5.5 Congestion

This chapter examines traffic congestion costs, that is, delay and increased risk due to interference between road users. It describes how congestion is measured, factors that affect congestion, various estimates of congestion costs, and the benefits of congestion reductions.

Definition

Traffic Congestion Costs consist of incremental delay, driver stress, vehicle costs, crash risk and pollution resulting from interference between vehicles in the traffic stream, particularly as a roadway system approaches its capacity. Each vehicle on a congested road system both imposes and bears congestion costs. This chapter focuses on *external* costs a vehicle imposes on other motorists, since the *internal* costs borne by a motorist are included in Vehicle Cost, Travel Time, and Crash Cost chapters. The Barrier Effect chapter discusses delays that motor vehicles impose on nonmotorized travel.

Discussion

Each additional vehicle in the traffic stream can interfere with other road users, which imposes an incremental delay and crash risk.[1] These impacts increase as traffic volumes approach a road's capacity. Traffic congestion is considered one of the most significant transportation problems. The capacity of a road depends on various design factors such as lane widths and intersection configurations.[2] Optimal performance values are shown in tables 5.5-1 and 5.5-2. These tables assume ideal conditions and no intersections. Many factors can decrease this optimal performance. Traffic speed and flow on urban streets are determined primarily by intersection capacity, which is affected by traffic volumes on cross streets and left turn signal phases.

Table 5.5-1 **Typical Roadway Speed, Flow and Density Relationships**[3]

LOS	Speed Range (mph)	Flow Range (veh./hour/lane)	Density Range (veh./mile)
A	Over 60	Under 700	Under 12
B	57-60	700-1,100	12-20
C	54-57	1,100-1,550	20-30
D	46-54	1,550-1,850	30-42
E	30-46	1,850-2,000	42-67
F	Under 30	Unstable	67-Maximum

This table shows the speed, flow and density of traffic under each Level of Service (LOS) rating, a standard measure of traffic congestion.

[1] Timothy Hau's *Economic Fundamentals of Road Pricing*, Working Paper, World Bank (www.worldbank.org), 1992.
[2] *A Policy on Geometric Design of Highways and Streets (Green Book)*, AASHTO (Washington DC; www.aashto.org), 1990, pp. 53-97.
[3] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UBC (Berkeley; www.its.berkeley.edu), 1992, p. 4-4.

Traffic congestion is a non-linear function: when roadways are congested a small reduction in traffic volumes can provide a relatively large reduction in delays. For example, Table 5.5-1 indicates that reducing traffic volumes from 2,000 to 1,800 vehicles per hour (a 10% reduction) shifts a roadway from LOS E to LOS D, increasing traffic speeds by about 15 mph, a 30% increase. This indicates that a 5-10% reduction in traffic volumes on a congested highway typically causes a 10-30% reduction in congestion delay.

Table 5.5-2 **Maximum Service Volumes** (Passenger Cars Per Hour Per Lane)[4]

	LOS A	LOS B	LOS C	LOS D	LOS E
4-lane Freeway	700	1,100	1,550	1,850	2,000
2-lane Highway	210	375	600	900	1,400
4-lane Highway	720	1,200	1,650	1,940	2,200

This table shows maximum traffic volume per lane for various types of roadways.

Modeling summarized in Table 5.5-3 indicates that a percentage reduction in urban vehicle mileage tends to produce about twice that percentage reduction in congestion delays. Of course, when, where and what type of mileage is reduced affects these congestion impacts.

Table 5.5-3 **Impacts of 2¢ Per Mile Fee**[5]

Region	VMT	Trips	Delay	Fuel	Emissions
Bay Area	-3.9%	-3.7%	-9.0%	-4.1%	-3.8%
Sacramento	-4.4%	-4.1%	-7.5%	-4.4%	-4.3%
San Diego	-4.2%	-4.0%	-8.5%	-4.2%	-4.1%
South Coast	-4.3%	-4.1%	-10.5%	-5.2%	-4.2%

VMT = change in total vehicle mileage. Trips = change in total vehicle trips. Delay = change in congestion delay. Fuel = change in fuel consumption. See original report for additional notes and analysis.

Larger and heavier vehicles cause more congestion than smaller, lighter vehicles because they require more road space and are slower to accelerate. The relative congestion impact of different vehicles is measured in terms of "Passenger Car Equivalents" or PCEs. Large trucks and buses tend to have 1.5-2.5 PCEs, depending on roadway conditions, as shown in Table 5.5-4, and even more through intersections, under stop-and-go driving conditions, or on steep inclines. Transit buses have 4.37 PCEs, when operating on city streets without bus bays where they must stop regularly at the curb for passengers.[6] A large SUV imposes 1.4 PCEs, and a van 1.3 PCEs, traveling through an intersection.[7]

[4] Homburger, Kell and Perkins, p. 8-3.

[5] Elizabeth Deakin and Greig Harvey, "The STEP Analysis Package: Description and Application Examples," Appendix B in USEPA, *Technical Methods for Analyzing Pricing Measures to Reduce Transportation Emissions*, USEPA Report #231-R-98-006, (www.epa.gov/clariton), 1998.

[6] *Highway Capacity Manual*, Transportation Research Board (www.trb.org), 1985.

[7] Raheel Shabih and Kara M. Kockelman, *Effect of Vehicle Type on the Capacity of Signalized Intersections: The Case of Light-Duty Trucks*, UT Austin (www.ce.utexas.edu/prof/kockelman), 1999.

Table 5.5-4 **Passenger Car Equivalents** (PCEs)[8]

	Traffic Flow	Level	Rolling	Mountainous
Two-Lane Highways	**PC/lane/hr**			
Trucks & Buses	0-300	1.7	2.5	N/A
Trucks & Buses	300-600	1.2	1.9	N/A
Trucks & Buses	> 600	1.1	1.5	N/A
Recreational Vehicles	0-300	1.0	1.1	N/A
Recreational Vehicles	300-600	1.0	1.1	N/A
Recreational Vehicles	> 600	1.0	1.1	N/A
Multi-Lane Highways				
Trucks & Buses	Any	1.5	2.5	4.5
Recreational Vehicles	Any	1.2	2.0	4.0

PC=passenger cars

Congestion costs per vehicle-mile increase with speed because faster vehicles require more "shy distance" between them and other objects. Traffic flow (the number of vehicles that can travel on a road over a particular time period) tends to be maximized at 30-55 mph on roads without intersections, and at lower speeds on roads with intersections. "Traffic incidents" (disabled vehicles and accidents) account for an estimated 60% of delay hours.[9] Although random events, they only cause significant delays where traffic volumes approach road capacity, and so are considered congestion costs. In uncongested conditions an incident causes little or no traffic delay, but a stalled car on the shoulder of a congested road can cause 100-200 vehicle hours of delay on adjacent lanes.

Calculating Congestion Costs and Congestion Reduction Benefits

Various methods are used to quantify congestion costs.[10] The most appropriate approach for many applications, although difficult to perform, is to calculate the marginal delay caused by an additional vehicle entering the traffic stream, taking into account the speed-flow relationship of each road segment.[11] Another approach is to determine the user fee needed to reduce demand to design capacity, which reflects travelers' willingness-to-pay for road use. A third approach is to calculate unit costs of current expenditures on congestion reduction projects. In theory these three methods should produce similar cost values, assuming that roadway capacity is expanded based on vehicle delay costs as reflected in vehicle users' willingness to pay, but in practice they often provide different results.[12]

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[8] TRB, *Highway Capacity Manual*, TRB (www.trb.org), 2000, exhibits 20-9 and 21-8.

[9] G. Giuliano, "Incident Characteristics, Frequency, and Duration on a High Volume Urban Freeway," *Transportation Research A*, Vol. 23, 1989, pp. 387-396.

[10] Miller and Li, *An Investigation of the Costs of Roadway Traffic Congestion*, California PATH, UCB, Berkeley, 1994; David Schrank and Tim Lomax, *Mobility Measures*, TTI (http://mobility.tamu.edu), 1999; Francois Schneider, Axel Nordmann and Friedrich Hinterberger, "Road Traffic Congestion: The Extent of the Problem," *World Transport Policy & Practice*, Vol. 8, No. 1 (http://ecoplan.org/wtpp/wt_index.htm), Jan. 2002, pp. 34-41.

[11] Anthony Downs, *Stuck in Traffic*, Brookings Institute (Washington DC; www.brookings.edu), 1992.

[12] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association (Chicago; www.planning.org), Report # 448/449, 1993.

A more common method to calculate congestion costs (an *engineering* approach, as opposed to the *economic* approaches described above) is to sum the additional travel time over free-flowing conditions caused by congestion. It involves the following steps.[13]

1. Estimate peak period vehicle mileage.

2. Categorize each road segment into one of five congestion levels, as summarized below.

Table 5.5-5 **Roadway Congestion Categories**

	Extreme	Severe	Heavy	Moderate	Freeflow
Highway					
Avg. Daily Traffic Per Lane	>25,000	20,001-25,000	17,501-20,000	15,001-17,500	< 15,000
Avg. Vehicle Speed (mph)	32	35	38	45	60
Arterial					
Avg. Daily Traffic Per Lane	> 10,000	8,501-10,000	7,001-8,500	5,001-7,000	< 5,500
Avg. Vehicle Speed (mph)	21	23	27	30	35

3. Calculate vehicle travel delay, based on the difference between average traffic speeds and freeflow speeds on each segment, times vehicle mileage on that segment.

4. Calculate average passenger-speed for each roadway portion based on vehicle occupancy.

This information is used to calculate a Travel Rate Index (TRI), the ratio of peak period to free-flow travel times, which indicates the extra time required to travel during peak periods. A TRI of 1.3, for example, indicates an off-peak trip that takes 20 minutes under uncongested conditions takes 26 minutes during peak periods. This is used to calculate congestion cost indicators such as annual hours of delay and portion of travel on congested roads.

This method uses free-flow travel speeds as a reference because it is easy to understand and calculate, although it does not represent a realistic goal for urban transport systems. It is equivalent to sizing a restaurant to accommodate the maximum number of patrons who would accept a free meal. This method overestimates congestion costs compared with what is economically efficient. As described by one leading transport economist,[14]

> The most widely quoted [congestion cost] studies may not be very useful for practical purposes, since they rely, essentially, on comparing the existing traffic conditions against a notional 'base' in which the traffic volumes are at the same high levels, but all vehicles all deemed to travel at completely congestion-free speeds. This situation could never exist in reality, nor (in my view) is it reasonable to encourage public opinion to imagine that this is an achievable aim of transport policy.

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[13] David Schrank and Tim Lomax, *Urban Mobility Study*, TTI (http://mobility.tamu.edu/ums), 2000.
[14] Phil Goodwin, *The Economic Cost of Congestion when Road Capacity is Constrained: Lessons from Congestion Charging in London*, European Conference of Ministers of Transport. 16th International Symposium on Theory and Practice in Transport Economics (www1.oecd.org/cem), 2003.

> Such huge, but non-achievable, benefits inflate the currency of debate and distract attention from the value for money of real policies. However, among the many estimates there were a few which take an entirely different approach. In these, the idea of a totally congestion-free target is ignored, and emphasis is put on the *change* in congestion that would be realistically achievable as a result of implementing specific more or less ambitious transport policies, such as road building, public transport improvements, and transport prices. The most useful applications of this approach have been developed in connection with congestion charging. The figures are of course typically smaller than the unrealistic estimates produced by comparing against zero congestion, though typically much larger than the benefits which are produced, in urban conditions, by road construction projects. They are also much easier to interpret and much more relevant for real policy purposes. Thus it would be better to shift the focus from the '*total* economic cost of congestion' to 'the economic value of the savings in congestion that could be achieved with congestion charging'.

Table 5.5-6 summarizes various indicators used to quantify and monetize congestion costs, and indicates whether they account for all impacts or just vehicle traffic impacts.

Table 5.5-6 **Roadway Congestion Indicators**

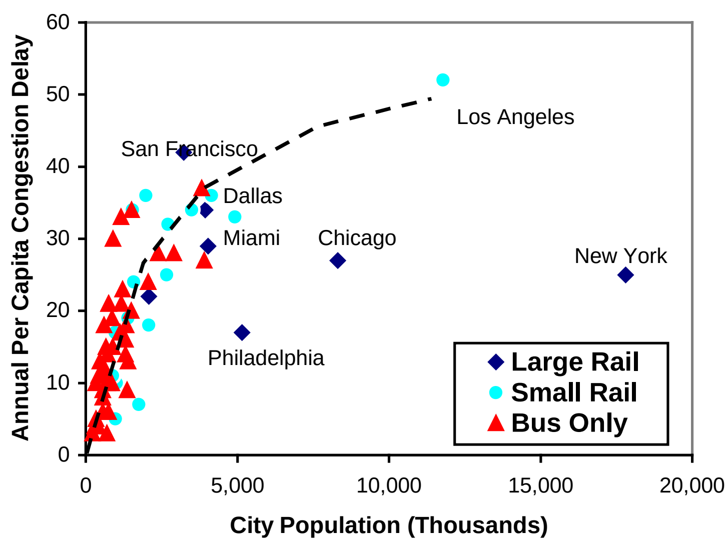
Indicator	Description	Comprehensive?
Roadway Level Of Service (LOS)	Intensity of congestion delays on a particular roadway or at an intersection, rated from A (uncongested) to F (most congested).	No
Travel Time Rate	The ratio of peak period to free-flow travel times, considering only reoccurring delays (normal congestion delays).	No
Travel Time Index	The ratio of peak period to free-flow travel times, considering both reoccurring and incident delays (e.g., traffic crashes).	No
Percent Travel Time In Congestion	Portion of peak-period vehicle or person travel that occurs under congested conditions.	No if for vehicles, yes if for people.
Congested Road Miles	Portion of roadway miles that are congested during peak periods.	No
Congested Time	Estimate of how long congested "rush hour" conditions exist	No
Congested Lane Miles	The number of peak-period lane miles that have 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	Hours of extra travel time divided by the number of peak period road users.	Yes
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
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 vehicle traffic and so are unsuited for evaluating the congestion reduction benefits of shifts to alternative modes and other demand management strategies.

Different indicators represent different perspectives and assumptions, which can favor one group or set of solutions over others. Some congestion indicators, such as roadway LOS and the Travel Time Index, only consider delays to motorists. Percent Travel Time actually declines if the total amount of driving on uncongested roads increases, implying that congestion declines if per capita VMT increases, for example, due to increased sprawl. These indicators ignore congestion cost reductions to travelers who shift to alternative modes, or from land use changes that reduce the distance between destinations, and so are unsuited for evaluating the congestion reduction benefits of improvements of many mobility management strategies. For example, a shift from driving to transit, the use of telecommuting, or more accessible land use patterns, can reduce total per capita congestion costs, because people drive less, although the intensity of motorist congestion delays does not decline. Indicators that reflect *per capita* rather than *per vehicle* impacts are more suitable for evaluating overall congestion costs.

When measured in terms of roadway LOS or delay per vehicle trip, higher development densities tend to increase congestion, since more trips are generated per acre. From this perspective, infill development is harmful and sprawl is helpful for reducing congestion problems.[15] However, density tends to increase land use accessibility and transport diversity, resulting in shorter trip distances and shifts to other modes such as walking and transit. Although streets in higher density urban areas may experience more LOS E or F, implying serious congestion problems, urban residents experience less per capita congestion costs because they have better travel options and closer destinations.

Figure 1 **Traffic Congestion**[16]



Cities with large, well-established rail transit systems tend to have less per capita traffic congestion than comparable size cities that lack such systems. This benefit is not reflected in roadway LOS or Travel Time Index ratings.

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15 Brian D. Taylor, "Rethinking Traffic Congestion", *Access*, Number 21, University of California Transportation Center (www.uctc.net), Fall 2002, p. 8-16.
16 Todd Litman, *Critique of 'Great Rail Disasters'*, VTPI (www.vtpi.org), 2004.

As a result, *per capita* (as opposed to *per-vehicle trip*) congestion delay tends to be greater in lower-density, automobile-dependent areas such as Los Angeles and Houston than in higher-density areas such as New York and San Francisco, because low-density areas have more per capita vehicle mileage.[17] Figure 1 shows compares per capita congestion delays in various U.S. cities. Similarly, strategies such as HOV Priority (e.g., transit and carpool lanes) and traffic calming may increase congestion when measured as roadway LOS, but reduce it when measured as per capita congestion delay, by improving travel options and reducing per capita vehicle travel.

Some congestion reduction strategies, such as HOV priority and transit improvements are most effective under congested conditions, when automobile traffic experiences the greatest delay. Such strategies do not eliminate congestion, since automobile traffic delays make these alternatives relatively attractive, but they can significantly reduce congestion delays both to people who shift mode and those who continue driving. For example, they may improve a roadway from LOS E to LOS D, which is a significant improvement, but by themselves will never provide LOS B. As a result, the cost value applied to high levels of congestion have a major effect on their evaluation. Extreme congestion tends to impose high travel time costs (see Travel Time Cost chapter), which increases the justification for such strategies.

The economic value of congestion reduction strategies are difficult to evaluate because urban traffic tends to maintain equilibrium: traffic volumes grow until congestion delays discourage additional peak-period trips. Efforts to reduce congestion by increasing urban roadway capacity or convincing a few individuals to shift mode causes generated traffic (additional vehicle traffic using a roadway that would not otherwise occur), which over the long term fills a significant portion (50-90%) of the space created.[18]

This changes the nature of benefits that result: congestion reductions tend to be modest and temporary, while more benefits consist of increased mobility and urban fringe property values, and reduced congestion during shoulder periods (just before or after peaks). It also means that increasing highway capacity can exacerbate problems such as downstream congestion, crashes, pollution and sprawl. On the other hand, strategies that reduce the point of equilibrium by raising the price of driving, improving travel alternatives, or reducing the need for travel can reduce congestion, although they might never eliminate it. For example, they may improve a roadway from LOS E to LOS D, which is a significant improvement, but by themselves will never result in LOS B. These strategies include HOV priority, transit and rideshare improvements, telecommunications that substitute for travel, and land use changes, as indicated in Table 5.5-7.[19]

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[17] STPP, *Easing the Burden: A Companion Analysis of the Texas Transportation Institute's Congestion Study,* Surface Transportation Policy Project (www.transact.org), 2001.

[18] Todd Litman, "Generated Traffic; Implications for Transport Planning," *ITE Journal*, Vol. 71, No. 4, Institute of Transport. Engineers (www.ite.org), April, 2001, pp. 38-47; available at VTPI (www.vtpi.org).

[19] Todd Litman, *Evaluating Public Transit Benefits and Costs*, VTPI (www.vtpi.org), 2002.

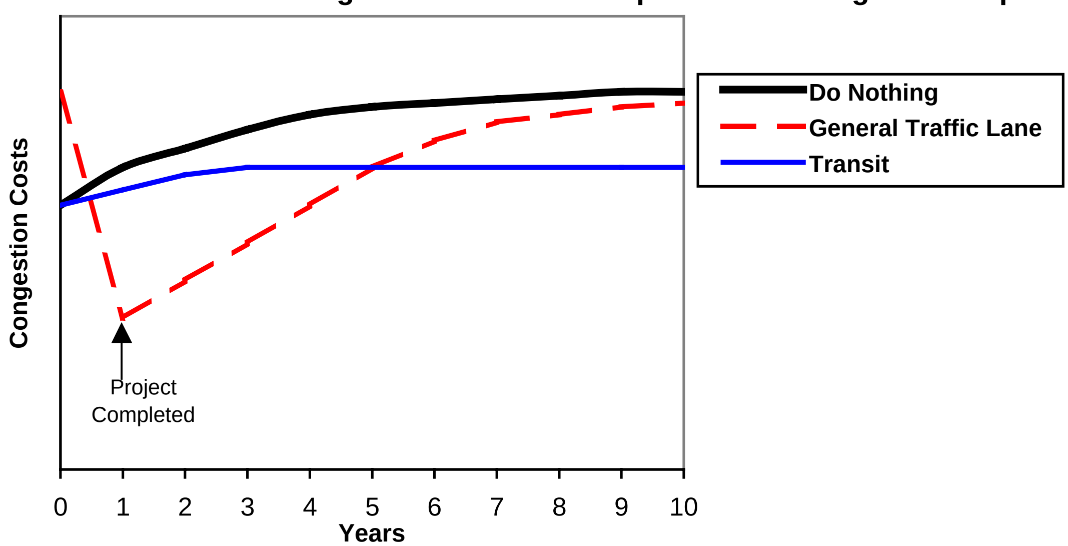
Table 5.5-7 **Effects of Generated Traffic On Congestion Reduction**

Affected by Generated Traffic	Not Affected by Generated Traffic
• Increased road capacity (new lanes, grade-separated intersections, etc). • Traffic signal synchronization. • Small, individual TDM programs that cause small mode shifts.	• Congestion pricing. • HOV and transit priority and grade-separated service. • Large, comprehensive TDM programs that cause significant mode shifts. • Improved travel alternative and mobility substitutes. • More accessible land use.

Some congestion reduction strategies result in generated traffic (additional vehicle traffic using a roadway that would not otherwise occur), which reduces their congestion reduction benefits. Other strategies generate little or no traffic and so provide more congestion reduction benefits.

The time frame used for analysis can significantly affect the evaluation of congestion reduction strategies. Figure 2 compares how road widening and transit improvements affect congestion. If no project is implemented, traffic volumes increase to equilibrium, when congestion delays discourage further growth in peak-period traffic. Adding general traffic lanes reduces congestion in the short term, but traffic volumes grow over time so congestion nearly returns to its pervious level. A transit improvement, such as grade separated rail, a busway or HOV facility, provides little reduction short-term congestion reduction, but its congestion reduction benefits increase over time as delays on parallel highways make alternative modes increasingly attractive. Although congestion continues, it never becomes as bad as would otherwise occur. As a result, shorter-term analysis of congestion reduction benefits tends to favor roadway capacity expansion, while longer-term analysis tends to favor transit and HOV improvements.

Figure 2 **Road Widening and Transit/HOV Improvement Congestion Impacts**



Adding traffic lanes increases congestion during the construction period and reduces it on completion, but generated traffic fills much of the added capacity, reducing long-term congestion reduction benefits. Grade separated transit provides modest short-term congestion reductions, but benefits increase over time as transit becomes relatively attractive to peak-period travelers.

Internal or External Cost?

Traffic congestion is an example of a cost that is external to individual motorists but considered largely internal to motorists as a group: each vehicle user both imposes and bears this cost. As a result, some analysts consider congestion an internal impact, at least from an equity perspective.[20] However, for most planning, evaluation and pricing applications congestion should be treated as an external cost, for the following reasons.

The incremental congestion delay an individual traveler imposes when making an urban-peak vehicle trip is often much greater than the incremental cost they bear. This violates the principle that prices (consumers' internal costs, in this case including both financial and time costs) should reflect the marginal costs they impose.[21] As a result, congestion is economically inefficient. As Franzi Poldy states,

> "While it is true that road users bear congestion costs collectively, they make their decisions to travel individually. For each individual, a decision to travel requires only that the benefits exceed the delay costs that each traveller would expect to face on the congested road network...By deciding to join the congested traffic flow, the marginal traveller adds to the congestion, and causes a small increase in the delay experienced by each of the other users. The sum (over all road users) of these additional delays can be very much greater than the average delay (experienced by each individual) which formed the basis of the decision to travel. It is because cost bearing and decision making are separated that these costs are appropriately considered external."[22]

Congestion is inequitable because the costs imposed and borne vary significantly between modes. Congestion costs imposed per passenger-mile are lower for bus and rideshare passengers, but they bear the same congestion delay costs as single occupant drivers (except on HOV priority facilities). This is unfair and inefficient because travelers have no incentive to choose space efficient modes.

Congestion is also an externality because it delays nonmotorized travel (discussed in Chapter 5.13), and increases pollution emissions. The external nature of congestion costs is also indicated by the considerable resources society spends to increase road capacity, only part of which are paid by automobile user fees (as discussed in Chapter 5.6).

For these reasons, even non-drivers are negatively impacted by traffic congestion, and can benefit from reduced congestion.

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[20] Mark Hanson, "Automobile Subsidies and Land Use," *APA Journal*, Winter 1992, pp. 60, 68; Per Kågeson, *Getting the Prices Right*, European Federation for Transport and Environment (Broxelles), 1993.

[21] "Market Principles," *Online TDM Encyclopedia*, VTPI, (www.vtpi.org/tdm/tdm60.htm), 2002.

[22] BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Vol. 1, Environment Protection Authority (Melbourne, Australia), 1994.

"No One Goes There Anymore. It's Too Crowded."

A contrary view of congestion costs by Peter Jacobsen

One of the biggest debates in transportation policy is whether improving drivability is a good thing. From a personal perspective, we all dislike waiting at traffic signals and stop-and-go traffic. Yet should our personal experience be the basis of transportation policy?

It's should be easy to calculate congestion delay costs – multiply time spent in traffic by a cost of time. But it's really not that easy. How much is that time worth – some analysis shows that people actually appreciate their travel time. Does reducing travel time encourage further trips – induced demand is another hot topic of research. Many uncertainties make valuing congestion difficult.

For setting transportation investment decisions, the question really evolves to the more complex: does improving drivability improve economic wealth?

Recently, Sperling's BestPlaces ranked 77 U.S. cities based on how easy it is for residents to motor around their city (www.bestplaces.net/drive/drive_study1.asp). They say the most drivable cities have smooth driving surfaces, free-flowing traffic, low gas prices and a pleasant climate. Topping their list were cities along the Texas Gulf coast, whereas the poorest performing cities were along the East and West coast.

Curiously enough, the least drivable cities appear to be thriving. Comparing drivability against per capita income (Commerce Department shows that the average per capita income of the ten least drivable cities is over half again greater than the ten most drivable cities. (www.bea.doc.gov/bea/regional/data.htm)

	The 10 Most Drivable Cities	Income	The 10 Least Drivable Cities	Income
1	Corpus Christi, TX	24,280	Los Angeles-Long Beach, CA	30,611
2	Brownsville-Harlingen, TX	15,334	San Francisco, CA	57,714
3	Beaumont-Port Arthur, TX	24,296	Chicago, IL	36,624
4	Pensacola, FL	24,140	Denver, CO	38,513
5	Fort Myers-Cape Coral, FL	29,540	Boston, MA	39,873
6	Oklahoma City, OK	26,970	Oakland, CA	39,963
7	Birmingham, AL	30,620	Detroit, MI	34,035
8	El Paso, TX	19,186	New York, NY	40,450
9	Memphis, TN	30,559	Seattle-Bellevue-Everett, WA	41,229
10	Tulsa, OK	30,650	Washington, DC	41,754
	Average	$25,558	Average	$40,077

Although Yogi Berra was thinking of New York City nightclubs, he summed up the fallacy of using drivability as a measure of transportation policy decisions with his famous line: "No one goes there anymore. It's too crowded." No matter how much we personally dislike congestion, it measures economic vitality.

Estimates

Note: all monetary units in U.S. dollars unless indicated otherwise.

- Table 5.5-13 summarizes congestion factors for bicycles. "Opposed" means that a bicycle encounters interference from other road users, such as when making a left turn. Bicyclists probably contribute relatively little congestion overall because they avoid high traffic roads.[23]

Table 5.5-13 **Passenger-Car Equivalents (PCEs) for Bicycles by Lane Width**[24]

Riding Condition	< 11 ft. Lane	11-14 ft. Lane	> 14 ft. Lane
Unopposed	1.0	0.2	0.0
Opposed	1.2	0.5	0.0

- Table 5.5-8 summarizes marginal highway congestion costs for various vehicles.

Table 5.5-8 **Estimated Highway Congestion Costs** (Cents Per Vehicle Mile)[25]

	Rural Highways			Urban Highways			All Highways		
	High	Med.	Low	High	Med.	Low	High	Med.	Low
Automobile	3.76	1.28	0.34	18.27	6.21	1.64	13.17	4.48	1.19
Pickup & Van	3.80	1.29	0.34	17.78	6.04	1.60	11.75	4.00	1.06
Buses	6.96	2.37	0.63	37.59	12.78	3.38	24.79	8.43	2.23
Single Unit Trucks	7.43	2.53	0.67	42.65	14.50	3.84	26.81	9.11	2.41
Combination Trucks	10.87	3.70	0.98	49.34	16.78	4.44	25.81	8.78	2.32
All Vehicles	4.40	1.50	0.40	19.72	6.71	1.78	13.81	4.70	1.24

- Delucchi estimates U.S. traffic congestion external costs, including delay and increased fuel consumption, totaled $34-146 billion in 1991 ($44-190 billion in 2001 dollars).[26] This averages 7-32¢ per urban-peak vehicle-mile (10-42¢ in 2001 dollars).

- Vehicle fuel consumption increases approximately 30% under heavily congestion.[27] Increased fuel consumption and air pollution costs represent about 17% the total external cost of congestion.[28]

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23 Todd Litman, "Bicycling and Transportation Demand Management," *Transportation Research Record 1441*, 1994, pp. 134-140.

24 AASHTO, *Policy on Geometric Design for Streets and Highways*, AASHTO (www.aashto.org), 1990.

25 FHWA, *1997 Federal Highway Cost Allocation Study*, USDOT (www.fhwa.dot.gov/policy/hcas/summary/index.htm), Table V-23.

26 Mark Delucchi, *Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991*, Institute of Transportation Studies (Davis; www.engr.ucdavis.edu/~its), UCD-ITS-RR-96-3, 1997.

27 I.D. Greenwood and C.R. Bennett, "The Effects of Traffic Congestion on Fuel Consumption," *Road & Transport Research*, Vol. 5, No. 2, June 1996, pp. 18-31.

28 Olof Johansson, "Optimal Road Pricing: Simultaneous Treatment of Time Losses, Increased Fuel Consumption, and Emissions," *Transportation Research D*, Vol. 2, No. 2, June 1997, pp. 77-87.

- Table 5.5-9 shows marginal arterial congestion costs for various Australian cities.

Table 5.5-9 **Marginal External Congestion Costs** (Aus. Cents per Veh. Km)[29]

	Melbourne	Sydney	Brisbane	Adelaide	Perth
Freeways	14¢	13¢	14¢	0	14¢
CBD Streets	57¢	62¢	40¢	40¢	40¢
Inner Arterials	20¢	21¢	16¢	16¢	16¢
Outer Arterials	7¢	7¢	5¢	5¢	5¢

- Keeler, et al's marginal congestion cost estimates for San Francisco area highways in the early 1970s are summarized in Table 5.5-10, presented in 1994 dollars.

Table 5.5-10 **Marginal Highway Congestion Costs** (¢/mile)[30] (Travel time = $13.50)

	Interest	Peak	Near Peak	Day Avg.	Night Avg.	Weekend
Rural-Suburban	6%	8.1	3.3	1.8	1.2	0.3
	12%	15.6	4.5	2.4	1.5	0.3
Urban-Suburban	6%	9.9	3.6	2.1	1.5	0.3
	12%	21.0	4.8	2.4	1.5	0.3
Central City	6%	45.6	5.4	2.7	1.8	0.6
	12%	80.1	5.4	2.7	1.8	0.6

- Large SUVs impose about 1.41 PCEs (Passenger Car Equivalents) and vans 1.34 PCEs when traveling through an intersection, due to their slower acceleration and large size, which reduces traffic flow and increases traffic congestion problems.[31]

- Levinson calculates that marginal peak period congestion costs for urban freeway average 6-9¢ when traffic flows faster than 50 mph, and 37¢ when traffic flows at less than 40 mph, based on *Highway Capacity Manual* speed-flow curves.[32]

- John McDonald emphasizes that congestion prices should reflect network congestion costs, not just costs on the road that is tolled.[33] He concludes that prices should be

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[29] BTCE, *Traffic Congestion and Road User Charges in Australian Capital Cities*, Australian Gov. Publishing Service (Canberra), 1996, Table 5.1.

[30] Theodore Keeler, et al., *The Full Costs of Urban Transport: Part III Automobile Costs and Final Intermodal Cost Comparisons*, Institute of Urban and Regional Development (Berkeley), 1975, p. 47.

[31] Kara M. Kockelman, "Effects of Light-Duty Trucks on the Capacity of Signalized Intersections," *Journal of Transportation Engineering*, Vol. 126, No. 6, 2000, pp. 506-512; available at www.ce.utexas.edu/prof/kockelman/home.html.

[32] Herbert Levinson, "Freeway Congestion Pricing: Another Look," *TRR 1450*, 1995, pp. 8-12.

[33] John McDonald, "Urban Highway Congestion; An Analysis of Second-best Tolls," *Transportation*, Vol. 22, 1995, pp. 353-369.

higher if a road is complementary to other congested roads (such as a tolled bridge or highway that adds traffic to congested surface streets), and *lower* if a road substitutes for other congested roads (such as a tolled highway with parallel untolled roads).

- Estimated marginal congestion costs in the U.K. are summarized in Table 5.5-11.[34]

Table 5.5-11 **Marginal External Costs of Congestion in the U.K.**

	1990 Pence Per Vehicle Km	1996 US$ Per Vehicle Mile
Motorway	0.26	$0.009
Urban Central Peak	36.37	$1.25
Urban Central Off Peak	29.23	$1.00
Non-central Peak	15.86	$0.55
Non-central Off Peak	8.74	$0.30
Small Town Peak	6.89	$0.034
Small Town Off Peak	4.2	$0.144
Other Urban	0.08	$0.003
Rural Dual Carriageway	0.07	$0.003
Other Trunk and Principal	0.19	$0.007
Other Rural	0.05	$0.002
Weighted Average	*3.4*	*$0.117*

- Mohring and Anderson estimate average congestion costs for Twin City roads shown in Table 5.5-12.

Table 5.5-12 **Average Marginal Congestion Costs**[35]

	Morning Peak	Afternoon Peak
All Road Links	20.7¢	17.0¢
Expressways	23.6¢	20.1¢

- Transport Concepts estimates truck congestion costs at 62¢ per ton-mile for intercity semi-trailer trucks and 79¢ per ton-mile for B-Train trucks.[36]

- A Transportation Research Board special report indicates that optimal congestion prices (which are considered to represent congestion costs) ranging from about 5¢ to 36¢ per vehicle mile on congested urban roads, with averages of 10¢ to 15¢.[37]

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34 David Morrison, et al., *The True Costs of Road Transport*, Earthscan (London), 1996, p. 111.
35 Herbert Mohring and David Anderson, *Congestion Pricing for the Twin Cities Metropolitan Area*, Dept. of Economics, University of Minnesota (Minneapolis), January 1994. Also see their "Congestion Costs and Congestion Pricing," in *Buying Time; Research and Policy Symposium on the Land Use and Equity Impacts of Congestion Pricing*, Humphrey Institute (Minneapolis; www.hhh.umn.edu), 1996.
36 *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994, p.23.
37 *Curbing Gridlock*, TRB, National Academy Press (www.trb.org), 1994, Appendix B.

- Passenger Car Equivalents (PCEs) measured in developing country urban conditions (Bandung, Yogyakarta, Jakarta, Semarang) are summarized below.[38]

Bicycle 0.19	Motorcycle 0.27
Trishaw 0.89	Medium vehicle 1.53
Heavy vehicle 2.33	Trailer 2.98

- The Texas Transportation Institute has developed a congestion index, which is used to calculate congestion costs in major U.S. cities, the results of which are published in their annual *Urban Mobility Study*.[39] These costs are widely cited and used for comparing and evaluating urban congestion problems. The 2001 report estimates that congestion costs in the 68 major urban regions studied totaled $78 billion in 1999, which was the value of 4.5 billion hours of delay and 6.8 billion gallons of excess fuel consumed. This suggests that U.S. congestion costs total about $100 billion annually, taking into account congestion in areas not covered by the study. This averages about 20¢ per urban-peak vehicle mile.

- Winston and Langer review congestion costing methods, and using their own model estimate that U.S. congestion costs total $37.5 billion annually (2004 dollars), a third of which consists of freight vehicle delays.[40] They find that highway spending is not a cost effective way of reducing congestion costs.

- Analysis by Zupan indicates that each 1% increase in VMT in a U.S. urban region was associated with a 3.5% increase in congestion delays in that region during the 1980's, but this relationship disappeared during the 1990s.[41] This change may reflect increased ability of travelers to avoid peak-period driving, through flextime, telework and suburbanization of destinations, allowing VMT growth without comparable increases in congestion delay. The relationship between vehicle travel and congestion delay is probably must stronger when evaluated at a more disaggregated level, for example, on individual corridors or roads.

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[38] Heru Sutomo, PhD Thesis, Institute for Transport Studies, Leeds University (Leeds), 1992.

[39] David Schrank and Tim Lomax, *Urban Mobility Study*, Texas Transportation Institute (http://mobility.tamu.edu/ums), 2001.

[40] Clifford Winston and Ashley Langer, *The Effect of Government Highway Spending on Road Users' Congestion Costs*, Brookings Institute (www.brookings.edu), 2004.

[41] Jeffrey Zupan, *Vehicle Miles Traveled in the United States: Do Recent Trends Signal More Fundamental Changes?*, Surdna Foundation (www.surdna.org), Oct. 2001.

Variability

Congestion varies by location, time, and, to a lesser extent, vehicle type. This cost occurs primarily during Urban Peak travel.

Equity and Efficiency Issues

As described earlier, traffic congestion is an example of a cost that is external to individuals, but largely internal to road users as a group. To the degree that an individual bears the same amount of delay that they impose, it can be considered an equitable cost. It is inequitable when road users bear greater costs than they impose, for example, transit and rideshare passengers who are delayed in traffic the same as single occupant vehicle drivers.

Because it is an external cost at the individual level, traffic congestion in economically inefficient.

Congestion Costs Tend to Increase With Wealth

Traffic congestion problems tend to increase with wealth because consumers purchase more vehicles, which greatly increases the amount of space needed for travel (a car trip typically requires an order of magnitude more space than the same trip made by walking, cycling or transit). Although increased wealth allows greater facility construction expenditures, the supply of land does not increase. Road and parking facilities must compete for land that is increasingly expensive due to competition for other uses, so land costs become an increasing portion of project costs and a limiting factor in roadway and parking capacity expansion. Although sprawl may seem to overcome this problem by shifting travel to the urban fringe where land costs are lower, dispersed development increases per-capita vehicle mileage, requiring more lane-miles and parking spaces per capita, so land costs continue to be a major constraint. As a result, congestion costs tend to increase and alternative modes and demand management tend to become more important with increased wealth.

Conclusions

Congestion is a significant cost and an externality in terms of economic efficiency, and to some degree in terms of equity due to differences in congestion imposed per passenger-mile by different modes. It is an externality for individual vehicle users but internal to road users as a group. As a result, it is not appropriate to add congestion and user costs together when calculating total costs. Congestion costs borne by the individual whose costs are being considered are counted under travel time and vehicle operating costs. To avoid double counting, congestion costs are netted out when all costs are aggregated.

Viable estimates of total U.S. congestion costs range from $43 to $150 billion per year. $100 billion is used as a starting point for this study. Assuming that 20% of all driving and 80% of congestion costs occur under Urban Peak conditions,[42] and 2,300 billion miles are driving annually, the average cost is about 17¢ per Urban Peak mile ([$100 x 80%] / [2,300 x 20%]). Urban Off-Peak driving represents 40% of driving and is estimated here to impose 20% of congestion costs, for an estimate of 2¢ ([$100 x 20%] / [2,300 x 40%]). Rural driving is not considered to have significant congestion costs.

Compact and electric cars, vans, light trucks and motorcycles impose about the same congestion costs as an average car. Rideshare passengers cause no additional congestion. Buses and trolleys are considered to impose twice, and bicycles 5%, the congestion costs of an average car. Walking can impose congestion costs when pedestrians block traffic while crossing a street, but this impact is small since pedestrians seldom cross many major roadways, and usually cross during a regular traffic signal cycle or a natural break in traffic flow. Telework imposes no congestion costs.

Estimate **Congestion Costs (1996 U.S. Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.170	0.020	0.000	0.042
Compact Car	0.170	0.020	0.000	0.042
Electric Car	0.170	0.020	0.000	0.042
Van/Light Truck	0.170	0.020	0.000	0.042
Rideshare Passenger	0.000	0.000	0.000	0.00
Diesel Bus	0.340	0.040	0.000	0.084
Electric Bus/Trolley	0.340	0.040	0.000	0.084
Motorcycle	0.170	0.020	0.000	0.042
Bicycle	0.009	0.001	0.000	0.002
Walk	0.003	0.001	0.000	0.001
Telework	0.000	0.000	0.000	0.00

Automobile (Urban Peak) Cost Range

Minimum and Maximum estimates are based on the literature cited.

Minimum	Maximum
$0.02	$0.06

[42] About 60% of driving is urban and about 33% occurs during peak periods.

Information Resources

Information sources on congestion costing are described below.

Jim Beamguard, "Packing Pavement," *Tampa Tribune* (www.tampabayonline.net/bguard/home.htm), 1999. Compares the road space used by transit patrons, motorists and cyclists.

BTS, *Improving Measurements of Road Congestion*, BTS (www.bts.gov), 2003.

FHWA, *Management and Operations Toolbox*, (http://plan2op.fhwa.dot.gov/toolbox/toolbox.htm) provides information and techniques for evaluating transportation systems management strategies.

Todd Litman, "Generated Traffic; Implications for Transport Planning," *ITE Journal*, Vol. 71, No. 4, Institute of Transportation Engineers (www.ite.org), April, 2001, pp. 38-47; available at www.vtpi.org/gentraf.pdf.

Herbert Mohring, "Congestion," in *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer*, Brooking Institution (www.brookings.edu), 1999, pp. 181-222; available at (http://brookings.nap.edu/books/0815731817/html/181.html).

Francois Schneider, Axel Nordmann and Friedrich Hinterberger, "Road Traffic Congestion: The Extent of the Problem," *World Transport Policy & Practice*, Vol. 8, No. 1 (http://ecoplan.org/wtpp/wt_index.htm), Jan. 2002, pp. 34-41.

David Schrank and Tim Lomax, *Mobility Measures* (1999) and the *Urban Mobility Study*, Texas Transportation Institute (http://mobility.tamu.edu/ums), annual reports.

STPP, *Easing the Burden: A Companion Analysis of the Texas Transportation Institute's Congestion Study*, Surface Transportation Policy Project (www.transact.org), May 2001.

TransPriceProject (www.cordis.lu/transport/src/transpricerep.htm) is a European study of various pricing strategies for reducing urban traffic congestion and air pollution emissions.

TRB, *Quantifying Congestion; Final Report and User's Guide*, NCHRP Project 7-13, Transportation Research Board (www.trb.org), 1997.

UCLA, *Traffic Congestion Issues and Options*, UCLA Extension Public Policy Program (www.uclaextension.edu/unex/departmentalPages/publicpolicy/report.pdf), June 2003.

VTPI, "Congestion Reduction Strategies" *Online TDM Encyclopedia* (www.vtpi.org/tdm/tdm96.htm), 2002.

Glen Weisbrod, Donald Vary and George Treyz, *Economic Implications of Road Congestion*, NCHRP Report 463, TRB (*http://gulliver.trb.org/publications/nchrp/nchrp_rpt_463-a.pdf*), 2001.

Clifford Winston and Ashley Langer, *The Effect of Government Highway Spending on Road Users' Congestion Costs*, Brookings Institute (www.brookings.edu), 2004.