COMM 446-101/ECON 480-001: Transportation Economics

PART III: COSTS

LECTURES TO BE PRESENTED IN CLASS

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1. INTRODUCTION

Motivation: Reasons to study transportation costs

1. Determine degree of scale economies:

   test for natural monopoly

   test for entry barriers (e.g. access to bus stops)

   level of subsidies required given marginal-cost pricing

2. Measure economies or diseconomies of scope

3. Compare costs of different modes

4. Cost-benefit analysis.

2. COST CONCEPTS

Need to account for:

- network industry ⇒ multiple products
- service quality
- distinction between mobile plant and infrastructure
- lumpiness of infrastructure capacity

2.1 Fixed and variable costs

Costs are variable in the “long run”. For railways:

- Labour, fuel, maintenance: immediate
- Locomotives: 15 years
- Rolling stock: 25 years
- Track and signalling: 40 years
- Earthworks: Infinite

  Complication: staggered life times

2.2 Specific, joint and common costs

2.2.1 Specific costs

Incurred to provide one particular transportation service

- Passenger meals

- Reinforcements of bridges for trucks

2.2.2 Joint costs

Exist when provision of one service necessarily entails provision of another service in fixed proportions.

- Return trips
- Road capacity is available 24 hrs/day. “Service” is the same day & night.

2.2.3 Common costs

Share the same input(s), but in variable proportions

- Numbers of passenger and freight trains.

2.3 Cost allocation problems

Railway infrastructure costs	Passenger and freight service
Airport terminals, runways, ground access, etc.	Types of flights: Scheduled, charter, civil aviation, military
Roadways	Cars, trucks, buses, motorcycles

3. ECONOMIES OF SCALE

3.1 General Economies of Scale

3.1.1 Measures of scale

Single output

$$S \equiv \left[\frac{dC}{dy}\frac{y}{C}\right]^{-1} = \left[\frac{dC/dy}{C/y}\right]^{-1} = \frac{C/y}{dC/dy} = \frac{Average\ Cost}{Marginal\ cost} \qquad (1)$$

S=1: constant returns, *S*>1: increasing returns, *S*<1: decreasing returns

Multiple outputs

What is average cost?

Define the total cost function for two outputs: $C\left(y_1, y_2\right)$.

Average incremental cost (AIC)

$$AIC_1 \equiv \frac{C\left(y_1, y_2\right) - C\left(0, y_2\right)}{y_1} \qquad \text{(A function of } y_1 \text{ and } y_2\text{)}$$

$$AIC_2 \equiv \frac{C\left(y_1, y_2\right) - C\left(y_1, 0\right)}{y_2} \qquad \text{(A function of } y_1 \text{ and } y_2\text{)}$$

Product-specific returns to scale

With *n* outputs, $y_1,\ y_2 \ldots\ y_n$:

$$S_i \equiv \frac{AIC_i}{dC/dy_i},\ i = 1,\ldots,n \qquad \text{(A function of } y_1,\ y_2 \ldots\ y_n\text{)}$$

3.1.2 Sources of economies of scale

1. Principle of bulk transactions

- Accounting costs
- Handling costs per unit
- Labour costs for vehicle drivers

2. Principle of multiples

Maritime port inputs	**Capacity**
Work crews (*W*)	350
Loading cranes (*C*)	500
Docks (*D*)	900

Output	**Underutilized**
350	*C* and *D*
500	*D* and 2nd *W*
900	3rd *W* and 2nd *C*

Smallest common integer multiple: 31,500

3. Principle of massed reserves

No. spare parts and maintenance personnel required to achieve given level of reliability increases less than in proportion to output.

3.2 Economies of traffic density, network size, vehicle size and length of haul

3.2.1 Economies of traffic density

Exist if unit costs decrease with traffic volume on a <u>given</u> network.

Traffic density units:

- Rail: Ton miles per mile of track per year
- Roads: Average Annual Daily Traffic (AADT)

$e_{y_i}^{c}$ ≡ elasticity of costs with respect to output *i*

$$S_D = \frac{1}{\sum_{i=1}^{n} e_{y_i}^{c}} \qquad \text{[Returns to density]}$$

$S_D > 1$: positive economies

$S_D < 1$: negative economies (diseconomies)

$S_D = 1$: neither economies nor diseconomies.

3.2.2 Economies of network size

Exist if unit costs decrease with the size of the transportation network.

Traffic density is held fixed.

Units of measurement:

Urban transit: route miles or route kilometres.

Rail: kilometres of track.

Airlines: number of nodes or routes.

e_N^c ≡ elasticity of costs with respect to network size

$$S_S = \frac{1}{\left(\sum_{i=1}^{n} e_{y_i}^c\right) + e_N^c} \qquad \text{[Returns to scale]}$$

Generally: $e_N^c > 0 \;\Rightarrow\; S_S < S_D$.

3.2.3 Economies from large vehicle size

- Drivers, pilots…
- Use of airport runways
- Other unit operating costs

Limitations on economies of vehicle size

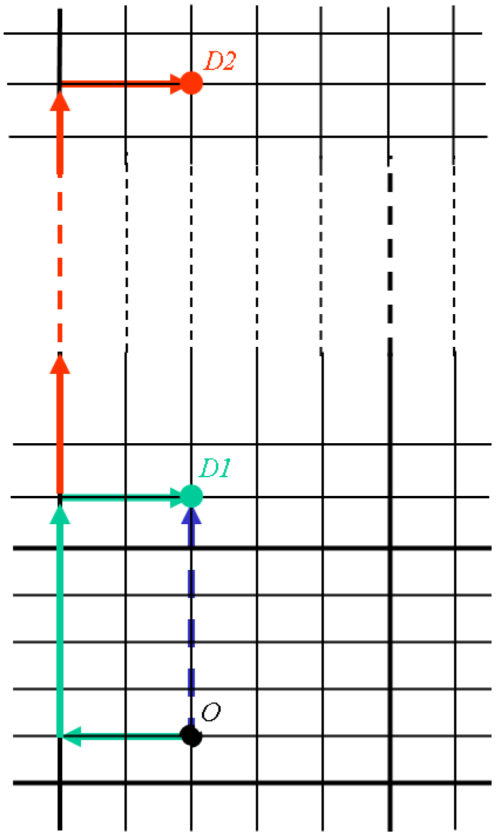
1. Infrastructure (bridges, runways, ports)
2. Small consignments
3. Loading time

3.2.4 Economies of length of haul or stage length

Exist if costs per km. decrease with length of haul.

Airlines (strong): refueling, passenger loading, take-off & landing, elevation change.

Roads (generally weak):



D2: Far destination (50 blocks)

D1: Close destination (5 blocks)

4. ECONOMIES IN ROAD INFRASTRUCTURE

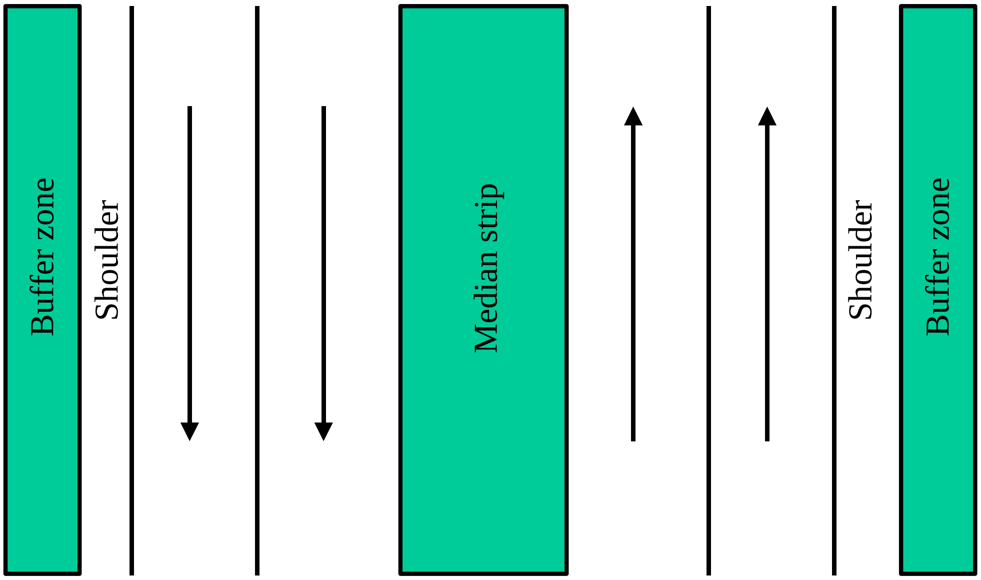
4.1 Highway scale economies and diseconomies

	Evidence	**Measure of scale**
Keeler and Small (1977)	Statistical	1.03
Kraus (1981b)	Engineering	1.18

4.2 Sources of scale economies

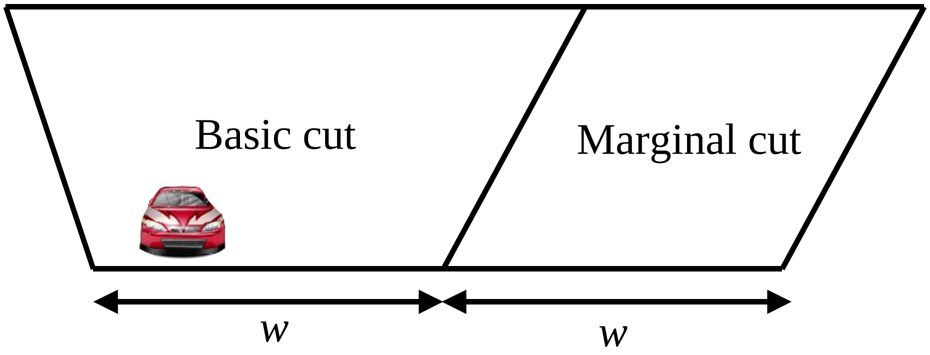
Highway design

Aerial view of a highway

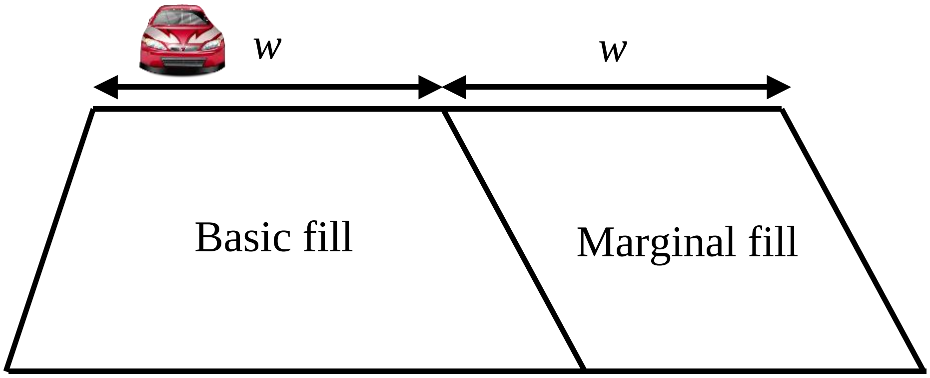


Earthworks

Earth removal



Earth foundations



4.3 Sources of scale diseconomies

Land acquisition costs

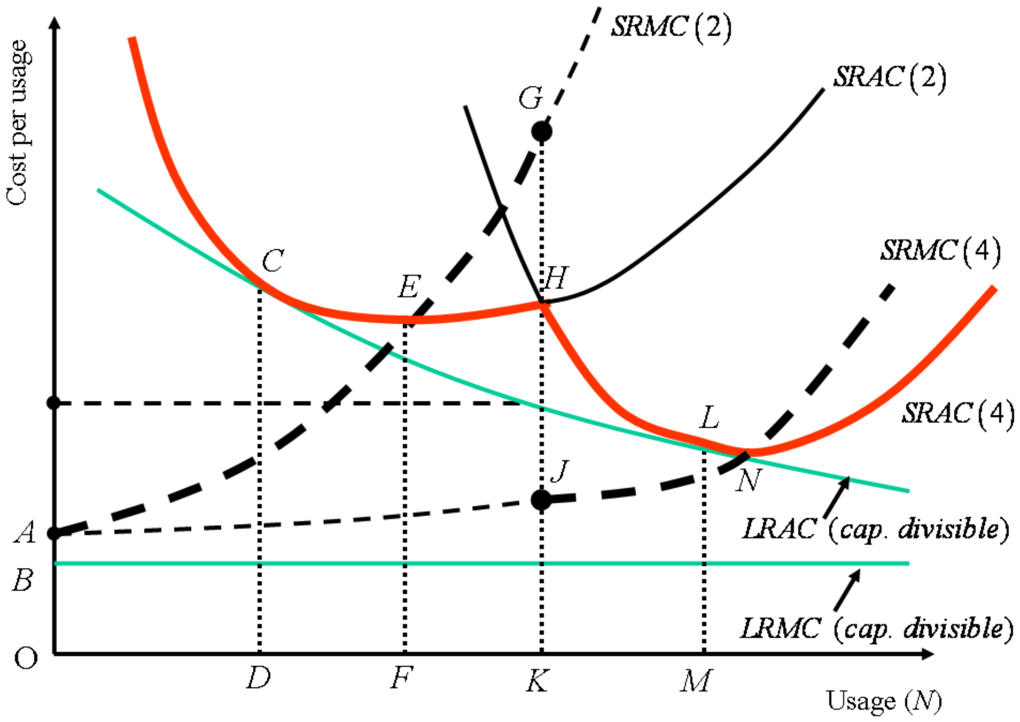
- More roads ⇒ less land for buildings, parking, recreational areas…
- Wider expressways concentrated where land costly (not technological)

Diseconomies with interchanges

Proportional to square of road network density

4.4 Indivisibilities in capacity

Cost of capacity: $F(L) = F_0 + c_L L$



4.5 Economies in durability of infrastructure

The AASHO road test 1958 – 1960. (Smith *et al.*, 2004)

Road damage determined by:

(a) pavement type

(b) pavement thickness

(c) axle weight [Equivalent Standard Axle Loads (ESALs) = 18,000 pounds]

4.5.1 Pavement type

Rigid pavements

Flexible pavements

4.5.2 Pavement thickness and axle weight

Study	**Damage elasticity wrt pavement thickness**	**Damage elasticity wrt axle load**
AASHO	Rigid: 7th power Flexible: 9th power	4th power
Small & Winston (1988)	Smaller	≅ 3rd power

5. ECONOMIES OF SCOPE

5.1 Analytics of economies of scope

$$S_{scope} \equiv \frac{C(y_1,0)+C(0,y_2)-C(y_1,y_2)}{C(y_1,y_2)}$$

$S_{scope} > 0$: positive economies

$S_{scope} < 0$: diseconomies Question: what are upper and lower limits on S_{scope}?

$$f_i \equiv \frac{(\partial C/\partial y_i)\cdot y_i}{(\partial C/\partial y_1)\cdot y_1 + (\partial C/\partial y_2)\cdot y_2}$$

Relationship between economies of scope, productive-specific returns to scale, and overall economies of scale:

$$S = \frac{f_1 S_1 + f_2 S_2}{1 - S_{scope}}. \tag{2}$$

Sufficient conditions for economies of scale

- $S_i > 1, \quad i = 1,2$
- $S_{scope} > 0$

Necessary and sufficient conditions for large, multi-product firm(s)

- Product-specific economies. (Otherwise having many small multi-product firms is more efficient than having a single firm.)
- Economies of scope. (Otherwise having large specialized firms is more efficient than a single general firm.)

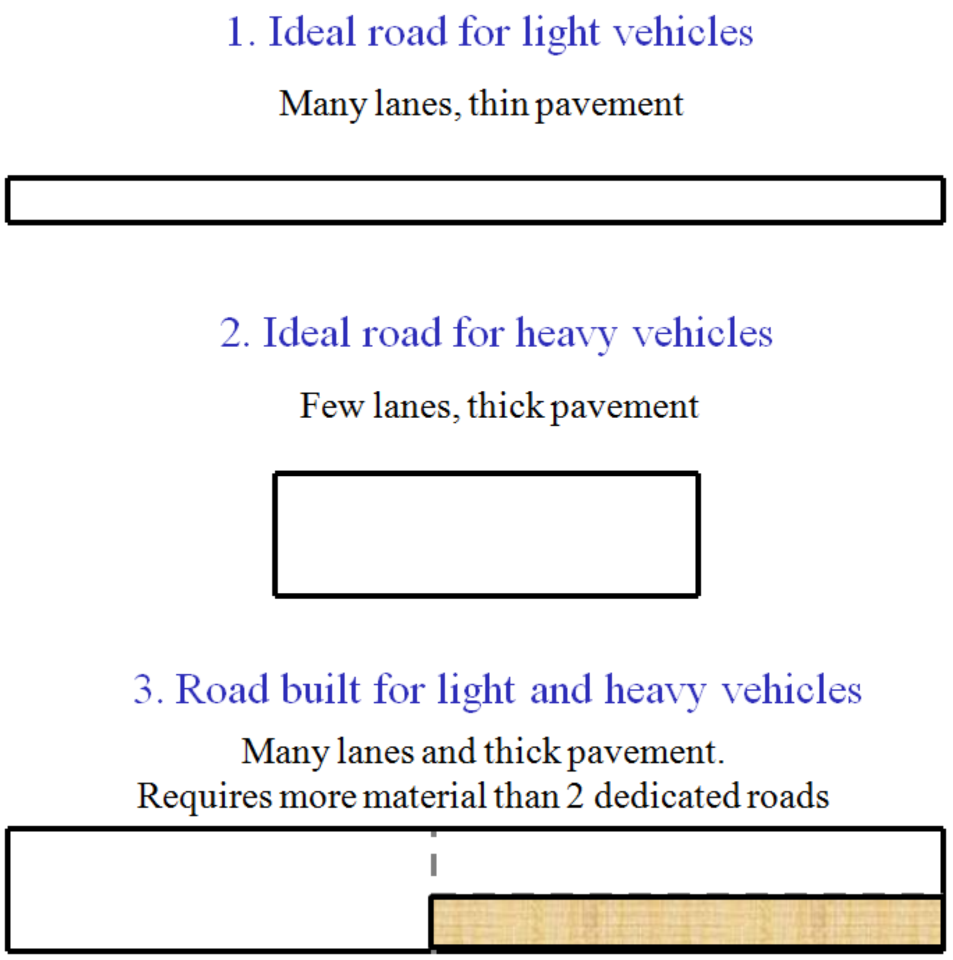
Diseconomies of scope for cars and trucks on roads

Output	**Index**
1. Road capacity	$S_1 \cong 1$
2. Road durability	$S_2 >> 1$
Scope	$S_{scope} < 0$ **Why?**

Answer to be revealed in class:

xxx

xxx



1. Ideal road for light vehicles

Many lanes, thin pavement

2. Ideal road for heavy vehicles

Few lanes, thick pavement

3. Road built for light and heavy vehicles

Many lanes and thick pavement.
Requires more material than 2 dedicated roads

Diseconomies of scope for passenger trains and freight trains

Reasons:

Different speeds

Heavy freight trains damage track & passenger trains require smooth track

5.2 Sources of scope economies

Source 1: Economies of scope from a shared factor

Service from A → B and service from B → A have joint costs

Air: Passengers in cabin, freight in hold (e.g., the passengers' bags)

Source 2: Economies of scope from an indivisible asset

Transportation infrastructure can be used by various types of traffic. This is a source of scope economies. But there are limitations.

Highways

Cars and trucks require different pavement thickness

Also different lane widths, grades, vertical clearances, etc.

Railway track

Conflict between passenger trains and freight trains (noted above)

Source 3: Economies of scope from networking economies

Trucking

- Consolidation of Less Than Load (LTL) shipments
  - Economies arise from indivisibilities in vehicles and drivers
- Service frequency
- Network coverage

6. SCALE ECONOMIES IN BUS TRANSPORTATION

6.1 Economies and diseconomies

(a) Constant returns to network/fleet size?

(b) Positive economies of traffic density.

Complication in measuring (b): Multiple system characteristics:

1. Number of routes
2. Path of routes
3. Spacing of stops
4. Bus frequency
5. Capacity constraints, crowding costs
6. Externality costs
7. Information about bus schedules

6.2 The square root rule

Mohring (1972). Considers only characteristic 4.

Assume passengers do not know schedule.

Schedule delay costs: Ignored.

Number of passenger trips per hour: n

Number of passengers on each bus: N

$\Rightarrow$ Time headway: N/n.

Average waiting time: $N/(2n)$.

Total waiting time per bus: $N^2/(2n)$.

Operating cost per bus: F.

Non-waiting time cost: cN.

Value of waiting time per hour for passengers: V

Total cost per bus:

$$TC(n, N) = F + cN + V\frac{N^2}{2n}.$$

<u>Average</u> cost per passenger:

$$AC(n, N) = \frac{F}{N} + c + V\frac{N}{2n}$$

Optimal bus capacity:

$$N^* = \left(\frac{2nF}{V}\right)^{1/2}$$

Time headway:

$$\frac{N^*}{n} = \left(\frac{2F}{nV}\right)^{1/2}$$

Minimum total cost per passenger:

$$AC^*(n, N^*) = c + \left(\frac{VF}{2n}\right)^{1/2}$$

6.3 The Circletown model

Jansson (1997). Adds to Mohring's model factors 3, 5 and 6 in the list above:

Spacing of bus stops (affects walking distance)

Bus capacity constraints and crowding costs

Externality costs

Treat traffic density as exogenous, increase it incrementally, and see how optimal design of bus service evolves.

Traffic density [Trips/hour]	Bus size	Service frequency [Buses/hour]	Average walking distance [km.]
100	20	3	0.35
250	27	4	0.26
500	34	5	0.21
750	39	6	018
1,000	43	6	0.16
2,000	54	8	0.13
4,000	68	10	0.10
8,000	86	12	0.08
15,000	105	15	0.06

Traffic density [Trips per hour]	Average operating + externality costs [ECUs]	Average rider cost [ECUs]	Average total cost [ECUs]
100	1.57	3.62	5.19
250	1.20	2.88	4.08
500	0.98	2.45	3.43
750	0.88	2.24	3.12
1,000	0.81	2.11	2.92
2,000	0.68	1.84	2.52
4,000	0.57	1.62	2.19
8,000	0.49	1.45	1.94
15,000	0.43	1.33	1.76

ECU = European Currency Unit (preceded the €)

6.4 Small urbanized areas

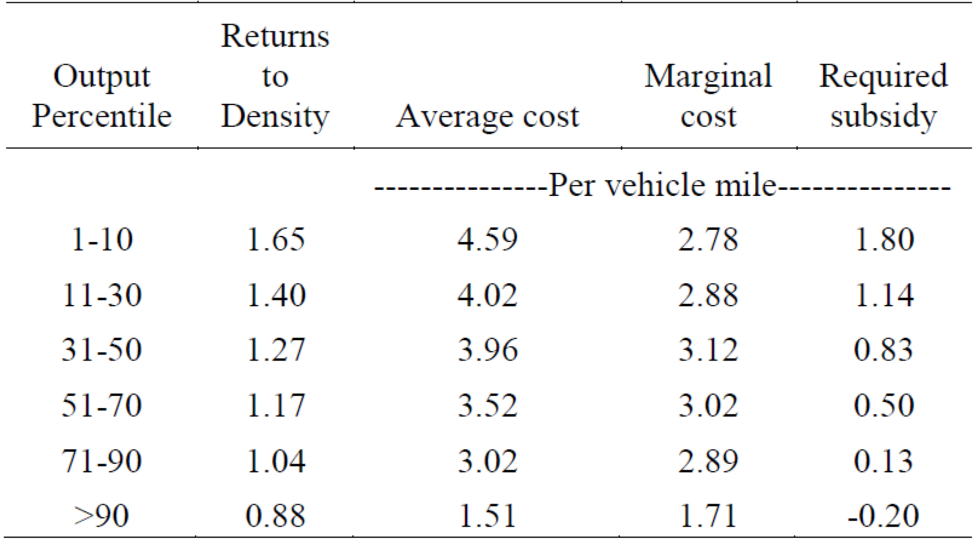
Mattson and Ripplinger (2011)

Estimate returns to density and required subsidy for sample of US cities with populations from 50,000 to 200,000.

Results

(a) Without accounting for external costs or benefits

Table 6.4 Returns to Density, Marginal Cost, and Required Subsidy by Size of Agency



Output Percentile	Returns to Density	Average cost	Marginal cost	Required subsidy
		---------------Per vehicle mile---------------		
1-10	1.65	4.59	2.78	1.80
11-30	1.40	4.02	2.88	1.14
31-50	1.27	3.96	3.12	0.83
51-70	1.17	3.52	3.02	0.50
71-90	1.04	3.02	2.89	0.13
>90	0.88	1.51	1.71	-0.20

Returns to density and subsidy very sensitive to scale of operations.

(b) Including external costs or benefits

Values used:

Marginal external cost:	$0.53 per vehicle-mile
Marginal external benefit in reduced waiting time:	$0.18 per vehicle-mile

Finding: Subsidy still implied for all but the largest operations.

General conclusions

Compared to larger cities:

- Congestion relief may not be an important benefit
- Given lower service frequencies, benefits from improved service from decreased waiting times may be larger.

6.5 Further considerations in the design of bus systems

Stochastic demand

\+ Adds economies of massed reserves which boost economies of traffic density. Perhaps of minor importance in case of scheduled service.

Choice of route

As traffic density ↑, routes straighten out.

Question: Why?

Answer: xxx

xxx

Delays at bus stops

Turvey and Mohring (1975):

Time per stop: $T + bB + aA$,

For two-man buses in London: *T*=21, *b*=1.15, *a*=1.0 [secs].

For one-man buses?

T shorter, *a* and *b* larger.

Question (tricky): How does the marginal externality cost (MEC) of a passenger vary with volume?

Answer: xxx

xxx

Passenger knowledge of the bus schedule

If service is infrequent: travellers learn the timetable. They still incur schedule delay costs, but not waiting time costs (provided the buses arrive on time). Inclination to learn the timetable increases with the quality of information and ease of obtaining it.

Peaked travel time preferences

Economies of traffic density are smaller than given by the square-root rule.

Congestion

Congestion is a source of diseconomies with respect to overall traffic density.

7. EXTERNAL COSTS: OVERVIEW

Definition: An externality exists when the actions of an agent or agents affect the utility or production possibilities of other agents without a market in which the effects are priced.

Imposed on Imposed by	Consumers	Producers
Consumers	- Noise, traffic congestion + Voting wisely	- Theft and vandalism
Producers	- Noise, pollution +/- Advertising	+/- Pesticides + Apiary (bee colony) and apple orchard

External benefits (from infrastructure)

- Wide streets
- Reduction of market power
- Facilitation of urban economies of agglomeration (called "wider impacts" in recent cost-benefit analysis)

Rest of these notes limited to external costs.

7.1 Estimates for the US (Small and Verhoef, 2007)

Congestion, accidents, noise, local air pollution, global climate change.

Also damage to infrastructure (mostly heavily vehicles).

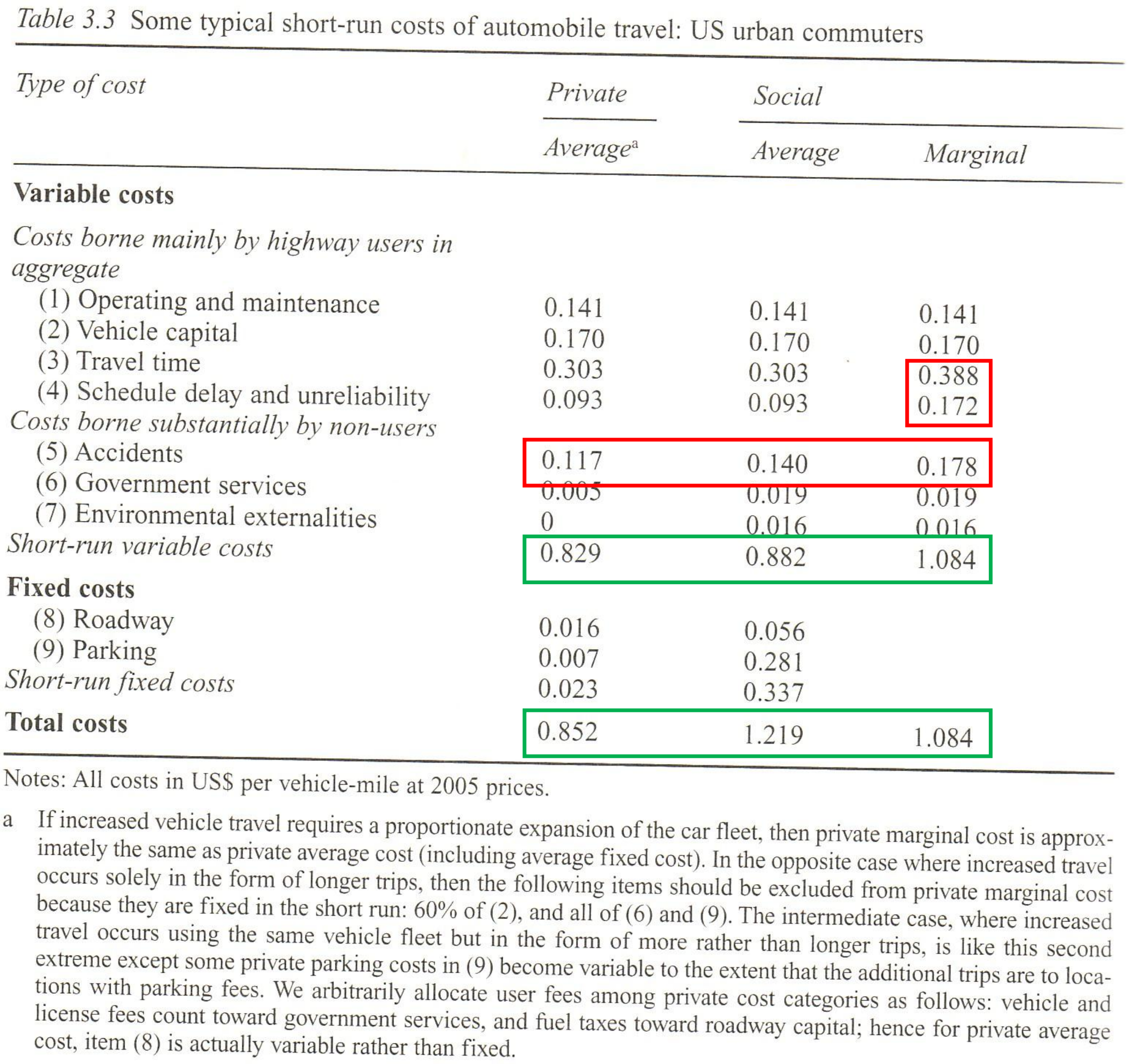


Table 3.3 Some typical short-run costs of automobile travel: US urban commuters

Type of cost	*Private*	*Social*	
	Average[a]	*Average*	*Marginal*
Variable costs			
Costs borne mainly by highway users in aggregate			
(1) Operating and maintenance	0.141	0.141	0.141
(2) Vehicle capital	0.170	0.170	0.170
(3) Travel time	0.303	0.303	0.388
(4) Schedule delay and unreliability	0.093	0.093	0.172
Costs borne substantially by non-users			
(5) Accidents	0.117	0.140	0.178
(6) Government services	0.005	0.019	0.019
(7) Environmental externalities	0	0.016	0.016
Short-run variable costs	0.829	0.882	1.084
Fixed costs			
(8) Roadway	0.016	0.056	
(9) Parking	0.007	0.281	
Short-run fixed costs	0.023	0.337	
Total costs	0.852	1.219	1.084

Notes: All costs in US$ per vehicle-mile at 2005 prices.

[a] If increased vehicle travel requires a proportionate expansion of the car fleet, then private marginal cost is approximately the same as private average cost (including average fixed cost). In the opposite case where increased travel occurs solely in the form of longer trips, then the following items should be excluded from private marginal cost because they are fixed in the short run: 60% of (2), and all of (6) and (9). The intermediate case, where increased travel occurs using the same vehicle fleet but in the form of more rather than longer trips, is like this second extreme except some private parking costs in (9) become variable to the extent that the additional trips are to locations with parking fees. We arbitrarily allocate user fees among private cost categories as follows: vehicle and license fees count toward government services, and fuel taxes toward roadway capital; hence for private average cost, item (8) is actually variable rather than fixed.

Marginal external costs

	Cents per mile	Cents per kilometre
Costs borne mainly by highway users in aggregate		
(1) Operating and maintenance	0	0
(2) Vehicle capital	0	0
(3) Travel time	8.5	5.3
(4) Schedule delay & unreliability	7.9	5.0
Costs borne substantially by non-users		
(5) Accidents	6.1	3.7
(6) Government services	1.4	0.9
(7) Environmental externalities	1.6	1.0
Total	25.5	15.8

Noise is excluded in these accounts.

7.2 Estimates for Australia (Glazebrook, 2009)

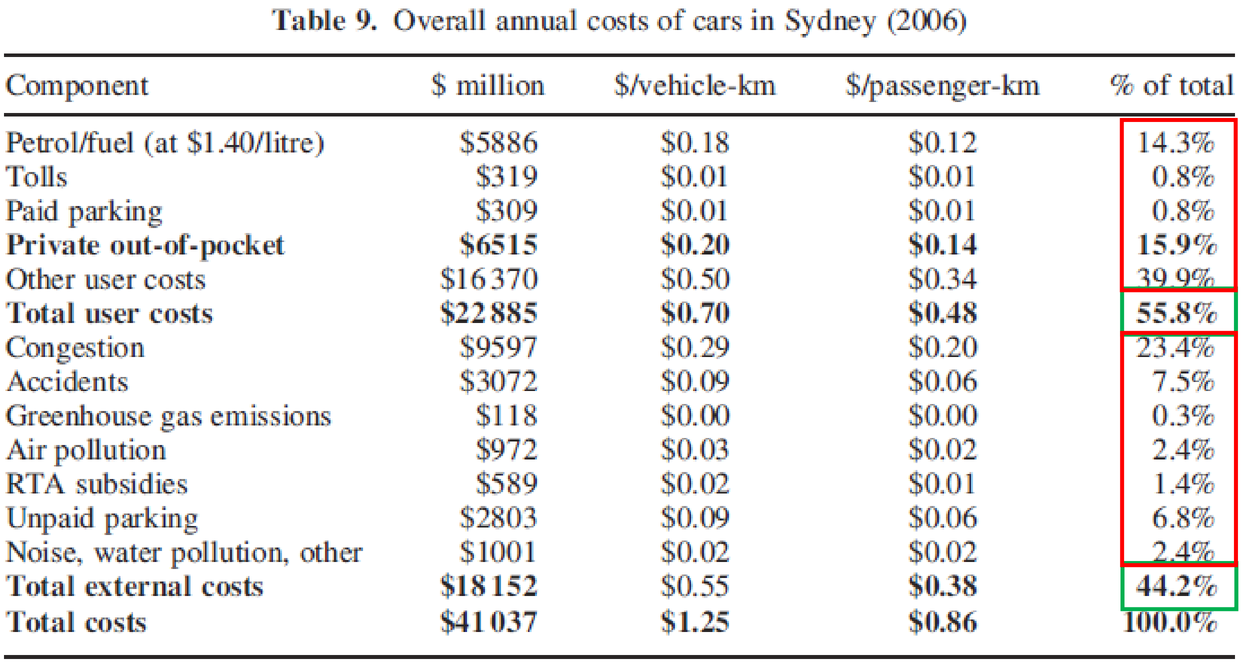


Table 9. Overall annual costs of cars in Sydney (2006)

Component	$ million	$/vehicle-km	$/passenger-km	% of total
Petrol/fuel (at $1.40/litre)	$5886	$0.18	$0.12	14.3%
Tolls	$319	$0.01	$0.01	0.8%
Paid parking	$309	$0.01	$0.01	0.8%
Private out-of-pocket	**$6515**	**$0.20**	**$0.14**	**15.9%**
Other user costs	$16 370	$0.50	$0.34	39.9%
Total user costs	**$22 885**	**$0.70**	**$0.48**	**55.8%**
Congestion	$9597	$0.29	$0.20	23.4%
Accidents	$3072	$0.09	$0.06	7.5%
Greenhouse gas emissions	$118	$0.00	$0.00	0.3%
Air pollution	$972	$0.03	$0.02	2.4%
RTA subsidies	$589	$0.02	$0.01	1.4%
Unpaid parking	$2803	$0.09	$0.06	6.8%
Noise, water pollution, other	$1001	$0.02	$0.02	2.4%
Total external costs	**$18 152**	$0.55	**$0.38**	**44.2%**
Total costs	**$41 037**	**$1.25**	**$0.86**	**100.0%**

Costs per vehicle-km much higher than for US Sydney is large, highly congested city.

Cost component	Per vehicle-km
Private out-of-pocket	AUS $0.20
Other user costs	AUS $0.50
External	AUS $0.55
Total	AUS $1.25

7.3 Estimates for Canada (Transport Canada, 2008)

Source: Transport Canada (2008), *Full Cost Investigation* study.

(a) Excluding external social costs

- Without parking costs: cost of a trip comparable for car and transit
- With parking costs: car cost doubles or triples

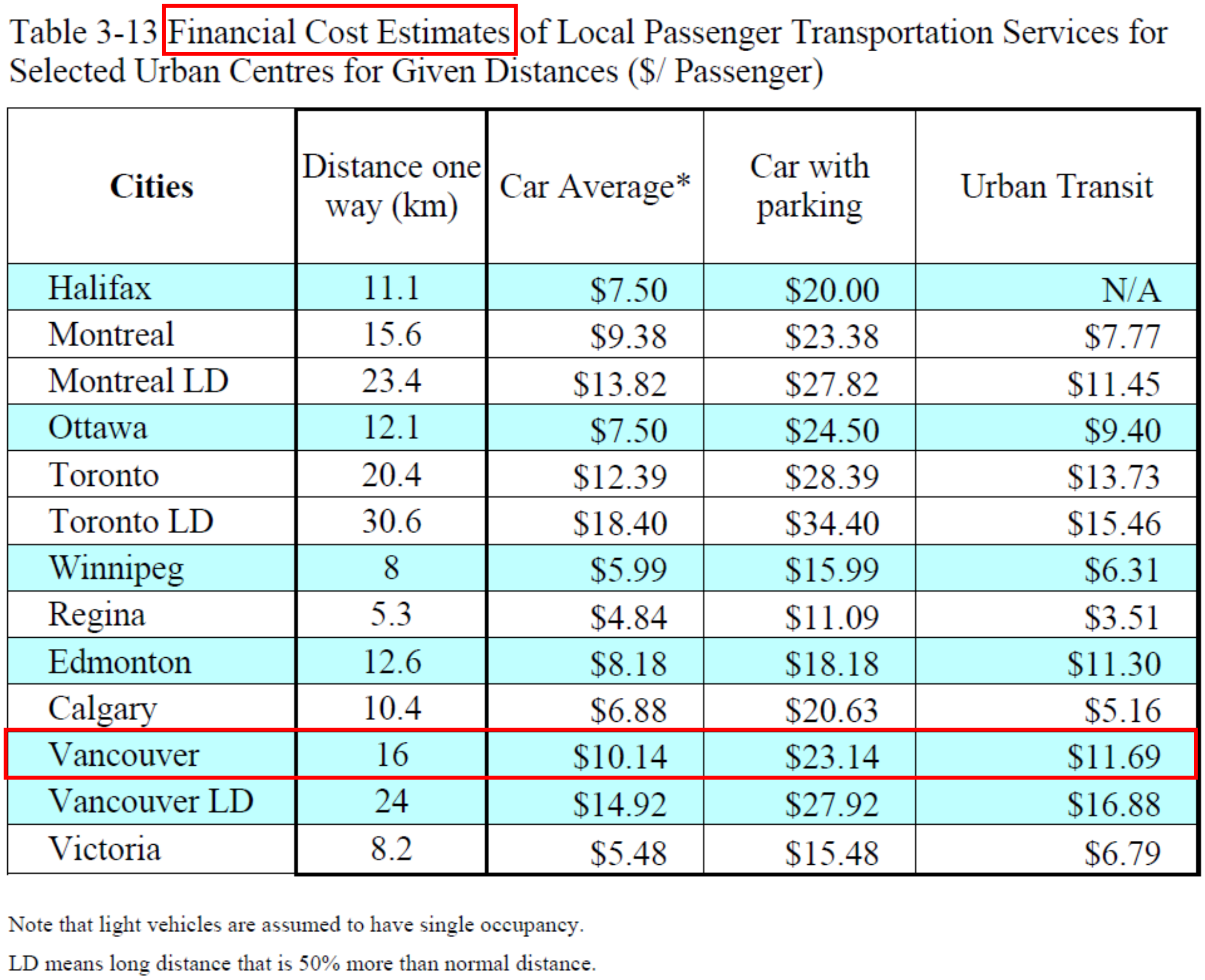


Table 3-13 Financial Cost Estimates of Local Passenger Transportation Services for Selected Urban Centres for Given Distances ($/ Passenger)

Cities	Distance one way (km)	Car Average*	Car with parking	Urban Transit
Halifax	11.1	$7.50	$20.00	N/A
Montreal	15.6	$9.38	$23.38	$7.77
Montreal LD	23.4	$13.82	$27.82	$11.45
Ottawa	12.1	$7.50	$24.50	$9.40
Toronto	20.4	$12.39	$28.39	$13.73
Toronto LD	30.6	$18.40	$34.40	$15.46
Winnipeg	8	$5.99	$15.99	$6.31
Regina	5.3	$4.84	$11.09	$3.51
Edmonton	12.6	$8.18	$18.18	$11.30
Calgary	10.4	$6.88	$20.63	$5.16
Vancouver	16	$10.14	$23.14	$11.69
Vancouver LD	24	$14.92	$27.92	$16.88
Victoria	8.2	$5.48	$15.48	$6.79

Note that light vehicles are assumed to have single occupancy.

LD means long distance that is 50% more than normal distance.

(b) Including external social costs

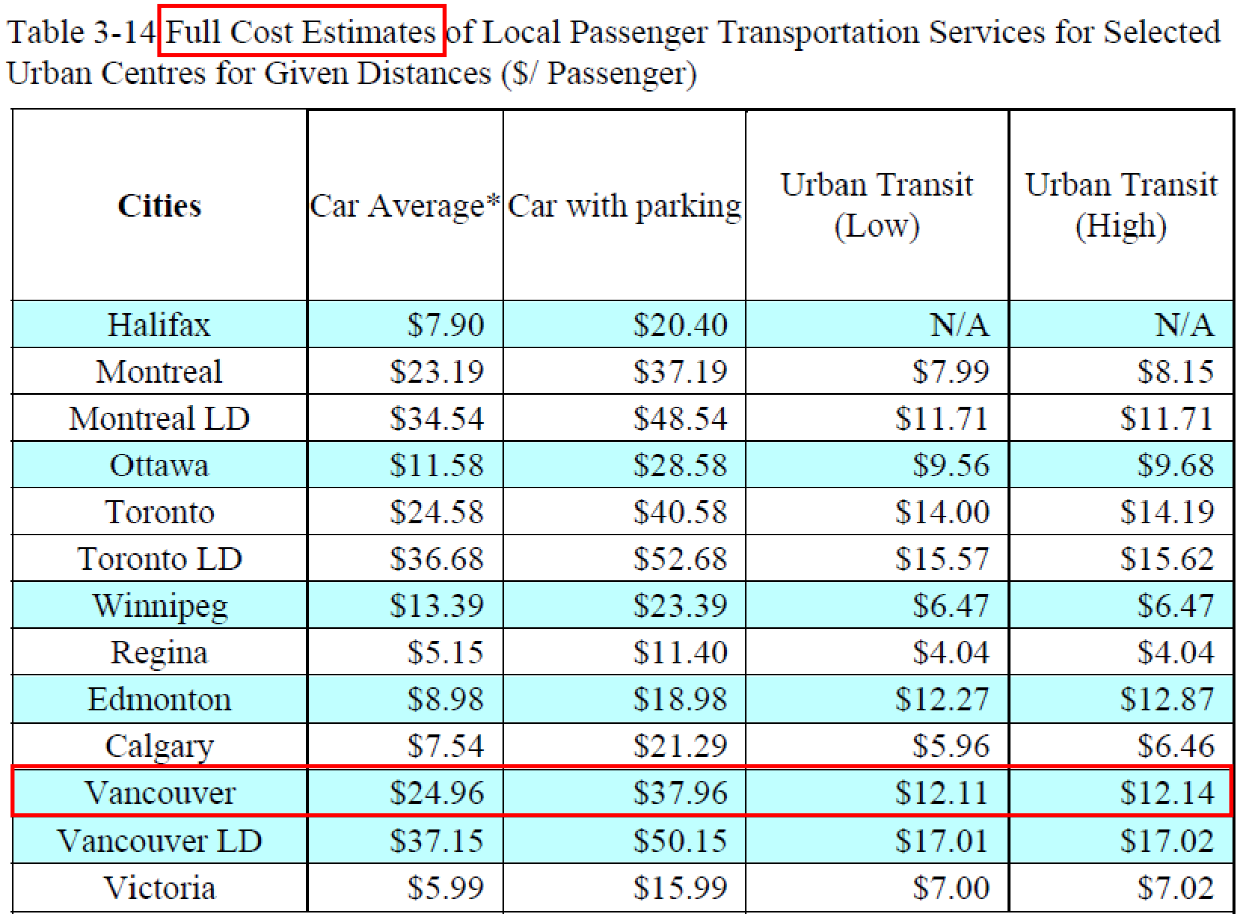


Table 3-14 Full Cost Estimates of Local Passenger Transportation Services for Selected Urban Centres for Given Distances ($/ Passenger)

Cities	Car Average*	Car with parking	Urban Transit (Low)	Urban Transit (High)
Halifax	$7.90	$20.40	N/A	N/A
Montreal	$23.19	$37.19	$7.99	$8.15
Montreal LD	$34.54	$48.54	$11.71	$11.71
Ottawa	$11.58	$28.58	$9.56	$9.68
Toronto	$24.58	$40.58	$14.00	$14.19
Toronto LD	$36.68	$52.68	$15.57	$15.62
Winnipeg	$13.39	$23.39	$6.47	$6.47
Regina	$5.15	$11.40	$4.04	$4.04
Edmonton	$8.98	$18.98	$12.27	$12.87
Calgary	$7.54	$21.29	$5.96	$6.46
Vancouver	$24.96	$37.96	$12.11	$12.14
Vancouver LD	$37.15	$50.15	$17.01	$17.02
Victoria	$5.99	$15.99	$7.00	$7.02

Effects of including external social costs:

- Little increase in cost for transit trips or costs of driving in smaller cities
- Huge increase for costs of driving in larger cities.

Vancouver: Car cost = 3x transit cost

Montreal: Car cost = 4.5x transit cost

8. ENVIRONMENTAL EXTERNALITIES

Contributions to overall cost of environmental externalities

Local air pollution: 4/5

Global warming: 1/5

8.1 Local pollution

Due mostly to fuel consumption. Also dust, tire wear, oil leaks on road.

A function of:

Fuel type
Engine displacement
Maintenance
Engine temperature (Cold start, hot soak)
Driving cycle

Main cost: adverse human health effects.

(a) Anas and Lindsey (2011)

Effects of converting conventional toll plazas to Electronic toll collection:

- Lin and Yu (2008): substantial reductions in CO concentrations and diesel particulate matter emissions
- Currie and Walker (2009): reductions in premature and low-weight births of about 11 percent.

(b) Taylor, Paul (2011), "Traffic pollution linked to premature births", The Globe and Mail, October 15, p. L6.

Increase in premature births due to pollution.

Premature births account for almost one in 10 deliveries.

Data source: 100,000 births over 22-month period in Los Angeles.

Effects of pollutants on rate of premature births:

- Polycyclic aromatic hydrocarbons: up to 30% increase
- Benzene and fine particulate matter: 10% increase
- Ammonium nitrate fine particles: 21% increase

Other costs: materials, buildings, crops, ecosystems, visibility

Costs rise with density of population and other road users

⇒ costs rises with congestion.

8.2 Global warming

Cost proportional to content of greenhouse gases in fuel.

CO_2 ; SO_2 …

Impacts on: sea level & temperature, precipitation, crop yields, demand for air conditioning.

Risks: catastrophic and/or abrupt climate change, spread of tropical diseases.

Thermohaline circulation. (The caterpillar.)

Estimated costs per tonne of carbon:

Up to $311 (Stern Report)

Intermediate range: $20 - $50.

8.3 Policy

Clear need for intervention.

For global warming:

- carbon tax ideal … throughout economy. Or cap and trade.
- no viable technologies for reducing emissions per gallon of fuel.

For local air pollution

- *Ideal*: Emissions tax differentiated with population exposure, season
- *Practice*: emissions standards, inspection programs, fuel taxes, fuel regulations, CAFE standards
- *Possible*: Combined with congestion charges

Mode shift

- Public transit usually less polluting per passenger-km.
- Bicycling and walking nearly emissions free. But susceptible to pollution.

9. ACCIDENTS

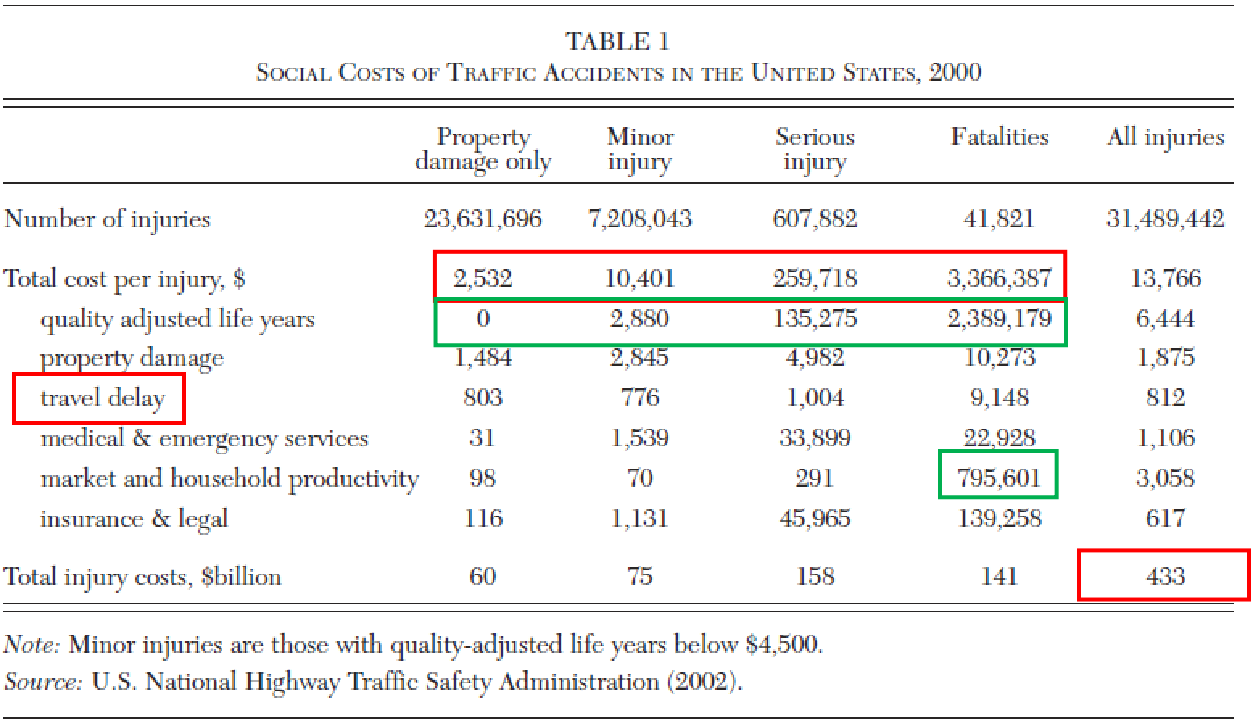


TABLE 1
SOCIAL COSTS OF TRAFFIC ACCIDENTS IN THE UNITED STATES, 2000

	Property damage only	Minor injury	Serious injury	Fatalities	All injuries
Number of injuries	23,631,696	7,208,043	607,882	41,821	31,489,442
Total cost per injury, $	2,532	10,401	259,718	3,366,387	13,766
quality adjusted life years	0	2,880	135,275	2,389,179	6,444
property damage	1,484	2,845	4,982	10,273	1,875
travel delay	803	776	1,004	9,148	812
medical & emergency services	31	1,539	33,899	22,928	1,106
market and household productivity	98	70	291	795,601	3,058
insurance & legal	116	1,131	45,965	139,258	617
Total injury costs, $billion	60	75	158	141	433

Note: Minor injuries are those with quality-adjusted life years below $4,500.
Source: U.S. National Highway Traffic Safety Administration (2002).

Source: Parry, Walls and Harrington (2007).

Categories of accident costs:

Cold-blooded: vehicular damage, loss of work output, hospital treatment

Warm-blooded: suffering, immobility, grief of relatives

Expected accident costs depend on:

Traffic volumes and speeds See below (*).
Mix of vehicle types. Heavy vehicles impose a greater hazard [?]
Presence of pedestrians & bicyclists
Road design
Frequency of entrances, exits & intersections

Pavement conditions
Weather. Reduce effective road capacity.

Components of accident externality

1. Cost of accident borne only partly by driver. External costs: uncovered property damage, higher automobile & medical insurance premiums, *etc*.

2. An additional driver affects accident rates (*):

   (+) More opportunity for multi-vehicle collisions
   (-) Slows other drivers down ⇒ more time to react, less severe collisions

Drivers trade off travel time, accident risk, safety effort.

Cost of accident risk and safety effort comparable to congestion delay.

Accidents create congestion delays.

Incident-related delays on US freeways = 52% - 58% of total delay

Accident rates per kilometre declining over calendar time due to:

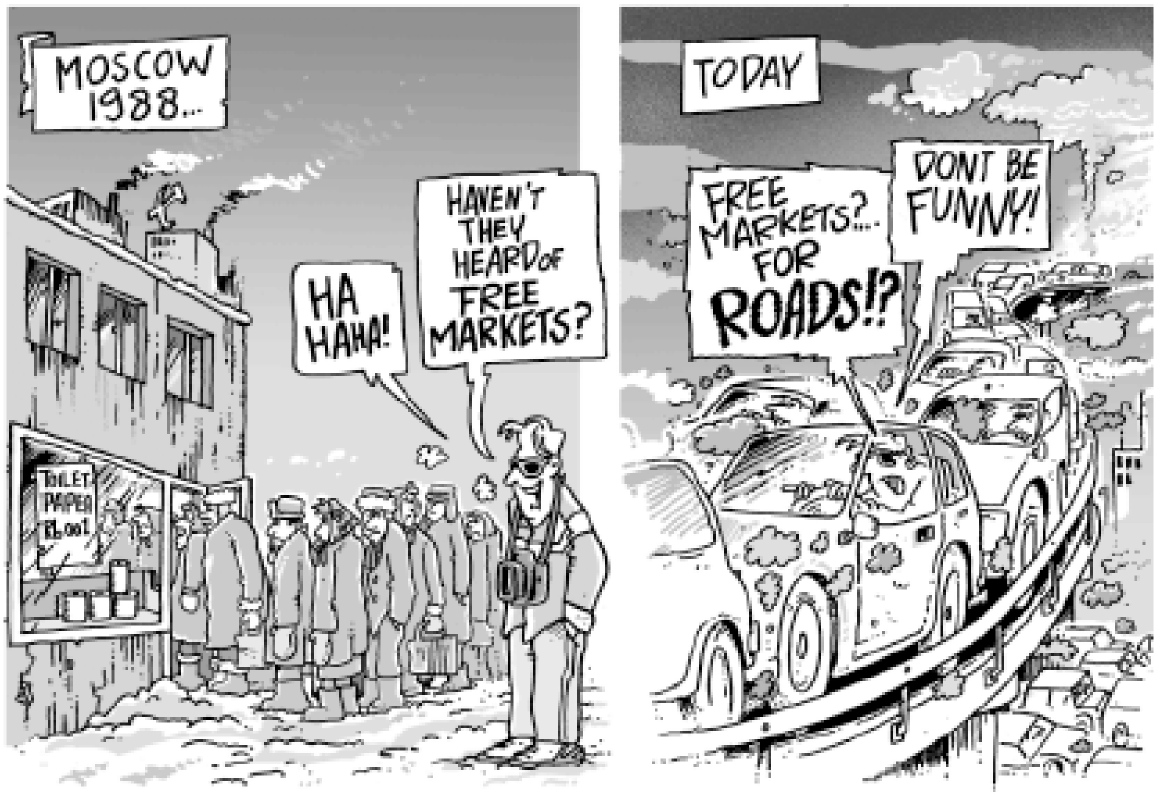
- Improved vehicle technology, safer road designs
- Seatbelt laws
- Tighter speed limits & enforcement
- Increases in minimum driving age, graduate licensing rules
- Reduced driving while impaired
- Driving bans or jail for severe infractions
- Fewer people walk

Limited scope for internalizing costs with user charges

Cost of insurance largely fixed.

But Pay-As-You-Drive insurance premiums are proportional to distance

10. CONGESTION



10.1 Why Does Congestion Occur?

10.1.1 Temporal Peaking

Road travel

- work & school schedules
- operating hours of businesses, shops, entertainment establishments

Air travel

- suitable departure & arrival times, time zone changes school holidays, religious festivals, sporting event schedules (Olympics)

outdoor recreation

Degree of peaking depends on strength & homogeneity of time preferences

10.1.2 Rigidity of Transportation Supply

Infrastructure: long-lived, costly & time-consuming to alter

Mobile plant: still costly, long-lived relative to period of demand fluctuations

Limited adaptation by:

Mobility of plant
Geographical heterogeneity in timing of peaks
Reversible traffic lanes

10.1.3 Output is Not Storable

Unlike for non-perishable goods.

10.1.4 Flawed Usage Incentives

Flawed individual incentives

Too many automobile trips, speeding/dawdling …

Flawed price system for driving

Fees independent of usage: registration, licensing, insurance, gasoline tax.

Capacity too costly to warrant elimination of congestion at all times.

Traditional policy of increasing capacity following “Predict and Provide” self-defeating.

10.2 Magnitude of the Congestion Problem

10.2.1 Costs of road traffic congestion

Source	Date	Region	Magnitude
Texas Transportation Institute (2011)	2010	Major urban areas in US	$101 billion annually 1.9 billion gallons of extra fuel
UNITE (2003)		Western Europe	UK: 1.5% GDP France 1.3% GDP Germany: 0.9% GDP
Glessen (2010)		Moscow	?

Total Annual Costs of Congestion in Selected Canadian Cities (C$ 2002 million)

Costs included: Recurring congestion delay, extra fuel consumption, global warming.

Urban Area (2001 population)	Year	at 50% threshold	at 60% threshold	At 70% threshold	Annual cost per capita at 60% threshold
Toronto (4,682,897)	2001	$889.6	$1,267.3	$1,631.7	$271
Montréal (3,426,350)	1998	$701.9	$854.0	$986.9	$249

Vancouver (1,986,965)	2003	$402.8	$516.8	$628.7	$260
Ottawa-Gatineau (all) (1,063,664)	1995	$39.6	$61.5	$88.6	$58
Calgary (951,395)	2001	$94.6	$112.4	$121.4	$118
Edmonton (937,845)	2000	$49.4	$62.1	$74.1	$66
Québec City (682,757)	2001	$37.5	$52.3	$68.4	$77
Winnipeg (671,274)	1992	$48.4	$77.2	$104.0	$115
Hamilton (all) (662,401)	2001	$6.6	$11.3	$16.9	$17
Total, all urban areas		$2,270.2	$3,015.0	$3,720.6	

Caveats regarding estimates of road traffic congestion costs

- Figures include costs of global warming, but exclude contributions to air pollution and noise.
- Figures exclude costs of schedule delay and other adjustments to congestion
- Comparison with hypothetical free-flow conditions (except for Transport Canada study).
- Costs assessed using single VTTS that ignores:
  - individual heterogeneity

possible dependency on duration of trip duration
possible dependency on severity of congestion or length of delay

- Figures exclude costs of nonrecurring congestion. Transport Canada (2006) follow-up study included this. Costs increase by roughly 2/3.