Chapter 10: Externalities from Traffic

A. Theory of External Costs

External costs are costs that are borne by bystanders (that are neither demand nor supply). Transportation related examples include pollution, noise, accidents and time losses in traffic jams. This means: The "true cost" (i.e., the social cost) of transportation is larger than the incurred private cost.

Private Cost is the cost that is covered by the consumer who pays for his/her gasoline, car, maintenance etc.
External cost is incurred by third parties, the society or by nature
Social cost is the sum of private cost and externality.

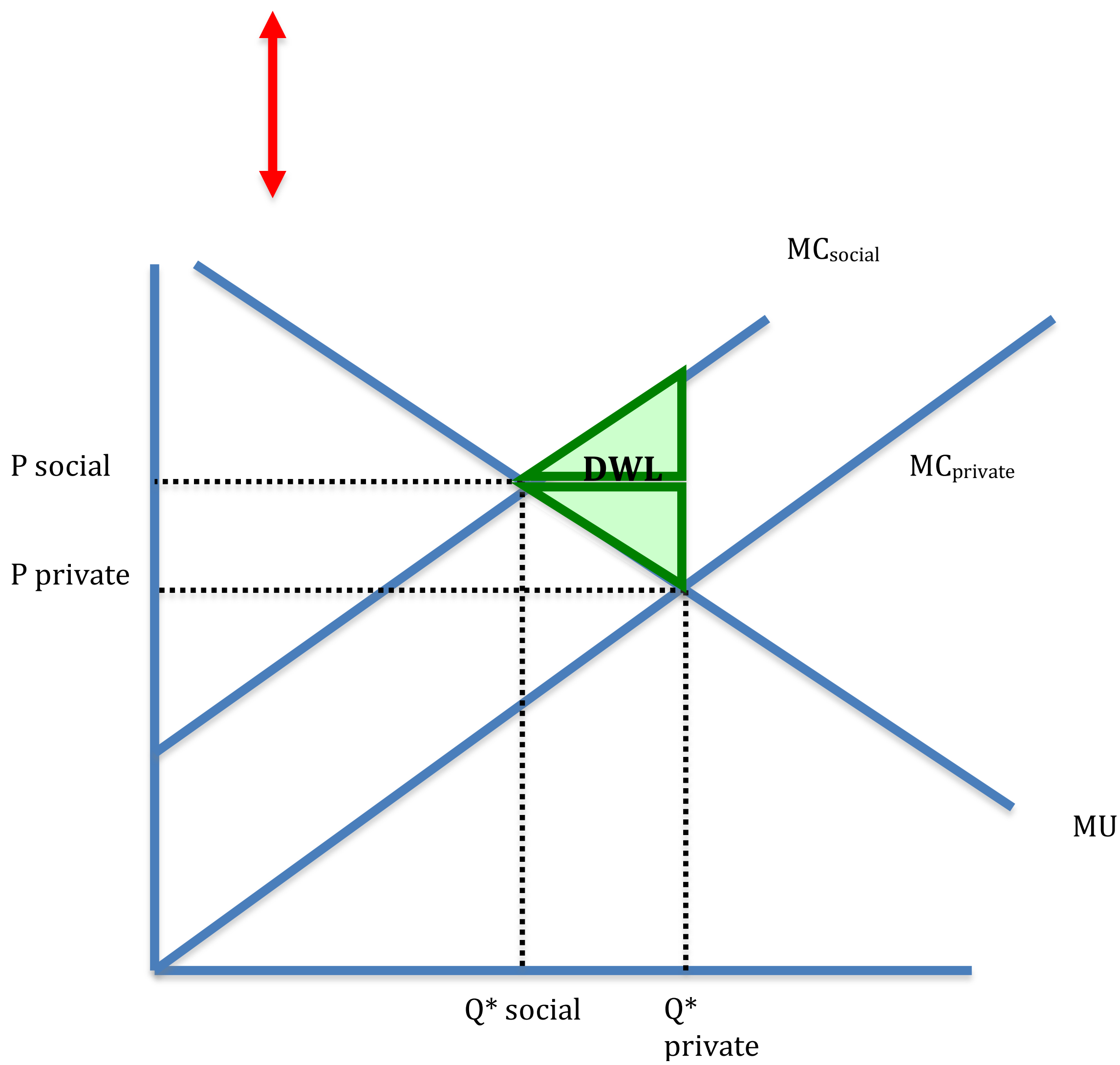
The Figure below shows the corresponding marginal cost and benefit curves.
Private Solution: The private optimum is determined by the intersection of marginal private cost and marginal utility and results in *Q*private*. The market-clearing price is *P private*.

Social Solution: A constant per unit external cost (depicted by the red arrow) leads to a marginal social cost curve that is shifted up exactly by the constant external cost. The difference between private and social cost curve is identical at any quantity. The social optimum is given where the marginal utility curve intersects the marginal social cost curve and yields *Q* social* and *P social*.

DWL of Private Solution: In the private solution, the marginal social cost curve is above the marginal utility curve for all quantities exceeding *Q*social*. As a result the quantity consumed is sub-optimally high resulting in a deadweight loss (DWL).

Mathematical Example:
Assume the following curves: MC private: P=Q, MU=100-Q and an external cost of 10 per unit.

Private solution: MU=MCprivate → 100-Q=Q → Q=50, P=50
Social solution: MU=MCsocial → 100-Q = Q+10 → Q=45, P=55
DWL of private solution: equals half the area of (quantity difference)*(external effect per Q) = 0.5*5*10=25



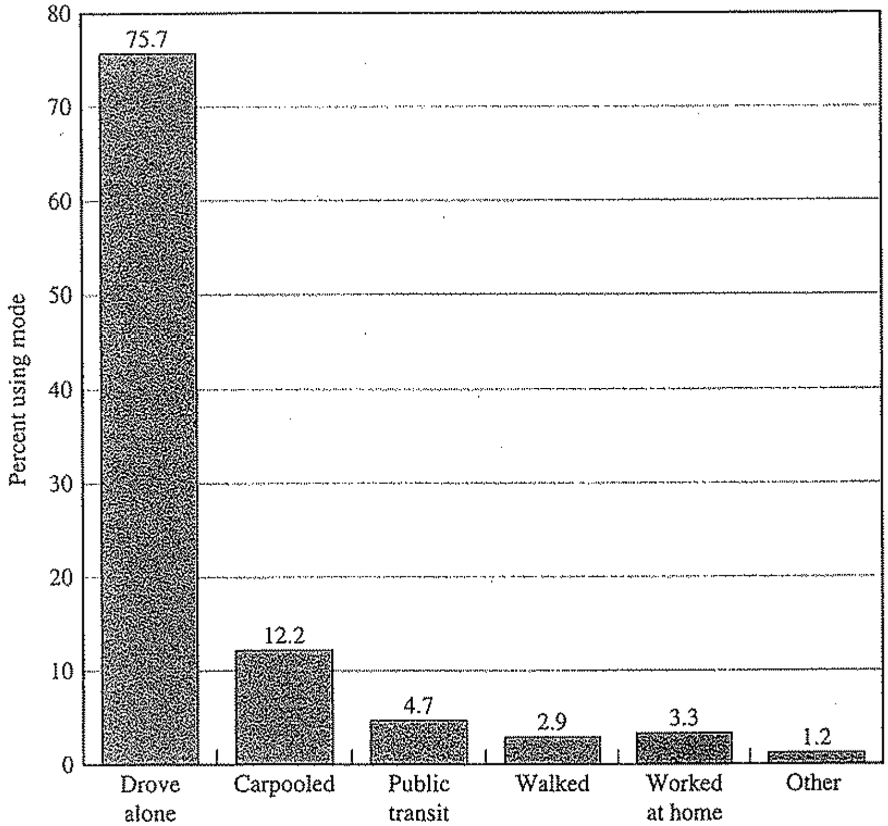
MC_social
P social
DWL
MC_private
P private
MU
Q* social
Q*
private

B. Some Data on Transportation

As shown in Fig 10-1 and Table 10-1 below,
Almost all trips to work in 2000 were done by single car drivers (75. 7%). Almost nobody walks or rides his/her bicycle. Less than 5% of all trips are served by public transit. When multiplied with the average trip distance these differences will only grow (because car trips are usually longer than trips on foot or by mass transit).

However, are maybe surprisingly, most trips are undertaken for leisure purposes (almost 1/3).

FIGURE 10–1 Modal Choice for U.S. Commuters



Source: U.S. Census Bureau. *Journey to Work: 2000.* Washington DC: U.S. Census Bureau, 2004.

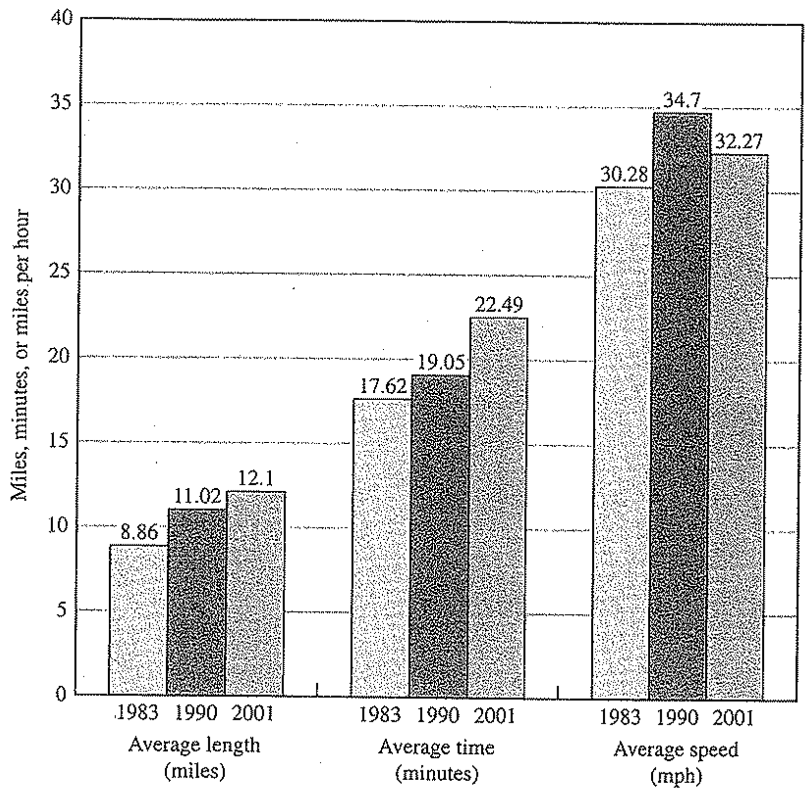
TABLE 10–1 Purposes of Travel

	Share of Travel (percent)	Average Trip Length (miles)
Social and recreational	30	11.36
To/from work	19	12.11
All other family and personal business	19	7.84
Shopping	14	7.02
Work-related business	9	28.26
School/church	6	6.00
Other	4	43.08

Source: U.S. Department of Transportation. *Summary of Travel Trends, 2001 National Household Travel Survey* (2004).

Figure 10-2 shows some time series developments. From 1983 to 2001, commuting distances have increased by almost 50%, a sign of urban sprawl (*flight to the suburbs*) while the average commuting speed has even fallen between 1990 and 2001. This reflects the increasing number and length of traffic congestions, especially during the daily rush hours. As a result of these trends, the average time spend in commuter traffic has steadily risen from 17.6 minutes to 22.5 minutes.

FIGURE 10–2 Commuting Distance, Time, and Speed



The Tables below, drawn from the *2021 Urban Mobility Report* of the Texas Transportation Institute https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2021.pdf show that the congestion cost (lost time and wasted fuel) per auto commuter is about $1,170 (2019). COVID-related, congestion cost fell to $605 in 2020. Overall, traffic jams lead to an annual economic cost of $190 billion (2019) or $101 billion (2020)m respectively.

Exhibit 1. Major Findings of the *2021 Urban Mobility Report* (494 U.S. Urban Areas)

Measures of…	1982	2000	2019	2020	The Crash
… Individual Congestion					
Yearly delay per auto commuter (hours)	20	38	54	27	-50%
Travel Time Index	1.10	1.19	1.23	1.09	-14 points
"Wasted" fuel per auto commuter (gallons)	5	15	22	11	-50%
Congestion cost per auto commuter (in 2020 $)	$640	$960	$1,170	$605	-48%
… The Nation's Congestion Problem					
Travel delay (billion hours)	1.7	5.1	8.7	4.3	-51%
"Wasted" fuel (billion gallons)	0.8	2.4	3.5	1.7	-51%
Excess greenhouse gas emissions (million tons)	8	25	36	18	-50%
Truck congestion cost (billions of 2020 dollars)	$1.8	$7	$20	$11	-44%
Congestion cost (billions of 2020 dollars)	$15	$77	$190	$101	-47%
Travel volume (billion miles traveled)	670	1,160	1,600	1,300	-18%

Yearly delay per auto commuter — The extra time spent during the year traveling at congested speeds rather than free-flow speeds by private vehicle drivers and passengers who typically travel in the peak periods.

Travel Time Index (TTI) — The ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak period.

Excess fuel and greenhouse gas emissions — The amount beyond what would have been expected at free-flow speeds.

Congestion cost — The yearly value of delay time and wasted fuel by all vehicles.

Travel volume — Miles traveled by all vehicles during the year.

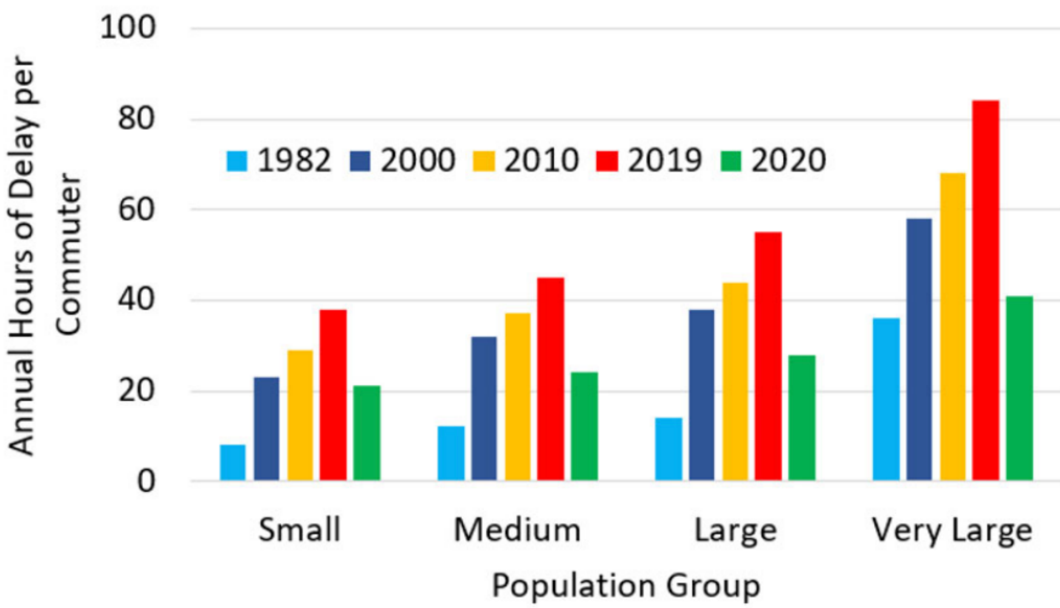
Exhibit 3. National Congestion Measures, 1982 to 2020

Year	U.S. Jobs (Millions)	Delay Hours/ Commuter	Total Delay (Billion Hours)	Fuel Wasted (Billion Gallons)	Total Cost (Billions of 2020 Dollars)
2020	143.8	27	4.3	1.7	101
2019	157.6	54	8.7	3.5	190
2018	156.2	54	8.6	3.4	188
2017	153.5	53	8.5	3.3	182
2016	151.4	52	8.3	3.3	175
2015	148.8	51	8.1	3.3	168
2014	146.3	49	7.9	3.2	166
2013	143.9	48	7.7	3.2	160
2012	142.5	46	7.4	3.1	153
2011	139.9	45	7.2	3.1	145
2010	139.1	44	6.9	3.0	135
2009	139.9	43	6.7	3.0	127
2008	145.4	42	6.6	3.1	129
2007	146.1	42	6.6	3.1	123
2006	144.4	42	6.5	3.0	117
2005	141.7	42	6.3	2.9	109
2004	139.2	41	6.1	2.8	101
2003	137.7	41	5.9	2.7	94
2002	136.5	40	5.6	2.6	88
2001	136.9	39	5.4	2.5	83
2000	136.9	38	5.1	2.4	77
1999	133.5	37	4.9	2.3	70
1998	131.5	36	4.6	2.1	65
1997	129.6	35	4.4	2.0	61
1996	126.7	34	4.2	1.9	56
1995	124.9	33	3.9	1.8	52
1994	123.1	32	3.7	1.7	47
1993	120.3	31	3.5	1.6	44
1992	118.5	30	3.3	1.5	40
1991	117.7	29	3.1	1.4	37
1990	118.8	28	2.9	1.3	33
1989	117.3	27	2.7	1.3	30
1988	115.0	26	2.6	1.2	27
1987	112.4	25	2.4	1.1	24
1986	109.6	24	2.3	1.1	22
1985	107.2	23	2.2	1.0	21
1984	105.0	22	2.0	0.9	19
1983	100.8	21	1.9	0.9	17
1982	99.5	20	1.7	0.8	15

Note: See Exhibit 1 for explanation of measures. For more congestion information see Tables 1 to 9. For congestion information on your city, see https://mobility.tamu.edu/umr/.

Very large urban clusters (> 3 million population) have not only experienced the largest congestions but also the largest delays per commuter. Covid-related, all city sizes experienced substantial traffic declines in 2020.

Exhibit 15. Congestion Growth Trend — Hours of Delay per Auto Commuter



Small = less than 500,000
Medium = 500,000 to 1 million
Large = 1 million to 3 million
Very Large = more than 3 million

Most delays occur on Fridays during the afternoon rush hour:

Exhibit 4. Percent of Delay for Each Day

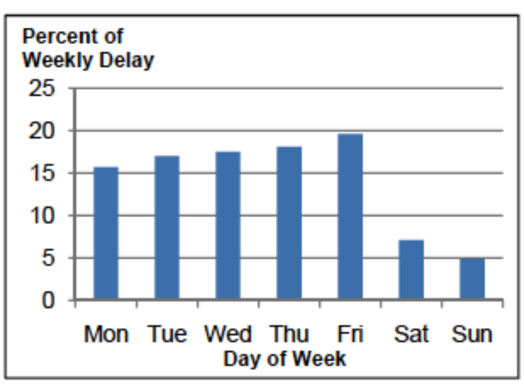
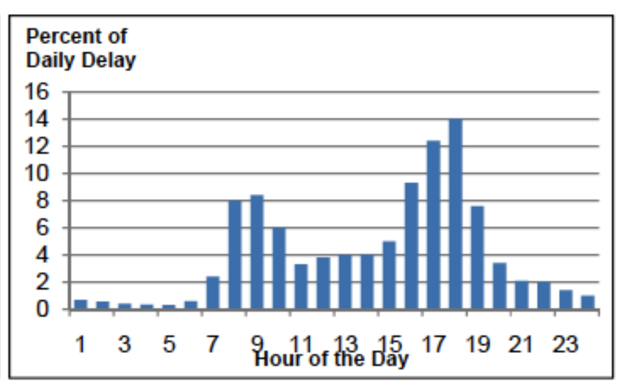
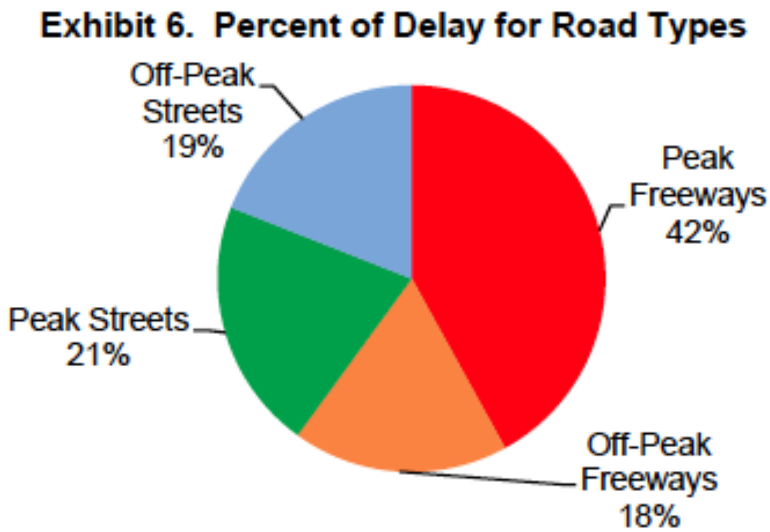


Exhibit 5. Percent of Delay by Time of Day



Most of all delays occur on Freeways (60%) and during "rush hour" (63%):



C. Congestion Externalities

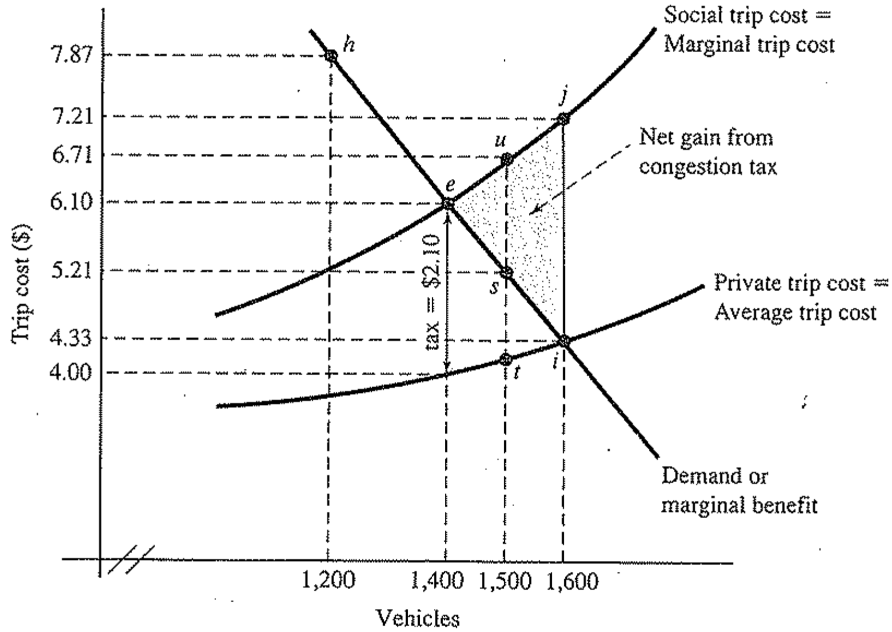
The following Table explains congestion externalities.

TABLE 10–2 Traffic Volume, Travel Time, and the Congestion Externality

A	B	C	D	E	F	G	H
Volume (vehicles per lane)	Trip Time (minutes)	Private Trip Cost ($)	Increase in Time per Vehicle (minutes)	Increase in Total Travel Time (minutes)	External Trip Cost ($)	Social Trip Cost ($)	Marginal Benefit (demand)
200	12.000	3.20	0.000	0.00	0.00	3.20	16.73
400	12.000	3.20	0.000	0.00	0.00	3.20	14.96
599	12.476						
600	12.480	3.248	0.004	2.40	0.24	3.49	13.19
1,199	17.268						
1,200	17.280	3.728	0.012	14.40	1.44	5.17	7.87
1,399	19.985						
1,400	20.000	4.000	0.015	21.00	2.10	6.10	6.10
1,599	23.262						
1,600	23.280	4.328	0.018	28.80	2.88	7.21	4.33
1,799	27.100						
1,800	27.120	4.712	0.020	36.00	3.60	8.31	2.56

The external cost per marginal car is increasing leading to a widening gap between private and social cost.

FIGURE 10–3 Congestion Externalities and the Congestion Tax



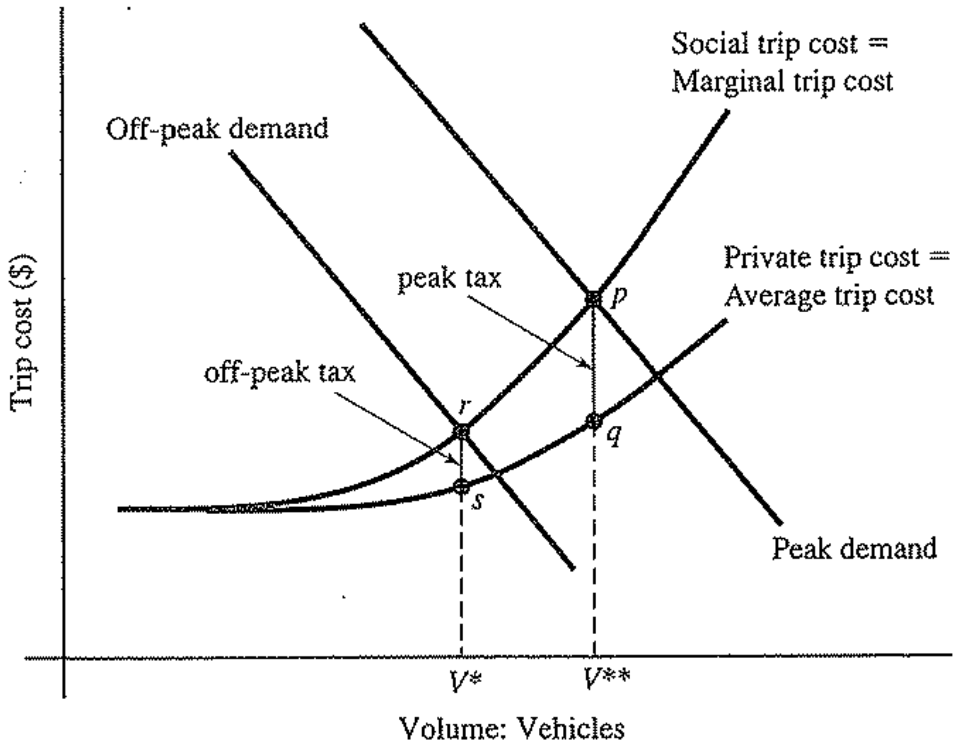
The equilibrium is shown by point *i*: When drivers pay the private trip cost, traffic volume is 1,600. The optimum is shown by point *e*, where the marginal benefit (shown by the demand curve) equals the marginal cost (the Social trip cost), generating a volume of 1,400 vehicles. The net gain from congestion tax is shown by the shaded area.

The darkened field, that is, the gap between marginal benefit and social cost beyond the optimal quantity of 1,400 vehicles, denotes a deadweight loss causes by too many cars.

In turn, a tax (or any other policy) that reduces the number of vehicles will lead to a welfare gain!

Below you see a graph that shows a two-tariff tax. During off-peak times, when the external cost per additional car relatively low, the tax rate (r-s) is low. In contrast, during peak times, the optimal tax rate is higher (p-q). In both cases:
<u>The optimal tax rate always equals the marginal external cost.</u>

FIGURE 10–5 Congestion Tax in Peak versus Off-Peak Periods



During the peak travel period, traffic volume is relatively high, generating a large gap between the private and social cost of travel (shown by points *p* and *q*) and thus a higher congestion tax. During the off-peak period, the gap between the social and private cost of travel is lower (points *r* and *s*), so the congestion tax is lower.