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Peak period tolls: Precepts and prospects

PATRICK DECORLA-SOUZA & ANTHONY R. KANE
FHWA, 400 Seventh St. SW, Washington DC 20590, USA

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Abstract. This article presents the economic rationale for road pricing and provides some scale on the magnitude of peak period tolls that might be justified. It discusses the impacts of such tolls on congestion, air quality and economic development and suggests a long term strategy towards areawide implementation of peak period pricing. It discusses current trends which are increasing the likelihood for implementation of congestion pricing and toll roads in the future. In particular, it discusses some aspects of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) which will eliminate some of the current restraints on congestion pricing and toll highways.

Abbreviations: ETC – Electronic toll collection, FHWA – Federal Highway Administration, HOV – High occupancy vehicle, ISTEA – Intermodal Surface Transportation Efficiency Act, LOS – Level of service, TCM – Transportation control measure, V/C – Volume-to-capacity ratio, VMT – Vehicle mile(s) of travel, vphpl – Vehicles per hour per lane

Introduction

Transportation planners considering peak period tolls as a potential solution to rush hour traffic woes are faced with several questions. What are the benefits of this strategy? What would be the amount of toll that might be needed? What effect would a peak period pricing strategy have on the problems of concern in larger urban areas – traffic congestion, air quality and economic development? What is the outlook for getting such a strategy implemented?

In this paper, we attempt to provide some answers to these questions. We present the economic rationale for road pricing, and provide some scale on the magnitude of peak period tolls that might be needed. We discuss the impacts of such tolls on congestion, air quality and economic development and suggest a long term strategy towards areawide implementation of peak period pricing. We discuss current trends which are increasing the likelihood for implementation of congestion pricing and toll roads in the future. In particular, we discuss some aspects of the 1991 Intermodal Surface Transportation Efficiency Act

(ISTEA) which will eliminate some of the current restraints on congestion pricing and toll highways.

Rationale for peak period tolls

Theoretically, individual highway users decide whether or not to use a particular highway facility by weighing the costs they will have to bear against the benefits to themselves. If the benefits to the user exceed or are equal to the costs to be borne by the user, the user will decide to use the facility. In Fig. 1, the benefits to each incremental user are indicated on the demand curve "D", while the costs borne by each user as a result of the addition of each incremental user (primarily costs for vehicle operation and travel time which increase due to increasing congestion) are indicated on the user cost curve "C_1". The volume of traffic on the highway "Q" is determined by the intersection of the two curves, at the point where user benefits and user costs are in balance.

The user costs indicated on the user cost curve reflect only the costs *borne* by each user as new users (i.e. "marginal" users) are added. However, the marginal user occasions additional social costs, such as air pollution and delay to other users, which he does not bear. The total of costs borne by each marginal user (i.e. user cost) and the social costs occasioned by him are the "marginal costs" of each trip, i.e. costs which would not be incurred if the vehicle did not make the trip. These costs are indicated by the marginal cost curve "C_2" in Fig. 1.

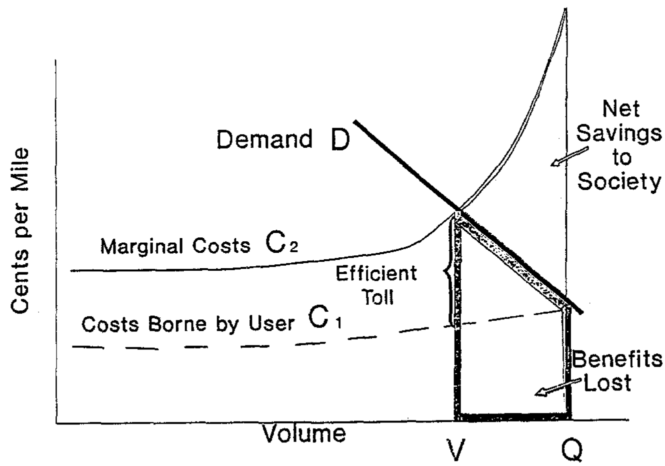

Fig. 1. Effect of tolls.

The point at which the marginal cost curve "C_2" intersects the demand curve indicates the volume of traffic "V" which would occur on the highway if the marginal social costs could be charged to all users by means of a toll. Such a toll is called the "efficient" toll because, according to economic theory, efficiency is maximized when users are charged a price (in this case the total of toll charge and "C_1" cost) which is equal to the marginal cost of a trip. During peak travel periods, highways are overused because users are not confronted with the full social costs of their decision to drive. Overuse causes congestion, inefficiency and waste of economic resources.

Magnitude of social costs

What is the magnitude of costs to society occasioned by failure to confront users with the social costs of their decision to drive? Let us first consider delay costs. If we assume values of travel time of $5.00 to $10.00 per hour, social costs due to delay as freeway traffic volumes increases from 1700 vehicles per lane to 2000 vehicles per lane (i.e. LOS D service volume to theoretical capacity) are about 27 to 54 cents per vehicle mile added. Table 1 shows how these costs are estimated.

A recent study for the Illinois State Toll Authority (Aschauer 1990) estimated average (not marginal) peak period costs for delay and excess fuel consumption on two major north-south arterials in the Chicago region at 36.6 and 45.5 cents per vehicle mile, respectively.

A freeway bottleneck with a mile-long backup (about 300 vehicles queued in each lane) indicates a marginal delay cost of $10 to $20 per vehicle in excess of capacity. These costs may be estimated as follows. We first assume (see Fig.

Table 1. Freeway congestion costs.

For addition of 300 new vehicles per lane to a freeway lane initnially operating at LOS D	
Initial conditions:	Average speed at LOS D = 42 mph
	Traffic service volume at LOS D = 1700 vphpl
	Total travel time/mile for 1700 veh = 40.5 hrs
Changes with addition of 300 vehicles:	
	Average speed, at LOS E = 30 mph
	Traffic service volume (1700 + 300) = 2000 veh
	Total travel time per mile for original 1700 vehicles = 56.5 hrs
Delay per mile caused to original 1700 veh. (56.5 hrs − 40.5 hrs) = 16.0 hrs	
Delay per mile per vehicle added (16 hrs/300 added vehicles) = 3.2 min	
Social cost:	At $5.00 per hour = 27 cents/mile
	At $10 per hour = 54 cents/mile

2) that prior to the first hour of the period during which queueing begins, the freeway is operating at capacity i.e. at a vehicular flow rate of 2000 vehicles per hour per lane (vphpl). Thereafter, 300 vehicles are added evenly to this flow in first hour, vehicle arrival rate reverts back to the capacity flow rate (2000 vphpl) in the second hour, and the vehicle arrivals drop further over the third hour by another 300 vehicles evenly distributed over the third hour. Delay due to queueing at the bottleneck is then estimated from the shaded area in Fig. 2 and converted to monetary costs as follows:

First hour: 0.5(2300 − 2000)	150 hours
Second hour: (300 × 1)	300 hours
Third hour: 0.5(300)	150 hours
Total	600 hours

Delay per vehicle added: 600 hours/300 = 2 hours
Delay cost: At \$5.00 per hour = \$10.00/added vehicle
At \$10.00 per hour = \$20.00/added vehicle

Of course, some might argue that the delay costs are borne by those driving during peak periods in the form of lost time. The costs imposed on others by the marginal user are not, however, fully borne by the marginal user.

There are other marginal social costs which are unrelated to traffic congestion and only partially recovered through user fees. Damage is caused by heavy vehicles to pavement, imposing greater fuel costs on all road users

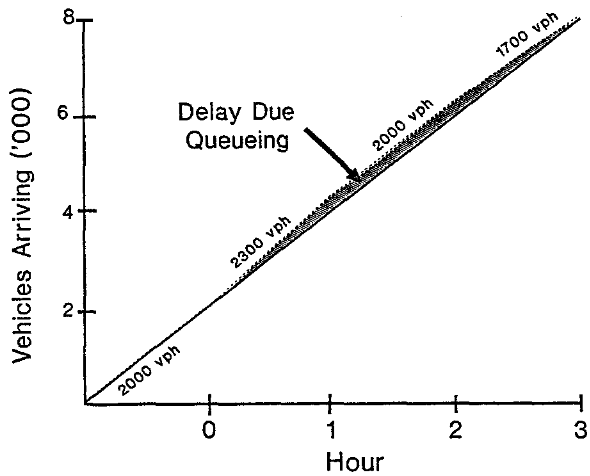

Fig. 2. Delay due to queueing.

and more wear and tear on their vehicles, and increasing public expenditures for road maintenance. Other marginal social costs not recovered from users directly include costs due to:

- *Accidents* – fatality costs and personal injury costs which are not paid from automobile insurance e.g. lost wages or medical costs paid out of health insurance.
- *Air pollution* – damage to human health and agriculture.
- *Water pollution* – damage caused to vegetation, fish and wildlife due to road salt in runoff in snow-belt states.
- *Noise* – annoyance and health impacts; the monetary value of noise may be conservatively estimated from losses in value of real estate affected by noise.
- *Public services* – police department costs for highway patrol, auto theft, parking enforcement, traffic law enforcement and accident investigation; related court system expenses; municipal administrative services; and emergency medical services for accidents.

Table 2 provides some scale on the magnitude of other social costs, based on conservative estimates from the literature. As indicated, the total of these costs are estimated to range from about 2 cents to 17 cents per vehicle mile in 1991 cents. There is an additional subsidy to highway users for highway infrastructure expenditures as indicated in Table 3. Nationally, while about 3.3 cents per mile are spent on highways, only 2 cents per mile are recov-

Table 2. Other social costs of urban travel.

	Cents per VMT			
	FHWA[1] (1980)	HANSON[2] (1989)	KHISTY[3] (1988)	KEELER[4] (1974)
Accidents	–	4.1	12.5	–
Air pollution	1.5	1.5	2.5	0.2
Water pollution	–	0.2	–	–
Noise	0.1	–	0.4	–
Public services	0.7	1.1	–	0.45
Total	2.3	6.9	15.4	0.65
Total (1991 cents)	3.7	7.4	17.2	1.8

Source: [1] Appendix E of FHWA 1992.
[2] Hanson 1989 (Tables 3 and 4)
[3] Khisty et al. 1988
[4] Keeler & Small 1977

Table 3. Highway expenditures and revenues.[1]

	Cents per VMT
EXPENDITURES	
Operation	1.8
Capital	1.5
Total	3.3
REVENUES	
User taxes and tolls	2.0
Other	1.3
Total	3.3

[1] Derived from 1987 nationwide VMT and expenditures nationwide in FHWA's *Highway Statistics*.

ered from user fees. The balance of 1.3 cents is borne by society as a whole through property taxes, income taxes and other general revenues.

Using the FHWA estimate of 3.7 cents for external costs other than delay costs (from Table 2), and adding to it the 1.3 cents social subsidy for highway system public expenditures (indicated in Table 3) yields a total of 5 cents per vehicle mile in non-delay costs currently unrecovered from users. This is equivalent to a fuel tax of about $1.00 a gallon assuming a gas mileage of 20 mpg. External costs for air pollution are higher during congested peak period travel than during off-peak travel due to higher vehicle emission rates at congested travel speeds, giving additional support for peak period tolls to reduce congestion.

Net social benefits of tolls

The analysis presented above indicates that there are significant costs that are not borne by highway users during peak as well as off-peak periods. During peak periods, however, there is a sharp increase in marginal social costs as traffic volumes approach capacity levels, as indicated in Fig. 1 by the marginal cost curve C_2. (Note that the curve includes delay costs as well as other external costs). Consequently, a reduction in traffic volumes during peak periods can result in dramatic reductions in social costs. Therefore, reducing traffic volumes by charging tolls during peak periods can result in considerable savings to society.

Figure 1 demonstrates the societal savings from charging the efficient toll on a currently congested urban facility. The societal cost savings are the difference between the costs that are not incurred (i.e. the area under the marginal cost curve between volumes V and Q) and the benefits to users that are foregone (i.e. the area under the demand curve between volumes V and Q).

A 1982 study (FHWA 1982) estimated net benefits to society of about $5.65 billion with efficient tolls (based on short run marginal costs) applied nationally, based on congestion levels in 1980. The benefits were measured in 1980 dollars and were largely from time savings to users. In addition, the study showed that about $54 billion would be collected in tolls. More recently, a study by the Texas Transportation Institute (Hanks et al. 1989) estimated annual congestion costs in 39 major urban areas at $41 billion in 1987 dollars, with almost $8 billion in the Los Angeles area alone, again largely due to delay costs. A large portion of these costs could be saved with tolls based on marginal social costs.

Estimating the magnitude of needed tolls

Morrison (Morrison 1986) provides a review of various estimates of efficient peak period tolls from prior literature. Estimates of efficient tolls as high as 38 cents per vehicle mile are listed. Efficient tolls may be estimated on the basis of two different principles. The first, usually favored by economists, is based on short run marginal social costs. The second, preferred by engineers and finance professionals, is based on long run costs for providing new capacity to eliminate congestion.

Tolls based on short run marginal costs

Social costs which are not related to congestion are not as time-of-day specific as congestion-related costs. Mechanisms such as fuel taxes could therefore be used more conveniently to recover such costs from highway users. Congestion-related costs (primarily delay costs) could be recovered through peak period tolls.

Figure 3 demonstrates the procedure to estimate the efficient toll based on the difference between marginal time costs and the average time costs actually borne by the marginal user. In order to convert time to money, time is valued at $4.00 per person hour which equates to $5.00 per vehicle hour at an average vehicle occupancy of 1.25. (Transit studies generally use 40% of the median urban area wage rate to estimate the value of travel time per person hour.) The marginal and average cost curves are for an urban non-freeway facility (FHWA 1982) and are based on a value of time of $5.00 per vehicle hour and time in minutes per mile for volume/capacity (V/C) ratios between 0.05 and 0.95 based on a linear speed-density relationship and free

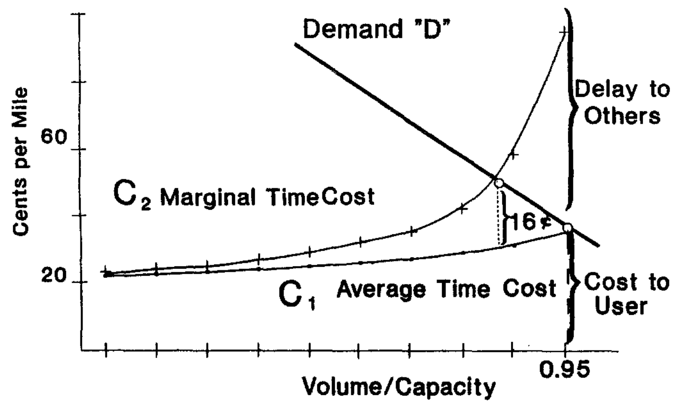

Fig. 3. Delay based toll; urban non-freeway.

speed of 28 mph. The following equations were used to estimate time in minutes per mile:

$$\text{Average time} = \frac{4.29}{1 + (1 - V/C)^{0.5}}$$

$$\text{Marginal time} = \text{Average time} + \text{Average time}^* \frac{0.5\ V/C}{(1 - V/C) + (1 - V/C)^{0.5}}$$

The demand curve is based on an elasticity of travel demand with respect to cost of –0.3 imputed from recent estimates of the price elasticity of parking demand (Shoup et al. 1990) by making an assumption that parking cost accounts for about half the user cost of a vehicle trip.

In this example, thevolume-to-capacity ratio of the facility is currently 0.95 and the demand curve D intersects the average cost curve C_1 at this point. The economically efficient V/C ratio would be the point at which the demand curve D intersects the marginal cost curve C_2, at a V/C ratio of about 0.82. A vertical line drawn from the intersection of the demand curve D and C_2 (the marginal cost curve) down to the average cost curve C_1 then represents the amount of toll that would be needed to maximize efficiency. The required toll may be calculated using the above equations to estimate average and marginal time and converting to costs using a value of 8.3 cents per minute, as folows:

Marginal time at V/C of 0.82	5.0 min.
Average time at V/C of 0.83	3.0 min.
Difference	2.0 min.
Efficient toll (8.3 cents/min.)	16.6 cents

As indicated above, a toll equivalent to 16.6 cents per mile would be necessary in this case. The toll estimate is sensitive to the assumed value of time. Our example was based on an assumed value of time of $5.00 per vehicle hour or 8.3 cents per vehicle minute. The toll would be 33.2 cents a mile if we assumed a value of $10.00 per vehicle hour or 16.6 cents per vehicle minute.

In estimating the magnitude of toll needed, accuracy is not critical. The impacts on net societal savings as a result of charging tolls higher or lower than the true "efficient" toll can be gauged from the slopes of the cost and demand curves in Fig. 3. Only small reductions in the savings to society result from a toll charge as much as 50 percent less than the efficient toll charge, due to the sharp rate of increase in marginal costs as traffic volumes are very close to capacity, as demonstrated in Fig. 4. Of course, the actual differences in societal savings would depend on the shapes of the cost and demand curves.

Tolls based on long run costs

While the toll estimated by the above procedure would be the approximate efficient toll in the short run under the given highway capacity conditions, the situation could be quite different in the long run if it were possible to increase capacity (i.e. the denominator in the V/C ratio) because of changes in social costs after new capacity is in place. With new capacity in place, tolls based on short run marginal costs would be lower as congestion delay would be lower. However, such tolls may be inadequate to recover public costs for providing new capacity. An alternative procedure to estimate needed tolls might be based on the long run marginal costs to provide new capacity. However, it should be noted that under certain conditions, namely if capacity

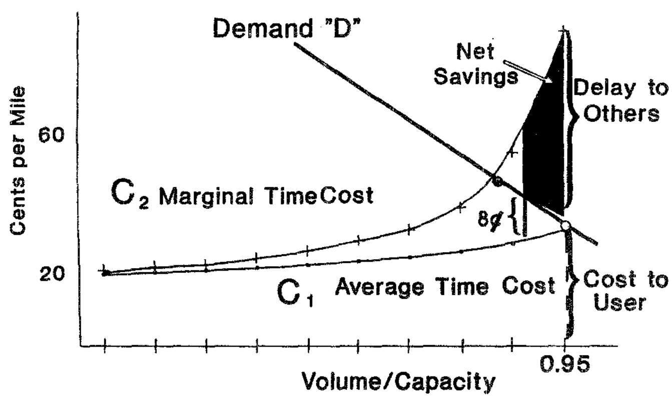

Fig. 4. Effect of tolls 50% less than efficient tolls.

is optimal and capacity costs show constant returns to scale, both procedures are exactly equivalent (Keeler & Small 1977).

We can derive marginal costs for new capacity built primarily to serve peak period users from estimates of marginal costs for new capacity. These are presented for large urban areas by functional class and location within the urban area, i.e. built-up areas and outlying areas, in Table 4. As indicated in the Table, on average, adding lanes in built-up areas costs about 22.3 cents per vehicle mile of peak period travel (VMT) served on the added lane, while adding lanes in outlying areas costs about 16.8 cents per peak period VMT. These unit costs were derived from average nationwide costs for built-up and outlying areas (Jack Faucett & Associates 1991), a discount rate of 10%, 20 year service life, and appropriate peak period shares of daily VMT, shares of VMT on the various functional classes and service volumes for a V/C ratio of 0.85. After the average highway operation costs of 1.8 cents per VMT (see Table 3) are added and user charges through taxes (about 2 cents per mile) are subtracted from the costs for new capacity, the resulting amounts (22.1 cents and 16.6 cents, respectively) would be the toll charge that would be necessary based on long run *marginal* costs to the government.

Table 4. Marginal costs for new capacity on added lanes to serve peak period users.[1]

	Cents per vehicle mile	
	Built-up	Outlying
Freeways	13.4	10.1
Other arterials	25.7	19.4
Collectors	30.8	23.2
Average	22.3	16.8

[1] Based on construction costs from Faucett & Associates 1991; daily travel shares by functional class and LOS D service volumes in DeCorla-Souza & Fleet 1990; travel shares in peak periods based on Sosslau et al. 1978; discount rate of 10%; and 20 year service life with no salvage value.

It should be noted that charging all users the long run *marginal* costs would result in a surplus of revenues on widened facilities, because tolls would apply to users of all lanes and not just the added lane. Also, it should be noted that the imposition of tolls will reduce demand on the facility, and may even eliminate the need for widening the facility. The decision to construct the needed capacity would of course need to be based on an assessment which shows that overall benefits exceed the costs.

Systemwide new capacity tolls

The long run marginal cost estimates discussed in the previous section were based on nationwide average costs for highway construction and are applicable to individual improved segments; therefore the toll charges derived from them would apply only to improved segments. However, it could be argued that users of unimproved roads would also benefit from improvements to nearby parallel facilities as traffic shifts to improved facilities reducing congestion on unimproved roads; therefore, they could share the cost burden based on benefits received but not on any cost responsibility theory. In other words, it could be argued that since benefits extend systemwide one could raise the needed revenue by charging users of the road system throughout the urban area.

What might be the order of magnitude of such systemwide charges? We could get some scale on such charges by taking costs for new capacity (both widenings and new facilities) proposed in each category in a region and dividing them by projected peak period vehicle miles of travel (VMT). Overall regionwide average charges have been estimated at 12.5 to 20 cents per mile in Table 5 for three fast-growing urban areas, based on data from their transportation plans (North Central Texas Council of Governments 1986, Denver Regional Council of Governments 1987, Southern California Association of Governments 1988). The estimates are based on assumptions that:

Table 5. Regionwide costs for new capacity to serve peak period users.

	Dallas	Denver	Los Angeles
Vehicle miles of travel (millions):			
Base yr (peak)[1]	22.4	12.8	88.5
Target yr (peak)[1]	46.8	26.0	130.0
Peak period increase	24.4	13.2	41.5
Highway capital costs (million $):			
Total costs	12,500	8,900	54,900
Annualized[2]	1,468	1,045	6,446
Annualized costs attributed to peak period users (75%)	1,101	784	4,385
Unit costs (cent/peak period VMT):			
Average cost	12.5	16.1	19.8

[1] Assumes 40% of daily travel in peak period

[2] Assumes 10% interest rate and 20-year life with no salvage value.

- the new capacity proposed in these plans is needed primarily to meet peak period travel demand with about 75% of the new capacity needs resulting from peak period travel; and
- any amounts recovered from road users through fuel taxes would be just sufficient for road maintenance. (Based on FHWA's *Highway Statistics* for 1987, roadway operation and maintenance costs, as indicated in Table 3, amounted to 1.8 cents per VMT nationally, which is roughly the same as the amount recovered from fuel taxes per VMT nationally.)

Owing to the high growth rates in the three areas, there are relatively fewer existing VMT to share the burden of new capacity costs. The average costs per peak period VMT are therefore probably higher than what might be expected in moderately growing urban areas.

While funding shortfalls were identified in the plans of all three urban areas, the possibility of recovering costs for new capacity from peak period users through tolls was not considered in travel demand forecasts. Clearly, a toll charge of 20 cents a mile (which equates to a $4.00 per gallon fuel tax), such as would be needed in the Los Angeles area, would have a significant impact on the peak period travel demand, and reduce some new capacity needs.

Effects of pricing

There are four major problems of concern to major urban areas in the 1990's all of which could be significantly impacted through implementation of peak period pricing:

- Traffic congestion
- Air quality
- Economic development
- Revenue shortfalls for transportation

In this section we discuss the impacts peak period tolls can have on each of these problems.

Traffic congestion

The literature provides very different estimates of the responsiveness, or elasticity, of auto travel demand to changes in auto travel times and costs. Table 6 presents some elasticity values for downtown oriented travel and for general urban travel from the literature. Based on the elasticity values in Table 6, we can expect peak period tolls to have two concurrent effects: a decrease in travel demand related to the increase in travel cost, and a small increase in travel above this reduced demand level related to the reduction in travel times which would result from reduced congestion. The differences in price elasticity of travel demand illustrated in Table 6 for downtown-oriented travel

Table 6. Elasticity of auto travel demand.

PRICE ELASTICITY	
Elasticities for an auto commute trip to downtown Boston [1]	
Charles River Associates model	–2.00
Cambridge Systematics Inc. model	–0.36
McFadden/Train model	–0.32
Elasticity of demand for parking [2]	
Mid Wilshire, Los Angeles	–0.23
Warner Center, Los Angeles	–0.18
Century, City, Los Angeles	–0.08
Civic Center, Los Angeles	–0.22
Downtown Ottawa, Canada	–0.10
Average	–0.16
TRAVEL TIME ELASTICITY	
Elasticities for an auto commute trip to downtown Boston [1]	
Charles River Associates model	–1.6
Cambridge Systematics Inc. model	–0.62
McFadden/Train model	–1.85

[1] *Source:* Gomez-Ibanez & Fauth 1980
[2] *Source:* Shoup & Willson 1990

vs. other travel indicate the importance of alternative modes and supporting land use patterns for maximizing travel demand reduction.

In the long term, it can be expected that land rents closer to the city center will increase concurrently reflecting the desire of commuters to live closer to their jobs in the urban core or other activity center. Higher land rents will force development and redevelopment to take place at higher densities, making alternative transportation modes (i.e. transit, ridesharing, bicycling and walking) more viable.

Air quality

With respect to air quality impacts, it is clear that reduced travel demand in peak periods reflects fewer and shorter trips being made and results in higher travel speeds during peak periods, with consequent reductions in vehicle emissions during peak periods. However, the bulk of daily travel occurring in off-peak periods may be negatively affected, as some peak period travellers shift their time of travel to off-peak periods to avoid tolls. Overall beneficial impacts on air quality may thus be smaller than that suggested simply by peak period travel demand reductions. Also, traffic diversions may cause localized increased in carbon monoxide (CO) concentrations.

In the long term, higher urban densities resulting from peak period tolls could also lead to increases in use of alternative travel modes for all daily trips, reducing total daily emissions. However, higher densities could also increase the risk of the urban population's exposure to carbon monoxide concentrations.

Economic development

A major concern about the effects of peak period tolls is the shift in the relative economic attractiveness of downtown locations *vs.* suburban locations which could result if downtown oriented highways have higher tolls imposed on them either due to heavier congestion or due to higher roadway widening costs in heavily built-up areas. While areawide tolls could be designed to reduce the magnitude of differences in tolls by urban location, much of the effectiveness of toll pricing would also be reduced and negative impacts on some businesses could still occur due to shifts in relative attractiveness of different locations as a result of shifts in relative travel costs to different destinations.

In many urban areas highway congestion is seen as a hindrance to economic development. While money costs for tolls will be an additional production cost to commercial traffic and business travellers, the cost savings from shorter travel times will more than compensate, thus increasing production efficiency and competitiveness of manufacturers and service providers. Business growth and economic development can be expected to follow.

In areas where new capacity can be built, tolls will provide the necessary funds to build it, generating new construction jobs in the short term and jobs from a boost in development in the long term. In areas where restraints on building new capacity are in place because of air quality mandates, congestion's stifling effect on economic development will be minimized with congestion tolls. It should be noted that as long as revenues from tolls are expended by the government within the local economy, there will not be any net effect in the economy from the transfer of dollars from highway users to the government.

Revenue shortfalls

Partly due to increasing costs for maintenance and operation of the urban transportation infrastructure and partly due to a declining share of funding from federal sources, state and local governments are now being called upon to bear a larger share of public expenditures for transportation, both highways and transit. Meanwhile, taxpayer revolts are limiting their ability to raise revenues. They will have to look for new ways to fund transportation needs.

Peak period tolls can provide a new source of revenue. Tolls based on new capacity costs can pay for capital expenditures for highways, leaving fuel taxes to pay roadway operation and maintenance. If tolls are based on short run social costs and revenues exceed highway infrastructure needs, there is justification for spending the excess funds on other modes (i.e. transit, bicycle and pedestrian) on grounds of both efficiency as well as equity. By increasing the competitiveness of non-auto travel options, travel demand reduction effects of tolls are increased and consequently new highway capacity needs or short run social costs are decreased. On equity grounds, subsidies to non-auto modes can be justified because: (1) they compensate those "tolled-off" the highways (usually lower income users) for benefits lost by them; (2) they make up in a small way for the hidden incentives to drive provided by free or subsidized parking usually offered to auto users; (3) the resulting shifts to non-auto modes benefit auto users because congestion on the highway is lower when previous auto-users divert to other modes.

Implementation

Several trends are converging which are brightening the outlook for implementation of peak period tolls in the 1990's, and with thorough planning to ameliorate perceived negative impacts and gain public acceptance, peak period road pricing may become a reality. Some practical ideas:

- Test differential charges for peak periods on existing toll roads and existing parking spaces, both public and private, including employer provided "free" parking.
- Introduce charges for non-qualifying vehicles on HOV lanes which are under-utilized.
- Plan to dedicate some of the toll revenues to assist those "tolled off", by providing subsidies for alternative modes or by providing low-income employees with travel allowances.
- Start with tolls on new or improved segments only, with toll charges related to the cost for providing new capacity.
- Standardize toll charges to make it easy for the tripmaker to calculate the cost of his trip. Toll charge accuracy is not important.
- Develop compatible toll collection technology nationwide (with more uniformity in standard protocols) to allow non-local vehicles easy access to the toll system.

Some positive trends that will ease implementation are discussed below:

Changes in public opinion

Ever increasing levels of congestion are being experienced in urban areas, while funding to pay for new highway capacity continues to be difficult to raise.

Public frustration with congestion will make it easier for elected officials to consider tolls. Public opinion regarding the acceptability of tolls is shifting. A nationwide survey (Apogee Research Inc. 1990) revealed that 44 percent of commuters would be willing to pay $2.00 and another 21 percent would we willing to pay $0.50 to save the time lost due to congestion on their commute home.

Alternative fuels

As electric cars and vehicles fueled with alternative fuels become more common, alternative financing mechanisms will have to be sought as fuel taxes become less viable. For example, it may not be easy to tax electricity used for vehicles, since the same energy source is used for many other purposes. Mileage based fees may be the answer.

Electronic toll collection (ETC)

There are two basic methods for electronic toll collection (Hau 1992). The first uses automatic vehicle identification (AVI) technology. An AVI tag is a read-only transponder that communicates its encrypted identification code via high frequency radio waves to a roadside reader which sends it to a central computer for charging. A second option uses "smartcard" technology. A smartcard is a removable credit card-sized electronic purse with stored value (similar to subway farecards) which can be periodically replenished when the balance is low. It has both read and write capabilities for the purpose of deducting charges instantaneously on board the vehicle. Electronic toll collection technology has lowered costs for toll collection as well as delays at toll booths.

The technology for electronic toll collection continues to improve, and costs can be expected to fall with more widespread use. Such systems are currently fully operational on toll facilities in Dallas, New Orleans, Denver, San Diego, Oklahoma, Florida and Michigan. They are planned for implementation in the New York Metropolitan area, elsewhere in New York state, New Jersey, Pennsylvania, the New England states, California, Virginia, Illinois, and Georgia. In Europe – Norway, Sweden, France, Italy, the U.K., and the Netherlands – systems are either fully operational or planned for implementation soon. Seven regional transportation agencies in the Northeast, which account for 37 percent of the nation's toll traffic, have agreed to implement a coordinated automatic toll collection system. Such projects will instill greater acceptability of tolls and facilitate the implementation of differential tolls by time of day. People will get used to electronic charging and accept the small loss of privacy entailed to reduce delay. This will make it easier to implement systemwide peak period pricing later on.

Experience with areawide road pricing in other countries

Areawide road pricing has already been implemented in Singapore (1970's), in Bergen, Norway (1986) and in Oslo (1990). Areawide road pricing using electronic toll collection has been pilot tested successfully in Hong Kong; and Trondheim, Norway has become the first city to implement areawide electronic toll collection. Areawide ETC planned for implementation in the Netherlands (Amsterdam, Rotterdam, Utrecht, and The Hague) is currently on hold.

Clean Air Act requirements

The new Clean Air Act requirements may put greater pressure on local elected officials to give serious consideration to transportation control measures (TCM's) such as HOV lanes, congestion pricing, parking pricing, and differential tolls by time of day. Congestion pricing is under consideration currently in the San Francisco Bay area and in Southern California.

Intermodal Surface Transportation Efficiency Act

New Federal legislation – the Intermodal Surface Transportation Efficiency Act (ISTEA) – eliminates previous restrictions on toll financing for federally funded projects. The Act allows federal funding on both public as well as private toll highway projects, and provides new inducements to states to consider toll financing and congestion pricing. In addition, toll authorities would no longer need to remove tolls when bonds are paid off. Toll facilities can now be major sources of revenue for systemwide investment.

ISTEA allows federal funding for 4R work on existing toll facilities (80% federal match), new non-Interstate toll facilities (50% federal match), and conversions of existing free non-Interstate roads to toll roads (50% federal match). For new non-Interstate toll bridges, or replacement, reconstruction and conversion of existing free bridges (both Interstate and non-Interstate) to toll bridges, the Federal share can be 80%. Additionally, ISTEA provides 80% federal match for five congestion pricing pilot projects, three of which can include toll pricing of Interstate highway facilities. The Act also requires urban areas with more than 200,000 population to set up "Congestion Management Systems". The systems will include data and tools to identify congestion levels and locations and monitor changes in congestion, which could provide a framework for congestion pricing.

With the new legislation, we will see more interest in congestion pricing and toll roads. We will see the construction of several new toll roads, and conversion of existing free (non-Interstate) roads to toll facilities. Electronic toll collection technology will facilitate implementation of differential tolls by time of day on these facilities, and the new toll highways which are built under the new policy will get people used to paying for highway use. It is conceivable that future Acts may even eliminate the prohibition of tolls on currently free Interstates.

Conclusions

Implementation of peak period road pricing has potential to achieve huge economic savings to society through reduction or elimination of congestion which costs just 39 large urban areas of the nation about $41 billion per year. It appears that a toll charge of 16 to 33 cents per mile would suffice on congested highway facilities, based on delay costs alone. A toll charge of 33 cents per mile equates to $6.60 per gallon fuel tax at 20 mpg. Other marginal social costs, conservatively estimated at 5 cents per mile, could be recovered through a fuel tax of $1.00 per gallon.

Public acceptance of tolls may be greater if toll revenues are primarily dedicated for roadway improvements. If the concept of areawide tolls for new capacity becomes acceptable, average peak period tolls could be as high as 20 cents per mile in high-growth areas. Tolls of this magnitude will not be easy to enact. Twenty cents per mile is equivalent to a $4.00 per gallon tax for a vehicle which averages 20 mpg. Charges for typical toll roads today are 3 cents per mile for older facilities and perhaps as much as 10 cents per mile for newer and shorter facilities.

Travel demand reductions due to tolls could reduce new capacity needs. In addition, implementation of peak period tolls would benefit in air quality, promote economic development, and raise revenues to fund urban transportation needs.

The outlook for future implementation of peak period tolls is encouraging. Public opinion is changing, electronic toll collection is reducing toll collection cost and delay, the new Clear Air Act requirements are putting pressure on elected officials for more serious consideration of pricing policies, and the Intermodal Surface Transportation Efficiency Act will provide further incentives for building new toll roads and converting existing free facilities to toll facilities. Electronic toll collection technology will facilitate implementation of differential tolls by time of day on these facilities, and will get people use to the idea that a good level of service during peak periods is something that has to be paid for.

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