PERGAMON

Journal of Transport Geography 10 (2002) 29–38

JOURNAL OF TRANSPORT GEOGRAPHY

www.elsevier.com/locate/jtrangeo

Congestion management and electronic road pricing in Singapore

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Abstract

Government and policy makers today face the pressing problem of managing road congestion in urban areas. This paper details the experience of Singapore and the effort made to curb vehicular increase on the roads using a state-of-the-art regulated Electronic Road Pricing (ERP) scheme. Specifically, the paper looks at the public policy effort to forge ahead with road pricing, prepare the island for extensive congestion management, and cap the on-road vehicular population to ensure a smoother flow of commercial transport and distribution. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Electronic road pricing; Singapore; Case study

1. Introduction

Today, governments face a common problem of worsening traffic congestion in urban areas. Some reasons account for this. In developing countries, vehicle ownership represents growing affluence and social status. In developed countries, people have already grown accustomed to the ease of mobility through private ownership of vehicles, while public transportation is often perceived as unreliable, inefficient or inconvenient. As such, faced with rising transportation demand and growing negative impacts, the urban areas of most countries require new approaches to address their transportation needs. Cities cannot continue to expand their transportation systems forever. Although some expansion is necessary, the economic, social, and environmental costs of doing so are prohibitive. Cities need to re-examine urban transportation demand and devise new strategies which can provide maximum access at minimum total cost.

For years, the traditional solution for traffic congestion has been to build more and wider roads, but road building is not a viable long-term solution for small island states like Singapore, where land is scarce. Further, economists have long argued that traffic congestion arises because the marginal user of a crowded road takes into account only private cost and ignores the fact that a vehicle can slow down others. Rightly so, congestion has created a social cost, as delays in traffic are not only inconvenient to road users, but also trigger a chain reaction on various factors, from pollution to lost man-hours. Cars stuck in traffic can pollute three times as much as those purring along motorways (Anon., 1997), negating the effect of ever-cleaner exhaust emissions brought about by better catalytic converters and cleaner-burning engines. Recognizing the need to tackle worsening traffic congestion, governments realize the need to steel their nerves and force motorists to pay for road space.

This paper discusses some traffic congestion management approaches implemented in Singapore. This is followed by how Singapore has chosen to employ a regulated road pricing system to manage traffic congestion and prioritize road usage by harnessing the state-of-the-art technology. Through this, the case study can serve as an example for other cities, similar to Singapore, to follow in their search for improved traffic management.

2. Singapore's experience with congestion management

Singapore has only 3122 km of road, of which 3038 km are asphalt paved. In addition, there are eight expressways with a total length of 150 km in the network (see Fig. 1). Moreover, as indicated by Chart 1, there are 688,811 registered motor vehicles in 1999. If all the vehicles were to ply the streets at the same time, it would lead to an average of 1.1 vehicles per 5 m, giving rise to nearly bumper-to-bumper traffic. With a burgeoning

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PII: S0966-6923(01)00036-9

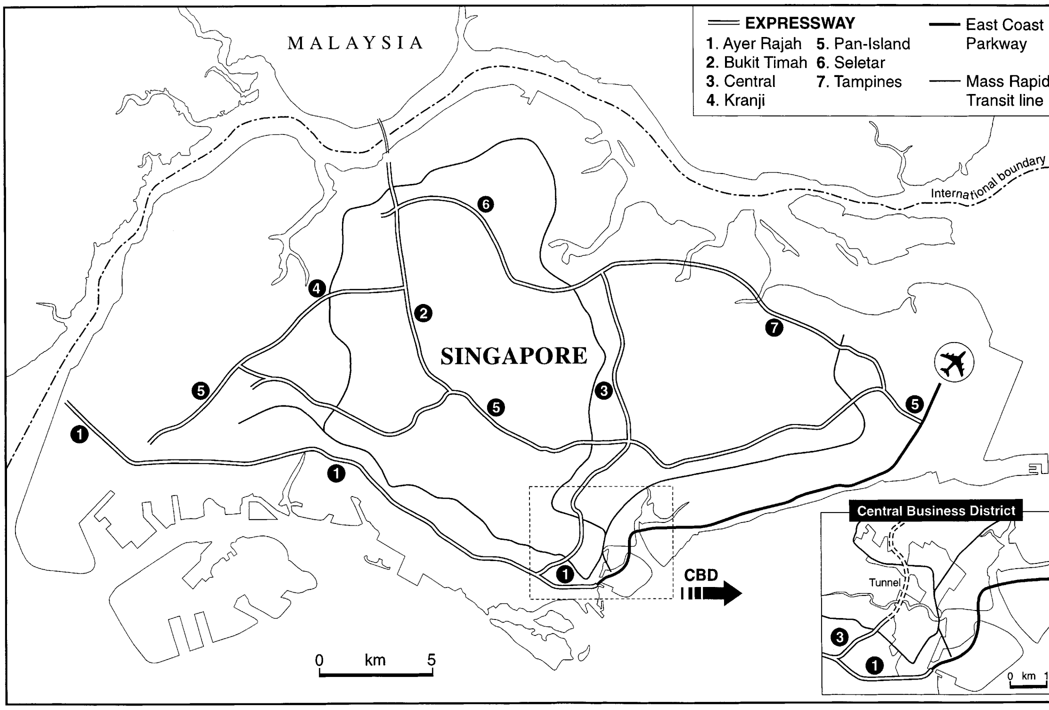

Fig. 1. Map of Singapore.

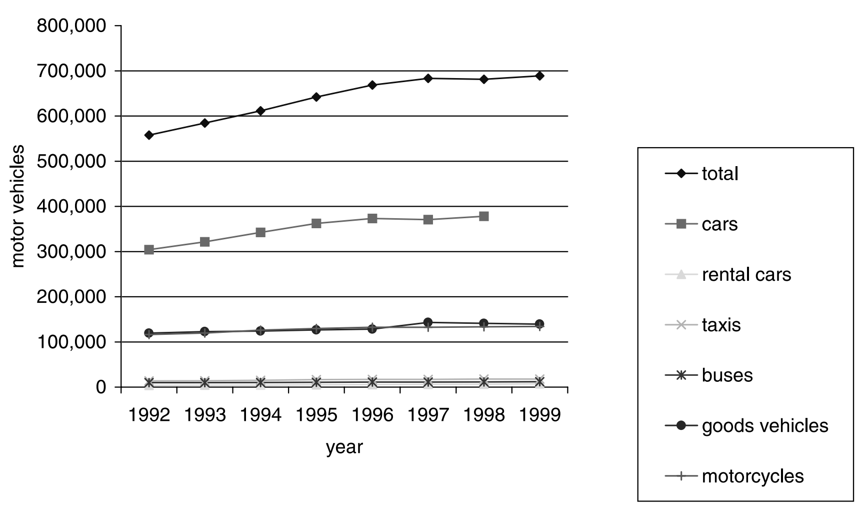

Chart 1. Motor vehicles population in Singapore, 1992–1999. (*Source*: Ministry of Information and the Arts, Singapore. * Includes private cars and company cars.)

middle class and more people aspiring to be vehicle owners, the challenge has been laid for Singapore since the 1970s to restrain rampant vehicular growth. The Asian financial crisis aside, this challenge is in general symptomatic of nearly all large cities in the Asia Pacific.

Singapore has always sought to make the case against congestion through economic terms as the government recognizes that driving creates social costs. As such, the government has always levied a high premium for the right to own and drive private vehicles. Thus, as long as motorists are prepared to pay the full social cost of their driving, they can drive as much as they want.

Since the 1970s, various measures have been implemented to manage the increase in the number and usage of vehicles on the road (see Table 1). These include the imposition of vehicle taxes, fuel taxes, parking charges, the Area Licensing Scheme (ALS), Road Pricing Scheme (RPS), Off-peak Car Scheme and Vehicle Quota System (VQS). However, the government has not been uniformly successful with its anti-congestion policies. For

Table 1
Major measures introduced to curb road congestion in Singapore

Year	Measure	Concise description of measures/systems	Success rate
1972	Additional Registration Fee (ARF)	Extra levy imposed on new vehicle, priced at 5% to 140% of the vehicle's open market value (OMV) depending on the vehicle's capacity and function.	Only initially. Scheme was revised in 1974 and 1975.
1975	Area Licensing Scheme (ALS)	Restrict access to CBD from 7.30 a.m. to 6.30 p.m. on weekdays from 7.30 a.m. to 2.00 p.m. on Saturdays through purchase of supplementary licences.	Initial drop in traffic into the CBD was 45%. By 1988, drop was not sustained due to increase in employment in the CBD.
1987	Mass Rapid Transit (MRT)	Serves heavy passenger transit corridors.	Ridership rose from 346 million in 1998 to 360 million in 1999, an increase of 14 million.
1990	Vehicle Quota System (VQS)	COE is introduced, i.e., new car population allowed to grow at 3% in tandem with road capacity growth. Motorists now need to bid for the right to own a car.	With VQS, 41,000 fewer vehicles were registered between 1990 and 1993.
1994	Off Peak Car (OPC) scheme	Offer new and existing car owners the option to save on car registration and taxes in return for lower car usage.	Not very successful as most motorists preferred ready use of car for convenience.
1995	Road Pricing Scheme (RPS)	Manual road pricing scheme introduced for linear passage vehicle flow, i.e., remove bottlenecks at congested expressways or arterials outside CBD.	Initial drop in traffic volume along RPS monitored expressways dropped by 41% from 12,400 to 7,300 vehicles while public transportation travel speed increased b 16%.
1998	Electronic Road Pricing (ERP)	Automated road pricing to reduce the 147 enforcement personnel needed for RPS and replace ALS, OPC and RPS.	Traffic volume on ERP monitored roads dropped by 17%.
1999	Light Rail Transit (LRT)	Serves as passenger feeder to existing MRT network.	Currently carrying payload of 39,000 passengers daily.

Source: The Straits Times (1998–2001).

example, in 1972, it initially tried to limit traffic growth by making cars more expensive to own. The vehicle import duty was raised from 30% to 45%, and car-buyers were taxed with an additional registration fee equal to 25% of the car's market value. However, this did not abate the demand for motor vehicles as the economy then was buoyant (growth was about 8%) and consumer aspirations were high.

To encourage more road users to consider using public transport, Singapore then implemented an area road pricing scheme for a cordoned area called the Restricted Zone (RZ) in 1975. Under the ALS, drivers would purchase a daily or monthly ALS licence from various ALS booths located near the boundary of the RZ, post offices, various petrol stations and designated retail stores. Only by displaying the licences on the windscreens can drivers enter the RZ during the assigned hours. Compliance was manually enforced by police personnel stationed at each of the entry points recording the licence plates of vehicles without valid ALS permits. When the scheme was first introduced, the reaction from the public was underestimated. Traffic into the RZ reduced by as much as 45%, exceeding the original target of 25–35% (Phang and Toh, 1997). However, there was also a noticeable increase in congestion during the non-ALS hours, so the ALS was subsequently modified to regulate the flow of traffic into the RZ, which comprised mainly the Central Business District (CBD).

Even then, the government had to introduce a slew of draconian measures to curb vehicular growth. In 1988, road taxes and car-park fees at public-housing estates were raised by 100%, followed by exorbitant petrol taxes. This, however, failed to deter the growth rate.

Concerned with the rising vehicle registrations, the Certificate of Entitlement (COE) Scheme was introduced in 1990. This scheme required anyone who wanted the right to buy a new motor vehicle and own it for 10 years to successfully pre-bid for a COE at quarterly (subsequently this became monthly) auctions in one of the several vehicular categories. By limiting the number of COEs available each month, the government essentially used supply driven economics to limit the number of new vehicles on the road. Sometimes, the COEs were bid at astronomical levels, occasionally in excess of US$58,000 for luxury cars, leading to much frustration on the part of many unsuccessful aspiring new car owners. This phenomenon led to some research on understanding the bidding behaviour of aspiring vehicle owners. The interested reader can refer to Chu and Goh (1997) for the details. Already, there were studies arguing that such a vehicle quota system should be abolished as it was administratively cumbersome for the government, inconvenient for the car-owning public, and a drastic curtailment of legitimate middle-class aspirations (Toh, 1994; Foo, 1998).

Recognizing that some of the previous measures had unintended side effects such as congestion on feeder roads and expressways leading to the CBD, the government decided to introduce the RPS specifically to regulate traffic on the expressways. The RPS was first implemented on the East Coast Parkway (an expressway) in June 1995, partly to familiarize Singaporeans with linear passage congestion tolls (to control congestion points on a highway) as opposed to the area congestion tolls imposed by the ALS. Overall, the RPS was successful in regulating traffic flow during peak hours. As a result, the RPS was expanded to other expressways, namely, the Central Expressway (CTE) and Pan Island Expressway (PIE) in mid-1997. When the RPS was extended to the three key expressways, surveys conducted by the Land Transport Authority (LTA) showed that about 7000 or 16% of the expressway motorists stopped using the expressways during the RPS operational hours (7:30–9:30 a.m.) (Straits Times, 16/8/97). About 3000 of them switched to major by-pass roads. The rest either changed their journey times to before 7.30 a.m., after 9.30 a.m., switched to public transport, carpooled or abandoned their trips altogether. In a sense, this was the purpose of the RPS, that is, to change the travel behaviour of motorists, encouraging them to take alternative forms of transport, or where it was not convenient or cost effective, to provide them with a smooth ride for a small fee.

Nevertheless, the scheme had its critics. While the expressways became less busy at rush hours, congestion was experienced on the feeder roads. Operationally, it was labor-intensive requiring more than 120 personnel to produce, administer and sell the RPS coupons. Enforcement by personnel stationed at the gantries was also subject to human error and inclement weather. The ability to differentiate charges based on time of travel, level of congestion and actual road usage was also limited. In addition, the use of a single coupon for unlimited travel on the three expressways, and entry into the RZ, had resulted in under penalized contributions to traffic congestion, making it difficult to equate marginal social costs with marginal social benefits.

Nonetheless, between 1975 and 1995, through the combined efforts of the various congestion control measures, the speed of traffic flow in the CBD during morning peak hours nearly doubled, to 36 km/h, as traffic volume declined by 45%. However, the degree of traffic jams occurring just outside the controlled zones worsened as drivers started to seek more non-RPS routes.

The static price RPS scheme became the pre-cursor to the Electronic Road Pricing (ERP) system, which involved both the area coverage as well as the linear passage concepts. The area coverage concept refers primarily to the restricted zone surrounding the CBD while the linear passage concept refers to the regulation of traffic demand during peak hours on certain roads/highways. It was the success of the RPS that prompted the government to move in that direction.

3. Electronic road pricing

Established in April 1998, the ERP system is used to electronically monitor and track only vehicles entering a restricted zone to ensure a smooth traffic flow. In short, it seeks to control the flow of inbound traffic into a restricted zone. The system is capable of automatically imposing a demand sensitive congestion toll on every vehicle without requiring them to slow down or stop, when the congestion level in the restricted zone exceeds a preferred threshold level.

When the ERP system was first tried out in Hong Kong from July 1983 to March 1985 (Hau, 1990), the Singapore government watched the trials with great interest. Although the system proved to be technically feasible, it was not implemented due to public rejection, arising from concerns over the privacy of movements (Hau, 1990; Gomez-Ibanez and Small, 1994). Likewise, when a limited-scale multiple cordon-based ERP system was tested in the Netherlands, privacy was also an important public concern (Phang and Toh, 1997).

Singapore opted to skirt the privacy and billing problems by implementing a less intrusive active system with automatic toll collections. The approach used is similar to that mentioned by Langmyhr (1999) who reported on Norway's toll ring experience. Like Norway, the ERP system implemented by Singapore involved 42 fixed position electronic gantries encircling the CBD and at heavy traffic points to collect tolls from motorists during certain times of the day. At present, no tolls are levied when leaving the restricted zone.

The ERP system is based on a relatively simple dashboard-mounted device. It works much like a miniature version of the electronic turnstiles at mass-transit rail stations. Motorists insert a cash card into the In-vehicle Unit (IU) when they are on the road. As their cars pass overhead gantries set up along the strategic roads, the card-reader is activated by a microwave signal. There is a beep and the toll is deducted from a CashCard – a pre-paid smart card, which can be credited at all local post offices, banks, petrol kiosks or automated teller machines. Cameras mounted on the gantries will record the vehicle's plate number and transmit the information to the traffic police headquarters. Entry into the restricted zone without an appropriate IU or CashCard would lead to an automatic fine of US$40 for each illegal entry. Computers at the traffic police headquarters will match it against government records, and a traffic ticket will be issued to the registered vehicle owner.

Put simply, this ERP technology employs a complicated combination of radio frequencies, imaging and smart card technologies, optical detection, and cameras and computers working in unison. The IU, which is only slightly larger than an audio cassette tape and costing about US$90, is installed on the windscreen, in front of the driver's seat. As the IUs for different vehicles are programmed differently, each time the vehicle passes under a set of gantries, the IU negotiates with the computers placed on the gantries, to determine the toll price for the respective vehicle. This allows the respective toll to be deducted automatically from a CashCard. Being permanent, the IUs cannot be swapped between different categories of vehicles that are charged varying rates based on vehicle size. All Singapore registered cars are installed with IUs while foreign cars coming into the island on a short-term basis would need to rent a temporary IU and CashCard from designated IU rental shops located outside the restricted zone.

3.1. Initial impact of ERP policy

On the first day of its implementation (April 1, 1998), the usual morning rush hour traffic from 7:30 a.m. to 9:30 a.m. along one of the heavily congested highways decreased by 17% from 16,203 vehicles to 13,451 vehicles (Kaur, 1998). This was in line with the policy planners' anticipated drop in volume between 10% and 20%. However, there was a small minority of 237 motorists who were fined for ERP related violations, namely, having no CashCard in their IUs, or no prerecorded cash value in their CashCard. These violators, local or otherwise, were caught on camera.

Generally, the public perceived this scheme as a better congestion management tool as the ERP scheme, unlike previous measures (see Table 1), charged motorists mainly for using congested areas or points and not so much for owning cars. Also, the cost for entering the CBD was no longer US$1.20 during the off-peak hours from 10:15 a.m. to 4:30 p.m.

Indeed, based on secondary data reported in the local press, from September to December 1998, the average monthly toll collected from the ERP system was US$3.38 million. In absolute terms, this might seem to be a huge amount of revenue generated from toll collections alone. However, the reported amount was significantly lower than the average monthly toll of US$5.37 million collected from the superceded ALS and RPS schemes in the corresponding period in 1997 (Business Times, March 4, 1999). Under the ERP system, entry into the RZ during off-peak hours was set at US$0.60 instead.

Further, with the ERP system in place, traffic was better spread out during the day, with the expressways and arterial roads carrying close to their designed capacity while remaining relatively less congested. During peak hours, travel speeds in the CBD were smoother while on the expressways, the travel speeds improved from 45 to 65 km/h.

3.2. Some advantages of ERP

The ERP system has several advantages over the other congestion pricing schemes. Firstly, it rations vehicle flow efficiently since it charges directly and can easily be adjusted to charge more during peak hours and high traffic volume periods. Unlike the traditional toll booths, electronically tagged vehicles can be accurately tolled even at a travelling speed of up to 100 km/h. Cars need not slow down, and drivers need not carry the correct change. Motorists will not be caught with the wrong permit or coupon used at the wrong time or place, and IUs are not removable or interchangeable. Cameras will provide objective documentary proof of violations, and the CashCards, which can retain information on the last 30 passings, can be checked in case of disputes. In addition, with the CashCard, concerns on forgery and bribery are reduced since all processes are now automated.

Secondly, the charges per entry are more efficiently allocated than the previous fixed daily permits with multiple entry privileges. From the perspective of welfare economics, the ERP system is generally seen as a rigorous technical mechanism for imposing regulatory road charges. The regulatory tax can now be differentiated according to the various dimensions affecting the actual marginal external costs of each trip such as the length of the trip, the time of driving, the route followed and the vehicles used (Verhoef et al., 1995). In addition, new charges for different kinds of vehicles travelling in different places at different times of the day can be quickly fed into the system when needed.

Motorists are made more aware of the true cost of driving as charges are now levied on a per-pass basis and can vary according to the time of the day and congestion levels. Under the pay-as-you-use principle, a motorist thus has to choose whether to drive, when to drive and where to drive to. This decision is based on cost, the importance of the trip, and the alternative routes or transport modes available. Those who choose to pay and stay on the road will encounter a smoother ride, rather than being caught in a traffic jam with no choice. More importantly, the manpower resources used to manage and maintain the ALS and RPS can now be efficiently relocated elsewhere. Thus, through this marginal social cost pricing, the road user can actually contribute directly to recover the full cost of the transport infrastructure. On the environmental aspect, the ERP system can be used by the government to reduce air pollution arising from excessive traffic flow on the major arterial roads.

3.3. Some challenges with ERP

No doubt, road pricing is a theoretically elegant way of bridging the gap between private and social costs of driving and hence is a measure with the potential to decrease pollution, congestion and accidents along motorways and in heavily populated urban areas with a growing vehicle population. However, the willingness to adopt road pricing depends on four factors, namely, political will, public acceptance, budgetary constraints and the availability of alternatives (Ison, 1998).

Road pricing is only one measure among many to curb or relieve traffic congestion. Unfortunately, road pricing remains highly controversial and debate about its desirability tends to be heated (Verhoef et al., 1997). Interestingly after much analysis, research, and discussion, a pure policy of road pricing has been adopted only in Singapore. While other cities, like London and Hong Kong, have come close to introducing a city centre licensing system, the proposals were withdrawn or stalled mainly due to political nervousness.

As with every system, the ERP system has some operational and social challenges. For instance, CashCards had to be placed into the IU 10 m before the first gantry for the IU to effectively communicate with the computers located on the gantry. Thus, the LTA in Singapore, the agency responsible for the maintenance of the ERP system, had to encourage vehicle users to insert their CashCards at the onset of a journey. The longer-term option is to opt for intelligent vehicles which can interface with the ERP technologies directly.

Cognizant of the need to regulate pricing to reflect actual load conditions on the roads, the LTA has been adjusting the ERP charges on a quarterly basis, according to the actual level of traffic congestion experienced. On the economically under-utilized roads, ERP rates are normally lowered to encourage greater road usage. Likewise, on heavier utilized roads (i.e., roads experiencing travel speeds of less than 20 km/h), the ERP rates are raised. However, it is difficult to gauge the precise effect of the ERP rate changes. There were occasions when the modified ERP rate restrained more traffic than necessary, resulting in traffic volumes at some gantries declining by about 44%. During peak hours, this sometimes led to unnecessary bottlenecks elsewhere in the local road transport system.

There are also concerns over the possibility of "big brother" misusing the information collected about the movements of cars (Hau, 1990). Although the use of CashCards is supposed to provide anonymity, each IU has a unique serial number. In short, each time a vehicle passes under a gantry, the serial number is recorded in a central computer.

4. State of ERP policy thus far

It was reported that the ERP revenue of US$39.5 million collected for the year 1999 was 33% less than the previous manual licensing schemes combined (ALS and RPS) (Business Times, August 9, 2000). Despite this loss in revenue to the government, the ERP system can be considered as the most promising instrument thus far to achieve equity in road usage because it is very flexible and, as presently conceived, is operationally non-intrusive (Phang and Toh, 1997). In addition, the automation of road pricing is in line with the government's drive to make Singapore an 'intelligent' island through the use of information technology while the use of the SMART card supports the move towards a cashless society and shift road usage onto a pay-on-demand basis. The greatest challenge in the foreseeable future is to obtain greater buy-in from the driving public when the ERP system is installed on a wider scale.

As Singaporeans become familiar with and accept the ERP system, more ERP gantries will be set up. Now, there are seven gantries for expressways and five gantries for ring roads. Pricing for the different categories of vehicles such as motorcycles, light goods vehicles, heavy goods vehicles/small buses, very heavy goods vehicles/ big buses, taxis, passenger cars is staggered, based on vehicle size, time of entry and location of entry. Tables 2 and 3 provide a detailed breakdown of the latest pricing. Overall, the charges are highest during the morning peak periods.

This effort at reducing traffic congestion without providing for more road capacity is expected to shift the trip pattern of motorists in various ways, notably to redistribute trips spatially, temporarily, and modally (Thomson, 1998). As shown in Table 1, the modal shift in favour of the Mass Rapid Transit (MRT) in 1999 is significant, an increase of 14 million passengers. The ERP system serves to encourage commuters to decide which mode of transport would serve them best, by comparing between the amount of time spent travelling and the cost outlay of the transport.

However, the big question is – "Is ERP the ultimate solution to traffic congestion in Singapore?" Those who have already paid a small fortune for a COE and car (this can be almost US$174,000) would be indifferent to the miniscule ERP rates of about US$1.20 per entry. On an island that measures barely 35 km East to West and 20 km North to South, the average car clocks about 20,000 km a year. Given this situation, it would appear that the financial impact on the individual motorist is minimal.

To ensure the success of the ERP system, the government has been continuously upgrading the public transport system and is expected to spend up to US$5.8 billion over the next five years on key land transportation projects, and increase the domestic MRT rail network by 50% to 130 km in five years. By building and expanding the MRT System and the Light Rail Transit (LRT), commuters between the city area and the satellite towns can expect to reduce the time spent in traffic jams.

As a further combined effort to complement the ERP system, the private sector has through the Singapore Bus Services, introduced an "on time" system in September

Table 2
ERP charges on arterial roads (in Singapore Dollars)

Arterial roads																														
Entrance	Bendemeer Rd southbound after Woodsville Interchange						Kallang Rd westbound after Kallang River						Thomson Rd southbound after Toa Payoh Rise						Restricted Zone (Nicoll Highway)						Restricted zone (All other gantries)					
Time	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
7.30–8.00 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.50	0.50	0.80	1.00	0.70	1.00	0.25	0.25	0.40	0.50	0.40	0.50
8.00–8.30 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.50	0.50	0.80	1.00	0.70	1.00	1.25	1.25	1.90	2.50	1.70	2.50	1.00	1.00	1.50	2.00	1.40	2.00
8.30–9.00 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.50	0.50	0.80	1.00	0.70	1.00	1.25	1.25	1.90	2.50	1.70	2.50	1.25	1.25	1.90	2.50	1.70	2.50
9.00–9.30 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	1.00	1.00	1.50	2.00	1.40	2.00	1.00	1.00	1.50	2.00	1.40	2.00
9.30–5.30 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	0.50	0.80	1.00	0.70	1.00	0.50	0.50	0.80	1.00	0.70	1.00
5.30–6.00 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.75	0.75	1.15	1.50	1.00	1.50	0.75	0.75	1.15	1.50	1.00	1.50
6.00–6.30 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.00	1.00	1.50	2.00	1.40	2.00	1.00	1.00	1.50	2.00	1.40	2.00
6.30–7.00 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.50	0.50	0.80	1.00	0.70	1.00	0.50	0.50	0.80	1.00	0.70	1.00

Source: ERP rates & location, 2000, LTA website (http://traffic.smart.lta.gov.sg/erprates.htm).
All figures are in Singapore Dollars. The conversion rate at the point of writing is US\$1 = S\$1.723.
1: Motorcycles, 2: Light goods vehicles, 3: Heavy goods vehicles/small buses, 4: Very heavy goods vehicles/ big buses, 5: Taxis, 6: Passenger cars.

Table 3
ERP charges on expressways (in Singapore Dollars)

Expressways	AYE						CTE											
Entrance	Between Portsdown Rd and Alexandra Rd						After Braddell Rd, Serangoon Rd and Balestier slip Rd						Between Ang Mo Kio Ave 1 and Braddell Rd					
Time	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
7.30–8.00 a.m.	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.80	1.00	0.70	1.00	0.50	0.50	0.80	1.00	0.70	1.00
8.00–8.30 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	1.25	1.25	1.90	2.50	1.70	2.50	0.50	0.50	0.80	1.00	0.70	1.00
8.30–9.00 a.m.	0.75	0.75	1.15	1.50	1.00	1.50	1.25	1.25	1.90	2.50	1.70	2.50	0.25	0.25	0.40	0.50	0.40	0.50
9.00–9.30 a.m.	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50
9.30–5.30 p.m.	–	–	–	–	–		–	–	–	–		–	–	–	–	–	–	–
5.30–6.00 p.m.	–	–	–	–	–		–	–	–	–		–	–	–	–	–	–	–
6.00–6.30 p.m.	–	–	–	–	–		–	–	–	–		–	–	–	–	–	–	–
6.30–7.00 p.m.	–	–	–	–	–		–	–	–	–		–	–	–	–	–	–	–

	ECP												PIE											
Entrance	After Tanjong Rhu flyover						After Kallang Bahru exit						Eastbound after Adam Rd and Mt Pleasant slip road into eastbound PIE						Slip road into CTE					
Time	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
7.30–8.00 a.m.	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.40	0.50	0.40	0.50	0.25	0.25	0.40	0.50	0.40	0.50	0.75	0.75	1.15	1.50	1.00	1.50
8.00–8.30 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.75	0.75	1.15	1.50	1.00	1.50	0.50	0.50	0.80	1.00	0.70	1.00	1.00	1.00	1.50	2.00	1.40	2.00
8.30–9.00 a.m.	1.00	1.00	1.50	2.00	1.40	2.00	0.50	0.50	0.80	1.00	0.70	1.00	0.50	0.50	0.80	1.00	0.70	1.00	1.00	1.00	1.50	2.00	1.40	2.00
9.00–9.30 a.m.	0.25	0.25	0.40	0.50	0.40	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.40	0.50	0.40	0.50	0.50	0.50	0.80	1.00	0.70	1.00
9.30–5.30 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5.30–6.00 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6.00–6.30 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6.30–7.00 p.m.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Source: ERP rates & location, 2000, LTA website (http://traffic.smart.lta.gov.sg/erprates.htm).
All figures in Singapore Dollars.
1: Motorcycles, 2: Light goods vehicles, 3: Heavy goods vehicles/small buses, 4: Very heavy goods vehicles/ big buses, 5: Taxis, 6: Passenger cars.

1997 using a differential global positioning system to track buses travelling on the road to provide customers with prompt, accurate information about bus arrival times. By 2001, electronic display panels will be installed at major bus stops to inform waiting passengers when the next bus will arrive. Commuters can also dial-in for the arrival time of their bus before leaving for their bus stop by keying in the bus service number and the bus stop code number.

5. Other congestion management systems in Singapore

The government recognizes that building a comprehensive network of roads and expressways is, in itself, not enough to ensure a smooth flow of traffic. Advanced traffic management systems, utilizing the latest technology to maximize road network capacity, are needed to enable the limited resources to be fully utilized. This section describes briefly the other congestion management systems being used in Singapore.

5.1. Green Link Determining (GLIDE) system

The GLIDE system is the first of the advanced traffic management systems utilized in Singapore. Essentially a central computer system, it allows traffic signals to be co-coordinated through centralized control and monitoring. Using detector loops which are laid at approaches to a signalized junction to collect data on traffic flow, data received are used to co-ordinate traffic signals. By allocating more 'green' time at junctions where the traffic flow is heavier, the GLIDE system helps to increase road usage efficiency. The GLIDE system has already been extended island-wide to encompass some 1250 traffic signals.

5.2. Expressway Monitoring and Advisory System (EMAS)

EMAS is a state-of-the-art system, which uses sophisticated technology to monitor traffic conditions on the expressway, and provides motorists with up-to-date traffic information. Intended to give timely information on traffic conditions and provide for a safer drive along the expressways, the first EMAS was implemented along the Central Expressway in March 1998.

The system uses a series of high-technology cameras, which are strategically located, to detect accidents or other conditions that may hinder traffic flow. This information is then automatically transmitted back to the staff manning the 24-hour Control Centre. The surveillance cameras, which act as remote eyes for the operators allow the staff to focus on these conditions. Once a road incident is detected, staff at the Control Centre will take the appropriate remedial action by alerting agencies such as the Traffic Police, ambulance or fire stations and towing services.

As EMAS uses a standardized lane numbering system, all messages would be clearly understood. Motorists are also given advance warning of adverse traffic conditions in three ways:

1. electronic signboards are placed at various approaches to expressways;
2. two types of electronic signboards (one on the divider, and the other, the shoulder) are placed at regular intervals along expressways; and
3. TV and radio stations forewarn motorists of the incident.

Motorists can now receive timely, on-site traffic updates that allow them to change their routes, if necessary, to divert from bottlenecks.

Vehicular breakdowns are towed to the nearest car park by official tow trucks which are on 24-hour standby, to get traffic flowing normally in the shortest time possible on expressways. In cases involving human injury, the team will work in collaboration with the Traffic Police. Since the system allows for the early detection of traffic problems and quicker action to solve these problems, congestion is minimized. Up-to-date traffic information on electronic signboards also gives motorists the opportunity to avoid problem areas, further minimizing congestion.

6. Conclusion

This paper has described the on-going attempts by an economically successful city state to manage congestion effectively, utilizing state-of-the-art and reliable technology. Building more roads in an already highly dense land transport network is not suggested as a viable sustainable solution. Rather, road pricing becomes necessary to stem the excess demand imposed by increasing commuter and commercial needs. Although such congestion management programmes can lead to a decline in overall welfare (Phang and Toh, 1997) for some road users, this can be mitigated by building more efficient alternative transport systems like the MRT and LRT, which can operate independent of road conditions. Above all, societal concerns have to be addressed and public education must be instituted to win the private users to the side of government. Thus, it is essential for governments to make it costly enough for a reduction in traffic into the area, yet provide efficient transportation to ensure the vibrancy of the city area. Any ERP system has to be planned, implemented and used in concert with other policy measures. Ultimately, however, the success of any programme depends heavily on the ability of governments to tackle the problems efficiently and effectively.

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