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ELECTRONIC ROAD PRICING

Developments in Hong Kong 1983-1989

By Timothy D. Hau*

The theory of road pricing is well known to economists. It dates back to the famous two-road example in Professor Arthur Pigou's *Economics of Welfare* (1920). If a tax could be imposed on only one of the roads, he argued that both speed and travel time would be better on the "toll" road than on the free road, and the result would be increased efficiency. This idea of imposing a (short-run) optimal toll was popularised and formalised by Sir Alan Walters (1954, 1961). Apart from proponents of an externality-corrective tax such as Walters, the support of road pricing by Vickrey (1959) in testimony to the US Congress influenced the British Government's decision in 1962 to form a committee to study the economic and technical feasibility of road pricing. This culminated in the famous Smeed Report of the Ministry of Transport (1964). Yet road pricing was not welcome even then, despite the proposal to use automatic meters. The report concluded that direct road pricing would yield substantial net benefits (£100 – £150 million at 1964 prices). Subsequent proposals on road pricing of a less radical form, such as central area licensing, also faced political obstacles and ultimate defeat (Greater London Council, 1974; Morrison, 1986).

Singapore in 1975 was the first city to adopt a form of congestion pricing based on area licensing. This was combined with an increased parking fee in central areas, and a park-and-ride scheme to provide a suitable alternative for private motorists (Holland and Watson, 1978). But the area licensing scheme is relatively crude.

The pursuit of a form of marginal cost pricing continued to be elusive until Alan Scott, then Secretary of Transport, announced in March 1983 that the Hong Kong Government would be the first in the world to commit itself to testing the technical, economic and administrative viability of electronic road pricing (ERP).

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Despite a stock market crash in the early seventies after the world-wide oil crisis, Hong Kong emerged from that decade with almost double-digit annual rates of real growth. Having also a steady growth in population, with migrants from the People's Republic of China, she enjoyed (and still enjoys today) an annual real GDP growth rate per capita of around 7 per cent. The doubling of real income during the same ten-year period resulted in growing demand for the private car – this also continues. Road congestion was increased by the doubling of the number of registered vehicles, while road length increased by only 17 per cent in the seventies – equivalent to an annual increase of only 2 per cent (see Hau, 1988). Thus road expansion lagged behind economic growth.

In view of the rapid increase of private cars, which in number then comprised two-thirds of the total vehicle fleet, the government decided in May 1982 to take a drastic fiscal restraint measure to curtail traffic. This decision was based on consultants' recommendations in the first Comprehensive Transport Study of 1976, the results of which formed the basis for the White Paper on Internal Transport Policy (Environment Branch, 1979). The White Paper of 1979 spells out the government's tripartite transport policy, namely: (1) to improve the road infrastructure, (2) to expand and improve the mass transit system, and (3) to make better economic use of road space. The Comprehensive Transport Study indicated that three-quarters of the road space catered for only one quarter of total passengers, so that the lion's share of scarce road space was taken up by a minority of occupants of private cars and taxis. This shows the government's hierarchical priority on moving vehicles. The Comprehensive Study also indicated that the least undesirable option available to government was the fiscal measure of restraint of auto ownership. It ruled out parking controls, supplementary licensing and physical restraint (Wilbur, Smith and Associates, 1976a,b).

In particular, the fiscal restraint measure of May 1982 included the trebling of annual license fees on private cars alone (to HK$3600 [US$462], for example, for a 3500 c.c. engine car), the doubling of first registration taxes of private cars and motor cycles (to 70–90 per cent of the import price of a vehicle, and the doubling of the existing duty on petrol (to HK$1.40 [US$0.18] per litre) (see for example Transport Department and Wilbur, Smith and Associates, 1989a). This action accounts mainly for a dramatic decrease in vehicle ownership, both public and private, for four consecutive years. (It has since resumed its previous upward trend.) By 1985, the proportion of private cars fell to only half of the vehicle fleet, while the number of taxis was one-tenth of that of private cars. On the other hand, three-quarters of total traffic flow is dominated by private cars and taxis, each with an equal share for the greater part of the day, and the number of private cars rises to half the total during the morning peak (Harrison, 1986).

Because private car *use* declined by only 10 per cent, the private car was singled out as the main culprit and therefore the sole party to incur direct road charges via ERP, even though less than one out of ten households then (and now) had access to a private car (Dawson and Brown, 1985). On the other hand, taxis – considered a personalised form of public transport – were to be exempt from ERP charges. Of course, the topography of Hong Kong was considered to be the ideal testing ground for ERP, with its enclosed territory and high density land use and development.

ELECTRONIC ROAD PRICING

The pilot stage

A 21-month pilot stage of Hong Kong's ERP system, lasting from July 1983 to March 1985, demonstrated the technical feasibility of ERP. It used a form of automatic vehicle identification (AVI), in which each vehicle has an electronic number plate – the size of a video-cassette tape – mounted underneath the vehicle (Dawson and Catling, 1983). Whenever a vehicle passes over a toll site, an interrogator power loop embedded beneath the road surface sends out electronic signals to the moving vehicle's number plate and relays the vehicle's identification code to a roadside computer. The data are transmitted to the control centre via dedicated lines. The system sends a monthly bill to the motorist, giving a break-down of the toll sites crossed, similar to a long-distance telephone bill. In addition, roadside closed-circuit television cameras automatically take pictures of vehicles with faulty or tampered number plates. The technical and economic feasibility of the ERP system, based on a true subset of the full system, was found to be above the performance requirement, attaining well over 99 per cent effectiveness and reliability (Catling and Harbord, 1985; Dawson, 1986).

The ERP schemes and the optimum option

At least three different zoning schemes, designed to deal with radial movements to the Central District, were proposed and analysed (Transpotech, 1985; Dawson and Catling, 1986). Scheme A involves five large zones and 130 toll sites. The charging periods are as follows: the morning peak period (8:00 – 9:30 a.m.), the inter-peak period (9:30 a.m. – 5:00 p.m.), the afternoon peak period (5:00 – 7:00 p.m.), and the shoulder periods immediately before and after the morning and afternoon peak (7:30 – 8:00 a.m. and 7:00 – 7:30 p.m.). Three zones have peak charges for most of the day, and shoulder charges are set at half the peak charge. For example, a driver who lives in the New Territories and works in Central Kowloon would have to incur a charge of HK$13 [US$1.67] during either peak period when crossing the zone boundaries. This scheme has boundary "tails" to prevent drivers from making orbital movements and by-passing the sides of the watertight zones. Scheme B is a simplified version of Scheme A, without tails and with only 115 toll sites. However, tidal charging is introduced as a requirement along one direction – the direction of work trips made during the peak period. Scheme C is the most complex, as there are 13 smaller zones and 185 toll sites. It is designed to capture shorter trips within the zone areas. In all three schemes, the off-peak periods without congestion – such as night-time and Sundays – are not charged. The net benefits of the three simulated schemes are compared with those of the car ownership restraint policy and the theoretical maximal net benefits derived from imposing marginal cost pricing. The net benefits of implementing marginal cost pricing are derived from the savings in resource costs (according to the drivers who remain on the road) from faster speed and reduced operating and time costs (converted to a money basis by an estimate of value of time), less the reduced benefits associated with travellers who are tolled off the road (see Thomson, 1982).

The aggregate net benefits are arrived at by summing the net benefits over all

times of the day and all modes throughout the road network. Values of time are estimated by logit modelling techniques, and differentiated between business and non-business time: non-business has a much lower valuation (Harrison, Pell, Jones and Ashton, 1986). The aggregate net benefits of introducing road pricing amount to HK$1.25 billion [US$160 million] annually, given a 1991 "do minimum" reference (see Table 1). The results indicate that Schemes A, B and C achieve 59 per cent, 70 per cent and 74 per cent respectively of the net benefits of HK$1250 million obtainable under a theoretical optimum (see Table 2). With the exception of taxis, the net benefits accrue mainly to public transport users in the form of increases in transit revenues. (Taxis are assumed to be treated in the same way as private cars and charged accordingly under marginal cost pricing (Harrison, 1986).) Goods vehicles and private cars each end up with a quarter of the net benefits. This pattern holds for all three schemes. Since charges would depend on individual origins and destinations, an average charge of HK$8 was used for Scheme A, whereas the toll which maximises the net benefits turns out to be HK$10. The option of restraining car ownership resulted in substantially less net benefits, because former (or would-be) car owners would be effectively priced off the road by a high entry fee: the figure for the private car vehicle class is then negative.

Scheme A, being the low charging scheme, and Scheme C, being the high charging scheme, produced estimates of 20 and 24 per cent reduction, respectively, in private car trips. Speed is slightly better under the ERP schemes than with the car ownership restraint option. Those travellers who switch modes are a larger proportion than those who change their choice of time periods.

In the only independent study of ERP in Hong Kong, Li Si-Ming estimated the net benefits, expressed in dollars per kilometre, for selected roads in Hong Kong. He estimated that the optimal toll was around HK$1 per kilometre [US$ 0.21 per mile] (see Li (1984) or Pretty (1988) for a summary).

Project cost and benefit-cost analysis

The preliminary estimate of the project cost of the ERP system was HK$350 million [US$45 million]; the pilot stage would cost a tenth of that figure. Subsequently it was revised downwards to HK$240 million [US$31 million]. In annualised terms, the capital cost is equivalent to HK$30 million per year at 1985 prices, and the operating and maintenance costs are estimated to be HK$20 million per year. So the total cost is HK$50 million per year. In terms of standard benefit-cost analysis, the benefit-cost ratio for ERP is at least 14 to 1. *Ceteris paribus,* the net benefits (less the project cost) of any ERP scheme exceed those of the car ownership restraint measure by at least a factor of 2.

Distributional and other effects

A priori, it may seem that road pricing is regressive in its incidence. However, a low-income worker is less likely to drive to work, even if he or she can afford to own a private car (Foster, 1975; Morrison, 1986). It is clear that high income groups would benefit more than low income groups, because the value of travel time is proportional to the wage rate (Foster, 1974). So, if time savings are proportionately the same for everyone, benefits rise with income. However, in the absence of an explicit assumption about the government's use of toll revenues,

it is difficult to state what are the full distributional impacts of road pricing.

Naturally, how much one has to pay under ERP depends on one's location, one's willingness to pay and one's tradeoff between time and money. For the average driver, ERP would cost less than HK$20 a month, because the average monthly bill of HK$120 is offset by the government's promise to lower annual licence fees by HK$100. As expected, people who typically drive during the congested times and places will have to pay more than those who remain in the New Territories and uncongested areas. For a variety of motorists, the extra costs would still be less than the car ownership restraint of HK$500 per month. In addition, fuel savings and vehicle emissions would be reduced under ERP.

The modelling procedures used allow segmentation by characteristics; this facilitates the analysis of the distributional impacts of a simulated option, as in Hau (1986, 1987a). By area, ERP charges and benefits are evenly distributed. By trip purpose, those on employers' business trips would benefit more, because of the higher time valuation (Harrison, 1986).

To summarise, ERP is effective in reducing congestion by time of day and location, because of its inherent flexibility. Note that ERP is relatively inexpensive when compared with projects of road expansion. Witness the Island Eastern Corridor, which is 3.7 kilometres long and costs taxpayers HK$950 million [US$122 million] (at 1984 prices). By contrast, the car ownership restraint measure – essentially a sledge-hammer approach – is crude and inequitable: it prevents aspiring car owners from satisfying their desires, and ends up limiting ownership to the more well-off.

Yet, after all these arguments in favour of ERP and the positive results derived from the transport studies carried out by both the government consultants and Li Si-Ming (Li, 1984), the question naturally arises: what accounts for ERP's failure in 1985, which led to its being shelved?

Reasons for the failure to implement ERP in 1985

There are several contributing reasons why ERP failed in 1985. First, 1985 was a poor time for ERP to be considered. It witnessed in May the opening of the Island Line route of the Mass Transit Railway, the system which carried about one-fourth of total public transport boardings in 1988. This followed right after the opening of the Island Eastern Corridor a year earlier. Both these infrastructure developments served to ease congestion. Second, the stock and property market crashes in 1982 resulted in a decline of real income to considerably below the average real GDP growth rate of 8 per cent for the past two decades (Hau, 1988). This in turn led to a weakening in the demand for private cars. Third, the introduction of ERP came in the wake of the fiscal restraint measure of May 1982, the effects of which were still keenly felt in 1985, as indicated by the declining number of private cars and other vehicles. The average vehicle speed in the urban area actually improved from 20 to 28 kilometres per hour from 1979 to 1984, a remarkable 40 per cent improvement! This situation has now worsened, and average traffic speed in the urban area has dropped to 24 kilometres per hour in 1988 (Transport Department and Wilbur, Smith and Associates, 1989a,b). Fourth, as a result, private car drivers felt singled out and discriminated against, because taxis create considerably more congestion and yet are exempted from ERP

TABLE 1

Summary of the Effects of the Main Policy Options, Compared to 1991 Reference

Option	*ERP(A, B* and C)*	*Car ownership restraint*
I *Behavioural effects:*		
– Car available for use	275,000	200,000
Change in car trips:		
– in congested times/places	20–24% reduction	20% reduction
– outside congested times/places	20–25% increase	20% reduction
Switching behaviour (change with respect to reference weekday total):		
– mode	9–13%	(20%)
– time	5–6%	(0%)
Traffic flow:		
– during the day	Reduced significantly in congested areas, less so elsewhere	Reduced fairly evenly throughout the Territory
– at off-peak times	Increased	Reduced fairly evenly throughout the Territory
Speed:		
– peak overall	10% increase (for Scheme A)	6% increase
– peak Central	16% increase (for Scheme A)	11% increase
II *Efficiency effects* (in 1985 HK dollars):		
Net benefits	$734–$919 million/year	$301 million/year
Project cost (both annualised capital and recurrent costs)	$50 million/year	0
Government revenue:		
– Gross revenue generated	$395–$540 million/year	$1200 million/year
– Net government revenue generated	Nil (ERP annual revenue of $395–$540 million used to offset car ownership taxation)	$1000 million/year

TABLE 1 (continued)

Option	*ERP(A, B* and C)*	*Car ownership restraint*
III *Distributional effects* (in 1985 HK dollars):		
Extra costs to motorists (compared with reference monthly costs of about $2000 per month)		
– average use	Less than $20/month (average ERP monthly bill of $120–$160 mostly offset by reduction in ALF, etc.)†	$500/month
– high use in congested times/places	Typically $400/month (Sha Tin to Tsim Sha Tsui commuter) but more for heavy urban use during the day†	$500/month
– low use in congested times/places	Saving of more than $100/month †	$500/month
– central urban area residents	Average bill up to 30% higher (net extra cost less than $70/month)†	$500/month
– New Territories residents	Average bill (except Sha Tin and Tsuen Wan) 40% lower – average saving of more than $20/month †	$500/month
IV *Other effects:*		
Territory fuel savings	6–9%	8%
Vehicle emissions	Up to 17% reduction	Up to 17% reduction
Accident costs	2–4% reduction	6% reduction

Sources: Compiled from Transpotech (1985), Tables 8.6, 8.12, 8.14 and text; Dawson and Brown (1985), Table 1; and Harrison (1986), Table 2 and text.

HK$7.8 = US$1 and HK$10.1 = £1 (1985 figures).

* ERP Scheme B turns out to be the Area Pricing proposal (with minor variation) recommended in the Green Paper, Transport Branch (1989).

† This assumes an annual licence fee (ALF) reduction equivalent to approximately HK$100/month.

TABLE 2

Annual Net Benefits, by Vehicle Class, Compared to 1991 Reference
(in millions of 1985 HK dollars)

Option	*ERP Scheme A*	*ERP Scheme B**	*ERP Scheme C*	*Car ownership Restraint*	*Optimum Option*
Average peak charge	HK$8	N/A	N/A	–	HK$10
Net benefits					
Private cars	202 (0.28)	235 (0.27)	216 (0.24)	−29 (−0.10)	N/A
Taxis	53 (0.07)	61 (0.07)	68 (0.07)	38 (0.13)	N/A
Public transport	299 (0.41)	350 (0.40)	389 (0.42)	158 (0.52)	N/A
Goods vehicles	180 (0.25)	225 (0.26)	246 (0.27)	134 (0.45)	N/A
Net benefits for all vehicles	734	871	919	301	1250
As a share of the net benefits of the theoretical optimum	[0.59]	[0.70]	[0.74]	[0.24]	[1.00]

HK$7.8 = US$1 and HK$10.1 = £1 (1985 figures).
N/A means that the information is not available in these reports.
By inference, average peak charge for Scheme B is higher than for Scheme A, etc.
Figures in round parentheses are market shares.

* ERP Scheme B is actually the Area Pricing proposal (with slight variation) simulated in Transport Department and Wilbur, Smith and Associates (1989a).

Sources: Constructed from Transpotech (1985), Table 8.5; and Harrison (1986), Table 2 and text.

charges. Fifth, some thought that ERP was unnecessarily expensive; the forecasts of automobile growth were alleged to be overstated, so that ERP would presumably not be financially viable (Fong, 1985; Pretty, 1988). Others felt that there was exaggeration of future population growth figures and of the effectiveness of ERP in tackling congestion. Sixth, ERP was introduced at the most sensitive time, shortly after the initialling in December 1984 of the joint Sino-British declaration, under which Hong Kong was to be handed over to China in 1997. Naturally, the invasion of privacy and fear of a "big brother" government were foremost in people's minds. The installation of closed-circuit television

cameras for enforcement purposes did not help. Seventh, the government did not succeed in effectively selling ERP to the public. One strategic error, for example, was that Wanchai – a district located next to Central – was the first District Board in which the Government undertook public consultation. This ended with a unanimous vote of nay by the Wanchai District Board (Borins, 1988). Eighth, the Government could have made information more publicly accessible on the ERP system, together with the associated transport studies carried out, for discussion and comments. At the very least, certain academic economists and engineers, who have had a tradition of being favourably disposed to road pricing, would have been able to lend their support. This failure is unfortunate, because the public release of the volume entitled *Electronic Road Pricing Pilot Scheme: Main Report,* May 1985, prepared by Transpotech for the Government of Hong Kong, could have clarified many of the preconceived notions and misconceptions. In particular, the distributional results of the simulated schemes could have been publicised to support the government's assertion that ERP is fairer than alleged. Ninth, some transport specialists, including a Transport Advisory Committee member, noted that the use of the patented ERP technology by Plessey would be tantamount to exporting employment to the United Kingdom. Tenth, people were simply not convinced that the government would follow through with its promise to lower annual licence fees and first registration taxes. An indication of the government's intention may have been revealed in early 1984 when the then Secretary of Transport, Alan Scott, tried to raise substantially the annual licence fees of taxis. That resulted in a colony-wide taxi strike on 12–13 January 1984, which left the transport system paralysed, with taxis blocking traffic effectively in certain key areas. Government's backing down on this issue seemed to fuel the public's preconception, while at the same time unwittingly increasing the political clout of District Boards, especially within Hong Kong's evolving democratisation process. In short, there were reservations about whether ERP could work as an instrument for curtailing congestion.

THE GREEN PAPER OF MAY 1989

The Hong Kong Government circulated the Green Paper on Transport Policy on 31 May 1989, just as it did in 1974, to solicit comments and to stimulate discussion within a four-month consultation period (Hong Kong Government, 1974; Transport Branch, 1989). The goal is to review the changes that have developed in the transport scene within the past decade, together with the associated changes in transport policy, after the release of the White Paper of 1979. The second Green Paper was based on the findings and recommendations of the Second Comprehensive Transport Study (CTS–2), released in May 1989 (Transport Department and Wilbur, Smith and Associates, 1989a,b). A number of major changes occurred within this ten-year period: in particular, the number of goods vehicles increased from a fifth to less than half of the fleet size, and its number is expected to exceed half the total vehicle fleet by the turn of the century. Private cars increased at a rate of 10 per cent in 1988 alone. Together with taxis they represent more than a third of the vehicle fleet size. The entrances

of the Cross Harbour Tunnel and the Lion Rock Tunnel are frequently near gridlock -- despite increases in toll charges to alleviate congestion – as the population continues to fan northwards into the New Territories (Hau, 1987b). This massive migration is in response to the government's long-term housing strategy since 1972 for housing the lower income groups. The policy inadvertently results in peak period commuting from the New Territories to the central business district, thus contributing to and exacerbating the urban transport problem.

Of immediate interest here is the proposal for area pricing discussed in the Green Paper on Transport Policy, even though CTS–2 covers a whole gamut of transport policy options (analysed in Hau, 1990). It states that "area pricing" is being practised in Singapore (Transport Branch, 1989), and immediately conjures to mind the shortcomings of Singapore's area licensing scheme (see Hau, 1990). Area pricing is road pricing by electronic means for a particular area or a set of zones. A reading of the Second Comprehensive Transport Study shows that area pricing turns out to be a euphemism for electronic road pricing (since ERP has come to be a forbidden word, as ill-feelings are aroused throughout the Territory at the mention of that acronym). Area *pricing* is in fact ERP Scheme B resurrected (see Transport Department and Wilbur, Smith and Associates, 1989a, Figure 9.3 and Table 9.5). It is a minor variant of Scheme B, with the charging days extended to Saturdays. After all, Hong Kong operates widely on a work week of five-and-a-half days. The other minor difference is that charges are two-thirds of the 1985 ERP charges of Scheme B, and the results are shown using sensitivity analysis for low and high scenarios of economic growth rates. Thus the results of area pricing are almost the same as those of ERP Scheme B (with slightly less net benefits), with the base traffic conditions changed to 1996.

In short, all our analyses on the ERP schemes simulated in 1985 and discussed above apply.

ROAD PRICING: THE WAY FORWARD

The White Paper on Transport Policy in Hong Kong was released in January 1990, after the end of the public consultation period. Since privacy continues to be a matter of concern to the public, the government has retained area pricing as a longer term option for reducing congestion while monitoring the latest developments in area pricing technology (Transport Branch, 1990).

Given the political uncertainties in the face of 1997, it is not clear whether road pricing will be implemented ultimately in Hong Kong. Yet, if road pricing is to work at all, perhaps Hong Kong is the most suitable place, since she possesses the highest number of vehicles per kilometre of road space anywhere in the world. If ERP (or area pricing) is to succeed, the original reasons for its failure in 1983–85 must be tackled and the obstacles overcome. For this purpose an integrated financial package for road pricing and investment is proposed that is both economically efficient and fair (Hau, 1990). Under decreasing returns to scale in transport, congestion pricing yields revenues that are in excess of the construction, maintenance and operating costs of roads (Mohring and Harwitz, 1962; Keeler and Small, 1977). It is suggested that the (surplus) toll revenues generated elec-

tronically be channelled for investment in the transport infrastructure, as well as for expanding road capacity. Since at least eight-tenths of all daily trips in Hong Kong are made by public transport, this way of earmarking the money would be the most likely to be acceptable to the public, as well as to be successful in assuaging the opposition, which consists mainly of private car drivers. Moreover, the proposed system utilises state-of-the-art infra-red technology that assures privacy.

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