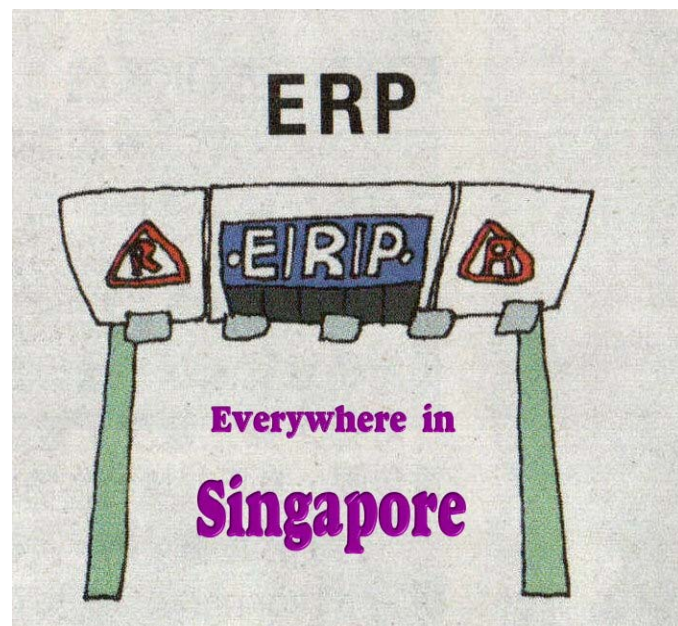


Electronic Road Pricing: Experience & Lessons from Singapore

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Singapore is the first city in the world to implement an Electronic Road Pricing (ERP) system in September 1998. Unlike toll road systems in operation in other countries, a road pricing system charges vehicles for usage of the road in accordance with the congestion they are causing. Also termed as “Congestion pricing”, in this practice, the motorists are charged to use a roadway, bridge, or tunnel during periods of the heaviest use¹. Its purpose is to reduce automobile (car) use during periods of peak congestion, thereby easing traffic and encouraging commuters to walk, bike or take mass transit rail/bus as an alternative. Hence higher rates are charged during the peak (or rush) hours and lower rates or no charges are levied at other times.



Figure 1: Road network and vehicle usage in Singapore, 2009

Total km of road: 3,240

Total km of Expressway: 164

Total km of main road: 604

Rush Hours: 7:30 AM to 9:30 AM

Traffic Speeds (City): 25-30 kph

Traffic Speeds (Expressway): 45-60 kph

Vehicle Population: 917,000

Car Population: 560,000

Bus Population: 3,100 buses; 3.1 million trips per day

MRT & LRT: 139 km; 89 stations with 1 million trips per day

Daily Modal Split for Public Transport: 51%

Modal Split for Public Transport for Work Trips: 59%

¹ “Paying for Road Use” by Commission for Integrated Transport

@ <http://cfit.independent.gov.uk/pubs/2002/pfru/index.htm>

“Congestion Pricing” Bibliography from Transport Research Information System

@ http://www.metro.net/about_us/library/Congestion_Pricing_Bibliography_TRIS.htm

“Road Pricing” TDM Encyclopedia by Victoria Transport Policy Institute

@ <http://www.vtpi.org/tdm/tdm35.htm>

Before Electronic Road Pricing

Prior to the implementation of ERP, Singapore had a manual road pricing system called the Area Licensing Scheme (ALS) in operation since 1975. The most congested parts of the city of about 720 ha was termed the Restricted Zone (RZ) (**Figure 1**) and an imaginary cordon was demarcated on the approach roads leading to it by 33 overhead gantries. This area which is about 1.2 % of the total area of the state of Singapore is served by a good arterial road network and has a ring road skirting it.

To enter this RZ during the period of 7.30am-7.00pm on weekdays and 7.30am-2.00pm on Saturdays, vehicles (other than emergency vehicles such as fire engines, ambulances and police cars) had to purchase and display an area license on their windscreens or handle bars (for motorcycles). Monthly and daily licenses² were coded by color and shape for easy identification by the enforcement personnel stationed at the entry points (**Figure 2**). Enforcement was only at the entry point. Policewomen stationed at the entry points during the hours of operation observed whether the vehicles displayed a valid area license, when entering the RZ. Violators were not stopped, but the details of the vehicles were noted and sent summons within two weeks to pay a fine.



Figure 2: Enforcement of road pricing in the Restricted Zone (RZ) prior to ERP

In the 1990's, following the success of ALS, a similar manual pricing system called the Road Pricing System (RPS) was introduced progressively along congested sections on three major expressways to operate on weekdays from 7.30am-9.30am. Vehicles had to purchase and display special road pricing licenses to pass under these priced points on the three expressways during the hours of operation.

² The area licenses had to be bought in advance from post offices, petrol stations, area license sales booths (located on the approach roads) or convenience stores prior to the entry. They could not be bought at the entry points, as in the case of a toll road. The area licenses had different prices for different categories of vehicles and also for peak and off-peak usage.

Need for Automatic Pricing System

The ALS and RPS are both labor-intensive in that they require many people for the sale of the area licenses and the policing. In total, more than 70 persons were required for license sales and 78 persons for enforcement.

ALS started off in 1975 in a simple manner by introducing restrictions for cars and taxis only, during the morning peak hours. As it was subsequently extended to cover more time during a work day, with different rates for different vehicle classes and lower rates during the off-peak hours and weekends, the number of licenses mushroomed. While the regular motorists who buy licenses often have no problems, the occasional user faced confusion and fines.

With the introduction of RPS, new licenses were required and this was another avenue for confusion. Before the introduction of an automatic system, the motorist had a choice of 14 licenses (**Figure 2**), which is considered too many and adding to the confusion.

With the paper license, motorists can make unlimited number of entries into the controlled area. This is not keeping in the spirit of the concept of congestion pricing, which is meant to make the driver pay for the use of the road at times and places when and where they cause congestion. The fairest way recognized was that the motorist **MUST** pay each time he/she uses the controlled area.

Therefore, a search for an automatic alternative started in 1989 when technologies for electronic toll collection started appearing and thus the Electronic Road Pricing (ERP) system.

Box 1: Chronology of ERP Implementation

- Sep 1998:** ERP starts operating on weekdays with 33 gantries.
- Nov 1998:** First revision to ERP rates (subsequently done at 3 months intervals)
- Apr 1999:** ERP for city removed for Saturday
- Jun 1999:** \$10 administrative fee + ERP charge for CashCard related violations (instead of the normal \$70 fine)
- Jul 1999:** An extra ERP gantry for the city
- Sep 1999:** 7 new ERP gantries on expressways and across the ring road
- Jul 2000:** 1 new ERP gantry on an expressway
- Aug 2001:** Enhancement of ERP gantries against Bluetooth operation, which also operates on the same radio frequency
- May 2002:** 2 new ERP gantries on a radial road
- Feb 2003:** Introduction of 5-min graduated rate change at ERP gantries where the difference in ERP charges between consecutive half-hours is \$1 or more
- Sep 2003:** Option for foreign vehicles to pay a flat charge of \$10 per day for unlimited use of ERP priced road
- 2005:** Saturday ERP in parts of the commercial areas added
- 2008:** 85th percentile speed used for determining ERP rates instead of average speeds (50th percentile);
Number of gantries progressively introduced to 66;
ERP rate changes to be in steps of S\$1 instead of S 50 cents
- 2009:** Dual mode IU accepting contact and contactless smart cards made available; ERP credit card scheme³ was introduced;

³ The ERP Credit Card is used for administering fines. If the driver passes under an ERP gantry without a valid Cashcard or with insufficient funds, the fee to be paid and an administrative fee will be automatically charged to the monthly credit card bill. He/She does not have make the effort to pay this separately.

ERP – How does it Work in Singapore?

Singapore's ERP System is the first of its kind meant purely for road congestion pricing, and not for toll collection. The capital cost of the ERP system, since its inception in September 1998 is S\$197 million and incurs an annual operational and maintenance cost of S\$25 million for 66 control gantries (in 2009). The program's annual revenue is estimated at S\$144 million in 2008-09.

The ERP system starts with the installation of an in-vehicle unit (IU) in each of the ~900,000 vehicles in Singapore. The IU is about the size of a small pocket diary (a new one costing about S\$155) and is powered by the vehicle battery. It is fixed permanently to the right bottom corner of the vehicle's windscreen by a bracket glued on by very high bond tape (**Figure 3**). The motorcycle IU that has a protective covering to prevent rainwater seeping in is fixed permanently to the front of the machine (e.g. on handlebar). The IU needs a direct line of sight to the radio antennae on the two gantries for effective communication.

In-Vehicle Unit



Types of IU and CashCards



ERP Gantry



ERP Gantry



Figure 3: ERP System in Singapore

The IU's are color coded for different types of vehicles because the ERP charges vary for them and this is to prevent the IU's from being switched around. The vehicle classes are cars, taxis, motorcycles, light goods vehicles, , heavy goods vehicles, buses and emergency vehicles. The emergency vehicles are exempt from the ERP charge.

Initially, the ERP only operated on weekdays. The ERP payment is made via a stored value on an integrated chip contact card (or smartcard), called CashCard, issued by NETS, a company owned by a consortium of seven local banks. The stored value can vary from S\$20 to S\$500. There is a \$2 deposit fee, which is refundable if the card is returned. The card is available at banks, convenience store and petrol stations. It can be topped up at many of the automatic teller machines. The CashCard plastic is able to withstand the high temperatures (e.g. 4 to 5 hours continuously at high temperatures) experienced inside the vehicle, when it is parked under the hot sun for long periods of time. Since 2009, modified IUs accepting both contact and contactless cards (CEPAS compliant in **Figure 3**) are available.

An ERP controlled point uses two overhead gantries at a height of 6 m above road level and spaced at about 11m apart and each gantry has two radio antennae per lane meant to communicate with the IU by radio frequency (**Figure 4**).

A set of optical vehicle presence detectors (optical line sensors) are setup to detect passage of vehicles (**Figure 4**). Two charge coupled device (CCD) cameras are placed on the first gantry to cover each lane to take electronic photographs of the rear license plates of the violating vehicles. The whole setup is controlled by a local controller and is connected by telephone cables to a central computer system at the control centre.

Box 2: Functional requirements for ERP in Singapore

- It should be a multi-lane system with no toll booths.
- There would be no manual payment.
- There would be no need to slow down at the ERP entry points.
- Provision to accommodate
 - When more than one vehicle passing simultaneously under the entry point.
 - Vehicles may straddle lanes as they pass under the gantry.
 - Vehicles could travel at speeds of up to 120kph.
- The In-vehicle-Unit (IU) should do a self-check and a check of the CashCard before the journey starts. The self-diagnostics include icons and sounds to alert the driver of any faults in the IU.
 - The IU should warn the driver when the cash balance in the CashCard become low.
 - The IU should preferably draw its power from the vehicle battery.
 - The IU should be permanently fixed to the vehicle and the fitting exercise should be simple and not take more than 20 mins.
 - The IU should carry a five-year warranty against manufacturing defects.
- Audible signals on the IU are to complement the visual displays.
- The enforcement photographs should be transmitted back to the control centre within 15 mins and initially checked by an optical character recognition system.

Payments are deducted automatically by the IU from the CashCard using a radio frequency of 2.45GHz between the ERP overhead gantry equipment and the IU, as the vehicle goes under the ERP gantry points. Violating vehicles have the photographs of their rear license plates automatically (taken by the red camera in **Figure 4**) for enforcement. Photographs are also taken if there are technical faults in the IU .

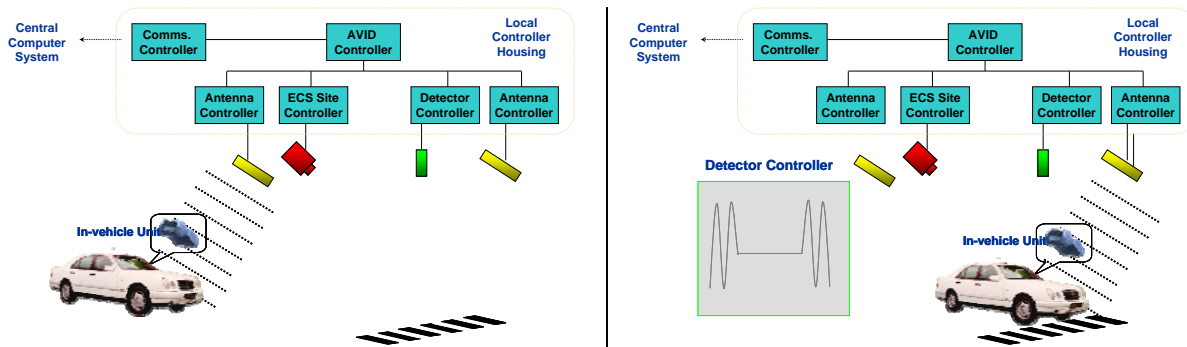


Figure 4: The operations at ERP gantry

In Singapore, the ERP started in 1998 with 28 ERP gantries forming an entry cordon around the downtown of an area of 720 hectares (Restricted Zone) and operate from 7.30am-7.00pm on weekdays. Initially, an additional 5 gantries were placed along the stretches of expressways, which were currently experiencing congestion. These are only switched on during the morning peak hours of 7.30am-9.30am. By 2009, the number of ERP gantries increased to 66 and the hours of restrictions have also been revised and lengthened. There is night charging at some gantries.

Payments vary for different half- hours from US\$1.60 (for a car) during the rush hours to US70cents during the quieter periods. Motorcycles, goods vehicles, taxis and buses have different types of IUs enabling differential payments. For example, a motorcycle only pays half of what an automobile (car) pays.

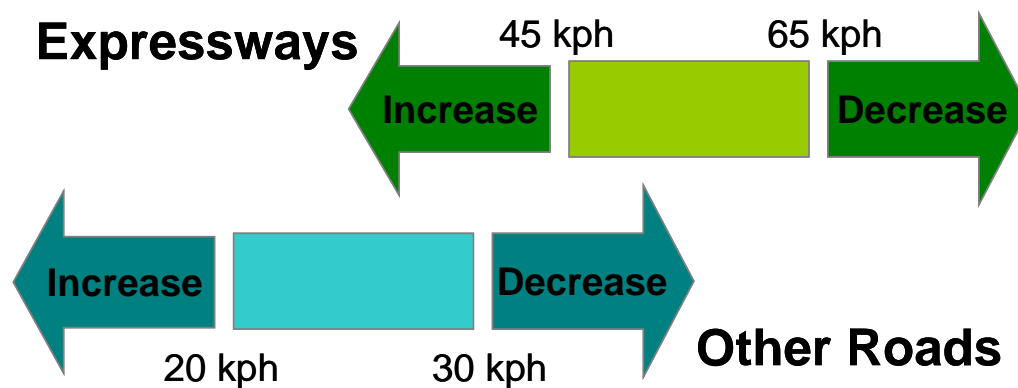


Figure 5: ERP prices vary with the 85 percentile speed along the corridors

ERP charges are reviewed at 3 monthly intervals and are tied to the prevailing speeds being experienced during a particular half-hour. The desired speed range for the roads in the downtown is 20-30 kph and for expressways 45-65 kph. If the 85th percentile speed during

the three months under review for a particular half-hour is below the lower limit, ERP charges are raised for that half-hour and if the average speed is above the higher limit, ERP rates are reduced. The charges remain fixed for a period of 3 months.

Public Awareness of ERP

Road pricing system had been operational in Singapore for the past two decades before ERP was implemented. Nevertheless, a mass publicity campaign was undertaken to inform and educate motorists on the ERP scheme.

After the government passed the legislation to introduce ERP, pamphlets (**Figure 6**) were sent to all motorists explaining how the ERP system works and whereabouts of IU installation centers, along with a notice for a free IU unit and installation. At the IU installation centre, motorists received another booklet on how it worked and on simple trouble-shooting tips.

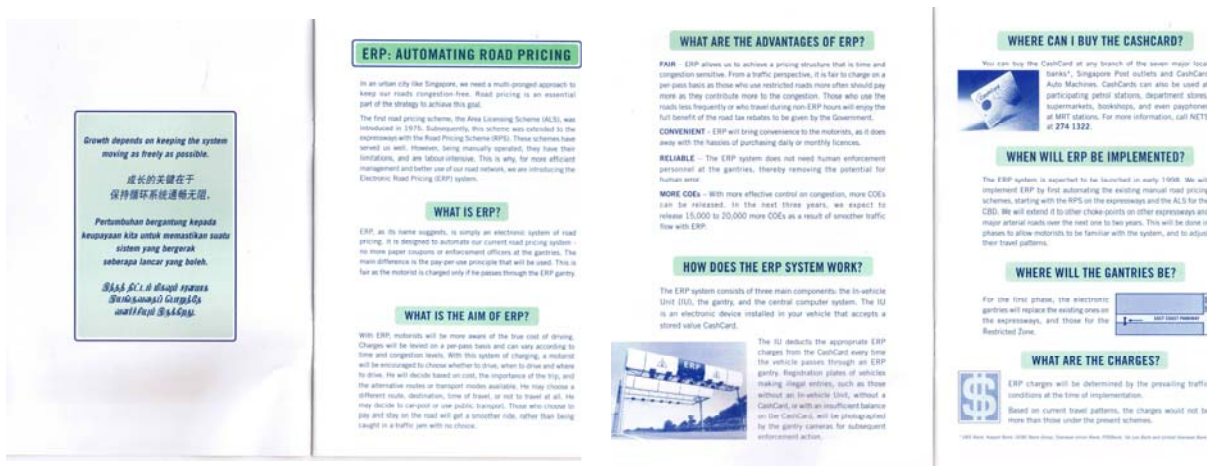


Figure 6: Sample pamphlet of ERP rules and regulations

There were frequent articles in the newspapers, on television and radio on ERP. Public forums were held with grassroots organizations to explain the ERP scheme and posters appeared at community centers.

An important event was the test drive that was initiated three months prior to ERP. By this time, most of the vehicles had their IUs fitted and Cashcards were readily available. During the trial period, the motorists were NOT charged (the charge table was set at zero), but advised to check their IUs and CashCards by driving under any operational ERP gantry and report errors, if any. Motorists experiencing problems with their IUs or CashCards were advised to return to the workshops to have their IUs checked or to exchange their faulty CashCards with new ones.

In August 1999 (one year after implementation), ~5.8 million ERP transactions were made per month. The error rate of transactions (between ERP gantry and IU and CashCard) was a low 0.03%, showing the system to be very reliable. Violations accounted for about 0.7% of

vehicle transactions. The majority were by motorists who had forgotten to insert CashCards. Operational errors accounted for a very small number of transactions, mainly by carelessness of motorists⁴, such as IUs were not properly powered; the CashCard is wrongly inserted. In general, there were a few genuine IU-CashCard incompatibility problems.



Figure 7: Public awareness campaigns in the newspapers brought about cartoons

For this violation of forgetting to insert CashCards or for having insufficient cash balance in the CashCard, drivers have to pay an administrative charge of US\$7.50 in addition to the ERP charge. However, if the violation is caused by a vehicle not fitting an IU, which was given free to all existing vehicles in 1998 and which is a mandatory requirement for all new vehicles, the fine is US\$45. Even after 12 years of operation, the violation rate and technical error rate have not increased significantly.

Experience and Lessons Learnt from ERP

The first ERP gantries on an expressway were switched at 2 locations (out of the final tally of 33) on April 1st 1998 between the hours of 7.30am-9.30am. From the word “go” the system worked smoothly. The widespread publicity had ensured that most motorists had become familiar with the system.

In summary, the ERP system has more than met the expectations. It is easily understood by the motorist, easy to use, technically sound and reliable. It has attained its objective of restraining traffic flow. The initial traffic monitoring showed that traffic volumes on the expressways reduced by 15% and speeds increased from 35 to 55 kph during the ERP hours, especially during the morning rush hours, when a reduction of ~14% was observed and resultant improved traffic speeds. There was a 16% reduction in traffic in the Restricted Zone and speeds were respectable between 25-35 kph. With ERP, motorists are given many choices such as paying the ERP charge, changing the time of the journey to pay a lesser charge, changing mode of travel or changing route to avoid the ERP charge.

⁴ Some motorists tended to slow down as they approached the ERP gantry. When questioned, they said that they wanted to make sure and see on the IU display that the correct deduction had been made OR a very small number of reckless drivers who came to a stop just before the gantry to insert the CashCard at the last moment.

Box 3: Lessons learnt from ERP in Singapore

- While introducing ERP, the system needs to be tailor-made to fit local traffic conditions. Off the shelf equipment will not be adequate.
- The success of the system depends much on its perceived reliability. Therefore, exhaustive testing is necessary to check its operational reliability.
- The fitting program for the gadgets (IU) has to be planned carefully and executed without causing unnecessary hassle to the motorist.
- Much effort has to go in educating the users, with extensive media coverage and awareness of the system and to help remove any of the unfounded apprehensions.
- Motorists' feedback should be taken seriously and there should be a willingness to help motorists who are having problems with their equipment or confused about the system operations.
- Traffic monitoring is necessary to understand exactly how this is affecting the traffic conditions and what remedial measures can be introduced.
- The implementation of the ERP has been an exciting and rewarding experience for the many who were involved in it.
- It is a pioneering effort.

Issues Raised in the Media by the Citizens

The IU clinics were widely reported by the press. Such wide publicity invited many letters from readers expressing their concerns on ERP. This raised an opportunity to answer many questions and clarify many doubts. The issues that were brought up were:-

In ERP, payment is made for each entry into the Restricted Zone. Under the old manual system, the area license gave unlimited entries. Will the motorists end up paying more with ERP?

- The answer was that the ERP better reflected the maxim "you pay for the actual use of the road". Furthermore, studies on the manual pricing system showed that the majority of the motorists use the area license only once a day. The average number was about 1.4 trips per license. Taxis made about 4 trips with a license, but the ERP charge would be paid by the commuter. It would of course discourage the taxi driver from empty cruising on the roads.

Will the motorist be penalized if the system failed and he/she was considered as a violator?

- Photographs will be taken of the vehicle if a violation took place or there was a technical error. In all cases, the reason for taking the photograph will be attached to the photograph. Violators will be penalized, but those with errors will only have to go for an inspection.

Will the IU, fitted on the windscreen, become a projectile in the event of an accident and injure the driver?

- Crash tests carried out with IUs in cars proved that the IU did not detach itself, even at collisions of speeds of up to 100kph.

Are the radiations harmful?

- The IU in the vehicle is a non-radiating device. It just reflects what it receives from the antenna, which is 6 m above the road surface. The radiated power from this antenna more than a thousand times less than what is allowable by the International Agencies on Radiation Protection.

Will vehicle movements be tracked?

- The system will only take photos of the rear license plate if a vehicle violates the system (**Figure 8**). Information on valid transactions and hence on the vehicles that passed under each gantry will be kept only as long as they are required to settle the daily claims with the banks. There are also strict controls on who would have access to such information. However, the CashCard will have the details of the last 25 transactions. The motorist could print out the last 10 transactions at any of the automatic teller machines. With special card readers, he could print out the last 25 transactions.

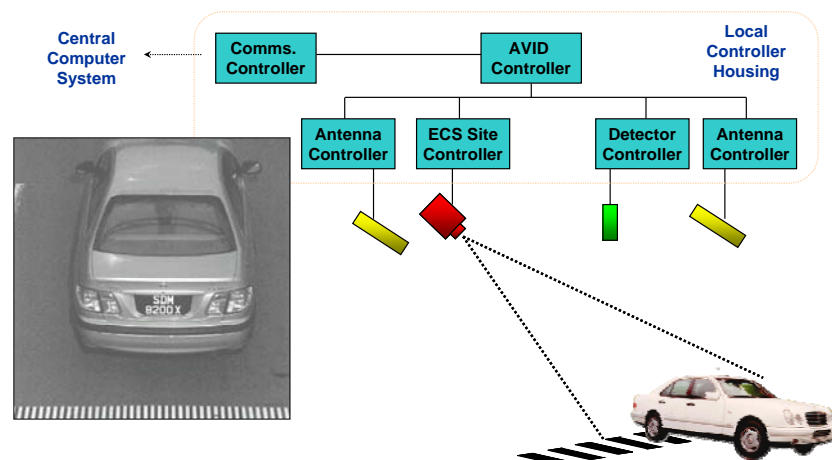


Figure 8: Photograph taken at a gantry for violating ERP

What would happen if the IUs (especially on motorbikes) are vandalized or stolen?

- Stolen IUs will be invalidated once a police report is made. Photographs will be taken if an invalid IU passes under any gantry. As for vandalism, this would be the responsibility of the motorist himself, as with any other part of his vehicle's equipment.

What should a motorist do if faulty IU is detected before the start the journey?

- The motorist is to call at the installation centers to repair the equipment. Some of these centers will be open from the early mornings.

Will the motorist be allowed to have a negative balance in the CashCard?

- This is not necessary because the system gives an early warning on low cash balance and the motorist is expected to top up the CashCard with sufficient value. At the low cash balance point, the motorist will still be able to make one or two trips without violating the system.

Will the motorist be excused if he/she forgets to insert the CashCard?

- This is considered as a violation. Motorists are advised to make it a habit to insert the CashCard before starting their journeys and to remove it at the end of the journey. The latter served two purposes-to remind the motorist that CashCard was equivalent to money and to ensure that the CashCard was not left too long in the sun.

Will ERP Work in Other Cities?

Congestion pricing in the urban centers is among the first of economic measures and successfully implemented in the cities of Singapore (Singapore), London (UK)⁵ and Stockholm (Sweden)⁶.



Figure 8: Congestion pricing (ERP) zones

It is important that city PROVIDES the alternative transport modes before implementing ERP. The road pricing should be only one part of the government's transportation strategy, which includes good transport planning, provision of a good road network, use of intelligent transportation systems for traffic management and the provision of a good bus and rail public transport system; all of which are fully integrated in the cities of Singapore, London, and Stockholm. ERP cannot be sold to the traveling public on its own. It has to be part of a package that includes transport supply and transport demand management measures.

On an average, in London, congestion pricing is estimated to have reduced 20-30% of the downtown passenger car traffic and promote the non-motorized transport⁷. In Singapore, the average traffic speeds increased by at least 15 kph. In 2006, Stockholm experienced an immediate reduction of at least 20% in the daily car use⁸. In all three cities, a reduction in eCO₂ emissions between 10-20% was estimated, along with health benefits of reducing the

⁵ London Congestion Pricing website @ <http://www.tfl.gov.uk/roadusers/congestioncharging/>

⁶ Stockholm congestion pricing scheme reducing 25 percent traffic in one month @ <http://www.edf.org/page.cfm?tagID=6241>

⁷ London's two wheel transformation and congestion pricing @ <http://www.guardian.co.uk/uk/2008/feb/09/transport.world1>

⁸ Stockholm Syndrome by Wall Street Journal @ <http://online.wsj.com/article/SB115681726625048040.html>

local pollutants – firstly, by improving the fuel efficiency of the vehicles by improving the average speeds and also by reducing the congestion idling along the major corridors⁹.

Box 4: London Companies Learn To Love Congestion Charge, The Guardian, February 16th, 2004

London's £5-a-day congestion charge will celebrate its first birthday tomorrow with a qualified thumbs-up from the capital's businesses, which overwhelmingly back the scheme but want improvements to its administration. A study by the business lobbying firm London First will reveal that 72% of companies believe the road charging experiment is working, with 14% convinced it is a failure.

London First's findings, which are based on a survey of 500 firms by an independent polling agency, suggest that the impact has been exaggerated. Just 26% said the charge has had a "negative" impact on the capital's economy, while 32% said it was neutral and a further 26% judged it to be positive.

The controversial charging scheme is also considered an asset for London's reputation. Some 58% reckoned it had improved London's image, while only 15% judged it to give a bad impression to outsiders.

London First has called on mayor Ken Livingstone to create an easier system for registering and paying the charge. Many firms have complained about the "red tape" involved in paying for fleets of vehicles, while the appeals system for penalty notices has been criticized as cumbersome.

Independent experts say the impact has been insufficiently dramatic to cause significant damage to the capital's economy. Tony Travers, of the London School of Economics, said: "There is no evidence yet of a mass exodus by businesses, and supermarkets are still opening convenience stores across the capital. "Even if the congestion charge has had an impact on the economy, whether good or bad, it hasn't been an overwhelming one."

Full article @

<http://www.guardian.co.uk/environment/2004/feb/16/londonpolitics.greaterlondonauthority>

In all three cases, the ERP system gives motorists options to

- Pay ERP charge and enjoy good traffic conditions
- Change the time of the journey to pay a lesser charge if the system has differential charges for different periods
- Change to an un-priced or lower prices alternative route
- Change to a public transport mode
- Change destination
- Abandon journey

⁹ "The Congestion Problem – Case studies from US Cities" (2007) by US DoT, Federal Highway Administration @ <http://www.tfhrc.gov/pubrds/07july/01.htm>

In conclusion, the ERP or congestion pricing system was successful in these cities for one important reason - the cities operate a widely accessible public transport system (road and rail) which can support the shift to car-free transport. Also affected motorists have a ring roads around the city to which they can divert. the public transport is still not up to par in many Asian cities (compared to the levels comparable in developed countries) and the social and economic structure of the cities is a barrier yet to cross for effective implementation of this option.

Nevertheless, traffic demand management such as road pricing is a measure that many Asian cities will be forced to consider as traffic conditions become more acute.