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Smart Congestion Relief

Comprehensive Analysis Of Traffic Congestion Costs and Congestion Reduction Benefits

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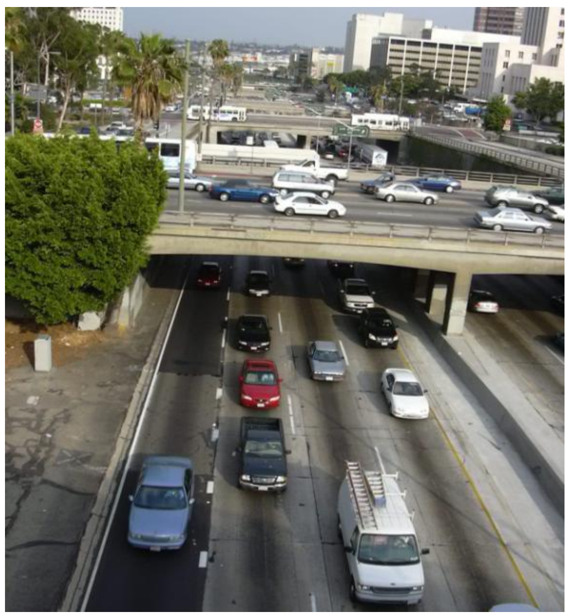

Abstract
This report examines the methods used to evaluate traffic congestion costs and the benefits of various congestion reduction strategies. It describes various biases in current congestion evaluation practices. It develops a more comprehensive evaluation framework which is applied to four congestion 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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Executive Summary

Traffic congestion refers to incremental delay and vehicle operating costs caused by interactions among vehicles, particularly as traffic volumes approach roadway capacity. Conventional planning tends to consider traffic congestion a major problem and congestion reduction an important planning objective. It uses various methods to evaluate congestion such as roadway level-of-service and monetized congestion costs. These methods have significant weaknesses:

- They reflect *mobility-based* planning which assumes that mobility is an end in itself rather than a way to achieve accessibility. They tend to overlook impacts on other forms of access, such as the tendency of wider roads and faster vehicle traffic to degrade non-motorized conditions and stimulate sprawl.
- 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 the monetized value of congestion by using unrealistic baseline speeds and travel time costs. Commonly-cited congestion cost estimates, such as those published by the Texas Transportation Institute, represent the higher range of congestion costs; more realistic estimates based on economic principles are much lower.
- 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 often overlook alternative congestion reduction strategies, such as improvements to alternative modes, transport pricing reforms, and smart growth policies when evaluating potential solutions to congestion problems.
- They undervalue alternative congestion reduction strategies by ignoring their co-benefits.

These omissions and biases tend to exaggerate the benefits of roadway expansion and undervalue other transport system improvements, including improvement to alternative modes, transportation demand management strategies such as pricing reforms, and smart growth land use policies. More comprehensive analysis is needed to identify truly optimal policies and projects. Excessive estimates of congestion costs and congestion reduction benefits tend to contradict other planning objectives: they favor motorists over non-motorists and reduce overall transport system efficiency.

Congestion is a modest cost overall. For example, the Texas Transportation Institute (TTI) estimates that in 2010 U.S. congestion caused 4.8 billion person-hours of delay and wasted 1.9 billion gallons of fuel, estimated at $101 billion total costs, which averages 15.5 hours, 6.2 gallons and $327 per capita. (These are upper bound estimates. Applying more realistic baseline and unit time costs would reduce estimated costs to approximately $110 per capita). This compares with about $4,000 in vehicle costs, $1,500 in crash damages, more than $1,000 in vehicle parking costs, $400 in roadway costs and $357 in environmental costs per capita.

Automobile dependency and sprawl can increase transport costs far more than traffic congestion. For example, according to TTI analysis, Washington DC *automobile commuters* experienced 74 average annual hours of delay, but since that region has only 43% auto commute mode share this averages just 32 hours per *commuter overall*. In contrast, Houston *automobile commuters* experience 57 annual hours of delay, but since it has a 88% auto mode share this averages 50 hours per *commuter overall*, much

higher than Washington DC. Cities with high quality public transit, such as New York, Boston and San Francisco, rate much better when congestion is measured per commuter rather than automobile commuter due to their low auto mode shares.

Similarly, in the largest U.S. cities congestion adds 34 annual hours and 16.5 gallons of fuel per commuter, while residents of automobile-dependent regions spend an estimated 104 additional hours and 183 additional gallons of fuel compared with more compact, multi-modal regions, plus increases various other costs. This suggests that policies which stimulate sprawl impose more than three times the total cost of traffic congestion.

There are many possible ways to reduce congestion, including roadway expansion, improving alternative modes, pricing reforms and smart growth development policies. Table ES-1 summarizes their impacts, including their effectiveness at reducing traffic congestion and their co-benefits, and the degree that they are considered in traffic modeling and current transport planning.

Table ES-1 **Congestion Reduction Strategies**

	Roadway Expansion	Improve Alternative Modes	Pricing Reforms	Smart Growth
Congestion impacts	Reduces congestion in the short-run, but this declines over time due to generated traffic	Reduces but does not eliminate congestion	Can significantly reduce congestion	May increase local congestion intensity but reduces per capita congestion costs
Indirect costs and benefits	By inducing additional vehicle travel and sprawl it tends to increase indirect costs. Minimal co-benefits. Small energy savings and emission reductions.	Numerous co-benefits. Parking savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Revenues, parking savings, traffic safety, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Parking savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.
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. Can generally evaluate congestion pricing but are less accurate for other reforms such as parking pricing	Many models underestimate the ability of smart growth strategies to reduce vehicle travel and therefore congestion
Consideration in current planning	Commonly considered and funded	Sometimes considered and funded, particularly in large cities	Sometimes considered but seldom implemented	Not generally considered a congestion reduction strategy

Different congestion reduction strategies have different types of impacts and benefits. Current traffic models and planning practices tend to ignore many of these impacts.

Roadway expansion often provides little long-term congestion reductions due to latent demand (additional vehicle travel that people would make if congestion delays are reduced). Roadway expansion provides minimal co-benefits, besides congestion reductions, and often imposes costs, including creating barriers to walking and cycling, degrading neighborhood livability, and stimulating sprawl. Improving travel options (particularly grade-separated public transit), transport pricing reforms, and smart growth development policies tends to provide more modest short term congestion reductions, as measured using roadway level-of-service or a travel time index, but by reducing congestion equilibrium and total vehicle travel they can reduce per capita congestion costs, particularly over the long run, and provide many other benefits. Current traffic modeling and transport planning practices tend to exaggerate roadway expansion benefits and undervalue the full benefits of other congestion reduction strategies.

How High Quality Transit and High Occupant Vehicles Can Reduce Congestion Equilibrium
Urban traffic congestion tends to maintain equilibrium. If congestion increases travelers avoid it by changing route, schedule, destination and mode, and if it declines they take additional peak-period vehicle trips until congestion again increases to discourage additional trips. Reducing the point of equilibrium is the only way to reduce long-term congestion. The quality of transport options available affects this point of equilibrium.

If alternatives are inferior travelers will drive even if congestion is severe. If alternatives are attractive, some drivers will 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. Even small shifts can significantly reduce congestion. For example, a 5% reduction from 2,000 to 1,900 vehicles per lane-hour typically increases traffic speeds from 40 to 50 mph and eliminates stop-and-go conditions. Congestion does not disappear but is less severe. Several studies indicate that faster transit service increases parallel highway traffic speeds.

More comprehensive evaluation tends to reduce the priority given congestion compared with other impacts, reduce the justification for roadway expansion, and increase support for other congestion reduction strategies that provide additional benefits.

Various trends are increasing the importance of comprehensive congestion analysis. In many countries vehicle travel demand is peaking while demand for alternatives 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.

This is not to suggest that driving is bad or that roadways should never be improved. However, when all impacts and options are considered, highway expansion is less effective and more costly, and alternative congestion reduction strategies tend to be overall better, than indicated by conventional evaluation methods. It is important that people involved in transport planning understand these issues when considering solutions to congestion problems.

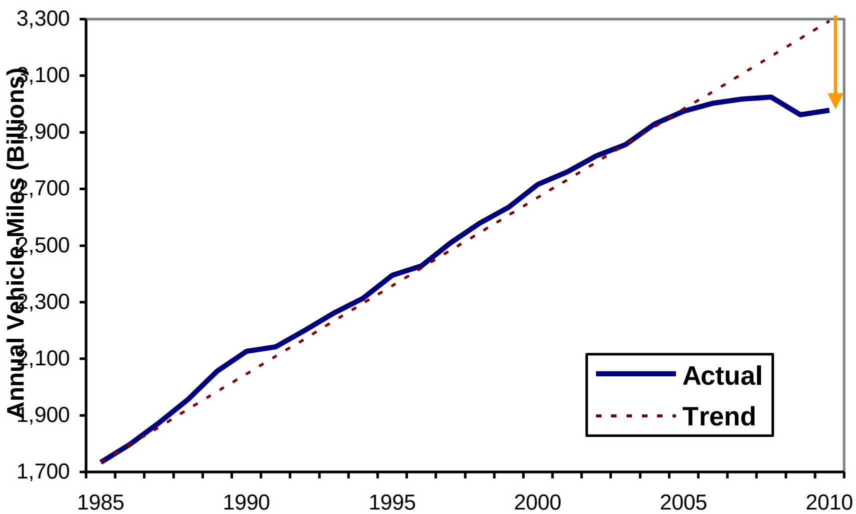
Introduction

Traffic congestion refers to incremental delays and vehicle operating costs caused by interactions among vehicles, particularly as traffic volumes approach roadway capacity. It is understandable that many people consider congestion a significant problem: typical urban residents spend more than ten hours a week driving of which 10-30% (one to three hours) occurs in congested conditions. Traffic congestion reduces travel speeds, creates uncertainly and requires more driver effort. It is a major source of frustration for busy, productive people. Motorists often feel that reducing congestion would make their lives more efficient and satisfied. As a result, conventional planning considers congestion a major problem and congestion reduction a dominant planning objective.

However, there are good reasons to question the ways that conventional planning practices defines congestion problems and evaluates potential solutions. Congestion is one of many transport costs, larger than some but smaller than others, and roadway expansion is often ineffective at reducing congestion and exacerbates other problems. More comprehensive analysis can identify more efficient and equitable solutions.

This is a timely issue. Motor vehicle travel grew steadily during the Twentieth Century so it made sense to devote significant resources to roadway expansion. During that period there was little risk of overbuilding since any additional capacity would eventually fill. However, vehicle travel has peaked in most developed countries (Figure 1) and current demographic and economic trends are shifting demand to alternative modes (Litman 2006; Millard-Ball and Schipper 2010; OECD 2012). A new planning paradigm emphasizes the value of more comprehensive analysis to better serve future travel demands.

Figure 1 **U.S. Annual Vehicles Mileage Trends** (USDOT 2010)



Vehicle travel peaked about 2006, while demand for other modes (walking, cycling and public transport) is growing. It is rational to shift resources previously devoted to roadway expansion to support other types of transport system improvements.

This report discusses these issues. It critically examines congestion evaluation practices, identifies omissions and biases, and provides guidance for more comprehensive and objective analysis. It evaluates potential congestion reduction strategies including roadway expansion, improvements to alternative modes, pricing reforms, TDM and smart growth policies. Much of this analysis also applies to parking congestion analysis.

The New Planning Paradigm

Transportation planning is undergoing a *paradigm shift* (a change in the way problems are defined and solutions evaluated) which affects how traffic congestion is evaluated. Conventional planning is *mobility-based*, which assumes that the goal is to maximize travel speed and distance. But mobility is seldom an end in itself, the ultimate goal of most travel activity is *accessibility* (or just *access*) which refers to people's ability to reach desired services and activities (CTS 2010). Various factors affect accessibility including the quality of transport options available (walking, cycling, public transport, automobile, etc.), transport network connectivity and affordability, the geographic distribution of activities, and mobility substitutes such as telecommunications and delivery services. Table 1 compares these two perspectives.

Table 1 **Transport Planning Paradigms** (Litman 2003)

	Mobility	Accessibility
Definition of *Transportation*	Movement of people and goods	Ability to obtain goods, services and activities
Measurement units	Person-miles and ton-miles	Accessibility index, generalized costs
Modes considered	Automobile, truck and transit	Multiple modes and transport services
Common indicators	Vehicle travel speeds, roadway Level of Service, cost per person-mile	Quality of available transport options. Proximity of destinations. Per capita transport costs.
Consideration of land use	Recognizes that land use can affect travel choice	Recognizes that land use has major impacts on transportation
Favored transport improvements	Transportation system improvements that increase capacity, speeds and safety	Projects and management strategies that increase transport system efficiency

This table compares three common perspectives used to measure transportation.

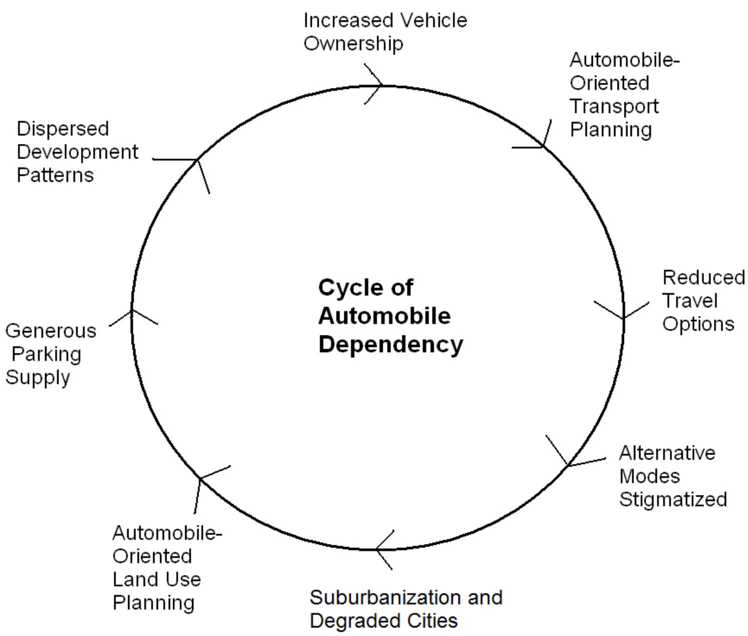
The new paradigm has significant implications for congestion evaluation. Mobility-based planning evaluates transport system performance primarily based on vehicle travel speeds and costs and so considers congestion a significant problem. Accessibility-based planning recognizes that traffic speeds are just one of many factors affecting overall accessibility, and that planning decisions often involve trade-offs between different forms of access. For example, wider roads and higher traffic speeds tend to improve motor vehicle access but create barriers to non-motorized travel, and since most public transit trips include walking and cycling links, they can reduce transit access. Similarly, a location along a major highway tends to provide good automobile access but poor access by other modes, while a more central location tends to provide good walking, cycling and public transport access, but poorer automobile access due to traffic and parking congestion.

Mobility-based planning favors faster modes over slower modes, and so considers walking inefficient. Accessibility-based planning recognizes the important and unique role that walking plays in an efficient and equitable transport system, because it is universal and affordable, and to access and connect other modes. For example, most transit trips include walking links, and motorists walk from parked cars to destinations. As a result, improving walkability helps improve public transit and automobile access.

Empirical research indicates that proximity tends to be more important than travel speed in overall accessibility. For example, analysis of the number of destinations that can be reached within a given travel time by mode (automobile and transit) and purpose (work and non-work trips) for about 30 US metropolitan areas indicates that increased proximity from more compact and centralized development is about ten times more influential than vehicle traffic speed on a metropolitan area's overall accessibility (Levine, et al. 2012).

This suggests that mobility-based planning which evaluates transport system performance based on travel speeds, congestion delay and roadway level-of-service favors transport and land use planning decisions that reduce overall accessibility and increase total travel costs. Mobility-based analysis often results in "predict and provide" planning, in which roads are expanded and parking requirements increased in anticipation of growing demand. Such automobile-oriented planning reduces access by other modes, which induces additional vehicle traffic, leading to more roadway expansion and dispersed development. The result is a self-reinforcing cycle of automobile dependency and sprawl, as illustrated in Figure 2. Accessibility-based analysis recognizes ways that such planning practices can reduce overall accessibility and increase transport costs.

Figure 2 **Cycle of Automobile Dependency and Sprawl**



This figure illustrates the self-reinforcing cycle of increased automobile dependency and sprawl.

Conventional Congestion Evaluation Practices

This section describes conventional congestion cost evaluation practices and how they can be more comprehensive and responsive to community needs.

Quantifying and Monetizing Congestion Costs

Various methods are used to *quantify* (measure) and *monetize* (measure in monetary units) congestion costs and congestion reduction benefits (Grant-Muller and Laird 2007; "Congestion Costs," Litman 2009). Conventional planning often uses roadway level-of-service (LOS) to evaluate transport system performance. Roadway LOS indicates the degree to which peak-period traffic volumes fills a road's capacity (described as a *volume to capacity ratio*, or *V/C*), and therefore congestion intensity, rated from A (best) to F (worst), similar to school report cards. This is quantified in the following way:

1. Measure peak and off-peak traffic speeds on roads being analyzed. If such data are unavailable, estimate speeds using volume-to-capacity-ratios summarized in Table 2.

Table 2 **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+

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

2. Calculate traffic speed differences between peak-period and baseline conditions 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 3. For example, a 1.3 TTR indicates that trips which take 20 minutes off-peak take 26 minutes during peak periods.

3. Multiple additional travel time by unit cost values (typically 30-50% of average wages) to monetize congestion delay costs. Use vehicle operating cost models to estimate the additional fuel consumption and pollution emissions, and multiply these by fuel and emission times unit costs (dollars per gallon of fuel and ton of emissions) to calculate monetized vehicle costs.

4. Use these estimates to predict the time and economic savings of various proposed congestion reduction strategies, such as roadway expansion.

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

Table 3 summarizes various congestion indicators. The right column indicates whether each is multi-modal, that is, whether they consider delays to just motorists or to all forms of travel.

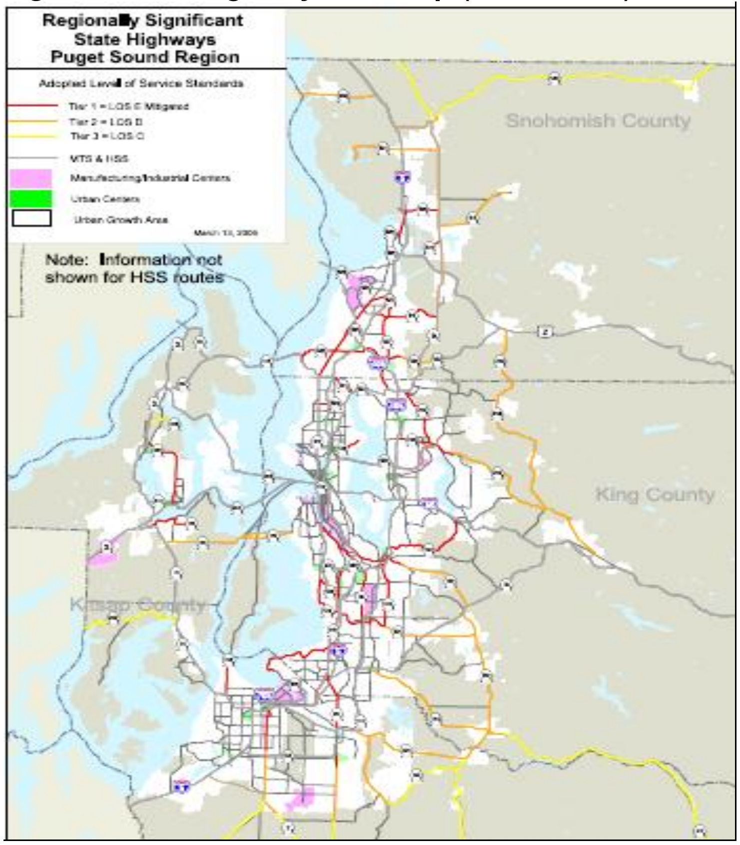
Table 3 **Roadway Congestion Indicators** ("Congestion Costs" Litman 2009)

Indicator	Description	Multi-Modal
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.

These congestion impacts are presented in various ways. Figure 3 shows a typical planning map which indicates the highways that are predicted to have excessive traffic congestion (below level-of-service C) in the Puget Sound region. Similar analysis is used to evaluate how a particular development is expected to affect traffic flow on nearby streets.

Figure 3 **Highway LOS Map** (PSRC 2008)



This typical transport planning map indicates the roadways projected 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 system improvement options.

In recent years transportation professionals have started to develop better tools for evaluating overall accessibility (CTS 2010; Litman 2008 and 2012) and more multi-modal performance indicators (Dowling, et al. 2008) which allow more comprehensive evaluation of transportation problems and improvement strategies. However, these are new and not widely used, so in practice, most communities continue to evaluate transport system performance based primarily on motor vehicle travel speeds and delays.

Various studies have estimated monetized congestion costs for particular areas:

- 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.
- 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) estimated 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.

- Transport Canada research calculated congestion costs (the value of excess delay, fuel use and pollution emissions) using various roadway speed baselines (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 4 summarizes the results.

Table 4 **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 (2000 CA$ millions annual).

These study results vary significantly depending on methods and assumptions. A key factor is the baseline used to calculate incremental delays. Some studies, such as the Texas Transportation Institute's *Urban Mobility Report*, use free-flowing traffic (LOS A), which is generally not economically optimal due to the high costs of urban roadway expansion. Others use a more realistic baseline of LOS C/D (45-55 mph on highways), since that maximizes traffic throughput and fuel efficiency, and probably reflects consumers' willingness-to-pay for faster travel (iTrans 2006). Estimates based on free-flow speed baselines are typically three to five times higher than those using economically optimal baselines.

Another key factor is the travel time unit costs used. Most studies use 30-60% of average wages (Table 5), implying that average motorists are willingly to pay 10-20¢ per minute saved. Although some motorists are willing to pay tolls of this magnitude for time savings, many are not (Prozzi, et al. 2009; Williams-Derry 2011).

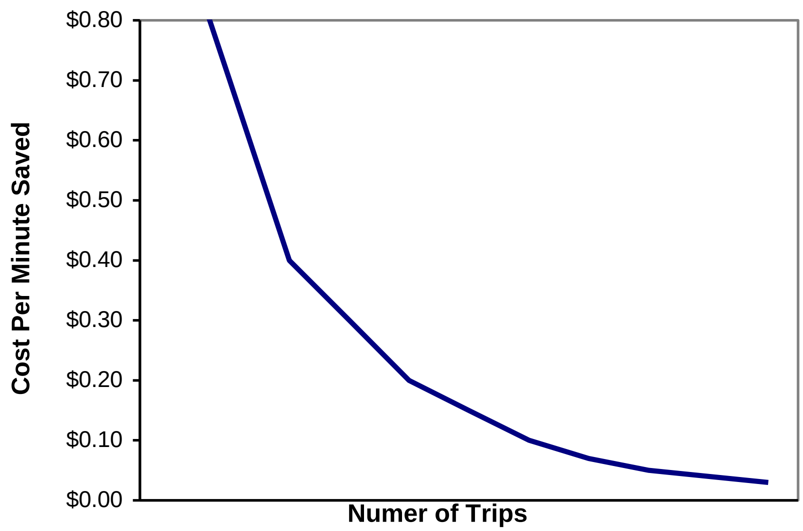
Table 5 **Plausible Ranges for Values of Travel Time Savings** (USDOT 2011)

Category	Surface Modes (except High-Speed Rail)	Air and High-Speed Rail
	Relative to wages (2011 U.S. dollars)	Relative to wages (2011 U.S. dollars)
Local Travel -		
Personal	35% - 60% ($12.00)	--
Business	80% - 120% ($22.90)	--
Average	($12.50)	
Intercity Travel-		
Personal	60% - 90% ($16.70)	60% - 90% ($31.90)
Business	80% - 120% ($22.90)	80% - 120% ($57.20)
	($18.00)	($42.10)

Congestion reduction benefits are often monetized using travel time unit costs of 30-60% of average wages. This is higher than many motorists are actually willing to pay.

This makes sense since these values reflect *average* cost values. The demand curve for faster vehicle travel typically includes a few high-value trips and many lower-value trips, as illustrated in Figure 4. Delivery and service vehicles, transit buses, business travelers, and travelers with urgent errands are often willingly pay more than 20¢ per minute for reduced delay, but these are generally a minority of total vehicles. Without a rationing system, such as road tolls, expanded roadways tend to fill with lower-value vehicle travel, which is worth less than roadway expansion costs. For example, society may spend 20¢ to save a minute of travel that users only value at 10¢.

Figure 4 **Demand Curve for Faster Vehicle Travel**



The demand curve for faster travel usually includes a minority of higher-value trips that have willingness-to-pay above roadway expansion costs, and a large number of lower-value trips for which motorists are unwilling to pay incremental costs. In such cases, roadway expansion is inefficient because the additional capacity will fill with trips that have willingness-to-pay below incremental costs, causing the higher value trips to again be slowed by congestion.

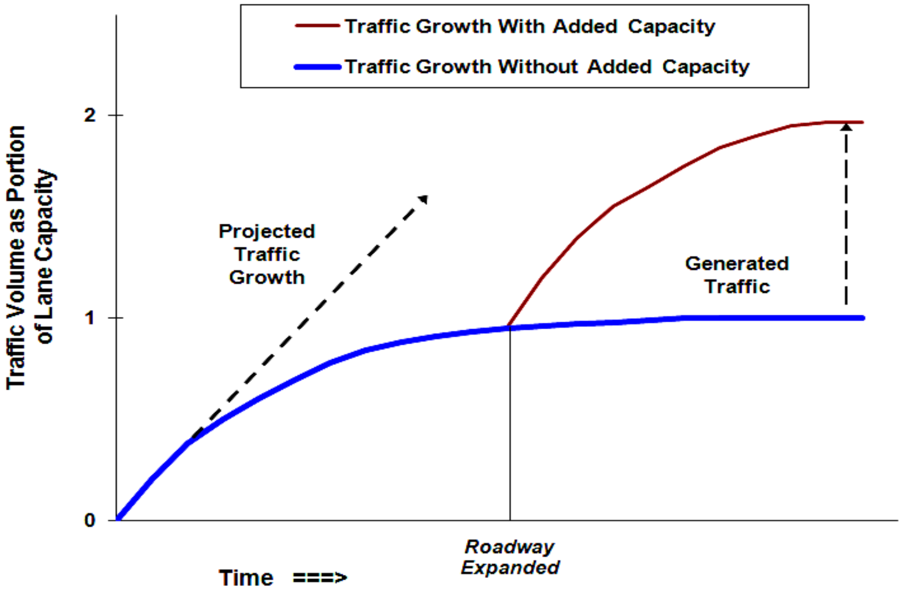
Described differently, conventional planning defines vehicle travel demand based on underpriced driving, equivalent to asking how many people would choose to eat at an expensive restaurant if they were only required to pay the tip. This exaggerates congestion costs and leads to economically excessive road supply (Vickrey 1992).

Congestion Equilibrium and Generated Traffic

Another factor that complicates congestion evaluation is the tendency of congestion to maintain equilibrium: it increases until delays constrain further peak-period vehicle trips, causing travelers to shift travel times, routes and mode, and reduce trips (Cervero 2003; Litman 2001). 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.

Generated traffic refers to the additional vehicle traffic that often results when roadway capacity is expanded. This can result from shifts in travel time, route, mode, destination and trip frequency. Figure 5 illustrates this effect. *Induced travel* refers to absolute increases in vehicle travel that results from expanded roadways, which results from shifts in travel mode, destination, trip frequency, and sometimes route, but not from time shifts.

Figure 5 **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 the following implications for congestion evaluation (Litman 2001):

- Congestion seldom gets as severe as predicted by extrapolating past trends. As traffic congestion increases it discourages further peak-period traffic growth, leading to equilibrium. Doing nothing seldom actually results in traffic gridlock (conditions where traffic becomes totally stuck for hours) as people sometimes fear.
- Roadway expansion provides less long-term congestion reduction benefit than often predicted, particularly because the additional capacity is filled with generated traffic.
- Roadway expansion induces additional vehicle travel which increases various 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.

Funding and Planning Bias

Another major transport planning bias is that a major portion of transportation funds are dedicated to roadway improvements and cannot be used for other types of accessibility improvements even if they are more cost effective overall.

For example, in the U.S., federal and state funds are available to finance highways, but in many cases the same funds cannot be used or have much higher match requirements (state, regional or local governments must pay a much larger portion of costs) to finance improvements to other modes or transportation demand management programs, such as commute trip reduction services.

Similarly, most regional and local governments require developers to provide generous parking supply which subsidizes automobile ownership and use. In most cases it would be difficult for them to use the same resources to support other modes or parking management strategies.

In addition, the roadway planning process is well established and coordinated by government agencies and professional organizations; other types of transportation improvements, such as non-motorized improvements, transportation demand management programs, and smart growth policies that improve land use accessibility, are not as well established or coordinated.

As a result of these biases, decision-makers are encouraged to define transportation problems in terms of inadequate roadway capacity, since there are established funds and institutions for expanding roads and parking facilities, rather than defining problems as inefficient management of existing capacity, inadequate transport options, roadway and parking facility underpricing, or inaccessible land development which increases the distances that people must travel to reach destinations. A community or developer that wants to implement other types of transportation improvements, such as improving sidewalks and bike lanes, establishing bus-lanes, or implementing pricing reforms and other transportation demand management strategies, will receive less support and face greater obstacles.

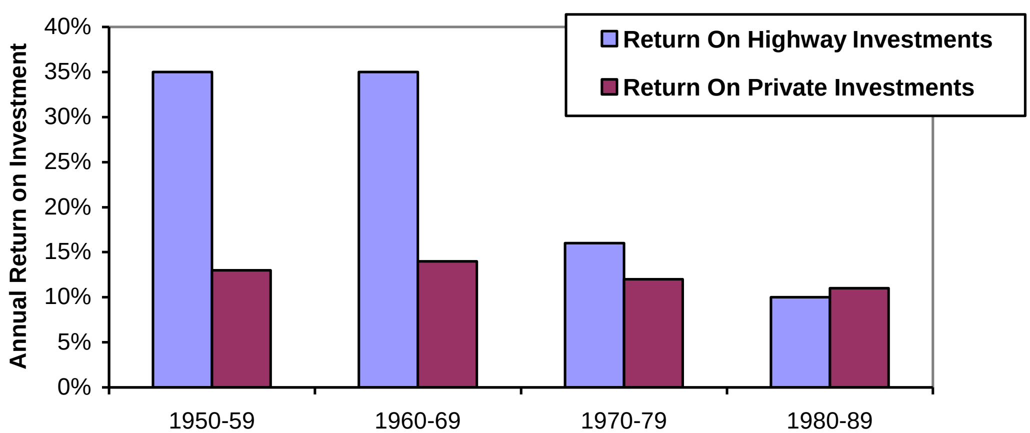
Economic Development Impacts

Highway project proponents often claim that congestion imposes large economic costs and that roadway expansion supports economic development, but in fact, the relationship between traffic congestion intensity (such as roadway LOS) and economic development (such as per capita GDP, property values and wage rates) is generally *positive*. This does not mean that increasing congestion increases economic development, but it shows that traffic congestion is overall a minor cost that is usually offset by the economic efficiency gains of the increases in accessibility provided by more compact and multi-modal development. For example, a business located in a city center has far more potential employees, partners and customers available within a half-hour trip, despite traffic congestion. Of course, reducing traffic congestion reduces costs and so should marginally increase economic productivity.

Other congestion reduction strategies, such as efficient road pricing, is likely to increase economic productivity by favoring higher value trips and more efficient modes. Roadway expansion is likely to provide smaller or negative productivity impacts because most of the additional capacity tends to be filled with personal travel, for example, allowing commuters to live further from work and shoppers to visit more stores within their travel time budgets. Roadway expansion does not increase productivity and if it induces additional vehicle travel it will increase external costs.

Economic returns on highway expansion investments are modest and declining (Boarnet and Haughwout 2000; Shirley and Winston 2004). Figure 6 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 6 **Annual Rate of Return** (Nadri and Mamuneas 1996)

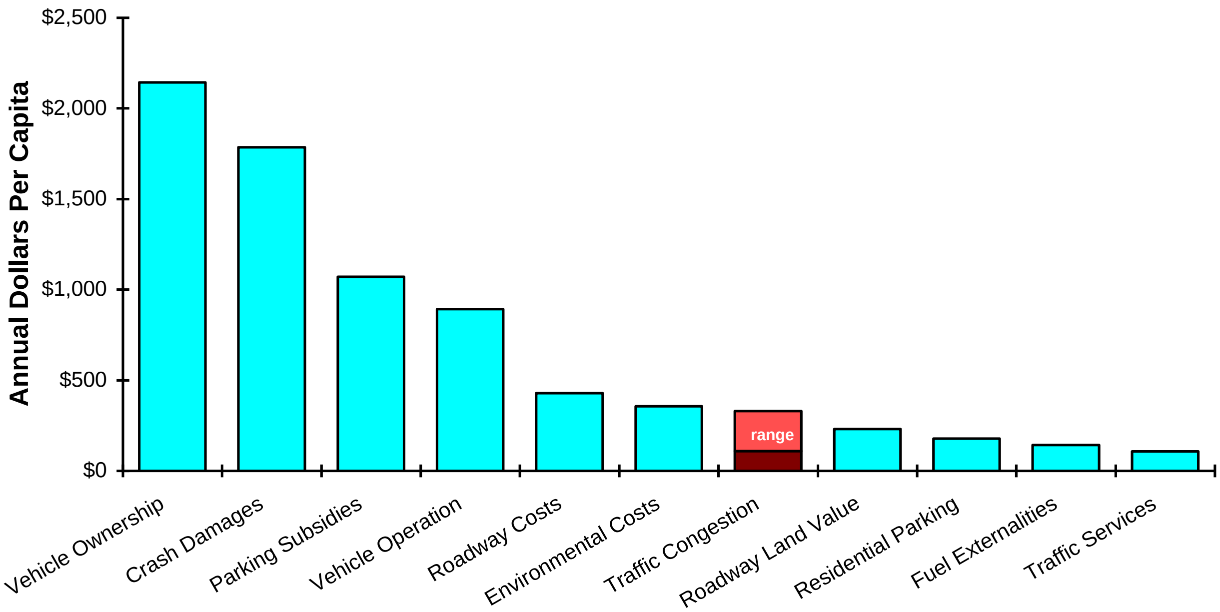


During the 1950s-70s, highway expenditures provided a high return on investment, but this has declined over time as economic theory predicts.

Congestion Compared With Other Costs

It is helpful to compare congestion with other transport costs. Several studies monetize transportation costs (CE, INFRAS, ISI 2011; Delucchi 2005; Litman 2009; TC 2005-08). Congestion costs are moderate overall, larger than some but smaller than others. For example, the Texas Transportation Institute (TTI) estimates that in 2010 U.S. congestion caused 4.8 billion person-hours of delay and 1.9 billion gallons of additional fuel consumption, worth $101 billion in total, which averages 15.5 hours, 6.2 gallons and $327 per capita. These are upper bound cost estimates because they use a free-flow baseline and a relatively high $16.30 per hour delay costs. Applying more realistic baseline and unit time costs could reduce this estimate to approximately $110 (Litman 2013). This compares with about $4,000 in vehicle costs, $1,500 in crash damages, $1,000 in parking costs, $400 in roadway costs, and $357 in environmental costs per capita, as illustrated in Figure 7.

Figure 7 **Costs Ranked by Magnitude** (Litman 2009)



Congestion costs are estimated to range between $110 and $330 annual per capita, depending analysis methods. Even using higher-range estimates they are moderate compared with other transport costs.

Using TTI estimates, about 90% of personal travel is by automobile, about 20% of this occurs under urban-peak conditions, and about half of urban-peak travel occurs on congested roads, and travel under these conditions requires about 20% more time than offpeak (a travel time index of 1.2), which indicates that congestion increases total travel time and fuel costs less than 2% (0.9 * 0.2 * 0.5 * 0.2 = 0.018).

It is also useful to compare congestion with the effects of other planning factors that affect travel time and vehicle operating costs, such as automobile commute mode share and urban sprawl. For example, the TTI (2011) estimates that in large U.S. cities congestion caused an average of 52 hours of delay and 25 gallons of fuel consumption per automobile commuter. Automobile commute mode shares vary significantly between cities, due to differences the quality of alternative modes. For example, Washington DC *automobile commuters* experience the greatest congestion delays, 74 annual hours, but since it has only 43% auto commute mode share this averages just 32 hours per *commuter overall*. In contrast, Houston *automobile commuters* experience 57 annual hours of delay, but since it has a 88% auto mode share this averages 50 hours per *commuter overall*, much higher than Washington DC. Table 6 compares automobile and total commuter congestion delays. Cities with high quality public transit, such as New York, Boston and San Francisco, rate much better when congestion is measured per commuter rather than automobile commuter due to their low auto mode shares.

Table 6 **Automobile Commute Mode Share**

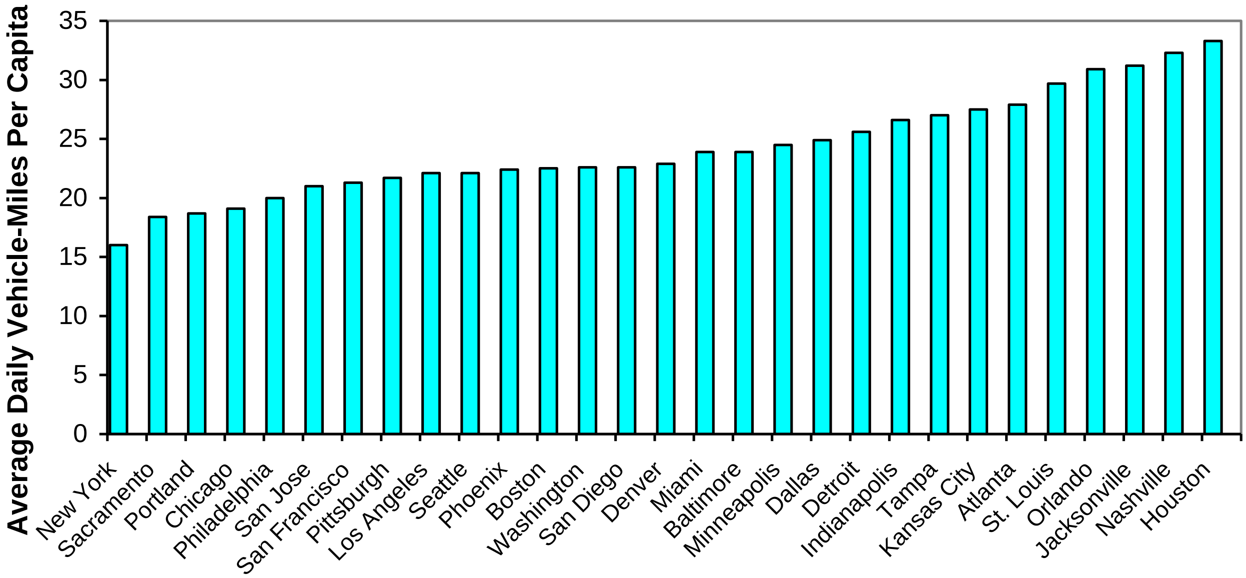
City	Delay Hours Per Auto Commuter (ranking)	Auto Mode Share	Delay Hours Per Commuter
Sources	TTI, 2011	ACS, 2009	Calculated
New York	54 (4)	28.7	15.5
Boston	47 (6)	44.7	21.0
San Francisco	50 (5)	46.4	23.2
Philadelphia	42 (9)	59.8	25.1
Detroit	33 (12)	82.8	27.3
Seattle	44 (8)	62.5	27.5
Phoenix	35 (11)	88	30.8
Washington D.C.	74 (1)	43.1	31.9
San Diego	38 (10)	84.9	32.3
Dallas	45 (7)	89.1	40.1
Los Angeles	54 (4)	77.6	41.9
Chicago	71 (2)	60.7	43.1
Houston	57 (3)	88.4	50.4

Automobile commute mode share, and therefore the portion of commuters who face traffic congestion, varies significantly between urban regions. (ACS = American Community Survey)

Land use planning decisions affect the amount that residents drive in a community and therefore their travel time and fuel consumption. Average per capita daily vehicle-travel varies significantly between urban regions, as illustrated in Figure 8, from less than 20 *average daily vehicle miles* (ADVM) in compact regions such as New York, Sacramento and Portland, to more than 30 in sprawled regions such as Jacksonville, Nashville and Houston. Similar variations occur between neighborhoods within urban regions.

As mentioned previously, the TTI estimates that in the largest U.S. cities congestion adds 52 annual hours and 25 gallons of fuel per automobile commuter or about 34 annual hours and 16.5 gallons of fuel per commuter, based on 66% automobile mode share (the average of these cities). In comparison, the ten additional daily vehicle-miles driven in automobile-dependent, sprawled regions compared with more compact, multi-modal regions requires 104 additional hours and 183 additional gallons of fuel annually (assuming 35 miles per hour and 20 miles per gallon averages), and increases other costs including road and parking facilities, accidents, pollution damages, and reduced public fitness and health. This suggests that sprawl imposes about three times as much incremental travel time and fuel consumption as traffic congestion.

Figure 8 **Vehicle Mileage in Major U.S. Urban Regions** (FHWA 2008)



Per capita vehicle mileage varies significantly between U.S. urban regions.

Does this additional automobile travel time have the same costs as congestion delays? Most people enjoy a certain amount of travel (Mokhtarian 2005), and travel time unit costs tend to lower in uncongested than congested conditions ("Travel Time Costs," Litman 2009). However, dispersed, automobile-oriented development patterns which significantly increase the amount that residents must drive for commuting, errands and chauffeuring non-drivers certainly does impose significant time and fuel costs, if only because it tends to increase their congestion delays. To the degree that some people want to live in more compact communities, drive less and rely more on alternative modes, but cannot due to inadequate housing and transport options, transport and land use planning that reduces sprawl, and improves walking, cycling and public transport conditions can provide benefits comparable to congestion reductions. For example, a planning strategy that reduces residents total vehicle travel by 10% is probably worth more than a strategy that reduces congestion 10%, since the first provides greater total time and fuel savings.

This comparison between congestion costs and total transportation costs has important implications. Conventional transport planning evaluation gives considerable attention to congestion costs, using performance indicators such as roadway level-of-service and congestion costs, while ignoring the incremental costs of increased driving. This favors congestion reduction over other planning objectives and can result in the implementation of congestion reduction strategies that stimulate automobile dependency and sprawl, since their incremental costs are generally ignored.

Summary of Congestion Evaluation Criticisms and Reforms

This analysis indicates that conventional congestion evaluation practices have various biases that can lead to suboptimal planning decisions. Other researchers have reached similar conclusions (Bertini 2005; Bevilacqua 2012; Cortright 2010; Dumbaugh 2012; Litman 2013). Table 7 summarizes these biases, their impacts on planning decisions, and corrections for more comprehensive and objective congestion costing.

Table 7 Congestion Costing Biases, Impacts and Corrections

Type of Bias	Planning Impacts	Corrections
Mobility-based planning measures congestion intensity rather than total congestion costs	Favors roadway expansion over other transport improvements	Measure overall accessibility, including per capita congestion costs
Assumes that compact development increases congestion	Encourage automobile-dependent sprawl over more compact, multi-modal infill development	Recognize that smart growth policies can increase accessibility and reduce congestion costs
Only considers impacts on motorists	Favors driving over other modes	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 congestion equilibrium and the additional costs of induced travel	Exaggerates future congestion problems and roadway expansion benefits	Recognize congestion equilibrium, and account for generated traffic and induced travel costs
Funding and planning biases such as dedicated road funding and minimum parking requirements	Makes road and parking improvements easier to implement than other types of transport improvements	Apply least-cost planning, so transport funds can be used for the most cost-effective solution. Reform minimum parking requirements.
Exaggerated roadway expansion economic productivity gains	Encourages roadway expansion over other transport improvements	Use critical analysis of congestion reduction economic benefits
Considers congestion costs but ignores the incremental costs of increased vehicle travel	Favors roadway expansion over other congestion reduction strategies	Use a comprehensive evaluation framework that considers all objectives and impacts

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

These biases tend to favor mobility over accessibility and automobile travel over other modes. Their cumulative impacts can be large, resulting in significantly more investment in roadway expansion, less investments in alternative modes, and less application of demand management strategies and smart growth policies than is overall optimal.

Comprehensive Evaluation of Congestion Reduction Strategies

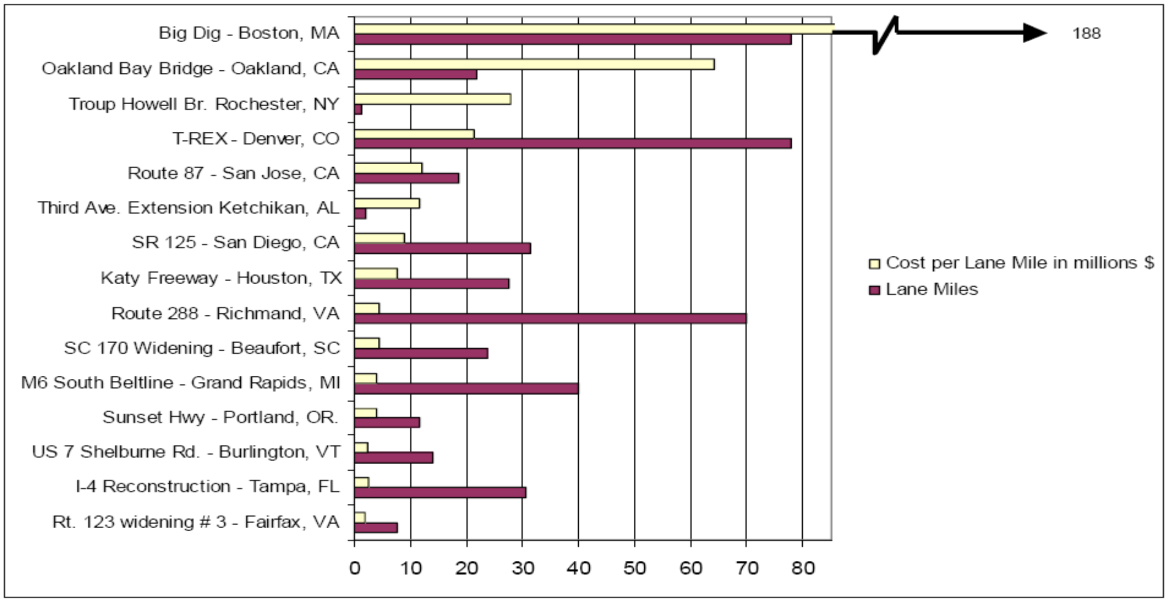
This section evaluates various congestion reduction strategies.

Roadway Capacity Expansion

Roadway capacity expansion can include traffic signal synchronization, automated highway technologies, intersection flyovers, wider and straighter lanes, additional traffic lanes, and entirely new roadways. Conventional planning tends to consider roadway expansion a 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 often costs $10-20 million per lane-mile, including land acquisition, lane pavement and intersection reconstruction costs, as illustrated in Figure 9. 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 9 **Urban Highway Expansion Costs** (WSDOT 2005)



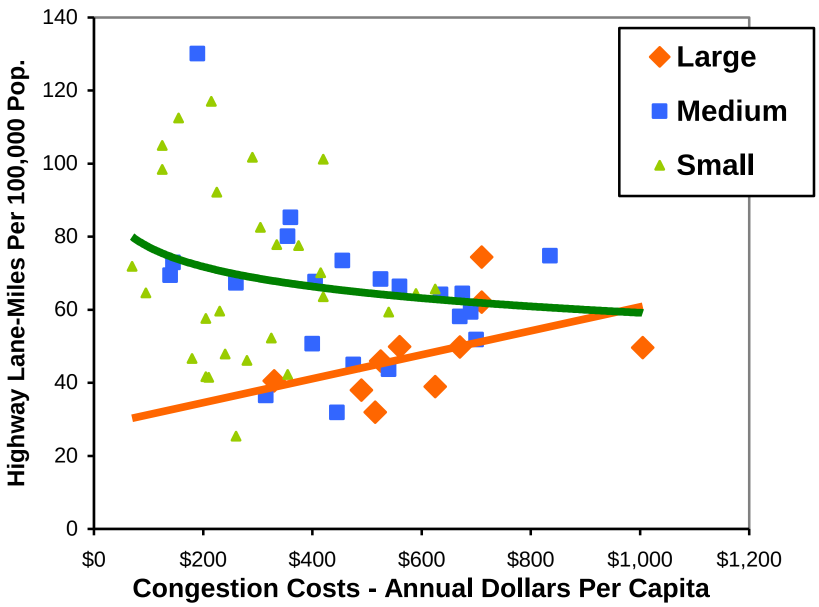
Of 36 highway projects studied by the Washington State Department of Transportation 13 had costs exceeding $10 million per lane-mile. Future projects are likely to have higher unit costs since most jurisdictions have already implemented the cheapest highway projects, and both construction costs and urban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

Given a choice with *value priced* lanes, some motorists will pay tolls of 20-40¢ per mile to for uncongested travel, but when applied to all road users such tolls typically reduce travel demand 20-30% (Spears, Boarnet and Handy 2010). Many recent toll road projects have failed to achieve their traffic volumes and revenue targets (NCHRP 2006; 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 through fuel taxes that 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 cost effective or economically efficient: users only want the additional capacity if it is subsidized. A more efficient approach is to apply congestion pricing (described below) to reduce peak-period traffic volumes to optimal levels (LOS B or C), and only if revenues would finance total project costs should roads be expanded.

Some research indicates that urban regions that expand highway capacity experience less traffic congestion (TTI 2010, p. 15), but these results are biased because most capacity expanding regions are smaller cities with slow growth. Empirical evidence indicates that roadway expansion provides only modest congestion reductions, particularly in large cities. Figure 10 illustrates the relationship between urban highway lane-miles and congestion costs. Considering all cities, congestion declines with more lane-miles but the relationship is weak (green line). Among the ten largest cities (orange diamonds) the relationship is negative (orange line), those with more highways tend to have more congestion, probably because the cities with more highway capacity are more sprawled and automobile dependent.

Figure 10 **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).

Even if roadway capacity can reduce traffic congestion, it is not necessarily cost effective, total incremental costs do not necessarily exceed total incremental benefits, particularly compared with other congestion reduction strategies.

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

Improving alternative modes (walking, cycling, ridesharing, public transport and telework) can reduce traffic congestion, particularly if they offer high quality service (relatively convenient, fast, comfortable and affordable) that attracts discretionary travelers who would otherwise drive. This can result from the following three mechanisms:

1. High-quality transport options, such as grade-separated rail or bus transit, tend to attract discretionary travelers who would otherwise drive, which reduces congestion on parallel roadways (see box below).
2. High quality transit with supportive land use policies can stimulate transit oriented development (TOD) – compact, mixed-use neighborhoods where residents tend to own fewer vehicles and drive less than in more automobile-dependent areas (Arrington and Sloop 2010).
3. High quality transport options can reduce unit travel time costs. Even if alternative modes take more time, many travelers consider their time costs reduced if, for example, transit passengers can relax or be productive, or if walking and cycling substitute for special time spent exercising ("Travel Time Costs" Litman 2009).

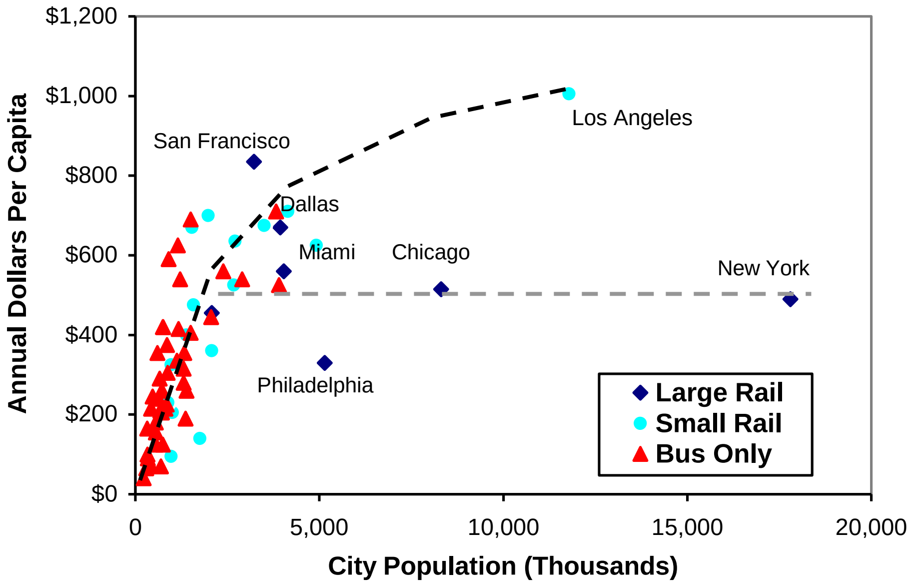
How High Quality Transit and High Occupant Vehicles Can Reduce Congestion Equilibrium
Urban traffic congestion tends to maintain equilibrium. If congestion increases travelers avoid it by changing route, schedule, destination and mode, and if it declines they take additional peak-period vehicle trips until congestion again increases to discourage additional trips. Reducing the point of equilibrium is the only way to reduce long-term congestion. The quality of transport options available affects this point of equilibrium.

If alternatives are inferior travelers will drive even if congestion is severe. If alternatives are attractive, some drivers will 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. Even small shifts can significantly reduce congestion. For example, a 5% reduction from 2,000 to 1,900 vehicles per lane-hour typically increases traffic speeds from 40 to 50 mph and eliminates stop-and-go conditions (Table 3). Congestion does not disappear but is less severe. Several studies indicate that faster transit service increases parallel highway traffic speeds (Vuchic 1999; Lewis and Williams 1999).

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 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 mileage expands, apparently because buses attract fewer motorists, contribute to congestion, and do little to stimulate TOD. Kuzmyak (2012) found significantly lower congestion on roads in older, multi-modal neighborhoods than in newer, automobile-oriented areas due in part to more transit ridership and transit oriented development. 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 11. As a result, New York and Chicago have far less congestion than Los Angeles.

Figure 11 **Congestion Costs** (Litman 2004)



Traffic congestion costs tend to increase with city size, except for cities with large rail systems.

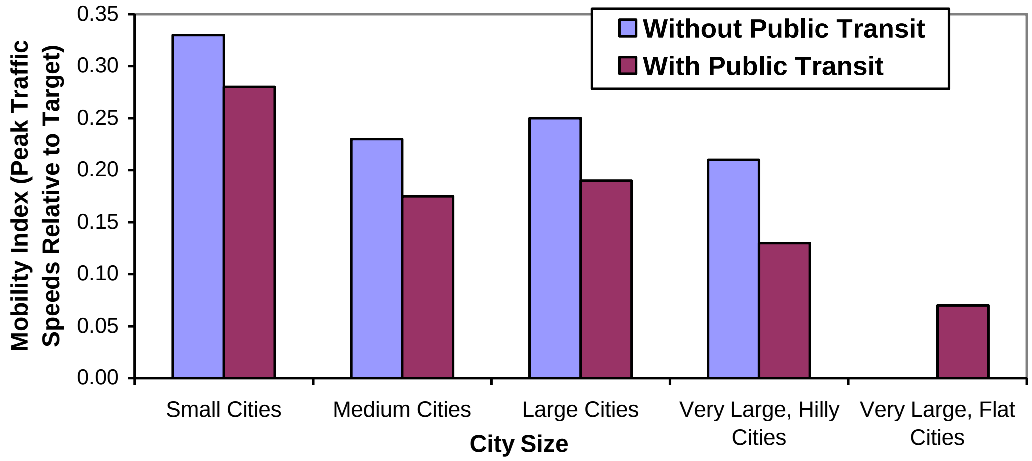
High quality public transit can leverage additional vehicle travel reductions by providing a catalyst for development of more compact and multi-modal neighborhoods where residents own fewer automobiles, take shorter trips, and rely more on walking and cycling. Where this occurs, each transit passenger-mile typically represents a reduction of 3 to 6 automobile vehicle-miles (ICF 2010; Lem, Chami and Tucker 2011; Litman 2007).

Although most studies of these impacts focus on rail transit, other modes should have similar impacts, although usually at a smaller scale. Alternative modes do not usually eliminate roadway congestion, but can significantly reduce congestion intensity on parallel roadways and total per capita 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. 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.

Similar patterns are found in developing countries, as summarized in Figure 12, which shows that Indian cities with rail transit systems tend to have a higher Mobility Index (less roadway congestion).

Figure 12 **Traffic Congestion in India** (Wilbur Smith 2008)



Average traffic speeds are significantly higher for cities with higher quality public transit.

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 of 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 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 are 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 alone. 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 mode 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).

A typical urban arterial can accommodate up to 1,000 vehicles (about 1,100 passengers) per hour, and a grade separated highway lane up to 2,200 vehicles (about 2,420 passengers) per hour, assuming 1.1 passengers per vehicle. As a result, it is more efficient to convert general traffic lanes to bus lanes if, after such a change and other cost-effective transit encouragement strategies are implemented, the bus lane carries at least that number of passengers. This requires about 22 buses per peak-hour on urban arterials and about 50 buses per peak hour on highways, assuming 50 average passengers. Evaluating road system performance using average traffic speeds or roadway level-of-service tends to overlook these efficiencies since it only recognizes reduced delays to motorists and so overlooks direct benefits to transit passengers.

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 8 **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 they 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. This 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 this is implemented most often in dense urban areas, it can provide large congestion reductions.
Fuel price increases	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, they tend 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 tend 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, this method achieve a given congestion reduction at the lowest total cost to society. 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. These include:

- More support for compact and mixed development. Reduced restrictions on density, building heights and mix.
- More support for infill development. More urban infrastructure improvements. Restrictions on urban expansion, including regulations and financial incentives.
- More diverse housing types, including townhouses, condominiums and apartments.
- More connected roadway networks.
- More multi-modal transport planning, particularly improved walking, cycling and public transit. Complete streets roadway designs. Transportation demand management.
- Reduced and more flexible parking requirements, and better parking management.

There is debate concerning how smart growth affects traffic congestion. People often assume that by increasing development density it increases congestion (Melia, Parkhurst and Barton 2011). This is codified in many jurisdictions which charge traffic impact fees for infill development that is predicted to increase local congestion. However, smart growth also includes features that reduce vehicle travel and increase route options. Smart growth community residents tend to drive significantly less than they would in more automobile dependent areas. Table 9 summarizes the congestion impacts of various smart growth features.

Table 9 **Smart Growth Congestion Impacts**

Smart Growth Feature	Congestion Impacts
Increased development density	Increases vehicle trips within an area, but reduces trip distances and supports use of alternative modes
Increased development mix	Reduces trip distances and supports use of alternative modes
More connected road network	Reduces the amount of traffic concentrated on arterials. Reduces trip distances. Supports use of alternative modes.
Improved transport options	Reduces total vehicle trips.
Transportation demand management	Reduces total vehicle trips, particularly under congested conditions.
Parking management	Can reduce vehicle trips and supports more compact development

Smart growth includes many features that can reduce traffic congestion.

A major study sponsored by the Arizona Department of Transportation, found substantially lower vehicle ownership and use in older, high-density, mixed-used urban areas than in more contemporary, sprawled, automobile-dependent areas in the Phoenix, Arizona region (Kuzmyak 2012). Residents of higher-density neighborhoods make substantially shorter trips on average. For example, the average work trip was a little longer than seven miles for higher-density neighborhoods compared with almost 11 miles in more suburban neighborhoods, and the average shopping trip was less than three miles compared with over four miles in suburban areas. These differences result in urban dwellers driving about a third fewer daily miles than their suburban counterparts. Smart growth area roads had considerably less traffic congestion despite much higher densities. This appears to result from better mix of uses and more connected streets, which reduce vehicle travel and allow more walking and public transit trips and shifts to alternative routes.

Table 10 **Phoenix Household Vehicle Travel**

	Smart Growth	Sprawled
Vehicle ownership per household	1.55	1.92
Daily VMT per capita	10.5	15.4
Average home-based work trip length (miles)	7.4	10.7
Home-based shopping trip length (miles)	2.7	4.3
Home-based other trip length (miles)	4.4	5.2
Non-home-based trip length	4.6	5.3

Smart Growth community residents make shorter trips and drive less per capita. This helps reduce traffic congestion in such areas.

This suggests that transportation impact fees should be higher for automobile-oriented, dispersed development, and that smart growth development policies should be recognized as a potential congestion reduction strategy.

Summary

Table 11 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 11 **Congestion Reduction Strategies**

	Roadway Expansion	Improve Alternative Modes	Pricing Reforms	Smart Growth
Congestion impacts	Reduces congestion in the short-run, but this declines over time due to generated traffic.	Reduces but does not eliminate congestion.	Can significantly reduce congestion.	May increase local congestion intensity but reduces per capita congestion costs.
Indirect costs and benefits	By inducing additional vehicle travel and sprawl it tends to increase indirect costs. Minimal co-benefits. Small energy savings and emission reductions.	Numerous co-benefits. Parking savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Revenues, parking savings, traffic safety, energy conservation, emission reductions, improved public health, etc.	Numerous co-benefits. Infrastructure savings, traffic safety, improved access for non-drivers, user savings, energy conservation, emission reductions, improved public health, etc.
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. Can generally evaluate congestion pricing but are less accurate for other reforms such as parking pricing	Many models underestimate the ability of smart growth strategies to reduce vehicle travel and therefore congestion
Consideration in current planning	Commonly considered and funded	Sometimes considered and funded, particularly in large cities	Sometimes considered but seldom implemented	Not generally considered a congestion reduction strategy

Different congestion reduction strategies have different types of impacts and benefits. Current traffic models and planning practices tend to ignore many of these impacts.

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 they are generally no more regressive than other transport 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 planning practices that exaggerate congestion costs and roadway expansion benefits, and therefore favor 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 objective planning can support congestion reduction strategies that also help achieve equity objectives such as more equitable funding (reducing taxes on lower-income households to finance roadway expansions that mainly benefit more affluent households), increased affordability and improving accessibility for non-drivers.

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.

Modeling of Puget Sound region transportation improvement options reached similar conclusions (WSDOT 2006). It found that neither highway widening nor transit investments by themselves are 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 13 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 13 **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.

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 would 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, it only makes sense to implement it if peak-period tolls 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 14 critiques common objections to alternative congestion reduction strategies.

Table 14 **Critique of Common Objections to Optimal Congestion Solutions**

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 on 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.

Accessibility-Based Evaluation

As discussed early, transport planning is shifting from mobility-based to accessibility-based evaluation. This recognizes that the ultimate goal of most transport activity is *accessibility* (people's ability to reach desired services and activities), and that many factors can affect accessibility including mobility, transport options, transport network connectivity and affordability, land use accessibility, and mobility substitutes.

Table 16 **Accessibility Impacts of Congestion Reduction Strategies**

Accessibility Factors	Roadway Expansion	Improve Alternative Modes	Pricing Reforms	Smart Growth
Mobility (travel speed and distance)	Increases vehicle mobility, *but reduces non-motorized mobility* (the barrier effect).	May increase alternative mode mobility (faster cycling, HOV, transit, etc.)	Minimal direct impact.	Some strategies such as traffic calming reduce mobility
Transport options (the quality of walking, cycling, public transport, automobile, ridesharing, etc.)	May improve cycling, HOV and bus transit conditions, but *often degrades non-motorized travel conditions*	By definition improves alternative modes	Often improves alternative modes by increasing demand.	Mixed impacts
Transport network connectivity (the number of connections between roads and among different modes)	*Tends to create limited-access highways which reduce connectivity*	Generally increases inter-modal connectivity	Minimal impact	Often significantly increases network connectivity
Transport affordability (transport costs relative to user incomes)	Can reduce vehicle operating costs	Often improves alt. mode affordability	Tends to reduce automobile affordability but increase other types of affordability	Tends to increase total transport affordability by reducing per capita transport costs
Land use accessibility (the geographic distribution of activities and therefore the distances that people must travel to reach services and activities)	*Tends to reduce land use accessibility by stimulating sprawl*	Tends to increase land use accessibility by encouraging compact, walkable and transit-oriented development	Tends to increase land use accessibility by encouraging compact, development	Increase land use accessibility by encouraging compact, development
Mobility substitutes (telecommunications and delivery services)	Minimal impact	May include improvements to mobility substitutes	Minimal impact	Minimal impact

Congestion reduction strategies can affect accessibility in several ways. Conventional planning tends to overlook many of these impacts, particularly ways that roadway expansion reduces non-motorized accessibility and stimulates less-accessible, sprawled development, and ways that alternative modes and smart growth can improve accessibility without increasing mobility.

By focusing on a limited set of impacts, conventional planning favors mobility over other forms of access, for example, justifying roadway expansion to the detriment of non-motorized access. More comprehensive and multi-modal planning recognizes these impacts, particularly the tendency of roadway expansion to reduce non-motorized accessibility and stimulate sprawl, and the ability of alternative modes and smart growth to improve accessibility in ways that reduce rather than increase mobility.

Considering Multiple Objectives

Although conventional planning tends to consider traffic congestion a major problem and congestion reduction a major planning objective, as previously discussed, traffic congestion is actually a modest cost overall, smaller than some other transport costs including the costs of owning and operating vehicles, crash damages, parking costs and environmental damages. Congestion reduction strategies can affect these other costs, or described differently, can affect other planning objectives. It is therefore important to use a comprehensive framework when evaluating congestion reduction options.

Table 15 compares how various congestion reduction strategies affect ten planning objectives. Roadway expansion reduces congestion and vehicle operating costs but if it induces additional vehicle travel it tends to contradict other objectives. Other congestion reduction strategies tend to achieve more planning objectives.

Table 15 **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.

This type of evaluation can indicate when a solution to one problem contradicts other planning objectives and can help identify win-win solutions, that is, the congestion reduction strategies that provide co-benefits such as parking cost savings, accident reductions and improved mobility for non-drivers. The monetized transportation cost values can be used for more detailed economic evaluation of congestion reduction options. For example, it would probably be inefficient to implement a strategy that reduced congestion by 20% if doing so increases total vehicle expenses, crash damages or parking costs by 5%. A congestion reduction strategy becomes far more cost effective if it provides even modest reductions in these other costs.

This is not to suggest that roadway expansion is always harmful and inappropriate, but it does illustrate how conventional planning which overlooks significant impacts can result in congestion reduction strategies which are not overall optimal, considering all objectives and impacts.

Best Practices

This section summarizes best practices for comprehensive evaluation of congestion costs and congestion-reduction strategies.

- *Accessibility-based evaluation.* Evaluation should recognize that the ultimate transport planning goal is to provide access to services and activities, which is affected by various factors including mobility, the quality of transport options, transport network connectivity and affordability, land use accessibility, and mobility substitutes. It should account for ways that policy and planning decisions can affect all of these factors, including the tendency of roadway expansion to reduce pedestrian accessibility and stimulate sprawl, and various ways that alternative modes, transport pricing and smart growth land use policies affect accessibility.

- *Rational congestion valuation.* Methods used to quantify and monetize congestion costs should use rational assumptions, including realistic baseline speeds reflecting LOS B or C, and travel time values that reflect motorists' willingness-to-pay for travel time savings.

- *Per capita impact analysis.* For economic analysis congestion costs should generally be measured per capita or per commuter. Commonly-used congestion indicators such as roadway level-of-service and the travel time index only indicate congestion intensity, which is inappropriate for economic analysis because it fails to account for amount people drive under congested conditions. The travel time index even implies that congestion is reduced if un-congested driving increases, for example, due to sprawl.

- *Account for congestion equilibrium, generated traffic, induced travel and.* Traffic congestion tends to maintain equilibrium, so it seldom becomes as severe as predicted by extrapolating past trends. Doing nothing seldom actually results in traffic gridlock as people sometimes fear. Consider the effects of generated traffic (additional peak-period traffic that occurs on a road after it is expanded) and induced travel (absolute increases in per capita vehicle travel caused by roadway improvements), including smaller congestion reductions, increases in external costs, and incremental increases in consumer benefits.

- *Diverse congestion reduction strategies.* Consider various potential congestion reduction strategies including roadway expansions, improvements to alternative modes, pricing reforms and smart growth development policies, plus integrated packages of these strategies such as a combination of walking and transit improvements integrated with transport pricing and transit-oriented development.

- *Additional impacts of congestion reduction options*. When evaluating potential congestion reduction strategies consider additional impacts such as indirect costs and co-benefits. These can include impacts on parking congestion, road and parking facility costs, consumer costs and affordability (user costs relative to user incomes), mobility for non-drivers, traffic risk, energy consumption, pollution emissions, public fitness and health, and strategic development objectives (such as urban redevelopment and open space preservation). Use a comprehensive framework for evaluating the degree to which various congestion reduction strategies support or contradict planning objectives, and if possible, monetize impacts for economic evaluation.

- *Avoid funding distortions.* Critically evaluate transport funding practices to avoid biases which arbitrarily favor roadway and parking facility expansion, or unjustifiably underprice vehicle travel. Apply least-cost planning, which invests resources (money and road right-of-way) in alternative modes and demand management strategies whenever they are more cost effective than facility expansion.

Conclusions

Conventional planning tends to consider traffic congestion a major problem and congestion reduction an important planning objective. It uses various methods to evaluate congestion, such as roadway level-of-service and monetized congestion costs. These methods have significant weaknesses:

- They assume that *transportation* means driving and so evaluate transport system performance based primarily on automobile travel conditions.
- They reflect *mobility-based* evaluation which assumes that mobility is an end in itself rather than a means for achieving accessibility. They tend to overlook impacts on other forms of access, such as the tendency of wider roads and faster vehicle traffic to degrade non-motorized conditions and stimulate sprawl.
- 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 a freeflow traffic speed baseline and excessive travel time unit costs.
- 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 overlook and undervalue alternative congestion reduction strategies by ignoring their co-benefits.
- The often dedicate funds to roadways and parking facilities and cannot be used to improve other modes or implement transportation demand management programs even if they are more cost effective and beneficial overall.

These omissions and biases tend to 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 often less effective and beneficial than indicated by conventional analysis.

Chronic traffic congestion can be considered a symptom of more fundamental transport system problems including inadequate transport options that force people to drive more than they actually want, price distortions, and sprawled development that increase travel distances. Under such circumstances, roadway expansion tends to provide little long term congestion reductions and increases other transport problems.

Efficiency requires that consumers bear the costs imposed by their activities unless subsidies are specifically justified. Despite frequent complaints about traffic congestion there appears to be insufficient willingness-to-pay for major urban roadway expansion, nor sufficient political support for congestion pricing, indicating that motorists do not really consider it a major problem. 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 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 physically, economically and socially disadvantaged people. Congestion reduction strategies can support transport equity objectives by improving affordable modes, progressive pricing, and more affordable housing in accessible, multi-modal locations.

Some congestion reduction strategies provide co-benefits. Improving alternative modes (particularly high quality public transit), pricing reforms and smart growth development polices can reduce traffic congestion and help achieve other planning objectives. These strategies do not necessarily eliminate congestion, they may even increase congestion intensity, but they improve overall accessibility and 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 roadways should never be improved. However, when all impacts and options are considered, highway expansion is less effective and more costly, and alternative congestion reduction strategies are often better overall, than indicated by conventional project economic evaluations. It is important that decision makers and the general public understand these issues when choosing solutions to congestion problems.

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