ROAD PRICING IN SINGAPORE: TOO MUCH OF A GOOD THING?

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INTRODUCTION

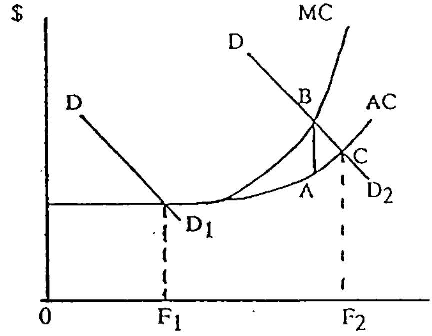
In the field of transportation economics, congestion or road pricing has been a topic of intense interest for a number of years. Although the theoretical underpinnings for congestion pricing are straightforward (Vickrey, 1967; Walters, 1968), political and technological constraints have, until recently, precluded the implementation of road pricing schemes. In 1975, Singapore implemented an Area License Scheme (ALS) which, at the time, came closest to a congestion pricing policy. More recently, the development of automobile vehicle identifier (AVI) technology that can be used on a system-wide basis and increasing urban congestion problems that demand attention from policy makers have so relaxed the technological and political constraints that a number of more sophisticated road pricing demonstration projects have been proposed and/or implemented. However, notwithstanding the increased interest in and funding of congestion pricing projects, Singapore's ALS remains the only scheme that has been implemented on a permanent basis.

In a continuing effort to reduce congestion on its road network, Singapore is currently working on converting its Area License Scheme into an electronic road pricing (ERP) system through a two step process. First, the existing ALS system will be automated. Second, the geographical coverage of the existing system will be expanded. Following a brief discussion on the economic rationale for road pricing and using recent experience with ERP as a frame of reference, the purpose of this paper is to examine Singapore's experience in the ALS and its current efforts towards developing and implementing an ERP system.

1. ROAD PRICING

The fundamental result underlying all discussions of road pricing is depicted in Figure 1 where flow (number of vehicles per hour) is on the abscissa and travel cost is on the ordinate. AC(x) is an individual's average travel cost associated with a given traffic flow x which implies that his/her total cost is TC(x) = AC(x)x. Solving for the marginal cost of travel yields MC(x) = AC(x) + x(dAC(x)/dx) where it's assumed

Figure 1



that, after some point, average cost increases with traffic flow. Thus, average cost for which reflects the lower speeds resulting from the increased flow.

It is important to recognize that the average cost curve reflects the perceived time and money costs directly incurred by an individual. The term x(dAC(x)/dx) is the congestion externality, that is, the increased cost that the addition of one more vehicle to the flow imposes on all other drivers. It is this cost that individual drivers are assumed to ignore when deciding upon their travel activities. Adding the congestion externality to average cost yields marginal social cost curve which reflects the cost to society from a one unit increase in the flow of traffic.

There are two demand curves in Figure 1. DD_1 represents demand for the road in off-peak periods, that is, when the flow is sufficiently low that no congestion externality is present. In this case, equilibrium flow is F_1 which represents an efficient allocation of resources.

DD_2 is peak period demand which, assuming that individuals act in their own interest and ignore the effects that their behavior has upon other travellers, yields an equilibrium, although not efficient, flow equal to F_2. In this case, however, too many resources are devoted to tripmaking which is reflected by the difference between the marginal value of the last addition to the flow and its marginal social cost. Relative to an efficient allocation of resources, given by the intersection between marginal cost and peak period demand, the size of the welfare loss is the area ABC.

In general, the misallocation of resources is manifested through its effects on various relative prices. Some trips which would not have been undertaken in the presence of marginal cost pricing are taken under average cost pricing. In addition, the relative price of automobile use is lower inducing a shift from other modes, particularly public transit, to the automobile. Moreover, since urban congestion is a spatial phenomenon, average cost pricing induces tripmakers towards heavily congested and away from less congested areas, which has economic implications for businesses operating in each area. There also exist implications with respect to transport investment decisions. When congestion externalities are not internalized, there is an incentive to overinvest in the highway system and, correspondingly, underinvest in alternative modes of transport, in order to accommodate the larger flow of highway traffic.

In sum, distortions created in the use of road space resulting from congestion externalities lead directly to non-optimal trip generation, modal and destination choice, and highway investment. In addition, there are secondary effects related to fuel consumption, environmental pollution, and highway safety.

The ideal solution to the misallocation of resources is to impose a "congestion tax", $x(dAC(x)/dx)$, which equals the difference between marginal social cost and average cost at the optimum traffic flow. In Figure 1, the congestion tax is AB.[1]

Notwithstanding the theoretical appeal of a congestion tax, implementation is not so simple. Ideal road pricing schemes require congestion charges such that, at the margin, the full cost of one's trip equals the value placed on the trip. Since congestion is not uniformly distributed over an area at any given point in time, varies by time of day for a given area, and varies by vehicle type in a given area and at a given time, an ideal congestion tax would vary continually as conditions on the network changed. Moreover, these charges would, minimally, be differentiated spatially, temporally, and by type of vehicle.[2]

2. RECENT EXPERIENCE WITH ROAD PRICING

During the past 15 years, there have been several proposed and/or actual experiments with road pricing in Europe, the United States, and South East Asia, some of which are summarized in Table 1. Singapore's ALS scheme, discussed in greater detail below, was not only the first initiated but is the only program that is a permanent fixture in the transport infrastructure. Despite the willingness in the United States to undertake road pricing demonstration projects, none of the cities contacted expressed sufficient interest for a project to be initiated, partially because road pricing was presented as another tax rather than a user fee which would be used to support roads (Higgins, 1986). This was also important in Norway's toll ring, the revenues from which were directly linked to road improvement. Presented as a measure of traffic restraint, the ring would have been rejected (Larson, 1987).

Among the road pricing projects attempted, Hong Kong's ERP pilot project best captures a marginal cost pricing principle. The net benefits of three pricing schemes were calculated and compared with the theoretical net benefits obtainable through marginal cost pricing. Table 2 presents these results where a general positive relationship between the complexity of the scheme and the theoretically obtainable gains is observed. Car ownership restraint schemes achieved only 24% of the

Table 1
Recent Road Pricing Experiments/Attempts

Country, Year	*Type of Scheme*	*Status*	*Major Objectives*	*Major Concerns*
Singapore, 1975	License	Implemented	Reduce peak hour traffic	Economic vitality of area, no subsidy required, easy to administer and enforce
United States, 1976-77	License	Proposed	Reduce auto use, means for public transit financing	Privacy, harm to business, regressive tax
Hong Kong, 1983-85	Multiple cordon-based ERP	Implemented	Reduce private auto use	Equity, privacy, government credibility
Norway, 1986	Toll Ring	Implemented	Funding to build new roads	None
Netherlands 1992-95	Multiple cordon-based ERP	To be implemented	Regulate traffic, control car use growth, generate revenues	Privacy, enforcement, reliability, security

Source: Holland and Watson (1978), Higgins (1986), Hau (1990), Larson (1987), Stoelhorst and Zandbergen (1990).

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available gains whereas Scheme C, the most complicated, garnered 74%. It is interesting to note, however, that Scheme B, which is a simplified version of A and represents a type of area pricing, produced nearly the same net gains as scheme C.

3. THE AREA LICENSING SCHEME IN SINGAPORE

To alleviate the congestion problem in the Central Business District (CBD), the Area Licensing Scheme (ALS) was implemented on June 2, 1975. The main objective of the scheme was to charge vehicles for road usage at times and places when and where they caused the most severe congestion. The CBD, also known as the "Restricted Zone," covers an area of about 725 hectares of the most congested parts of the city including the business and financial district in Shenton Way, the main downtown commercial region and the hotels and shopping strip along Orchard Road. It is estimated that about 315,000 people are employed within the Restricted Zone

Table 2
Net Benefits from Alternative Road Pricing Schemes in Hong Kong

Option	Scheme A	Scheme B	Scheme C	Car Ownership Restraint	Optimum Option
Average Peak Charge	HK $8	N/A	N/A	-	HK $10
Net Benefits					
Private Cars	202	235	216	-29	N/A
Taxis	53	61	68	38	N/A
Public Transport	299	350	389	158	N/A
Goods Vehicles	180	225	246	134	N/A
All Vehicles	734	871	919	301	1250
% Theoretical Optimum	59	70	74	24	100

Source: Hau (1990). N/A is not available. Scheme A has 5 zones, 115 toll booths, and 5 charging periods. Scheme B is a simplified version of A and represents an Area Pricing scheme. Scheme C has 13 zones, 185 toll booths, and 5 charging periods.

(Menon and Seddon (1991)). Under the scheme, all passenger cars entering the Restricted Zone during restricted hours are required to purchase a license and display it on their windscreens. By raising the cost of commuting into the CBD by privately owned automobiles, the scheme aimed to reduce road use and alleviate congestion. The basic target of the scheme was to reduce the number of vehicles entering the CBD during the morning peak hours by 25-30 per cent (Holland and Watson (1978)).

Initially, the ALS restricted entry of privately owned cars into the CDB during the morning rush hours between 7.30 am and 10.30 am from Monday to Saturday. The ALS did not apply on Sundays and public holidays. Car pools or cars with at least four passengers, inclusive of the driver, were exempted from the restriction. To enter the Restricted Zone, privately owned cars had to purchase a $3 daily license or a $60 monthly license. This surcharge had a dramatic impact on traffic flow. The number of cars entering the CBD during the restricted hours fell by 73% from 42,790 in March 1975 to an average of 11,363 in September and October 1975 (Holland and Watson (1978)). The volume of cars entering the Restricted Zone from 7.00-7.30 am rose by 23% as commuters adjusted their travelling times to avoid the surcharge. The proportion of car pooling increased 30%. Changes in the flows of other types of vehicles were smaller and the net result was a 44% reduction in total traffic, exceeding the target reduction.

Since its implementation, the levies have been revised several times without significant effects, apparently, on traffic volume. The morning peak traffic has remained relatively constant from 1976 to 1988. In August 1975, taxis were included in the ALS at the same rate as private cars. The license fees were raised to $4 per day for private cars and company cars were included in the scheme with a new levy of $8 per day in January 1976. The license fee for taxis was reduced to $2 per day in April 1977. And in March 1980, the daily surcharge imposed on cars was raised to $5.

Given that the $3 base price in 1975 translates into $4.85 in 1980, the real increase in the congestion tax was 3% which may partially explain the small change in road use over the period. In 1985, the Mass Rapid Transit (MRT) came into operation providing an additional substitute mode of travel which resulted in a decrease in the traffic into the restricted zone.

On June 1, 1989, a major revision in the ALS was enacted. All categories of vehicles except ambulances, fire engines, police and military vehicles and public buses were now required to pay area licenses. Car pools were no longer exempted from the toll. The daily licenses for motorcycles and company registered cars were now levied at $1 and $6 respectively while other vehicles were levied at $3. The corresponding monthly fees were $20, $120 and $60. The ALS was also extended to include the evening peak hours between 4.30-6.30 pm from Monday to Friday.

As expected, this revision produced a change in the travel behavior among the different commuter groups. The fall in the license fee for automobiles increased the number of cars travelling into the Restricted Zone during the morning peak hours about 30% (Menon and Seddon (1991)). On the other hand, the flow of motorcycles and commercial vehicles, not previously subjected to the area license, into the Restricted Zone, experienced an expected decrease. The overall impact on inbound traffic was a net increase.

Since, prior to the 1989 revision, all vehicles were not subjected to the evening toll, an across-the-board decrease in traffic volume was observed during the evening restricted hours. The rate of entry by cars into the restricted zone fell 70% while commercial vehicles rate fell 60%. Thus, the overall impact was a decrease of about 40% in outbound traffic (Menon and Seddon (1991)).

The ALS has so far achieved its traffic restraint objectives and target. There has been a diversion of travel from car to public transport, more evenly distributed traffic into the Restricted Zone, and a reduction in cross-town travel through the zone. However, very little has been done to analyze the economic and welfare implications of the ALS. The only study which undertook to quantify the welfare effects of the area license was that of Wilson (1988a), which concluded that although some individuals clearly benefited from the scheme, social welfare may actually have decreased due to scheduling and switching costs incurred by other commuters. Interestingly, he estimated that 44.1% of the commuters experienced an increase in travel time while only 36.1% experienced a decrease. This result seemed perverse since the policy was designed to alleviate congestion and reduce travel time. Based upon statistical tests and using several different welfare specifications and assumptions on the redistribution of the revenue generated from the ALS, the net change in societal welfare was consistently negative.

There are some aspects of the ALS that are rather puzzling from an economic perspective. First, as stated in Holland and Watson (1978), the specific target of 25-30% reduction in traffic flowing into the Restricted Zone was estimated as the level at which reasonably good traffic conditions equivalent to those found during off-peak hours would be restored. From an economic perspective, this level of reduction is likely to be too high since there exist strong incentives for higher travel during the peak hours (Small (1982), Hendrickson and Plank (1984), Wilson (1988b,1989)). Thus, reducing peak hours travel to the targeted objective would likely produce excessive scheduling and switching costs. Second, no comprehensive study was conducted to estimate the optimal congestion tax which makes it very difficult to evaluate the economic effects of any road pricing strategy.

After the $3 daily license fee was implemented in 1975, the reduction in the number of vehicles entering the Restricted Zone exceeded the target level but no readjustment was made to increase CBD traffic. In fact, there have been two increases in the license fee to keep the traffic flow stable and well above 50% reduction level. Even if the initial 25% - 30% target represented an optimal utilization rate, the ex-post reductions imply that the road system has been under-utilized for 15 years, reinforcing Wilson's conclusion.

Further insights on the economic effects of the ALS can be obtained from a 1990 traffic survey of Singapore's Restricted Zone which undertook an extensive traffic count of entering and exiting vehicles, by time of day, as well as a survey of journey times along two fixed circuits within the zone. Table 3 summarizes the average journey speed and average intersection delay around each circuit during a restricted period (9:00 am - 10:00 am) and a non-restricted period (1:00 pm - 4:00 pm). On both circuits, the average speed was <u>higher</u> and average intersection delay <u>lower</u> during the peak period. Consistent with these results, the study also found that the average number of vehicles per lane per hour in the Restricted Zone was 450 and 600 during the periods 9:00 -10:00 am and 1:00 - 4:00 pm respectively. In other words, the effect of Singapore's ALS has been to reduce peak period demand to such an extent that travelling during the peak period is faster.

The data in Table 3 can also be used to calculate a "back of the envelope" estimate of the congestion tax. Recall that the congestion tax is x(dAC(x)/dx) where x is traffic flow and AC(x) is the average cost of travel. Assume that each circuit is a separate trip with typical morning and afternoon flows equal to 450 and 600 vehicles per lane per hour respectively, that money costs per trip are negligible, and that the

Table 3
Speed and Delay Characteristics

Road Characteristic	*Circuit A*	*Circuit B*
Length (kilometers)	7.166	6.663
# Intersections	31	32
Average Journey Speed (km/hr)		
ALS	27.6	23.3
non-ALS	20.3	16.8
Average Intersection Delay (sec)		
ALS	7.4	9.9
non-ALS	11.5	16.6

Source: Olszewski and Tan, 1991.

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value of travel time (VOT) is constant and equal to $3.74 per hour.[3] Then average cost is VOT*trip length*(average speed)$^{-1}$. For circuit A, average cost is $0.97 and $1.31 for a flow of 450 and 600 respectively. Thus, an estimate for dAC(x)/dx is .0023 which, when multiplied by an average flow of 525 vehicles per lane per hour, gives an estimated congestion tax equal to $1.19. By a similar procedure, the estimated congestion tax on circuit B is $1.44. Relative to these congestion tax estimates, the existing license fees for private automobiles are 108% - 152% too high![4]

Two points follow from this illustration. First, caution must be exercised not to indiscriminately use road pricing as simple demand management tools. Although the ALS scheme has significantly reduced peak demands for road space, too much restraint is also wasteful. If a congestion tax prices an inefficient number of drivers off the network and causes an inefficient reallocation of trips to other modes and to different time periods, then the gains to peak period users will be more than offset by the losses to these other travelers. The admittedly simple calculations presented above suggest that the current ALS pricing scheme may indeed be too restrictive. Second, it is important to estimate the congestion externality. Without this information, it will not be possible to evaluate whether a particular road pricing strategy approximates an efficient allocation of resources.

4. AUTOMATING THE ALS

Although the ALS is seen as a successful demand management tool, it has some operational drawbacks. The restricted zone is demarcated by overhead gantry signs placed at each of the 27 entry points. Police officers are stationed at each entry point to check whether restricted vehicles have valid area licenses to enter the restricted zone. The registration number, color and make of "offending vehicles" are noted without stopping the vehicles and the owner will receive a traffic ticket with an offer to compound the offence within 2 weeks for a sum of $30. The job of the enforcement officers are often viewed as very boring and non-satisfying.

Daily licenses can be purchased at post offices and road side booths along the approach roads to the Restricted Zone. Monthly licenses are sold at the Registry of Vehicles, the Urban Redevelopment Authority Car Park Office and the major post offices. For the casual motorist, it is rather inconvenient to look for a place to purchase the license before entering the restricted zone. On the whole, the operation is very labour intensive and this is not desirable given the tight labor market in Singapore.

Furthermore, it is difficult to extend the existing system to cover other congested areas. From an economic perspective, the system should be further extended to graduated pricing by time, place, and vehicle. This form of congestion pricing would be more akin to marginal cost pricing which is welfare increasing. However, with the current ALS, it would require many types of licenses and this can create unnecessary confusion to both consumers and enforcement officers.

5. THE PROPOSED ELECTRONIC ROAD PRICING SYSTEM

Owning to these setbacks, the government has decided to fully automate the ALS by introducing Electronic Road Pricing (ERP). The proposed system will have in-vehicle units, out-stations and an in-station. In-vehicle units have smart cards that can perform logical operations, manipulate data and store information in their memory. They serve as stored-value devices or electronic purses. Motorists can purchase new cards, recharge or return depleted ones at designated sale outlets. When a vehicle passes a control point, the automatic vehicle identification system in the out-station will detect its approach and checks if the vehicle has a valid card with sufficient monetary value for entry into the Restricted Zone. If so, a certain amount is deducted from the stored-value card. Otherwise, the enforcement camera takes a picture of the vehicle and transmits it to the in-station. The in-station is a control centre which have a centralized computer for monitoring and altering system status, and for receiving violation reports and photographs as well as processing them.

Initially, the focus will be automating the existing operation. One proposed feature of the system is the ability to charge differential prices for different types of vehicles, like motorcycles, cars and heavy goods vehicles (Straits Times, 26/5/90). It is envisaged that the system will be extended in five to seven years to cover other areas on the island experiencing traffic congestion (Straits Times, 30/5/91). The government has considered expanding the ERP system to charge different rates for different roads, depending on the level of congestion (Straits Times, 9/9/89). Thus, the proposed ERP will have an island-wide computerized system with the ability to bill road users and control road use in congested areas (Straits Times, 20/4/91). However, the potential of such a system should be further exploited towards graduated pricing by types of vehicles, time and place in order to optimize on resource allocation in a manner as close to road pricing theory as possible.

The pilot scheme of the Hong Kong's ERP has demonstrated that such a system is technically viable, cost effective and administratively feasible (Dawson and Catling,1986). Most of the concerns which halted similar attempts and studies in the United States and Hong Kong were political or institutional. Singapore is unique in this respect since the political and institutional constraints on the government are extremely weak. The only concern the government has expressed is the business vitality in the Restricted Zone. However, since there has not been any major opposition from businesses in the zoned area during the 16 years of the ALS operation, it is almost certain that ERP will be implemented on a long term basis in Singapore.

6. CONCLUSION

Theoretically, the road pricing model provides a persuasive argument for congestion taxes.[5] Practically, recent technological advances have enabled governments to seriously consider the implementation of sophisticated road pricing mechanisms. Combined with increasing urban congestion problems, these developments provide significant opportunities for reducing existing economic inefficiencies associated with peak period travel. However, it is difficult to implement appropriate congestion charges and evaluate their economic effects unless there is some notion of the extent to which the marginal social cost, at the margin, deviates from the average cost of travel. The <u>presence</u> of congestion is <u>not</u> sufficient to justify intervention in the market. Thus, the feasibility of system-wide road pricing mandates that more attention be devoted to the measurement of the relevant costs and benefits. Without such information, road pricing applications are tantamount to traffic restraint policies whose welfare effects are as likely to negaitve as positive.

This is well illustrated by Singapore's experience with the Area License Scheme. The high tax on peak period travel has excessively decreased the quantity of peak period trips demanded and significantly increased off-peak demand. These changes have resulted in "perverse equilibria" where "peak demand" has become "off-peak demand" and vice-versa.

NOTES

1. Button and Pearman (1983) identify a number of problems in describing urban congestion with this simplified framework. It does not distinguish between types of users, e.g. public versus private transport and goods versus passenger vehicles. In addition, it ignores environmental effects of congestion as well as the impact on industrial location and, more generally, urban structure.
2. In general, the congestion tax will also vary by income since a user's value of time in is a function of income.
3. Wilson (1989) estimates that the value of travel time in Singapore was between 47% - 49% of the wage rate. In 1990, monthly average income in Singapore was $1557. Assuming 208 work hours per month, based upon Singapore's six day work week, this yields an average wage rate of $7.48 and a value of time, at 50% of wage rate, equal to $3.74.
4. It is interesting to note that for the Hong Kong experiment, the optimum toll was estimated to be HK$10 which was equivalent to about S$2.70 in 1985. Since Hong Kong's congestion problem was significantly worse than Singapore's, this also suggests that Singapore's license fees are set too high.
5. Although many believe that congestion taxes are regressive, Small's analysis (1983) argues against this.

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