ON ELECTRONIC ROAD PRICING & TRAFFIC MANAGEMENT IN HONG KONG

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This paper intends to do three things: to comment on the public objection to the proposed electronic road pricing scheme, to reexamine the principles for efficient road pricing, and finally to discuss efficient transportation pricing in a wider context with reference to Hong Kong.

I. The Public Objection to ERP

Electronic road pricing (ERP) has never been tried anywhere.[1] So the scepticism displayed by the public is understandable. The objection is based on the following considerations. First, many people see ERP as unnecessary at present and projected traffic conditions as tolerable. Second, some people see ERP as just another way of raising revenue by the Government. On balance, the motorist is seen to be taxed more heavily upon the introduction of the scheme. Third, some people worry that ERP will provide the Goveroment with more information on the private lives of individuals opening up possibilities of abuses. Finally, some people claim that the scheme is inequitable because their personal circumstances may require them to use their cars a lot in routes that are priced.

Many of those who have spoken against the scheme have implicitly assumed that ERP is a scheme to be introduced over and above prevailing policies. They pointed to the present road conditions and the low, indeed negative, rate of growth of vehicles in recent years as demonstrating the lack of a need for the scheme. The Crown Moter Co., for example, having conducted a survey of vehicles motoring in selected road junctions, concluded that ERP is unlikely to reduce road usage significantly since only private vehicles will be required to pay and they made up only a small percentage in the traffic.[2] While there is some validity in this general argument, both the assumption that ERP is intended to reduce the usage of roads from present levels and the assumption that the present composition of vehicles on the roads will prevail at the time ERP is introduced are wrong. As explained by the Transport Department, ERP is intended to replace licence fees as a means of congestion management. So it is reasonable to assume that the percentage of private vehicles in the traffic were higher and that road usage were heavier — at such levels as would prevail when licence fees were lowered or eliminated at the time ERP is introduced.

In order for ERP to be acceptable to the public it is important to allay the worst fears of the public. For this purpose a supervisory committee consisting of citizens may be formed to oversee the administration of the scheme: to make sure that the road pricing scheme works efficiently and is not designed to raise revenue, and that no illegal use of scheme-generated data takes place. At the same time, efficient pricing principles dictate that yearly licence fees for vehicles be very close to zero.[3] Such costs as arising from traffic policing, pollution, road maintenance and road management are all due to vehicle usage rather than vehicle ownership. Since they may not be related to congestion, a general tax on vehicle usage, such as the gasoline tax, may be justified in addition to a congestion-related charge, but annual licence fees, being an ownership tax, cannot be justified on these grounds.[4] As explained below, the supervisory committee should also see to it that motorists have alternative ways of moving around. It is only when good substitutes exist that motorists can be encouraged to switch to alternative modes of transport. When this is the case, the objection based on equity grounds will become less serious.

II. A Re-examination of Road Pricing Principles

Since the seminal paper of Walters in 1961 the subject of road pricing has gradually become a standard topic covered in most transportation economics and urban economics texts· e.g. Mills and Hamiltion (1984), Frankena (1979), Mohring (1970). Few of the published works, however, dealt adequately with the question of the unit for imposing charges. Most of them either use number of trips or number of vehicle miles as the unit and attempt to discuss the divergence between the marginal social cost and the marginal private cost of vehicle-trips or vehicle-miles as the basis for the optimal charges. The present paper argues that in general a vehicle-time measure, such as the vehicle-minute, is superior to these other units, and that the kind of technology having been considered by the Hong Kong Government will enable this pricing unit to be adopted efficiently.

Under special circumstances both the vehicle-trip and the vehicle-mile can serve as an appropriate pricing unit. In the case of a highway or a toll-bridge, for example, given demand conditions,imposing a price on the vehicle-trip can help achieve the desired flow of vehicles entering the highway or the bridge. In a network situation, too, using the vehicle-mile as the pricing unit can be appropriate, provided that congestion within the network is uniform and that the degree of congestion does not vary significantly over time. Pricing the vehicle-mile, then, will help adjust the intensity of use of the road network. However, whenever these conditions are violated problems can arise. First, if the degree of congestion changes from time to time, the optimal road-price also changes. Unless the charges can be adjusted promptly and correctly, overcharging or undercharging will occur, with adverse consequences on efficiency. A road price based on the vehicle-trip or the vehicle-mile provides for no automatic adjustment for the charges. A vehicle-minute charge, on the other hand, will minimize any inefficiency due to these overcharges or undercharges because when traffic conditions improve vehicles need less time to complete a trip or cover any given distance. This results in a de facto reduction in the per unit-distance road price. Similarly, when congestion gets worse the time needed to complete a trip or cover any given distance will increase, thus automatically increasing the charges for using the roads.

Second, if the given road network is not of uniform degree of congestion, an optimal road-price in one section of the network may imply that the road-price is not optimal in another section. Again the overcharge or undercharge will entail efficiency cost, which again is minimized if pricing is based on the vehicle-minute. Under vehicle-minute pricing, the per unit-distance charge in the congested sections of the network will automatically be higher than that in the uncongested sections.

A charge on the time a vehicle spends on a road or within a network also enjoys the advantage that it correctly discriminates against slow-moving, wait-intensive vehicles. It emphasizes that congestion is caused by the presence of vehicles within the network rather than by the number of miles travelled by vehicles.

III. The Administrative Set-up a Vehicles-time-based Charge

Rather surprisingly, this superior unit for pricing (henceforth referred to as the vehicle-minute) is actually easier to implement than other competing candidates. Basically, it requires that a road network be defined clearly and that devices be set up to monitor when a vehicle enters or leaves the network. This is in the spirit of the current proposal in Hong Kong. According to information released by the Hong Kong Government, "The pilot stage sites in Central demonstrate how charges can be made. It would be impossible to enter the Central zone without being charged the zone entry toll at one of (the designated sites). It is also impossible to enter any of the adjacent zones from Central without passing through (any of the designated exit sites.)"

Clearly, under such system it will be very difficult to record the number of miles driven by a car within the defined network, as there may be considerable variation in distance travelled between the entry and exit point. Requiring all traffic entering a given entry point to move only along a unique designated route will, however, clearly be inefficient.

According to the Results Brief: Consultation Document of the Government, the proposed ERP charges will be based on the number of times a vehicle passes over the boundaries of designated zones.[5] Regardless of the ways the zones are demarcated this approach is crude and inevitably fails to reflect the congestion a vehicle imposes on the system. Thus a vehicle that crosses zone boundaries more times need not impose more congestion than one that crosses zone boundaries fewer times. To the extent that drivers are imposed lump sum charges whenever they drive over toll sites during designated times their driving routes may be affected in a way which may not be efficient. To be efficient, marginal charges should be imposed on marginal congestion. It makes no economic sence to discourage short trips passing over toll sites while condoning longer trips that may cause more congestion.

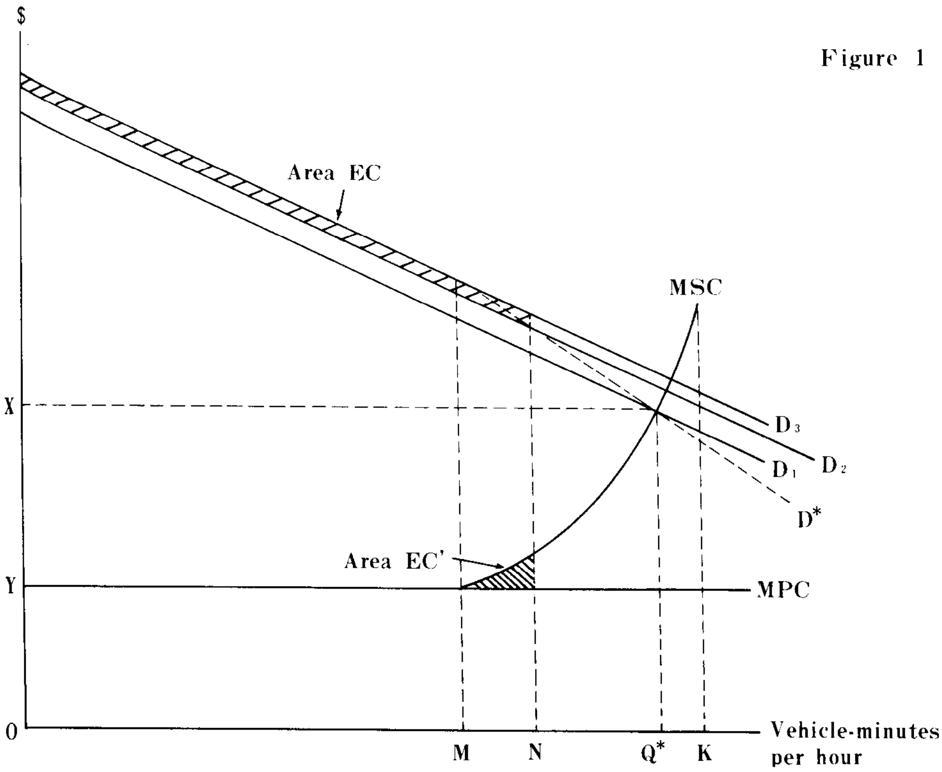
Under vehicle-minute pricing two alternative or complementary schemes may be considered. One involves the demarcation of pricing zones. One invovles the designation of pricing routes. Pricing zones should have the following characteristics. First, the entire zone is affected by congestion. Second, there should be no on-street parking within each pricing zone. Third, off-street parking should be strategically planned and set up within and outside the zone so as to avoid creating congestion. The set up of pricing zones is designed to relieve traffic congestion within the entire zone. In Hong Kong, there are areas that are congested fairly evenly throughout the entire area during certain times of the day. Example are the Central, Mongkok, and Tsimshatsui areas. At the same time as the zone pricing approach is adopted, the route pricing method can also be used. From the traffic design point of view, strategically designating certain main routes for pricing will not only ensure that those main routes are cleared up, but also relieve traffic cooditions in neighbouring streets that must be accessed from the main routes. Clearly, entry and exit points from these main routes should be carefully selected. Since congestion costs are often higher in main routes, charging a road price on main routes makes good economic sense and will improve economic efficiency.

To conclude this section, pricing zone boundary crossings tend to distort traffic flows since the congestion costs are not directly and closely related to such crossings. Ideally congestion pricing should tie the charges as closely as possible to the extent of congestion caused by driving behaviour. The available technology does allow close approximation of the charges to the congestion costs, and we have outlined alternatives to the boundary crossing approach.

IV. A Way to Approximate Optimal Charges

It is common to depict the problem of efficient road pricing using the external cost framework which can easily accommodate vehicle-minutes as the unit for imposing charges. In Figure 1, MSC is the marginal social cost and MPC is the marginal private cost of each vehicle-minute in the given network in the given hour. D_1, D_2, and D_3 are demand curves based on speeds of travel S_1, S_2, and S_3 respectively, where $S_3 > S_2 > S_1$. D^* represents the marginal willingness to pay per vehicle-minute within the hour as congestion steadily reduces the speed of travel with increasing intensity of use of the roads. The optimal road price is XY per vehicle-minute, and optimal utilization of the network occurs at Q^* vehicle-minutes per hour.

In order to estimate the optimal road-price, it is best to work with the underlying factors that determine the degree of divergence between the marginal social cost and marginal private cost. In the left panel of Figure 2, RR shows the technical relationship between time needed per mile of driving and the number of vehicle-minutes within the network per hour. Its curvature indicates that as a network is increasingly utilized, traffic congestion worsens at an increasing rate, so that total traffic flow will eventually decline. Traffic flow as measured by vehicle-miles per hour is maximized at K. In the right panel of Figure 2, DD shows how the number of vehicle-minutes demanded per hour vary with the road price charged. It is derived from D^* in Figure 1. The vertical distance between D^* and MPC in Figure 1 is the road price, while projection to the

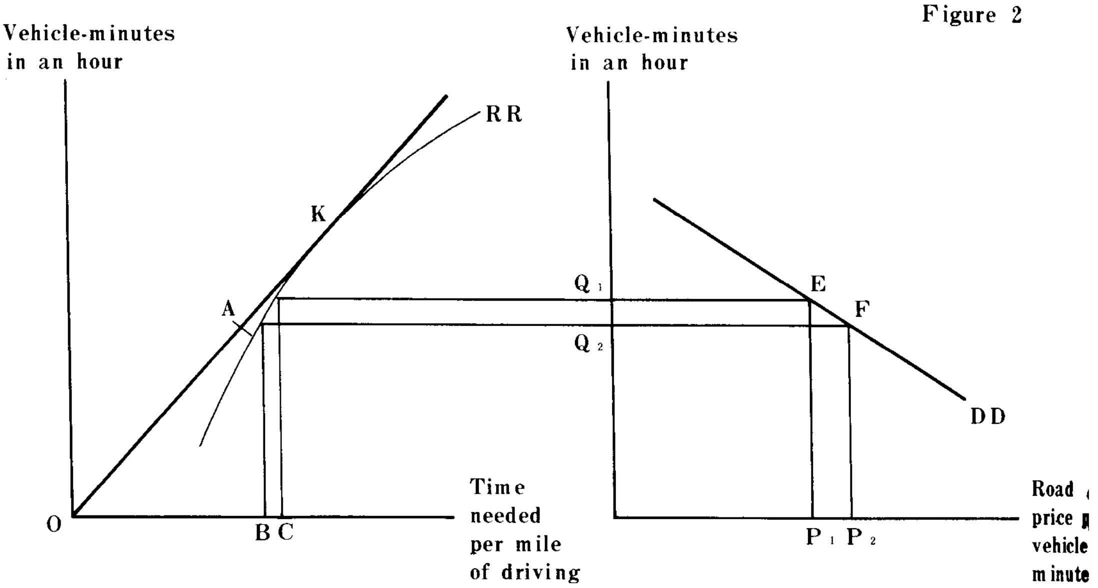


Note:
As speed deteriorates to the right of M demand shifts down, signalling a lower value of each vehicle-minute over and above the usual diminishing marginal rate of substitution effect. The external cost of an additional MN vehicle-minutes, for example, is reflected by area EC (equal to area EC') which is the total loss in value suffered by all ON vehicle-minutes. The marginal external cost of a vehicle-minute is added to the marginal private cost to produce the marginal social cost MSC. It should be noted that in the absence of road pricing, equilibrium vehicle-minutes is determined by the intersection of D* with MPC, which is beyond OK, the flow-maximizing demand.In constructing the diagram, the time cost of vehicle users is reckoned as a negative benefit affecting the position of the demand curves. So MPC consists essentially of fuel costs.

horizontal axis gives the total vehicle-minutes demanded per hour. Provided that we know these two schedules and the value of time of the road users, it is possible to find the optimal road price by equating the marginal cost of raising road price with the marginal benefit thereby obtained.

Suppose we start with road price P_1 and consider raising it marginally to P_2 . This will discourage use of the roads by $Q_1 Q_2$. Since each vehicle-minute discouraged is valued at the road price at which it is discouraged, the cost of raising the road price which is the value of the displaced traffic on account of

Figure 2



road pricing can be represented by the area Q_1EFQ_2. Repeating this procedure with further increments in the road price, we may trace out the marginal cost of raising the road price as shown in Figure 3 (MCRP). Similarly, we can also derive the marginal benefit of raising the road price (MBRP) in the following manner. From the left panel of Figure 2 we can see that the time needed per mile of driving is reduced from OC to OB as a result of the road price increase. The time saving BC is enjoyed by all the vehicle-miles driven in the hour. Total vehicle-miles is equal to number of vehicle-minutes in the hour $\times$ average mileage per minute. This is equal to $AB \times 1/OB = AB/OB$. Thus total time saving $= (AB/OB) \times BC$. Multiplying this with the dollar value of a minute gives the benefit of marginally raising the road price. Doing the same over a range of road prices will give the MBRP schedule.

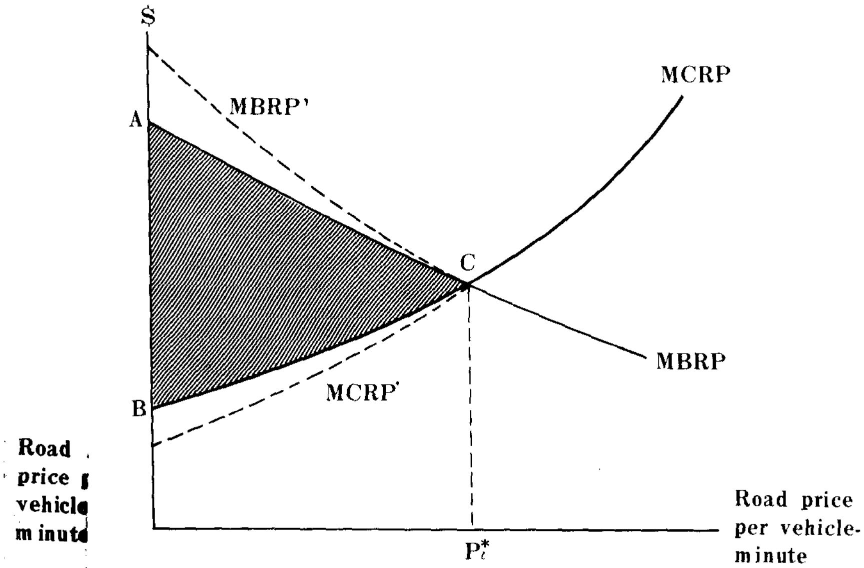
The optimal road price, clearly, is obtained where MBRP intersects MCRP as indicated in Figure 3.

Assuming that traffic demand follows the same pattern week after week it is possible to use this scheme to approximate the optimal charges as follows:

1. define the periods for which the same rates of charge are to apply, say 7 a.m. to 10 a.m., 10 a.m. to 4 p.m., and 4 p.m. to 7 p.m. on week-day. These will be referred to as "charging periods."

2. for each charging period note the average speed of flow

Figure 3



in the absence of any charge and the total vehicle-minutes within the network. These figures can be easily obtained given the technology now available.

3 . raise the road price incrementally. Observe the drop in total vehicle-minutes and the increase in the average speed of flow resulting form each increment in the road price. Calculate and compare MBRP with MCRP. So long as MBRP exceeds MCRP raies the road price by another increment.

4 . instead of (2) and (3), one could first estimate the rate of charge that will reduce the density of road users by a target percentage. This does not have to be accurate. Let this rate prevail until the total vehicle-minutes and the speed of flow can be estimated. Then adjust the road price by increments or decrements and test the desirability of these adjustments as discussed before.

V. Complementary Policies

In order to increase the benefit of road pricing, policies should be carried out to raise the MBRP and to lower the MCRP. The extent to which these other policies should be adopted should be determined by a separate cost-benefit analysis on those policies. In terms of Figure 3 , the net benefits of road pricing is represented by the shaded triangle ABC. If MBRP shifts up while MCRP shifts down the area of the triangle increases, while the optimal road price increases. Alternatively, the area of triangle ABC may increase without the road price increasing. This happens if, for instance, MBRP and MCRP assume the new position MBRP' and MCRP'.

As noted above, the social cost of raising the road price lies in the decrease in the welfare of those diverted from the traffic or shoved into less preferred modes. This welfare loss can be reduced if the quality of alternative modes of transport improves. Thus if private car users find public means of transport a close substitute to their own cars, they may readily abandon their cars at the slightest increase in the road price. This may increase the decongestion gains of the road price while minimizing any welfare loss for the "diverted" drivers.

It is therefore clear that improving the quality of public transport or providing adequate substitutes to private cars will increase the benefit from road pricing. This will also answer objection on grounds of inequity. If travellers can choose to avoid the charges by using public means of transport, any objection that road pricing discriminates against people who "have to" use private cars will be minimized.

Another complementary policy is to provide parking facilities selectively in suitable sites. These sites must be carefully chosen so that the traffic to and from the car parks will not cause too much congestion. Particularly at central locations, parking charges should also be high enough to eliminate any excess demand and thus the need for drivers to search for a car park. More parking facilities will be needed to enable drivers to park their cars where they can make connecting trips using the public transport system. Such "park and ride" facilities would normally be at the outskirts of the more congested zones of the city.

Of more relevance to Hong Kong, the implementation of electronic road pricing is expected to enable a substantial drop in annual licensing fees for private vehicles. This will increase car ownership which has been unduly curtailed by the licensing fees designed to improve traffic conditions in congested localities. With increased car ownership, the demand for parking facilities will no doubt rise.

The introduction of electronic road pricing in a city with access from other parts of the country will call for special arrangements for out-of-town and out-of-state vehicles. Special desensing devices will have to be made available for renting. Naturally, these devices either have to be very cheap or be able to stand multiple installations and uses.

VI. Conclusions

Economic theory has demonstrated that road pricing can improve welfare. Whether road pricing will actually improve welfare in a particular situation depends on the costs and benefits of introducing the scheme. Because of advances in computer technology, both system and running costs have come down tremendously. At $ 240 million in capital costs and less than $ 20 million per year in running costs according to 1985 Government estimate (see [6]), the annualized cost is about $ 50 million. This assumes a system life of 10 years and an interest rate of roughly 8 per cent. Assume that 4 million of Hong Kong's population regularly use the roads, on average this amounts to about $ 12.5 a year per person or about HK$ 1 per month. Thus, if the average benefit per road user runs in excess of $ 1 per month the scheme is worthwhile introducing. Whether this will indeed be the case will depend on the design of the pricing system and the other policies implemented along with ERP.

This paper demonstrates that efficient pricing requires not only that the price levels are right but also the unit for pricing be appropriate. In respect of road pricing, we recommend using a time-based measure, such as the vehicle-minute, for pricing, because congestion is directly related to the time a vehicle stays within the road system. Some people may object that it may not be fair to charge the driver when congestion forces him to stay longer on the road. In respect of congestion, however, there is not a single "culprit" who causes congestion. Each car is a victim and also a contributor to congestion. Efficiency demands that all cars in a congested network pay an appropriate price. Some people may also worry that the vehicle-minute when used as the pricing unit may cause speeding. This possibility need not worry us because in a congested network speeding is virtually impossible, and there will be no road price when the road is congestion-free. Moreover, the penalty for being caught speeding is much too formidable relative to the benefit of saving on the road charges for it to be worthwhile.

Many commentators argue that road constructions and other traditional methods of managing road usage should be used to solve Hong Kong's transportation problems. These policies no doubt should continue, but as long as road usage is underpriced cost benefit calculations in relation to road construction may be wrong. As pointed out by Mishan, "it is only after (the) optimal flow is established that one can proceed correctly to *estimate the returns to investment in road-widening, freeways* and other traffic-accommodating projects." [6] Particularly in an economy with limited space and rising incomes, the extent of road use underpricing grows over time in the absence of an explicit road pricing scheme. The economic losses due to underpricing also grow over time. In short, road pricing allows transportation planners to evaluate in a better light the costs and benefits of a whole range of transportation management policies. In the short run road pricing enables more efficient use of our existing road system. In the long run a properly priced transportation system will lead to better resource allocation and land use.

NOTES

1. Actually Singapore has already had 10 years of experience with road pricing. It relied, however, on the sale of daily licenses rather than on electronic gadgets. See Watson and Holland (1978).
2. In a survey conducted in August 1984, the Crown Motor Co. found that private cars constituted 26 per cent of the overall traffic volume during peak hours in Central District.
3. Annual license fees for petrol-using private cars were revised on February 25, 1987 and now range from HK$2,600 to HK$7,700 depending on the size of the engines. Licence fees are generally higher for diesel-fueled vehicles.
4. Notwithstanding the arguments in the text, second best considerations may still suggest that taxing car ownership is an acceptable way of raising revenue. Given the government budget constraint, departures from first best pricing may be necessary. Indeed, the efficiency loss due to raising a dollar of revenue through increasing the car licence fee marginally should be equated with the efficiency loss due to alternative ways of raising a dollar of revenue. Another valid argument for taxing car ownership, particularly luxury car ownership, is based on the consideration that the demand for luxury cars may be inelastic for the very rich. So both equity and efficiency considerations may favour taxing ownership.
5. This method may be classified under "engineering approach" to road pricing. The objective is to regulate traffic flow by regulating the "valves" as in the case of a pipe system. There is no conceptual way of knowing which set of prices are optimal.
6. See Mishan (1967). p. 238.

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