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Congestion Evaluation Best Practices

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Abstract

Traffic congestion can be evaluated in various ways that result in very different conclusions about the nature of the problem and optimal solutions. This paper describes various factors that affect congestion costing and the evaluation of potential congestion reduction strategies, including the scope of analysis, baseline speeds, travel time unit costs, the impacts of traffic speeds on accident and emission rates, consideration of induced travel impacts, and consideration of co-benefits. It discusses how these factors influence planning decisions, and describes best practices for comprehensive evaluation of congestion impacts. It applies this comprehensive framework to evaluate various congestion reduction strategies including roadway expansion, alternative mode improvements, pricing reforms, smart growth policies and demand management programs.

Keywords

Congestion, Mobility, Economic Evaluation, Transport Planning, Road Pricing

Introduction

Traffic congestion refers to the incremental delay caused by interactions among vehicles on a roadway, particularly as traffic volumes approach a road's capacity. Congestion can be evaluated in various ways that can result in very different estimates of its costs and the benefits of specific congestion reduction strategies. This paper describes best practices for congestion evaluation based on recommendations by international experts.

Commonly-used congestion indicators, such as roadway *level-of-service* (LOS) and the *Travel Time Index* (TTI) reflect congestion *intensity*, the amount that traffic speeds decline during peak periods (1). Comprehensive evaluation measures congestion *costs*, taking into account *exposure*, the amount that people must drive under urban-peak conditions (2). An area can have relatively intense congestion but low congestion costs due to good travel options, well connected roadway networks, and compact development that minimize peak period automobile travel.

How congestion is measured can affect planning decisions in various ways. For example:

- Converting a general traffic lane into a bus lane often reduces bus passenger delay but increases delay in the remaining traffic lanes. Congestion intensity indicators only measure vehicle traffic impacts, and so would conclude that congestion has increased, even if total per capita delay hours decline.
- Compact, transit-oriented cities such as New York, San Francisco and Boston tend to have relatively intense congestion but less congestion delay per commuter than dispersed, automobile-oriented cities such as Houston, Atlanta and Nashville due to lower auto mode shares and shorter trip distances. Compact cities rank worse than dispersed cities if compared by congestion intensity indicators but not if compared by congestion costs.
- More central, infill locations often experience more intense local congestion than urban fringe locations, but lower congestion costs, since a central location offers better travel options (better walking, cycling and public transit access) and shorter trip distances.

Described differently, congestion evaluation is affected by whether analysis measures *mobility* (travel speed) or *accessibility* (time and financial costs required to reach desired services and activities). Modern transportation planning recognizes that mobility is seldom an end in itself, accessibility is the ultimate goal of most travel activity. Comprehensive congestion evaluation is part of the paradigm shift toward accessibility-based planning.

This paper discusses various factors that affect congestion cost estimates and the evaluation of potential congestion reduction strategies, discusses how different methodologies and assumptions can influence planning decisions, and describes best practices for comprehensive and multi-modal congestion evaluation. It should be of interest to anybody involved in urban transportation planning.

Factors Affecting Congestion Evaluation

This section summarizes the methods recommended by experts for quantifying congestion costs and evaluating potential congestion reduction strategies (3, 4, 5, 6, 7, 8).

Congestion Indicators

Table 1 summarizes various traffic congestion indicators. Some measure congestion *intensity* (the percentage reduction in vehicle traffic speeds on particular roads), while others are more comprehensive (they consider total traffic delay, taking into account travelers' exposure to congestion as well congestion intensity) and multi-modal (they consider delays to all travelers, not just motorists), and so measure total congestion *costs*.

Table 1 **Congestion Indicators** (9)

Indicator	Description	Comprehensive	Multi-Modal
Roadway Level-Of-Service (LOS)	Intensity of congestion on a road or intersection, rated from A (uncongested) to F (most congested)	No	No
Multi-modal Level-Of-Service (LOS)	Service quality of walking, cycling, public transport and automobile, rated from A to F	No	Yes
Travel Time Index	The ratio of peak to off-peak travel speeds	No	No
Avg. Traffic Speed	Average peak-period vehicle traffic speeds	No	No
Avg. Commute Time	The average time spent per commute trip	Yes	Yes
Congested Duration	Duration of "rush hour"	No	No
Delay Hours	Hours of extra travel time due to congestion	Yes	No if for vehicles, yes if for people
Congestion Costs	Monetized value of delay plus additional vehicle operating costs	Yes	No if for vehicles, yes if for people

Various indicators are used to evaluate congestion. Only a few are comprehensive and multi-modal.

Intensity indicators are useful for making short-term decisions, such as how best to travel across town during rush hour, but are unsuitable for strategic planning decisions that affect the quality of travel options or land use development patterns. For example, a compact city may have a 1.3 Travel Time Index (traffic speeds decline 30% during peak periods), 60% automobile commute mode share, and 6-mile average trip lengths, resulting in 34 average annual hours of delay per commuter; while a sprawled city has a 1.2 Travel Time Index, 90% automobile mode share, and 10-mile average trip lengths, resulting in a much higher 45 average annual hours of delay. Intensity indicators imply that the compact city has worse congestion since it has greater speed reductions, although its residents experience lower total congestion costs because they drive less during peak periods. Similarly, converting general traffic lanes into bus or High Occupant Vehicle (HOV) lanes may increase congestion intensity but reduce total congestion costs if incremental delays to low-occupant vehicle occupants are offset by reduced bus and HOV passenger delays.

Described differently, intensity indicators reflect *mobility* while cost indicators reflect *accessibility*, people's ability to reach services and activities (10). Recent research improves our understanding of the trade-offs between them:

- Levine, et al. found that changes in development density affect the number of jobs and services available within a given travel time about ten times more than proportional changes in traffic speed (11).
- Kuzmyak found that travelers in more compact neighborhoods experience less congestion than in more sprawled, suburban neighborhoods due to shorter trip distances, more connected streets, and better travel options, which more than offset higher trip generation rates per square mile (12).
- A study that measured the number of jobs accessible by automobile within certain time periods for the 51 largest US metropolitan areas found that the five cities with the most intense congestion (the highest Travel Time Index ratings) are among the *best* for automobile employment access because their lower traffic speeds are more than offset by higher employment densities which reduce commute distances (13).
- Cortright found that roadway expansion that stimulates sprawl can increase residents' total travel times, because higher traffic speeds are more than offset by longer travel distances (14).

These studies indicate that transportation system changes intended to increase vehicle traffic speeds can reduce overall accessibility and increase total transportation costs by reducing the efficiency of other modes and stimulating sprawl.

Baseline Speeds

Baseline (also called *threshold*) speed is the speed below which congestion delays are calculated. For example, if the baseline speed is 60 miles per hour (mph), and peak-period traffic speeds are 50 mph, the 10 mph speed reduction is the basis for calculating congestion delay. Table 2 summaries ways to define and measure baseline speeds, and their equivalent roadway level-of-service (LOS) ratings.

Table 2 **Baseline Speed Definitions**

Name	Measurement Method	LOS Rating
Free-flow speeds	Measured off-peak speeds	A
Speed limits	Maximum legal speeds	A or B
Capacity-maximizing speeds	Speeds that maximizes traffic capacity	C or D
Economic efficiency-optimizing (also called *consumer-surplus maximizing*)	Users' willingness-to-pay for faster travel	C or D

There are several possible ways to define and measure baseline speeds. (LOS = Level-of-Service)

Roadway capacity tends to decline at speeds above 55 mph on limited access highways, and about 40 mph on urban arterials, so roads typically carry about twice as much traffic at LOS C than at LOS A (15). As a result, traffic engineers generally recommend capacity-maximizing speeds, and economists generally recommend economic efficiency-optimizing speeds, both of which result in level-of-service C or D baseline speeds (16).

For example, the Australian Bureau of Transport and Regional Economics calculates congestion costs based on estimates of motorists' willingness to pay for faster travel (17). Using this method they estimate that congestion costs in major Australian cities totaled $5.6 billion in 2005, less than half the $11.1 billion calculated using freeflow speeds. Similarly, using capacity-maximizing baseline speeds, Wallis and Lupton estimate that in 2006, Auckland, New Zealand congestion costs totaled $250 million, a third of the $1,250 million cost estimate using a freeflow baseline (18). Transport Canada calculates congestion costs use 50%, 60% and 70% of free-flow speeds, which they consider a reasonable range of optimal urban-peak traffic speeds (19). In contrast, traffic models often use speed limit baselines, and the *Urban Mobility Report* uses measured freeflow speed baselines, although they often exceed legal speed limits (20).

Travel Time Valuation
Another key factor is the cost assigned to travel delay. There is extensive research on travel time valuation (21, 22). Most studies conclude that on average motorists are willing to pay 25-50% of wages for reduced delay; a minority, including commercial travelers and travelers with urgent errands, would pay significantly more (23, 24). The U.S. Department of Transportation recommends valuing personal travel time at 35% to 60% of prevailing incomes (25).

The value of travel time used for analysis should reflect the travelers affected. A project that reduces delay for all motorists, such as a roadway expansion, should be evaluated based on overall average motorists' willingness-to-pay, while a project that reduces congestion for a particular group, such as value priced lanes, should be evaluated based on willingness-to-pay by those who would pay the fee.

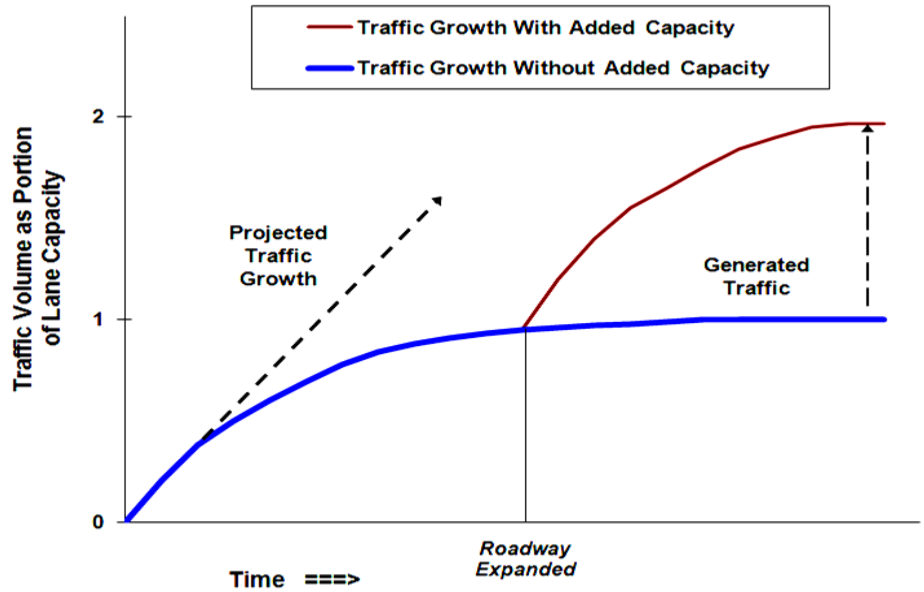
Fuel Consumption and Emission Impacts
The function used to calculate how traffic speed changes affect fuel economy and pollution emissions affects congestion costs. Fuel economy usually peaks at 40-50 mph, so reducing extreme congestion (such as shifting from LOS E-F to C-D) conserves fuel and reduces emissions, but eliminating congestion (shifting from level-of-service C-D to A-B) tends to increase fuel consumption and emissions (26, 27). Ignoring these effects tends to exaggerate congestion costs and roadway expansion benefits.

Safety Impacts
Total crash rates tend to be lowest on moderately congested roads (V/C=0.6), and increase at lower and higher congestion levels, while casualty rates (injuries and deaths) increase if congestion reductions lead to high traffic speeds (28). Although some interventions, such as roadway grade separation, can reduce both congestion and crash rates, some congestion reduction strategies increase total accident costs by increasing traffic speeds and inducing additional vehicle travel (29). These additional crash costs typically offset 5-10% of congestion reduction benefits (30).

Generated Traffic and Induced Travel

Congestion tends to maintain equilibrium: it increases until delays cause some travelers to reduce peak-period trips by shifting travel times, routes, modes or destinations (31, 32). When roads are expanded, increased peak-period vehicle travel is called *generated traffic*, and increases in total vehicle travel is called *induced travel* (Figure 1).

Figure 1 **How Road Capacity Expansion Generates Traffic** (33)



Urban traffic volumes can grow until congestion limits additional peak-period trips, at which point it maintains a self-limiting equilibrium (indicated by the curve becoming horizontal). If road capacity is expanded, traffic growth continues until it reaches a new equilibrium. The additional peak-period vehicle traffic is called "generated traffic." The portion that consists of absolute increases in vehicle travel (as opposed to time and route shifts) is called "induced travel."

Generated and induced vehicle travel has these implications for congestion evaluation:

- Traffic congestion seldom becomes as severe as predicted if past traffic growth trends are simply extrapolated into the future. As congestion increases it discourages further peak-period trips, eventually reaching equilibrium.
- Roadway expansion provides less long-term congestion reduction benefits than predicted if generated traffic is ignored.
- Induced vehicle travel increases various external costs including downstream congestion, parking costs, total accidents, and pollution emissions, reducing net benefits. External costs tend to be economically inefficient.
- The induced vehicle travel provides direct user benefits (it increases consumer surplus), but these benefits tend to be modest because it consists of marginal-value vehicle travel that users are most willing to forego if their costs increase.

Barrier Effect
Wider roads and increased vehicle traffic tend to degrade walking and cycling access, and therefore public transit access since most transit trips include walking and cycling links. This is called the *barrier effect* or *severance* (34, 35). This impact can be significant, particularly in urban areas (36).

Confounding Factors
All else being equal, traffic congestion tends to increase with city size (population), density and employment rates. It is important to account for confounding factors such as these when evaluating the effectiveness of specific congestion reduction strategies. For example, some researchers find a positive correlation between public transit travel and traffic congestion, which they claim proves that transit improvements are ineffective at reducing congestion (37), but their research failed to account for factors such as city size, density and employment, resulting in inaccurate results and conclusions (38).

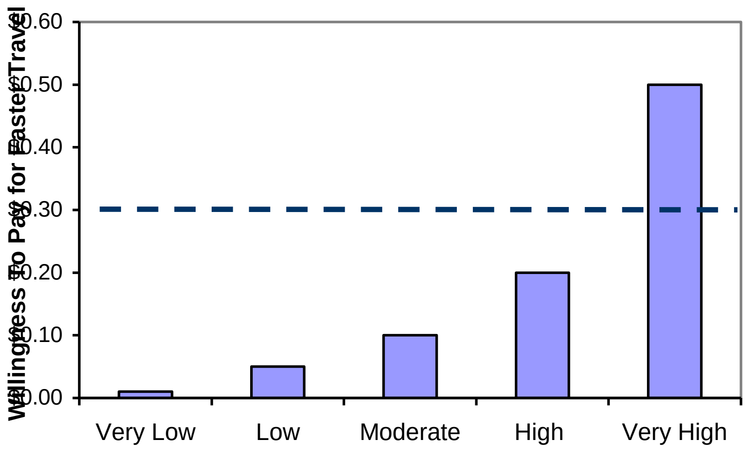
Analysis Scale
It is important to evaluate congestion impacts using appropriate geographic scale and scope. This usually means corridor scale analysis. Although transit only carries a minor portion of total regional travel, its mode share tends to be much higher on congested urban corridors. As a result, an automobile-to-transit mode shift that seems small measured at the regional scale may provide significant congestion reductions. For example, although Los Angeles has only 11% transit commute mode share, one study found that transit reduces regional congestion costs by 11% to 38%, and when a strike halted transit service, average highway congestion delay increased 47% (39, 40).

Evaluating Economic Efficiency
Efficiency refers to the ratio of benefits (outputs) to costs (inputs). Engineers and economists both use this term but define and measure it differently. Traditional traffic engineering evaluates roadway efficiency based on *vehicle* capacity and speed using indicators such as roadway level-of-service; the new planning paradigm evaluates roadway efficiency based on *mobility*, the capacity and speed of person and goods transport (41). This recognizes that roads can become more efficient by favoring higher-occupant vehicles. For example, a bus- and High Occupant Vehicles (HOV) lane often carries more passengers than a general traffic lane, so increasing travel speeds on such lanes increases roadway efficiency by allowing the road to carry more total passengers.

Economists also consider variations in the value of travel when evaluating transportation efficiency. Economic efficiency increases if higher value travel receives priority in traffic. For example, freight and other commercial vehicles, buses and other HOVs tend to have values of travel time, so giving them priority in traffic tends to increase economic efficiency. This can be achieved with special lanes, or even better, with congestion pricing (road tolls with higher fees during congested conditions) that allows vehicles with higher travel time values to outbid lower-value vehicles for scarce road space.

Economically optimal road pricing uses peak period tolls to reduce traffic volumes to optimal levels, which is typically level-of-service C or D (42), or higher based on consumer demand; in some situations users might be willing to pay tolls to allow LOS B or A. Efficient road pricing test users' willingness to pay for road expansions. For example, if an urban road expansion costs 30¢ per peak-period vehicle-mile, it is economically efficient to make such investments for motorists willing to pay this toll, but it is economically inefficient to expand such roads to serve motorist with lower willingness-to-pay (Figure 2). Such projects are particularly harmful if the added capacity induces additional vehicle travel which increases external cost.

Figure 2 **Faster Traffic Demand Curve**



On a typical road, users willingness-to-pay for faster travel varies from very low to very high. If expanding urban roadways cost 30¢ per peak-period vehicle-mile, economic efficiency increases if motorists willing to pay this amount can purchase faster travel, but it would be economically inefficient to spend this amount to increase the travel speed of motorists with lower willingness-to-pay. In some cases motorists might be willing to pay for LOS A or B.

On a typical roadway each 1¢ per vehicle-mile road toll typically reduces affected vehicle travel about 1%, with larger reductions on corridors with good alternatives, such as high quality public transport (43). For example, about 20% of peak-period motorists value their trips at less than 20¢ per vehicle-mile, and 30% value it less than 30¢; they would prefer to forego that vehicle trip than pay. Expanding urban roadways typically costs $0.50 to $1.50 per additional urban-peak trip accommodated, and urban-peak travel has external costs (accident, pollution, parking subsidies, barrier effect, etc.) of 20-30¢ per mile (44, 45). As a result, with unpriced urban highways, a significant portion of urban-peak vehicle travel may be worth less than its total (internal plus external) costs.

This has the following implications for congestion evaluation:

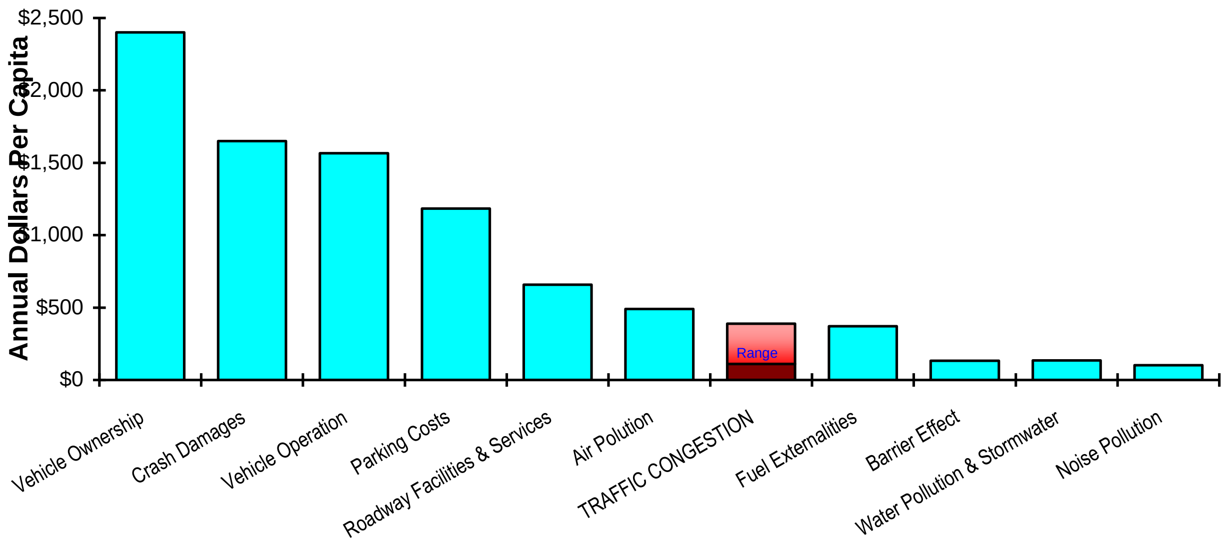
- There are large potential benefits from favoring higher-value travel. A roadway becomes more efficient (it provides more value per lane or vehicle-mile) if regulations, pricing or incentives allow higher value vehicles to avoid congestion.
- A significant portion of motor vehicle travel may have negative net value: its marginal user benefits are less than their total marginal costs, including external costs. It is economically inefficient to expand roads to accommodate such travel.
- Serving latent demand for alternative modes can provide direct and indirect benefits. For example, walking, cycling and transit improvements that increase use of those modes provide direct user benefits, plus indirect benefits from reduced automobile traffic.
- Improving traveler convenience and comfort, for example, by providing better public transit user information and improving comfort, can reduce travel time unit costs (dollars per hour) equivalent in value to increasing travel speed.

Additional Costs and Benefits

Several studies have monetized transportation costs (46, 47, 48). Figure 3 compares estimates of various motor vehicle costs, measured annual per capita. Congestion is estimated to cost between $112 to $388 (49) annual per capita, compared with approximately $2,400 in vehicle ownership costs (50, 51) $1,500 in crash damages (52, 53) $1,200 in parking costs (54), $658 in roadway costs (55) and $500 in pollution damage costs (56).

Comprehensive evaluation considers all of these impacts when evaluating potential congestion reduction strategies. A congestion reduction strategy can have much smaller net benefits if it increases other transportation costs, and greater total benefits if it provides additional benefits. For example, a roadway expansion may seem cost effective considering just congestion impacts, but not if, by inducing additional vehicle travel, it increases parking costs, accidents and pollution emissions. Conversely, a public transit improvement may not seem justified considering congestion reductions alone, but is cost effective overall when co-benefits (parking cost savings, increased safety, emission reductions, and improved mobility for non-drivers) are also considered.

Figure 3 **Costs Ranked by Magnitude** (57)



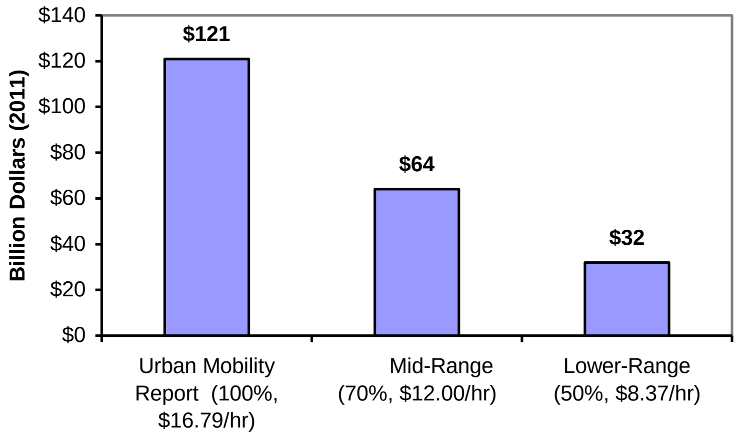
U.S. traffic congestion cost estimates range between about $112 and $388 annual per capita, depending on assumptions. These are modest compared with other transportation costs.

Addressing Uncertainty

When reporting congestion evaluation results it is important to identify possible sources of bias and uncertainty, such as using upper-bound baseline speeds, optimistic fuel savings estimates, or ignoring induced vehicle travel impacts. Reports should discuss how alternative assumptions would change cost estimates and the predicted benefits of potential congestion reduction strategies. For example, if congestion costs are calculated using freeflow baseline speeds, these should be reported as upper-bound values, and the effects of using alternative baseline speeds should be discussed.

It is a good practice to perform sensitivity analysis to indicate how results would change with different input values. For example, Figure 4 illustrates sensitivity analysis applied to the *Urban Mobility Report* (58) using alternative baseline and travel time values.

Figure 4 **Congestion Cost Estimate** (59)



The Urban Mobility Report's $121 billion cost estimate is based on higher baseline speeds and travel time unit costs than most economists recommend. The Mid-Range is based on 70% of baseline speeds and the U.S. Department of Transportation's recommended $12.00 per hour travel time unit costs; the lower-range estimate is based on 50% of baseline speed and the USDOT's lower travel time unit costs.

Summary of Congestion Costing Factors

Table 3 summarizes various factors to consider when evaluating traffic congestion costs.

Table 3 **Congestion Costing Factors**

Factor	Recommended Best Practices	Impacts on Evaluation
Congestion indicators	For planning purposes, congestion impacts should be evaluated using cost rather than intensity indicators.	Intensity indicators ignore the influence of mode share and trip distance on total congestion costs.
Baseline speeds	Capacity-optimizing or user willingness-to-pay for reduced delay.	Freeflow baseline speeds tend to exaggerate congestion costs.
Travel time cost values	Use values reflecting affected motorists' willingness-to-pay for faster travel.	Excessive travel time values tend to exaggerate congestion costs.
Speed-fuel economy function	Account for the increased fuel consumption and emissions caused by traffic speeds over 50 mph.	Ignoring these effects exaggerates congestion costs and roadway expansion benefits.
Crash risk	Account for increased crash costs that may result from reduced congestion.	Ignoring this effect exaggerates congestion costs and roadway expansion benefits.
Generated and induced vehicle travel	Recognize the tendency of traffic to be self-limiting when projecting future congestion costs. Account for generated and induced vehicle travel impacts when evaluating roadway expansions.	Ignoring the tendency of congestion to be self-limiting tends to exaggerate future congestion cost projections. Ignoring generated and induced travel tends to exaggerate roadway expansion benefits.
Confounding factors	Take into account positive relationships between traffic congestion, city size, density and employment when evaluating congestion reduction effectiveness.	Failing to account for these factors tends to underestimate the effectiveness of public transit improvements and smart growth policies in reducing congestion costs.
Analysis scale	Use appropriate geographic scale (generally urban corridors or centers).	Since traffic congestion is concentrated on specific corridors, regional analysis can seldom account for congestion impacts.
Barrier effect	Account for the tendency of wider roads and increased traffic to reduce walking, cycling and transit accessibility.	Ignoring this impact exaggerates roadway expansion benefits.
Economic efficiency	Consider economic efficiency when evaluating potential congestion reduction strategies. Recognize that some road users have high willingness to pay.	Ignoring economic efficiency undervalues congestion pricing and HOV priority policies. Expand roads based on users' willingness-to-pay (if demand is sufficient, expand roads and provide LOS A or B).
Additional costs and benefits	Consider other costs and benefits, besides congestion, when evaluating potential congestion reduction strategies.	Ignoring additional impacts tends to exaggerate roadway expansion benefits and undervalues other strategies that provide co-benefits.
Addressing uncertainty	Document all assumptions, discuss potential biases, and perform sensitivity analysis indicating how results would change with different inputs.	Failing to identify possible biases and failing to apply sensitivity analysis creates unjustified confidence in results.

This table summarizes recommendations for comprehensive congestion evaluation.

Comprehensive Evaluation of Potential Congestion Reduction Strategies

This analysis evaluates five potential traffic congestion reduction strategies:

- Unpriced (no toll is charged) *urban roadway expansions*.
- *Alternative mode improvements*, including walking, cycling, ridesharing, telework, and particularly high-quality, grade-separated public transit services.
- *Pricing reforms*, including road tolls, parking pricing (including cash out, which means that travelers have the option of choose cash instead of a parking subsidy), fuel price increases, distance-based insurance premiums, and particularly congestion pricing (road tolls that are higher under congested conditions)
- *Smart growth policies* that create more compact, mixed, multi-modal development.
- Various *Transportation Demand Management* (TDM) programs, such as commute trip reduction programs, mobility management marketing, parking management, and other programs that encourage travelers to use more efficient modes.

All of these strategies can reduce traffic congestion, but their overall impacts vary significantly. For example, roadway expansions reduce the traffic congestion intensity on the expanded roads, but this benefit tends to decline over the long-run due to induced vehicle travel which tends to increase external costs including downstream congestion, parking demand, accident damages, pollution emissions and sprawl-related costs. Analysis which ignores these factors will exaggerate roadway expansions net benefits.

Other congestion reduction strategies tend to have other impacts. For example, improving alternative modes tends to improve mobility options for non-drivers (and therefore helps achieve social equity objectives), increase affordability, reduce total accidents, pollution emissions and sprawl-related costs. Pricing reforms increase costs to motorists and generates revenue (an economic transfer, the resource costs are any additional transaction costs), and by reducing total traffic can reduce external costs. Smart growth policies tend to improve overall accessibility, may increase local congestion intensity (due increased density), reduce total vehicle travel and associated costs, reduce the costs of providing public services and preserve openspace. TDM programs have various benefits and costs, depending on type.

Most of these strategies have direct implementation costs, such as the costs of improving alternative modes, collecting tolls, or operating TDM programs, which are relatively easy to determine, and some impose user costs, such as the effort for motorists to pay tolls. The incremental user costs (changes in consumer surplus) associated with mode shifts varies depending on specific conditions: if travelers shift in response to negative incentives such as road tolls, they tend to be directly worse off (ignoring indirect impacts provided by the revenue, such as reductions in other taxes); if they shift in response to positive incentives such as improvements to alternative modes or financial rewards such as parking cash out, they are generally better off or they would not make the change. Some strategies have mixed user impacts. For example, converting a general traffic lane into a bus lane tends to benefit bus operators (due to improved operating efficiency) and bus passengers, but may increase congestion delay to motorists.

Some strategies have synergistic effects; they are more effective if implemented together. For example, public transit improvements, efficient parking pricing and more compact development might individually only reduce vehicle travel 5%, but if implemented together provide 30% reductions because their effects are complementary. For this reason, such strategies should be evaluated as integrated programs.

Comprehensive congestion evaluation considers all of these factors. Table 4 summarizes these impacts and the degree they are considered in conventional transport modelling and planning. This indicates that conventional evaluation tends to exaggerate roadway expansion benefits by ignoring induced travel and the resulting increases in external costs, and undervalues other strategies that provide significant co-benefits. Failure to consider some motorists high willingness-to-pay for high quality road services (e.g., LOS A or B) can undervalue congestion pricing and roadway capacity expansions.

Table 4 **Congestion Reduction Strategies**

	Roadway Expansion	Improve Alt. Modes	Pricing Reforms	Smart Growth	TDM Programs
Congestion impacts	Reduces short-run congestion, 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.	Can reduce congestion delays and the costs to users of those delays
Direct user impacts	Direct benefits to peak-period motorists.	Direct benefits to existing and new users.	Most increase user costs (except parking cash out and distance-based pricing).	Mixed, depending on specific conditions and user preferences.	Mixed, depending on specific conditions and user preferences.
Additional 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, improved, safety and health, better access for non-drivers, user savings, energy conservation, emission reductions, etc.	Numerous co-benefits. Revenue, parking savings, traffic safety, energy conservation, emission reductions, improved public health, etc. Overall impacts depend on use of revenues.	Numerous co-benefits including infrastructure savings, safety and health, user savings, emission reductions, improved accessibility for non-drivers, etc.	Depends on program type. Most provide significant co-benefits.
Consideration in traffic modeling	Models often exaggerate 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.	Models often underestimate smart growth's ability to reduce vehicle travel and therefore congestion.	Sometimes considered.
Consideration in current planning	Commonly considered and funded.	Sometimes considered, particularly in large cities.	Sometimes considered but seldom implemented.	Not generally considered a congestion reduction strategy.	Sometimes considered, particularly in large cities.

Congestion reduction strategies vary in their additional benefits and costs. Current traffic models and planning practices tend to overlook or undervalue many of these impacts.

Evaluating Economic Development Impacts

Since transportation is critical for most economic activities (production, employment, retail, etc.), traffic congestion tends to reduce productivity. All else being equal, reducing congestion increases productivity (e.g., lower delivery costs, larger employment pools, etc.). However, congestion reduction strategies often differ in their indirect economic impacts. Table 5 summarizes various congestion reduction strategies' economic impacts. This and other research suggests that congestion reduction strategies that reflect market principles (such as cost-based pricing) and increase overall accessibility (such as smart growth) most support economic e development (60).

Table 5 **Economic Impacts of Congestion Reduction Strategies** (61)

Economic Impacts	Roadway Expansion	Improve Alt. Modes	Efficient Pricing	Smart Growth	TDM Programs
Traffic congestion	Reduces short-run intensity, but increases long-run costs.	Reduces congestion.	Reduces congestion.	Increases intensity, reduces total costs.	Reduces congestion.
Labor pools	Expands car commuters' work options.	Expands all commuters' work options.	Expands most commuters' work options.	Improves worker accessibility.	Can improve access.
Parking costs	Increases parking costs.	Reduces parking costs.	Reduces parking costs.	Increases unit costs but reduces total costs.	Reduces parking costs.
Vehicle and fuel imports	Increases	Reduces	Reduces	Reduces	Reduces
Land use accessibility	Causes sprawl, which reduces accessibility.	Encourages compact development which improves accessibility.	Encourages compact development which improves accessibility.	Increases land use accessibility.	Supports more accessible development.

Congestion reduction strategies vary in their other economic impacts, including employment access, parking costs, vehicle and fuel expenditures and land use accessibility.

Conclusions

It is important to accurately evaluate congestion impacts for transport planning. Various factors can affect congestion cost estimates and the valuation of congestion reduction strategies. Best practices include:

- Evaluate transport system performance based on overall *accessibility* (people's overall ability to reach desired services and activities) rather than just *vehicle traffic speeds*.
- Measure congestion *costs* rather than *intensity*. Congestion intensity indicators do not account for congestion exposure (the amount residents drive during peak periods), and so undervalue strategies that improve transport options or reduce trip distances.
- Measure delays to *all travelers*, not just to *motorists*.
- Use *efficiency-optimizing* (typically LOS C), rather than *freeflow* baseline speeds. Efficiency-optimizing speeds maximize roadway capacity and fuel economy, and generally reflect average road users' willingness to pay for roadway capacity.
- Use *travel time values* that reflect users' actual willingness-to-pay for incremental speed gains. For value priced lanes (lanes available for a fee) use consumer surplus analysis. For general travel time savings, this is typically 30-50% of average wages for personal travel, and wages, benefits and equipment costs for commercial travel.
- Calculate the marginal congestion costs *imposed* by road users, rather than just the costs they bear, when calculating transport prices and comparing congestion costs of different modes.
- Recognize *variations in travel time values*, and therefore the efficiency gains provided by policies that favor higher value over lower-value trips, such as congestion pricing. Recognize that some motorists have very high values of time and are willing to pay for LOS A or B.
- Use accurate *fuel efficiency* functions. Vehicle fuel efficiency generally peaks at about 50 miles per hour, so reducing moderate congestion (LOS C) often increases fuel consumption and emissions, particularly if it induces additional vehicle travel.
- Recognize that congestion tends to *maintain self-limiting equilibrium*: it increases to the point that delays limit further peak-period vehicle travel. As a result, traffic volumes and congestion costs seldom increase as much as predicted by extrapolating past trends.
- Account for *generated* and *induced vehicle travel* when evaluating roadway capacity expansions. These tend to reduce predicted congestion reduction benefits, provide user benefits, and increase external costs.
- Account for increased *crash costs* that result if congestion reductions lead to high traffic speeds.
- Account for *co-benefits* when evaluating congestion reduction strategies. Strategies that improve alternative modes, reduce total vehicle travel or increase land use accessibility tend to reduce parking costs, provide user savings, improve non-drivers' accessibility, increase safety and health, reduce pollution emissions, and support strategic land use objectives.
- Evaluate impacts on *specific corridors*. Although alternative modes, such as public transit, may serve a small portion of total regional travel, their mode share is often much higher on major urban corridors, so they can provide significant congestion reductions.
- Apply comprehensive evaluation of economic productivity, including impacts on consumer expenditures, non-drivers employment access, and development patterns.
- Identify potential sources of bias and variability, and apply sensitivity analysis to test alternative assumptions.

It is important that everybody involved in urban transportation planning understand how these factors can influence congestion impact evaluation. More comprehensive and accurate evaluation can help practitioners identify truly optimal solutions to congestion problems that best respond to user demands and community values.

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Endnotes

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