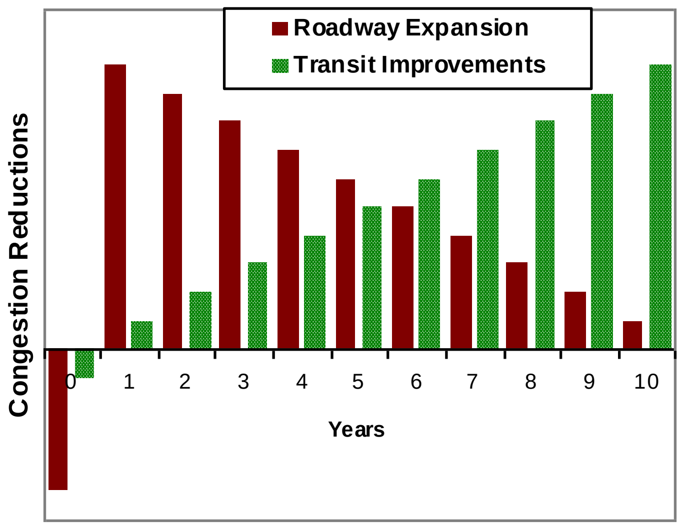
	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth
Congestion impacts	Reduces congestion in the short-run, but this declines over time due to generated traffic.	Does not generally eliminate congestion but prevents congestion from becoming extreme.	Can significantly reduce congestion.	May increase local congestion intensity but tends to reduce regional per capita congestion costs.
Consideration in traffic modeling	Models often exaggerate congestion reduction benefits by underestimating generated traffic and induced travel.	Models often underestimate the congestion reduction benefits of high quality alternative modes.	Varies. Models can generally evaluate congestion pricing but are less accurate for other pricing reforms, such as parking pricing.	Many models underestimate the ability of smart growth strategies to reduce vehicle travel and therefore regional congestion.
Co-benefits	Minimal. Small energy savings and emission reductions.	Numerous. Parking cost savings, traffic safety, improved mobility for non-drivers, consumer savings, energy saving, emission reductions, and improved public health.	Numerous. Revenues, parking cost savings, traffic safety, improved mobility for non-drivers, energy saving, emission reductions and improved public health.	Numerous. Parking cost savings, traffic safety, improved mobility for non-drivers, consumer savings, energy saving, emission reductions, improved public health, and habitat protection.
Degree considered in current planning	Commonly considered and funded.	Sometimes considered and funded, particularly in large cities.	Sometimes considered but seldom implemented.	Considered for infrastructure savings and environmental benefits.

Different congestion reduction strategies have different types of impacts and benefits. Most current traffic models fail to recognize all congestion impacts, including the effects of traffic generated by roadway expansions, and conventional planning tends to ignore many co-benefits.

This indicates that the perceived value of specific congestion reduction strategies is affected by the analysis perspective, methods and scope:

- *Mobility-based* analysis (which assumes that more and faster travel is always better) tends to favor roadway expansion. *Accessibility-based* analysis (which considers other factors that affect people's ability to access services and activities) tends to favor other congestion reduction strategies.
- Measuring congestion using *Level Of Service* and *Travel Time Index* tends to favor roadway expansion. Measuring total or per capita congestion costs tends to favor other congestion reduction strategies.
- The quality of traffic modeling affects evaluation. Most current models fail to recognize the full effects of traffic generated by roadway expansions, and many models are not very sensitive to factors such as improved transit comfort, more accessible transit stations, and parking pricing reforms, which tends to favor highway expansion.
- Conventional planning tends to ignore the additional external costs of travel induced by roadway expansion and the co-benefits provided by other congestion reduction strategies.
- The analysis time period can affect results, as illustrated in Figure 11. A shorter analysis period tends to favor roadway expansion, since congestion reduction benefits tend to decline over time. A longer time period tends to favor transit improvements, particularly rail transit projects, which often take many years or decades to achieve their full ridership and land use impacts.

Figure 11 **Road Widening Versus Transit Congestion Impacts**



This graph compares roadway expansion and transit improvement congestion reduction benefits over time. Congestion tends to increase during road construction. Once the road is expanded congestion is reduced, but this benefit declines over time due to generated traffic. Transit improvement projects cause little or no congestion. When completed they initially provide small congestion reductions, but this increases over time as transit ridership grows.

- Analyses that measure impacts *per driver* tends to favor roadway expansion. Analyses that measure impacts *per capita* tend to favor other congestion reduction strategies.

Comprehensive Impact Analysis

As discussed earlier, traffic congestion is overall a modest transportation costs, larger than some but smaller than others. It is therefore important to use a comprehensive evaluation framework to identify the truly optimal solutions. Table 9 illustrates such a framework. It evaluates various congestion reduction strategies relative to ten major planning objectives.

Roadway expansion reduces traffic congestion, but to the degree that it induces additional vehicle travel and stimulates sprawled land use, it tends to contradict most other planning objectives. Reduced congestion may provide fuel cost savings, but these tend to be offset by the increased transportation costs resulting from sprawled development. Similarly, reduced congestion tends to reduce crash frequency, but the crashes that do occur tend to be higher speed and therefore more severe.

Table 9 **Comparing Congestion Reduction Strategies**

Planning Objectives	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth
Congestion reduction	✓	✓	✓	✗/✓
Roadway cost savings	✗	✓	✓	✓
Parking savings	✗	✓	✓	✓
Consumer cost savings	✓/✗	✓	✓	✓
Transport diversity	✗	✓	✓	✓
Improved traffic safety	✗	✓	✓	✓
Reduced pollution	✗	✓	✓	✓
Energy conservation	✗	✓	✓	✓
Efficient land use	✗	✓	✓	✓
Improved fitness and health	✗	✓	✓	✓

(✓ = helps achieve that objective. ✗ = Contradicts that objective.) Roadway expansion helps reduce congestion but by inducing additional vehicle travel it exacerbates other transport problems. Transit improvements, pricing reforms and smart growth help achieve many objectives.

Most other congestion reduction strategies tend to reduce total vehicle travel and improve overall accessibility, and so provide a broader range of benefits. Although these strategies are not necessarily the most effective way of reducing traffic congestion, they are often the most cost effective and beneficial solution, when all impacts are considered.

Described differently, roadway expansion tends to provide more short-term benefits, but these tend to decline over time as generated traffic fills the added capacity, and tends to impose additional costs to society over the long-term due to induced travel. Other congestion reduction strategies tend to provide benefits that start small but increase over time, as transport and land use patterns develop. As a result, narrow, short-term analysis tends to favor roadway expansion, while comprehensive, long-term analysis tends to favor other congestion reduction strategies.

Equity Analysis

Equity refers to the distribution of benefits and costs, and the degree that distribution is considered fair and justified (Litman 2002). To the degree that current evaluation methods exaggerate congestion costs and roadway expansion benefits, they tend to favor roadway expansion projects over other types of transport system improvements. This contradicts social equity objectives: it favors motorists over non-motorists, reduces affordable transport options (wider roads and increased traffic degrade walking and cycling conditions, roadway investments instead of improved public transit services), and encourages more dispersed land use development. These result in transport systems that are costly to use, poorly serve non-drivers, and fail to provide basic mobility.

Transportation pricing reforms, including congestion pricing, are often criticized as regressive, but there are generally no more regressive than other transport system funding options such as sales and property taxes. Overall congestion pricing (road tolls intended to reduce peak-period traffic) equity impacts depend on specific price structures, the quality of travel options, and how revenues are used.

The table below evaluates the equity impacts of current congestion costing methods that exaggerate congestion costs and roadway expansion benefits, and therefore favors mobility over accessibility, and automobile travel over other modes.

Table 12 **Equity Analysis of Current Congestion Costing**

Equity Objectives	Effects Of Over-estimated Congestion Costs
Treat everybody equally.	Is unfair if it favors people who drive under urban-peak conditions over others who do not.
Individual should bear the costs they impose unless a subsidy is specifically justified.	Is unfair to the degree it justifies subsidized roadway expansion instead of more efficient road pricing.
Costs and benefits should be progressive with respect to income if possible (benefits lower-income people).	Is regressive to the degree that urban-peak driving increases with income and poorer people rely on alternative modes. Congestion reduction strategies can be designed to be progressive by improving affordable modes and providing income-based discounts for road pricing.
Benefits transport disadvantaged (benefits people whose mobility and accessibility are constrained by factors such as disabilities, low incomes or inability to drive).	Tends to harm transport disadvantaged people who rely on alternative modes. Congestion reduction strategies can help disadvantaged people by improving affordable modes.
Improves basic mobility (favors access to services and activities that society considers essential, such as emergency response, medical care, commuting, basic shopping, etc.).	To the degree that current practices reduce transport options and increase land use dispersion they reduce basic mobility.

Exaggerating congestion costs tends to contradict equity objectives.

Described more positively, more comprehensive and neutral analysis can help identify congestion reduction strategies that also help achieve equity objectives such as improving mobility for non-drivers and reducing regressive roadway expansion subsidies (lower-income people funding facilities used mainly by higher-income people).

What Does Modeling Indicate?

Older four-step traffic models are not very accurate at predicting long-term traffic congestion effects because they use fixed trip tables which assume the same number of trips will be made between locations regardless of the level of congestion between them. As a result, they account for shifts in route and mode, and sometime in time, but not in destination or trip frequency ("Model Improvements," VTPI 2009).

Newer models incorporate more factors and so are more accurate at predicting impacts of specific transportation and land use policies. Johnston (2006) summarizes results from more than three dozen long-range modeling exercises performed in the U.S. and Europe using integrated transport, land use and economic models. These indicate that the most effective way to reduce congestion is to implement integrated programs that include a combination of transit improvements, pricing (fuel taxes, parking charges, or tolls) and smart growth land use development policies. These studies indicate that a reasonable set of policies can reduce total vehicle travel by 10% to 20% over two decades, maintain or improve highway levels-of-service ratings (i.e., they reduce congestion), expand economic activity, increase transport system equity (by distributing benefits broadly), and reduce adverse environmental impacts compared to the base case. Expanding road capacity, along with transit capacity, but without changing market incentives to encourage more efficient use of existing roads and parking, results in expensive transit systems with low ridership.

Recent traffic modeling of Puget Sound region transportation improvement options reached similar conclusions (WSDOT 2006). It found that neither highway widening nor transit investments are by themselves cost effective congestion reduction strategies, although the model has fixed trip tables so it exaggerates highway expansion benefits and underestimates transit improvement benefits. The most effective congestion reduction program includes both transit service improvements and road pricing to give travelers better options and incentives. Table 10 summarizes estimated congestion reduction benefits and project costs. Both have costs that exceed congestion reduction benefits, but transit improvements are more cost effective overall since they provide many additional benefits including road and parking cost savings, consumer cost savings, crash reductions, improved mobility for non-drivers, energy conservation, emission reductions, and support for strategic land use.

Table 10 **Congestion Reduction Economic Analysis** (WSDOT 2006)

	Congestion Reduction Benefits		Direct Project Costs	
	Lower Estimate	Higher Estimate	Lower Estimate	Higher Estimate
Highway Expansion	$1,500	$2,200	$2,500	$3,700
Transit Improvements	$480	$730	$1,200	$1,500

This table indicates estimated highway and transit congestion reduction benefits and costs, in millions of annualized dollars. Neither approach provides congestion-reduction benefits that exceed costs, but transit provides many additional benefits.

Have Alternatives Failed?

Highway expansion advocates sometimes argue that alternatives, such as transit service improvements and mode shift incentives, have been tried but have failed and so should be abandoned. Such claims tend to overstate the amount that these strategies have been implemented and underestimate the congestion reductions that result.

Only a small portion of total transportation funding is devoted to alternative modes and mobility management programs. For example, in 2004 governments in the U.S. spent about $140 billion on roads and about $26 billion dollars to support public transit. Transit therefore receives about 16% of the total (FHWA 2005). About half of transit funding is intended to provide basic mobility to non-drivers, including special mobility services and bus transit in suburban and rural areas, so only about 8% of government transport budgets are spent on transit services to attract discretionary travelers (people who have the option of driving). In addition, U.S. consumers, businesses and governments spend more than $300 billion on off-street parking, so only about 3% of total transport expenditures are devoted to transit services that can reduce congestion. This does not include other external costs, such as accidents and pollution impacts, which are often reduced when travel shifts from automobile to transit (Litman 2006).

Highway expansion advocates argue that it is unfair and inefficient to devote significant resources to improve public transit that carry only a small portion of total trips. But transit carries a much greater portion of travel on major urban corridors, where roadway expansion is costly and transit demand is high, and so is often the most cost effective way to reduce congestion and improve mobility.

Similarly, it is wrong to claim that mobility management strategies, such as commute trip reduction programs, HOV priority, parking pricing and non-motorized transport improvements have been tried and failed. Although many communities have implemented some mobility management programs, most efforts are modest, representing a minority of employees, roads and parking facilities. Where appropriately implemented such programs have been successful, typically reducing vehicle trips by 10-30% among affected travelers, and are generally cheaper than the total costs (including roads, vehicles and parking facilities) of accommodating additional urban peak vehicle travel (USEPA 2005; VTPI 2011).

Highway expansion advocates exaggerate the portion of transportation resources devoted to alternative modes and mobility management programs because they focus on particular budgets, such as regional capital investments in cities developing major new transit systems, where more than half of total expenditures may be devoted to alternative modes for a few years. However, when all transportation budgets are considered, including parking facility expenditures, and averaged over a longer time period, the portion devoted to alternative modes is generally reasonable. Proportionately large investments in alternative modes can be justified in most communities to offset decades of planning and investments skewed toward automobiles.

Optimal Congestion Solutions

This analysis indicates that optimal congestion reduction involves the following steps:

1. Apply pricing reforms including road tolls, user-paid parking, fuel price increases, and distance-based insurance and vehicle registration fees to the degree justified by comprehensive evaluation, including consideration of road and parking facility cost recovery, traffic safety, energy conservation and emission reductions, etc.
2. Improve alternative modes, particularly grade-separated HOV facilities and public transit services to the degree justified by comprehensive evaluation, including consideration of road and parking facility cost savings, mobility for non-drivers, traffic safety, energy conservation and emission reductions, etc.
3. Apply congestion pricing (variable tolls or fees that are higher during congested periods), with prices set to reduce traffic volumes to optimal levels, which is typically LOS D. Ideally, this would involve a comprehensive system that allows congestion pricing at any location and time, but if that is infeasible apply special tolls where congestion problems are severe, such as major urban highways and commercial centers.
4. Expand roadway capacity where congestion pricing revenues can finance their full costs. For example, if a particular roadway expansion would have annualized costs of $5 million, implement it if a toll on peak-period travelers will generate that much revenue. Tolls on off-peak travelers can be used to finance other roadway costs (maintenance and operations, and safety improvements) but not capacity expansion.

Current transport policies do not support these solutions. Pricing reforms are seldom implemented. There tends to be considerable political opposition to pricing reforms, and current planning treats roadway expansion as the preferred solution to congestion. Table 11 critiques common objections to alternative congestion reduction strategies.

Table 11 **Critique of Common Objections to Optimal Congestion Reductions**

Objection	Critique
Motorists already pay their share of costs.	User fees finance less than half of roadway costs and an even smaller share of total costs, including parking facilities, pollution damages, etc. Driving under congested roadways imposes additional costs.
Pricing is ineffective. It does not reduce driving.	Automobile travel is actually quite sensitive to prices, particularly road tolls and parking fees. Even a 10¢ per mile toll or $2.00 per day parking fee can significantly reduce traffic congestion.
Pricing is regressive. It harms poor people.	Regressivity depends on the price structure, the quality of alternatives, and how revenues are used. Pricing can be implemented in ways that are progressive and help achieve other equity objectives.
Pricing is economically harmful.	More efficient transport pricing is actually economically beneficial.
Transit is an inefficient way to reduce traffic congestion.	High quality public transit can help reduce congestion, particularly in conjunction with pricing reforms, and provides other benefits. When all impacts are considered it is often cost effective.
Transit-oriented development (TOD) and smart growth increase traffic congestion.	By increasing development density, TOD and smart growth tend to increase congestion intensity but by reducing per capita vehicle travel they tend to reduce total congestion costs.

Many objections to optimal congestion reduction strategies are based on inaccurate arguments.

Efficient Investment Example

Here is a simple example illustrating efficient congestion reduction investments. Assume a four-lane highway is on a corridor with demand of 5,000 peak period trips. Because the road can only accommodate 4,000 peak period users (2,000 vehicles per lane) it experiences congestion that causes 1,000 potential peak-period travelers to shift to other times, routes or modes.

The most efficient solution is to price peak-period use of the highway with tolls set to maintain optimal traffic flow. This also causes 1,000 potential peak period trips to shift, preventing congestion and providing revenue. The optimal toll would vary to reflect demand, perhaps 2¢ per vehicle-mile for most of the commute period (such as 7:00 until 9:00 in the morning, and 4:00 until 6:00 in the evening), but up to 10¢ per vehicle-mile at the maximum peak (such as 7:50 until 8:00 in the morning, and 5:10 until 5:20 in the evening).

Expanding the highway is only efficient if peak-period revenues are sufficient to repay all incremental costs, which tests users' willingness-to-pay. Highway expansion advocates often violate efficiency principles by requiring off-peak highway users to also pay for such projects, but it is inefficient and unfair to force them to pay for projects that only benefit peak period drivers. Off-peak users should only be required to pay for project features that benefit them, such as improved safety guards.

Assume the highway expansion would cost $8 million per lane-mile, which equals approximately $300,000 per lane-mile in annual costs, or $1,000 per day if there are 300 congested days per year. Since the expanded highway can efficiently carry up to 6,000 vehicles per hour, tolls would need to average at least 17¢ per vehicle-mile ($1,000/6,000 = $0.17) if each lane is only congested and priced one hour per day (inbound in the morning, outbound in the evening), or 8.5¢ per vehicle-mile if congested and priced twice daily. If tolls high enough to recover costs would reduce peak-period travel below 4,000 vehicles the project would not be cost effective; users would be better off with a four-lane highway and lower tolls than a six-lane highway with higher tolls.

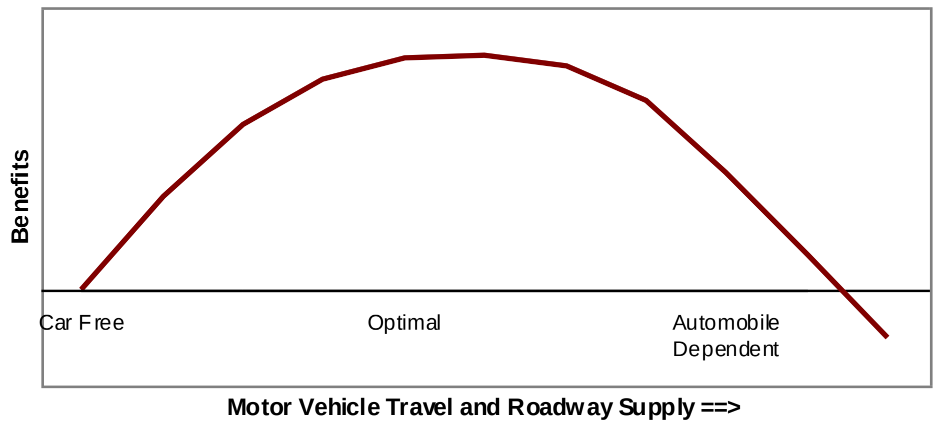
It may be efficient to use some toll revenue to improve travel options on the corridor, such as subsidizing vanpool and bus service, contributing to construction of a rail-transit line, or support commute trip reduction programs if doing so reduces peak-period automobile travel demand and therefore highway congestion. Many factors affect the degree to which such services reduce congestion, including their quality and speed, the ease of accessing destinations (such as worksites) by these modes, and community attitudes about their use. In some situations, alternative modes may attract few motorists and do little to reduce congestion, so highway widening is more cost effective. On the other hand, improving alternative modes provides other benefits besides highway congestion reduction, including improved mobility for non-drivers, reduced downstream congestion, parking cost savings, consumer cost savings, accident reductions, energy conservation and reduced pollution, and so may be the preferred solution even if highway widening is cheaper.

Implications for Developing Countries

This analysis has important implications for developing countries. Over-estimating congestion costs and roadway expansion benefits creates excessively automobile-oriented transport systems, which exacerbates various economic, social and environmental problems. Many developed country cities are now working to correct the excessive automobile-dependency that results. Developing countries can avoid future problems by applying more comprehensive and balanced analysis which considers congestion reduction in proper perspective with other planning objectives, and considers other congestion reduction strategies besides roadway expansion.

Conventional transport planning tends to assume that any increase in per capita motor vehicle travel and therefore roadway supply is desirable, as reflected by the emphasis on congestion problems and roadway expansion solutions. But economic theory recognizes that too much vehicle travel is as harmful as too little since vehicle travel and the facilities they require are costly. Figure 12 illustrates this concept. As a transport system increases from being totally car-free (no automobiles at all) there are significant benefits, but beyond an optimal point, benefits decline and become negative.

Figure 12 **Optimal Vehicle Travel and Road Supply**



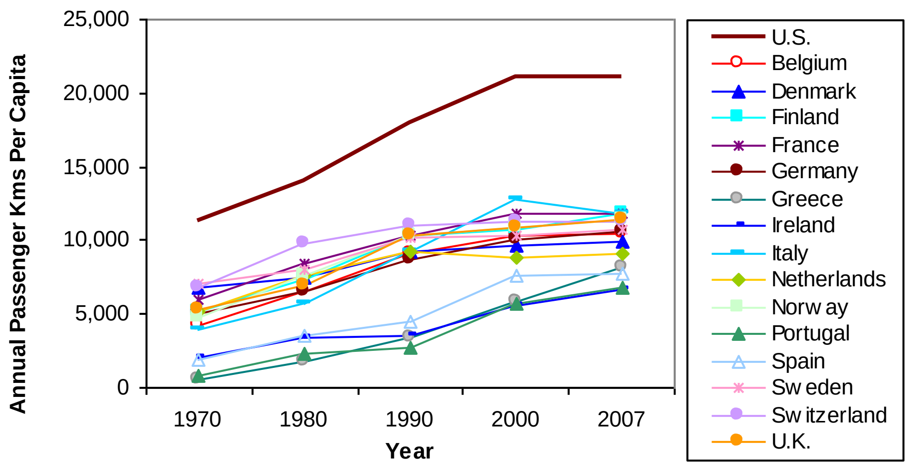
Automobile transport can provide substantial benefits, but beyond an optimal level, benefits decline and become negative.

One way to help identify the economically optimal level of automobile travel is to determine how much vehicle travel and roadway supply people would choose if:

- Roads, parking facilities, fuel, accident costs and pollution emissions were efficiently priced (for example, motorists would pay directly every time they used a road or parking space, fuel prices incorporated all production costs, and insurance was distance-based).
- Consumers had good transport options (good walking and cycling conditions, convenient and comfortable public transit and delivery services, and good telecommunications).
- Accessible location options (including affordable housing in accessible, multi-modal neighborhoods).

Various studies indicate that with more efficient pricing and better travel options consumers would choose to drive significantly less and use alternative modes more than currently occurs in North America (Litman 2010). Even in European countries, where per capita vehicle travel is about half of what occurs in North America (Figure 13), automobile travel would probably decline further if motorists paid directly for parking at most destinations, and insurance and registration fees were distance-based.

Figure 13 **International Vehicle Travel** (European Commission and FHWA Data)



Per capita vehicle travel is much lower in European countries than in the U.S.

This suggests that for wealthy countries, at a national level, the economically optimal level of automobile travel is less than half of what occurs in North America, that is, less than 10,000 annual kilometers per capita. The optimal is even lower:

- For urban locations.
- For poorer people.
- If fuel prices increase.
- If other impacts and planning objectives are considered.

As a result, developing countries benefit from planning practices that support transport system diversity, efficient pricing, and accessible land use development. Evaluation that exaggerates congestion costs and road expansion benefits, and undervalues other congestion reduction strategies, contradict strategic planning goals. Although many developing countries can justify roadway improvements to accommodate growing traffic volumes, these should consist of local road paving and intercity highways. Roadways should be multi-modal (designed to accommodate walking and cycling, and incorporate bus stations and bus lanes), and roads, parking, fuel and insurance should be efficiently priced. It is important to avoid solving urban traffic congestion by expanding unpriced roads, and instead use more efficient programs that include a combination of alternative mode improvements, pricing reforms and smart growth policies.

Conclusions

Conventional transport planning tends to consider traffic congestion a major cost and congestion reduction a primary planning objective. It often evaluates transport system performance based largely on congestion indicators such as roadway Level Of Service and the Travel Time Index. This tends to justify congestion reduction over other planning objectives and roadway expansion over other congestion reduction strategies.

Congestion cost and congestion reduction benefit estimates are sensitive to the evaluation methods used. Current planning practices tend to exaggerate congestion costs and roadway expansion benefits in various ways:

- They measure congestion *intensity* rather than total congestion costs. This ignores congestion avoided when travelers shift mode or reduce total vehicle travel. The Travel Time Index even implies that congestion declines if uncongested vehicle travel increases.
- They exaggerate congestion cost values by using freeflow traffic speeds as a baseline, and excessive values of travel time savings.
- They ignore or underestimate generated traffic and induced travel impacts, including increased downstream congestion, traffic accidents, energy consumption, pollution emissions, and dispersed development patterns.
- They ignore the negative impacts that wider roads and increased vehicle traffic has on non-motorized travel.
- They overlook and undervalue alternative congestion reduction strategies (improvements to alternative modes, transport pricing reforms and smart growth policies) by ignoring the additional benefits they provide.

These omissions and biases favor mobility over accessibility and roadway expansion over other congestion reduction options. More comprehensive and objective analysis indicates that traffic congestion is actually a moderate transport cost overall – larger than some but smaller than others – and roadway expansion is generally less effective and beneficial overall than other congestion reduction strategies.

Chronic traffic congestion can be considered a symptom of more fundamental transport system problems, such as inadequate mobility options that force people to drive for every trip, underpricing, and dispersed land use patterns that increase travel distances. Pricing distortions, including underpriced road, parking, fuel and vehicle insurance, results in economically excessive vehicle travel. Under such circumstances, roadway expansion does little to reduce long term congestion and increases other transport problems.

Efficiency requires that consumers bear the costs they impose unless subsidies are specifically justified. Despite the high priority congestion receives in the transport planning process, there appears to be little willingness-to-pay for congestion reductions either through major roadway expansions or through road tolls and congestion pricing, indicating that motorists do not really consider it a major problem. Inflation-adjusted road user payments through fuel taxes and tolls have declined substantially during the last decade due to public opposition to such user fees.

Although conventional analyses often conclude that roadway expansion projects are cost effective, user toll revenues are seldom sufficient to finance major highway expansion. Financing highway expansion using other funding sources is economically inefficient and unfair because it forces people who don't use the added capacity to subsidize the costs of people who do.

Excessive estimates of congestion costs and congestion reduction benefits tend to contradict transport equity objectives: they favor motorists over non-motorists and reduce the quality of transport options available to people who are physically, economically and socially disadvantaged. Congestion reduction strategies can be designed to support transport equity objectives by improving affordable modes, progressive pricing, and more affordable housing in accessible, multi-modal locations.

Other congestion reduction strategies tend to provide a broader range of benefits. Improving non-motorized modes (particularly high quality public transit), pricing reforms and smart growth development polices reduce traffic congestion and provide other important benefits including parking cost savings, improved safety, energy conservation, emission reductions, consumer savings, improved mobility options for non-drivers, support for land use planning objectives, and improved public fitness and health. These strategies do not necessarily eliminate congestion, in fact, they may increase congestion intensity, but they can significantly reduce per capita congestion costs.

Various trends are increasing the importance of comprehensive congestion analysis. In most developed countries, vehicle travel demand is peaking while demand for travel by alternative modes is increasing: many travelers would prefer to drive less and rely more on other modes, provided they are convenient, comfortable and affordable. Roadway systems are mature, expansion is costly and provides little marginal benefit. When all impacts and objectives are considered, roadway expansion is generally less cost effective than other congestion reduction strategies.

Comprehensive congestion analysis is particularly important in developing countries where vehicle travel is growing rapidly. Although many countries are at a point in their development in which travel demand is growing and roadway improvements are cost effective, it is important to use comprehensive analysis when evaluating urban congestion reduction options. A combination of alternative mode improvements, pricing reforms and smart growth policies will be more cost effective, beneficial and equitable than expanding unpriced urban roadways.

This is not to suggest that driving is bad or that highways should never be improved. However, when all impacts and options are considered, highway expansion is significantly more costly than advocates claim and provides less overall benefit than many alternative policies and programs. It is important that decision makers and the general public understand the omissions and biases.

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