

Singapore's Experience with Road User Charges

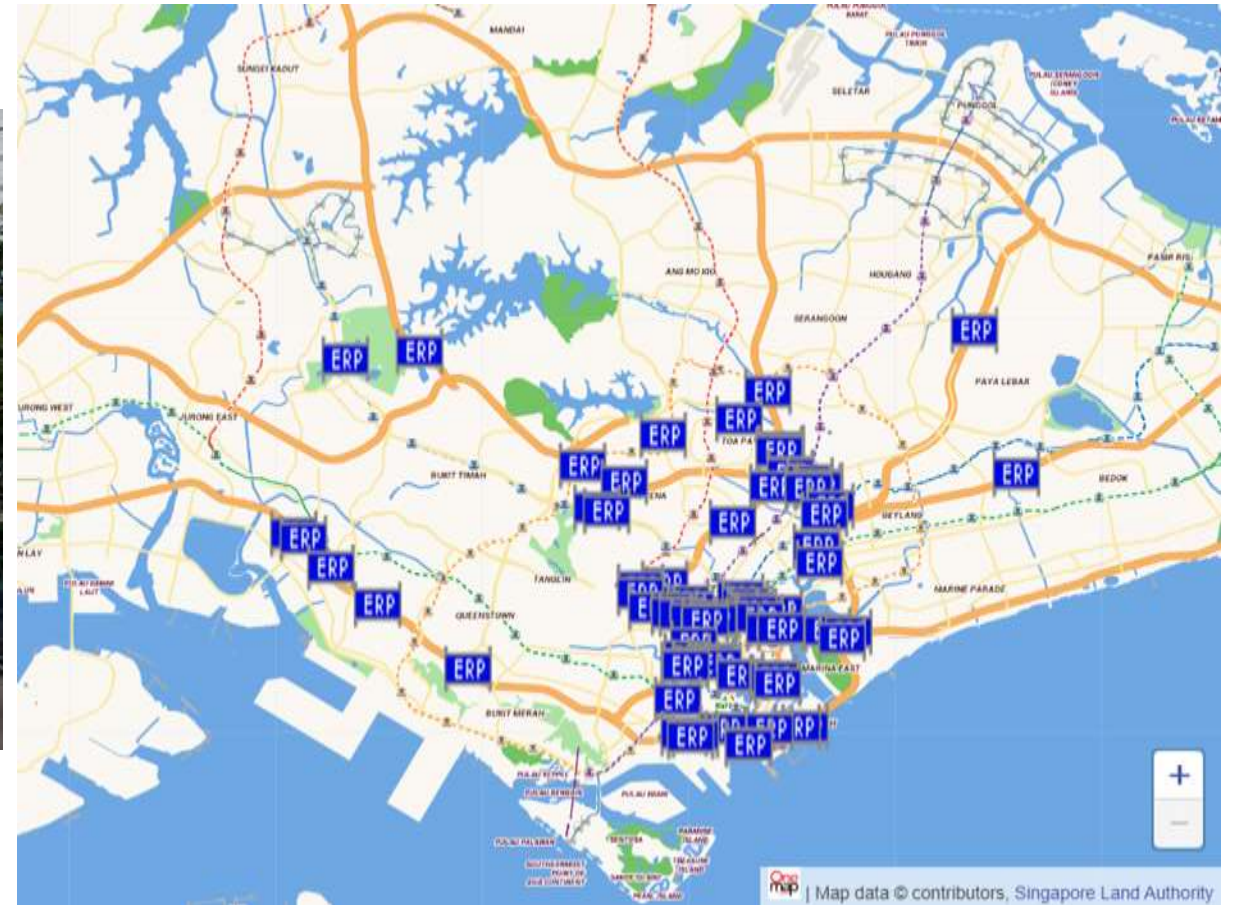
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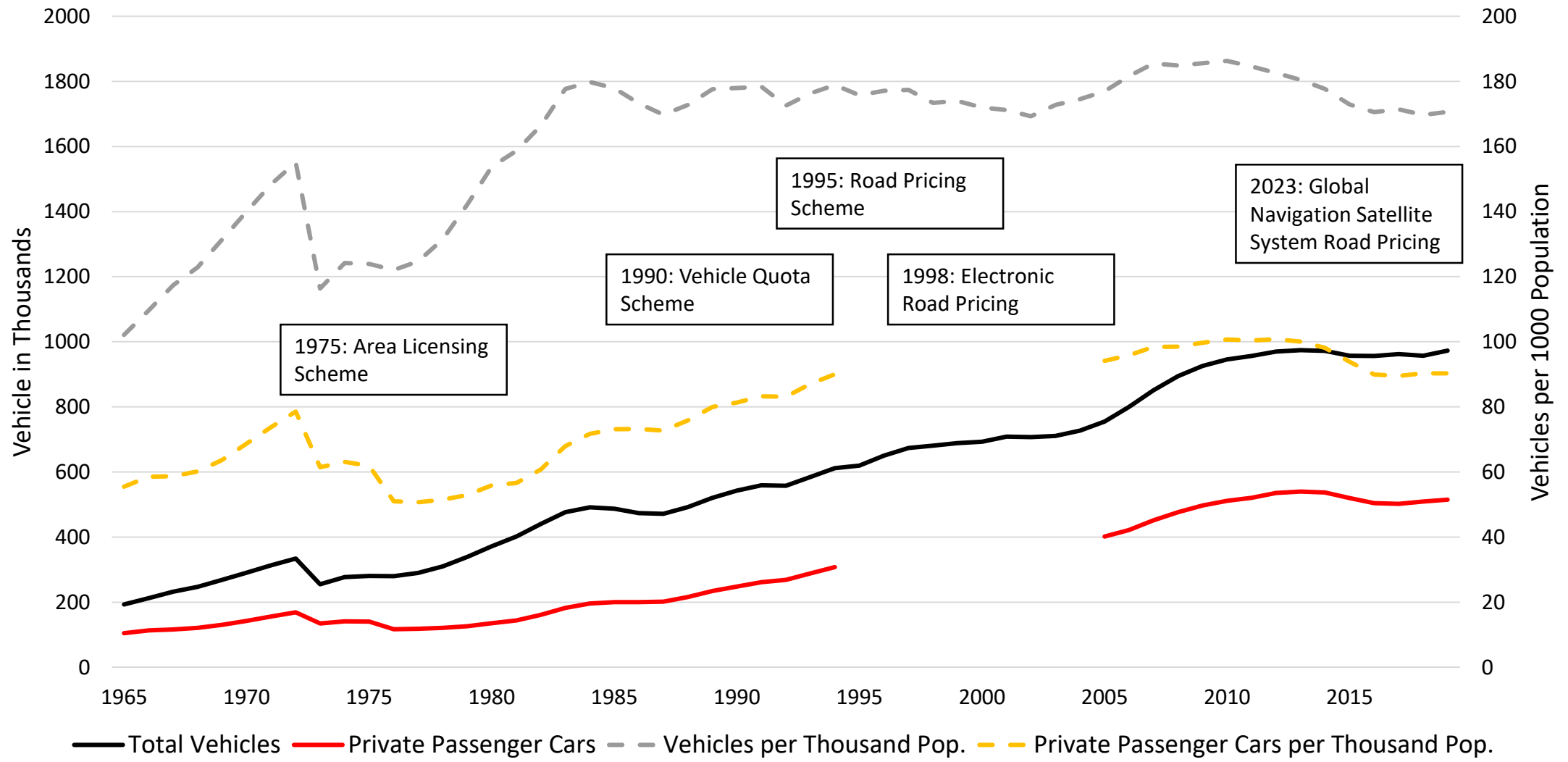
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Singapore's Electronic Road Pricing System



Vehicle Growth and Vehicle Use Restraint Policy in Singapore, 1965 - 2019



Notes: Vehicle count adjusted downward in 1973 due to computerisation of vehicle registry; private passenger car breakdown not readily available for 1995-2004

Overview of Vehicle Restraint Policy Development

- 1965 – 1975: Public transport underfunded, disorganized; Road infrastructure inadequate. Policy for restructuring bus services, road expansion, economic development.
- 1975 – 1995: **Area Licensing Scheme + Road Pricing Scheme** introduced to address growing car ownership, rapid economic growth, causing high congestion in CBD. Car ownership curbed through high taxes and fees. Mass Rapid Transit metro developed in 1980s.
- 1990: **Vehicle Quota Scheme** introduced. Vehicle ownership requires license, obtained by auction from available quota. Road user charges argued necessary to balance expansion of vehicle ownership – carrot-and-stick policy approach.
- 1998: **Electronic Road Pricing** introduced. Shift towards greater reliance on vehicle use restraint (road user charges), allowing expansion of vehicle ownership and reduction in fixed vehicle taxes.
 - Prices adjusted to maintain peak-hour speed of 45km/h – 65km/h on expressways and 20km/h – 30km/h on arterial roads.
- 2010s: **Car-lite urban mobility** policy introduced, emphasis on public transport and active mobility instead of vehicle ownership and vehicle usage optimization.

Technical Considerations in Singapore's Road Pricing Development

Area Licensing Scheme / Road Pricing Scheme based on pay-and-display labels.

- Tollbooths unsuitable due to road network constraints. Multiple CBD entry points, insufficient land.
- Expansion of pricing schemes required many different paid labels – high administrative overhead.

Electronic Road Pricing addressed inflexibility of paid label system.

- ERP implements tollgate without land take or traffic congestion. Allows marginal cost pricing.
- Based on proprietary V2I communications. System expansion requires construction of costly and unsightly overhead gantries.

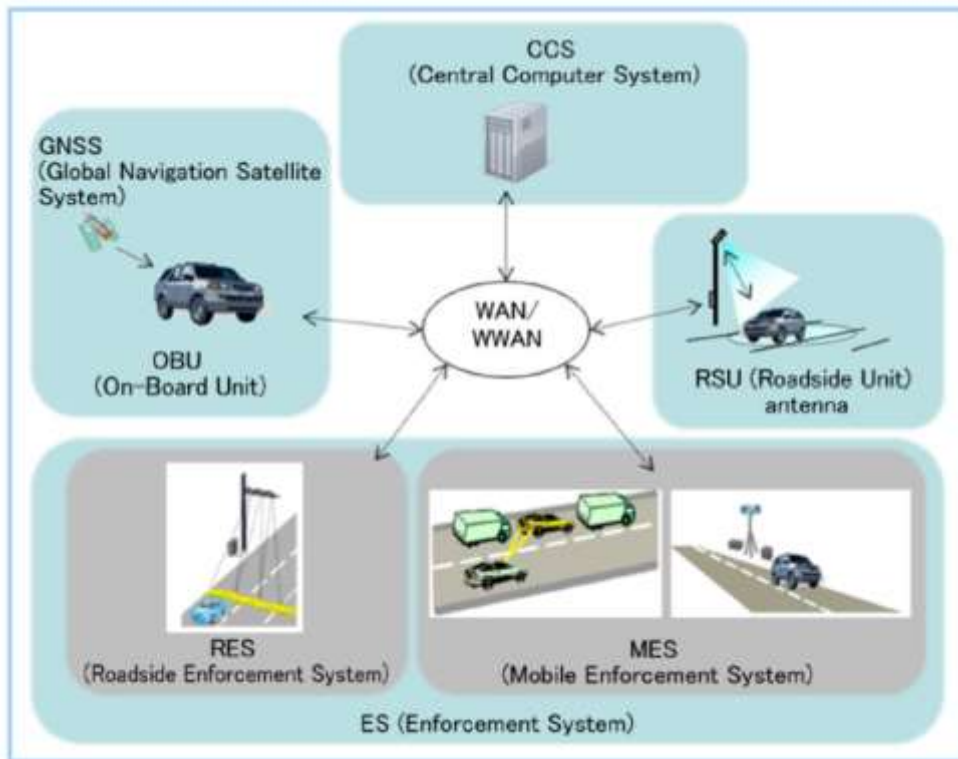
Global Navigation Satellite System Road Pricing expected to allow more flexible expansion of road pricing, particularly to suburban areas.

- GNSS also allows new pricing methods, such as distance-based pricing (no plans yet).
- GNSS On-Board Units to be installed 2021-2023, system activation in 2023.



GNSS ERP System Overview

GNSS System Component Architecture (Source: Hiura et al 2013)



On-Board Unit

(Source: Land Transport Authority 2020)



Implementation Issues with GNSS ERP

- Accuracy
 - In built-up areas, GNSS alone does not have sufficient accuracy for road pricing. GNSS has to be supplemented by Road-Side Units that use legacy Dedicated Short Range Communications (V2I) or GNSS Signal boosters.
- Tolling/Charging
 - The On-Board Unit has primary responsibility for assessing the correct road user charge and advising motorists of charges.
- System Costs
 - ERP gantries expensive to install and maintain. However, ERP gantries must be replaced by GNSS Road-Side Units in built-up areas. Unclear if GNSS Road-Side Unit costs substantially lower than legacy ERP gantry.
 - Proprietary technology in present ERP system factor behind decision to replace with GNSS. Unclear if GNSS system has allowed substantial shift to open-source technologies.
 - OBU criticised for being primitive (by 2020 standards); costs and performance unclear. While modern smartphones have similar functionality to OBU, unknown if accuracy can be maintained over a wide range of different handsets – charging must also be accurate since OBU levies charges, not the central computer system.

Using GNSS ITS to enhance Eco-Friendly Vehicle Policy

- Singapore generally promotes public transport, shared transport, and active mobility instead of encouraging private EV use. EVs not exempt from vehicle quota, tax, road pricing.
- Singapore targets phase-out of ICE by 2040. Low/zero emissions vehicle policy now implements purchase tax incentives / surcharges; engine-capacity based annual road tax; fuel excise duty. However, no marginal vehicle charges or usage restrictions based on eco-friendly criteria are planned.
- GNSS ERP would allow policies such as (not implemented or planned in Singapore yet):
 - Charging vehicles by location, distance, and emissions intensity
 - Restricting usage by location / time of day or emissions-gating vehicles
 - Replacing fuel excise duty with distance-based charges
 - Replacing time-based vehicle quota policy (new vehicle registrations are valid for 10 years) with distance-based policy (e.g. valid for 100,000km)

Lessons Learnt - Technical

- Road User Charging System planners should consider lifecycle costs, particularly with respect to maintenance, upgrading, and system expansion.
 - Technological obsolescence is fact of life, so replacement planning should take place soon after implementation.
 - Backwards compatibility may need to be addressed through mandatory, Govt-paid installation of OBUs (Singapore's approach to implement both ERP and GNSS ERP).
- GNSS-based systems, while proven in long-distance tolling, have to be supported by infrastructure and tested in built-up areas for performance and reliability.
- An open system architecture will allow for additional value-added services.
 - Current ERP V2I technology is also used for parking in Singapore.
 - GNSS On-Board Unit is intended to allow third party location-based VAS.

Lessons Learnt - Political

- While road user charges are controversial, emphasising positive outcomes in addressing congestion, emissions, and funding road infrastructure could overcome resistance.
- In Singapore, road user charges were argued to be necessary so that the vehicle population could be expanded without causing congestion (carrot and stick approach)
- In other cities, road user charges could be argued to pay for road infrastructure maintenance and development (possibly more popular than earmarking for public transport infrastructure); protecting local environment (by surcharging high emissions vehicles).

No one-size-fits-all eco-friendly vehicle policy?

- Singapore pioneered the use of road pricing and vehicle quotas to successfully manage congestion in a densely urbanised small city-state.
- However, eco-friendly passenger vehicle policy has taken a backseat until recent plans to phase-out ICE by 2040. Some reasons:
 - Singapore is a small market and has no automotive industry, so manufacturer standards may greatly reduce consumer choice whilst being ineffective.
 - Promoting and investing in public transport, transit-oriented development, active mobility, have greater environmental impact than enhancing eco-friendliness of private motor vehicles.
 - Private motor vehicle owners are higher income, so policies favouring eco-friendly passenger cars are often regressive.
 - EVs still cause local congestion and pollution!
- Singapore's experience can be instructive for small states and cities, who may not want to adopt eco-friendly policies designed for large states with automotive industries and non-urban travel demand.

Appendix

Report of the Parliamentary Select Committee on Land Transport Policy (1990)

The Committee observes that there is a tendency for members of the public to regard usage restriction measures like Electronic Road Pricing (ERP) as the panacea for the road congestion problem. This misconception should be dispelled. Usage measures, when extensively applied, are likely to be just as painful if not more painful than ownership measures. They also carry the odium of being recurrent, on a daily basis, as compared to ownership restraints which are largely of a one-time nature.

The correct way to view usage restraint is that it is a supplementary instrument to sharpen the efficacy of ownership restraint measures. Effective usage measures such as the ALS make it more costly to operate a vehicle during heavy traffic periods in congestion prone areas such as the Central Business District (CBD). They therefore restrain the use of vehicles during these hours and enable the road system to sustain a higher rate of car ownership by the population...

The judicious application of usage measures can therefore raise the level of car ownership in Singapore and help satisfy the aspirations of a proportion of the population who wish to own cars for reasons of prestige or convenience for social activities and are willing to leave them at home and use the public transportation system for commuting to work.

- Vehicle usage restraints (road pricing) were considered more politically costly than ownership restraints (purchase taxes / quotas)
- But, vehicle usage restraints allow expansion of vehicle ownership while restraining congestion
- Start of 'carrot and stick' vehicle management policy where expanded vehicle ownership (carrot) is balanced with road user charges (stick).

The Vehicle Quota Scheme 1990

- Up till 1990 vehicle ownership was managed through increasingly heavy purchase taxes and annual road taxes. Intent was to target vehicle growth rate in line with road network expansion but outcomes were suboptimal.
- The Vehicle Quota Scheme gave the Government full control over vehicle growth rates:
 - All motor vehicles must have valid “Certificate of Entitlement” to be registered. Registration can be renewed for up to 10 years.
 - New “COE” is required at end of 10 years.
 - COE Price or Quota Premium is set by auction.
- While VQS ensured total control over vehicle growth rates, high demand for vehicle ownership resulted in COE prices several times annual income – creating political pressure.
- This further reinforced the political importance of balancing road user charges with expanded vehicle growth rates.

The Debate on Electronic Road Pricing (1998)

[The] ERP system will make motorists more aware of the cost of road use. It will encourage motorists to choose the most optimal time, route and mode of transport for their journeys. The result will be a reduction in the number of trips made by private vehicles, more efficient use of our roads, smoother flowing traffic and less pollution. As the roads become less congested, we can review our vehicle quotas and, if feasible, release more COEs. Together, ERP and the Vehicle Quota System will provide a long-term sustainable and effective framework for managing the traffic on our roads. – Minister for Communications on the introduction of Electronic Road Pricing

- Introduction of ERP tied to ongoing expansion of car ownership.
- To ease introduction, ERP rates set below that of the ALS (which it replaced). Vehicle taxes restructured and lowered as part of gradual move towards usage-based restraints.

Continuing policy shift from Ownership to Usage-based Restraints in 2000s

To better manage the demand and usage of vehicles, we are also planning to shift the balance from ownership costs to usage costs such as congestion pricing. Congestion pricing will help to relieve choke points and encourage more optimal usage of the road network, thereby ensuring that our roads remain free-flowing even as more Singaporeans are given the opportunity to fulfill their aspirations to own cars. To achieve this, we would need to consider expanding the existing ERP cordon to other areas and times of the day, where traffic conditions warrant. (Ministry of Transport 2005)

- Expansions of the ERP system politically supported by argument that shifting to usage-based restraints would allow greater car ownership.
- Future ERP systems argued to provide flexibility to charge users according to marginal impact of congestion and road use, or allow conversion of car ownership quota from time-based to distance-based, allowing further expansion of car ownership.

Towards Car-Lite Urban Mobility in the 2010s

- Since the mid-2010s, no more policy statements that road pricing allows for expanded car ownership. Passenger car growth rate cut to 0% in Feb 2018; projected to remain at 0% through Jan 2022.
- Emphasis in new Land Transport Master Plans shifted to supporting “Car-lite” Urban Mobility, with significant increase in subsidies for public transit; new metro lines; cycling infrastructure.
- Policymakers likely to be more constrained in expanding road pricing methods in future.

Timeline for the GNSS ERP System

- 2000s: Planning begins for next-generation GNSS ERP System, led by existing ERP system technology / maintenance vendors.
- 2011: 18-month System Evaluation Test commences.
- 2014: Tender called for GNSS ERP System.
- 2016: Tender awarded for \$556M to National Computer Systems & Mitsubishi Heavy Industries Engine System Asia.
- 2020: LTA announces installation of GNSS on-board units to begin in 2021 with full changeover in 2023.

Legislative Issues

- Singapore has Westminster Parliamentary System. Unitary Govt, with National Govt also responsible for entire public road network.
- Government prices (tax rates, charges) are specified in Primary/Secondary legislation, or left to regulatory discretion subject to legislative limits.
 - Primary legislation requires formal Parliamentary vote
 - Secondary legislation becomes law once published formally in Govt Gazette.
- Road pricing implemented entirely in Secondary Legislation. Complete schedule of road prices and charged roads specified in law, all changes must be published.
- **Implications:** More complex forms of dynamic road pricing could require change in legislative framework.
 - Straightforward formulas (e.g. fixed increment for given road speed deterioration) likely implementable under existing framework.
 - Complex, algorithm-driven pricing (of the type used by ride-hailing companies, airlines) may not be feasible without legislative changes.

Overview of Eco-Friendly Vehicle Policy in Singapore

- Tax-incentive Vehicle Emissions Scheme (EVs have CO2 factor applied based on energy efficiency)
 - 2013-2015: Up to \$30,000 Tax rebate/surcharge based on CO2 emissions bands.
 - 2015-2017: CO2 emissions bands tightened; Up to \$45,000 rebate/surcharge.
 - 2018-2020: HC, CO, NOx, PM added to CO2 for emissions bands. Up to \$20,000 rebate/surcharge.
 - 2021-2022: Emissions bands tightened. Up to \$25,000 rebate/surcharge.
- Engine-capacity or Power-rating based annual road tax.
- Fuel excise tax. Additional road-tax based surcharges for diesel vehicles and electric vehicles.
- Schemes based on existing vehicle tax structure which imposes 100% to 180% registration tax on new vehicles.
- Like many countries, these taxes and incentives are point-of-purchase based, or annual. They are not marginal charges.

Theory and Performance of Singapore Road Pricing Systems

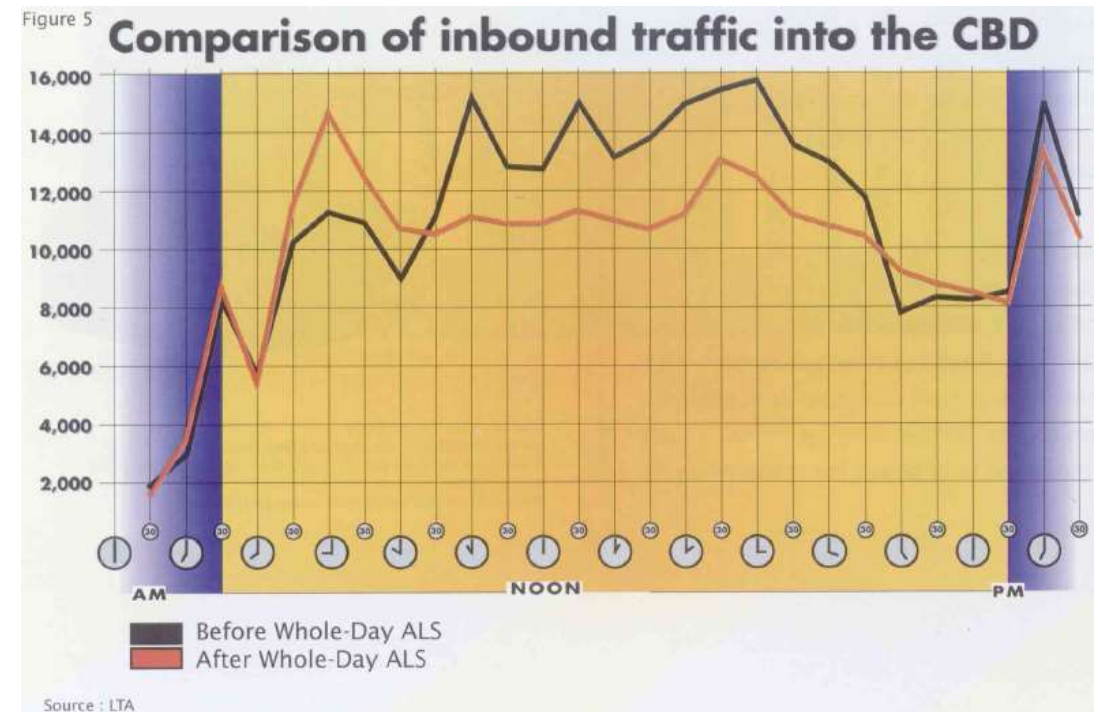
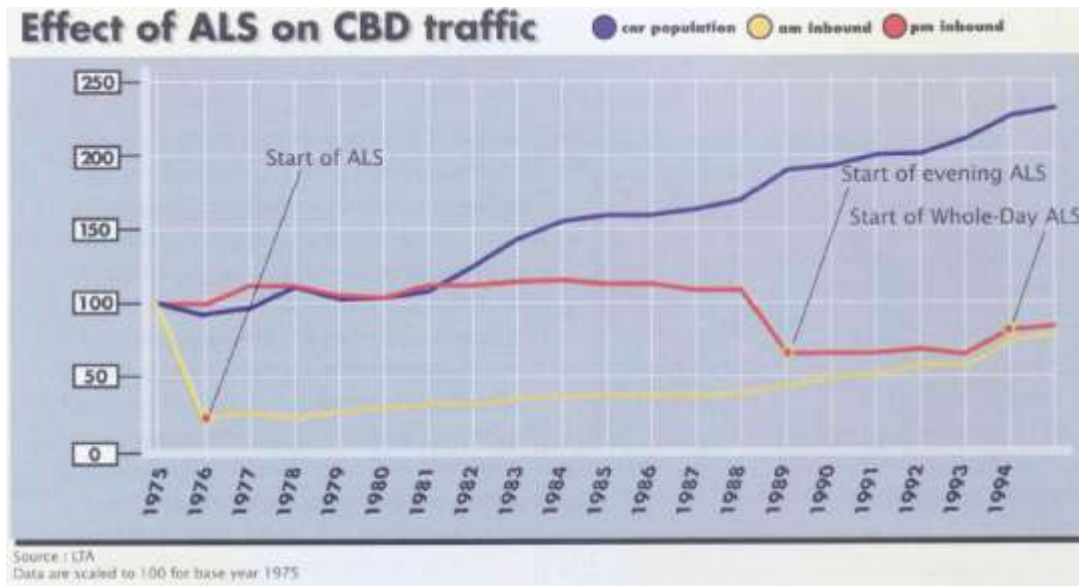
Area Licensing Scheme 1975

- Initially targeted 25% reduction in AM peak passenger car traffic (~7,000 out of ~28,000 cars entering CBD “Restricted Zone” from 7.30am to 9.30am).
- All low-occupancy passenger cars required to buy day license at \$3.00 to enter CBD during AM peak. Parking surcharge imposed on parking spaces within CBD. Bus lanes created within CBD.
- To support alternatives to driving, 10,000 park and ride carpark spaces created at CBD fringe, supported by subsidised shuttles.
- ALS generally regarded as inefficiently successful (Phang and Toh 2004); AM peak passenger car traffic fell by 76.2%. Heavy congestion during shoulder periods and in CBD fringe. Minimal effect on PM peak congestion.

ALS extended from 1975 – 1998

Vehicle exemptions were removed; Park and ride facilities and subsidies withdrawn; Whole-day pricing introduced.

Growing complexity of ALS provided impetus for ERP development



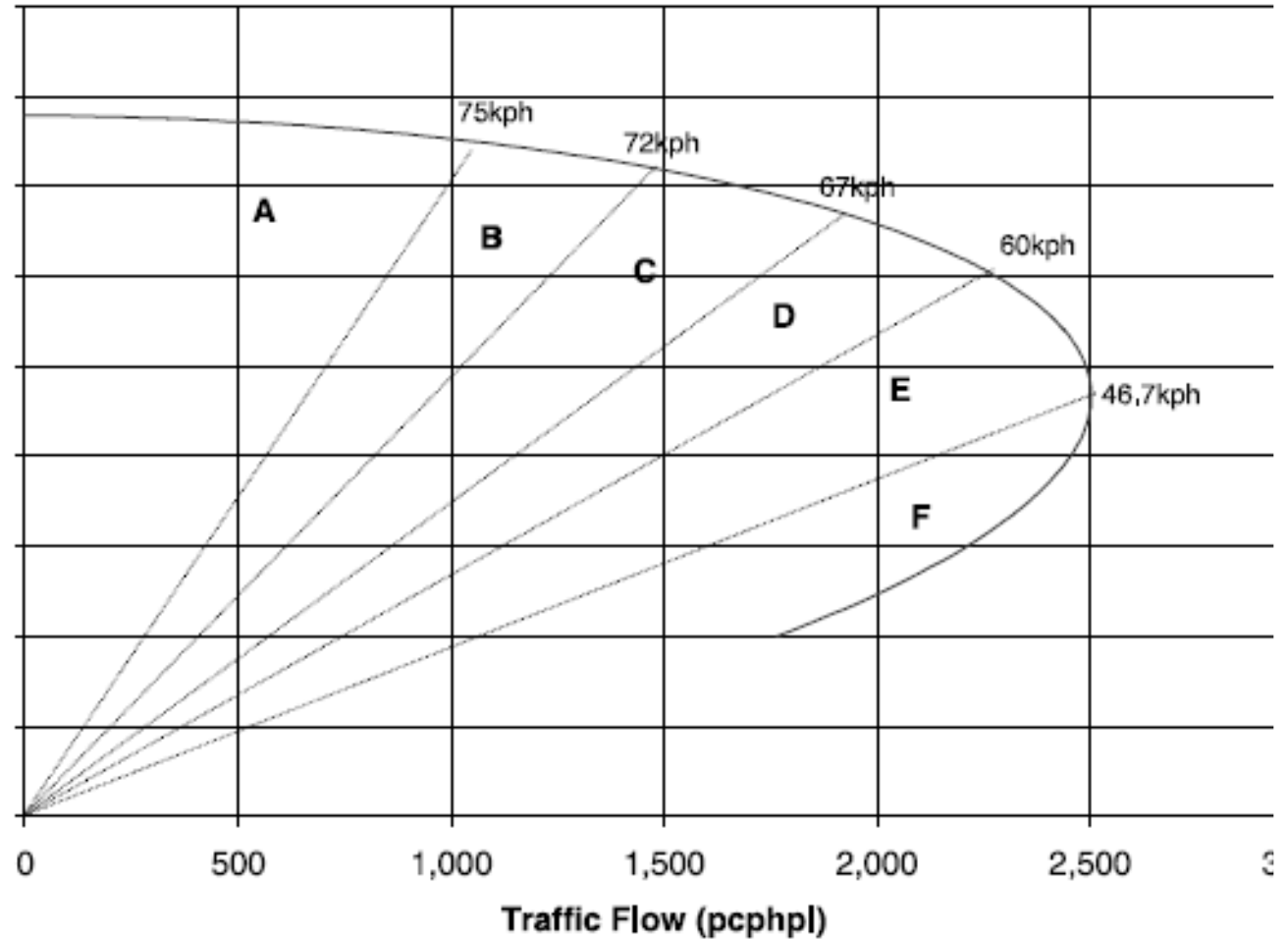
Source: White Paper on a World Class Land Transport System 1996

ERP Rate-Setting Policy

ERP rates are revised quarterly with the intent of maintaining traffic flows at Levels of Service D-E (which maximises vehicle throughput).

This means a speed of 45km/h – 65km/h on Expressways and 20km/h – 30km/h in the CBD/Arterial Roads.

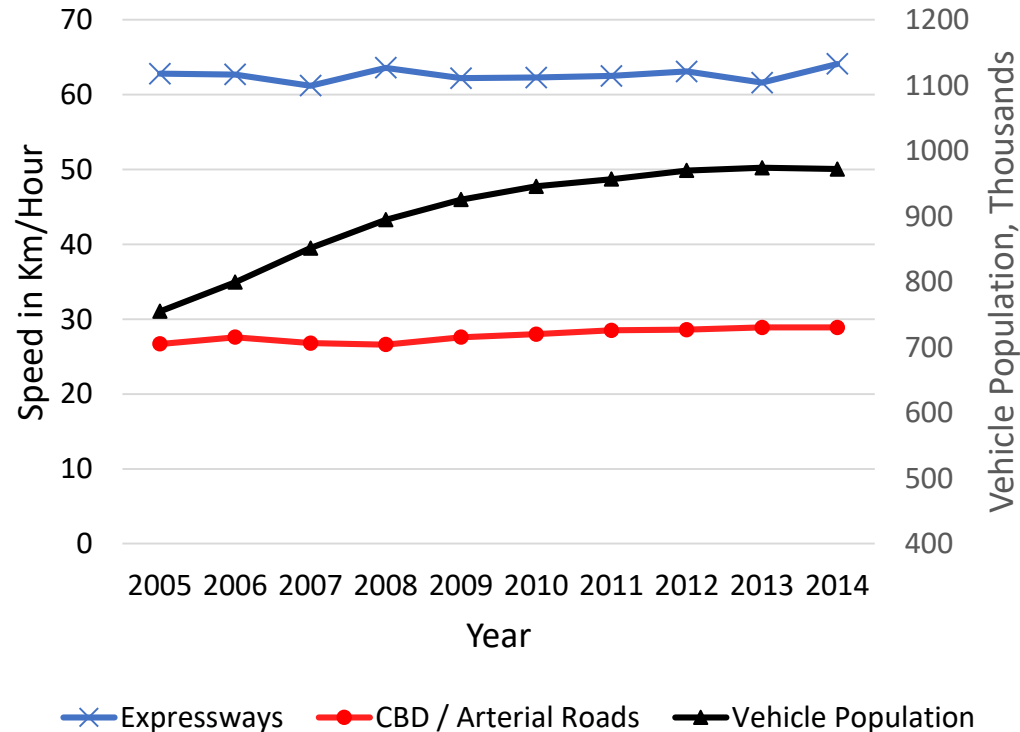
Li (2002) argues that tolling based on traffic-flow targeting approximates the optimal toll charge without requirement to estimate demand function.



Effect of ERP on Road Speeds and Peak-Spreading

Average Speed on Singapore Roads During Peak Hours in km/hour

(Note: Average of AM Peak (8am - 9am) and PM Peak (6pm - 7pm); Source: https://www.lta.gov.sg/content/dam/ltagov/who_we_are/statistics_and_publications/statistics/pdf/Traffic_Flow.pdf Accessed on 1 Sep 2020



Peak-Spreading Effect of Shoulder Pricing Method

Source: Figure 2, Olszewski and Xie 2005

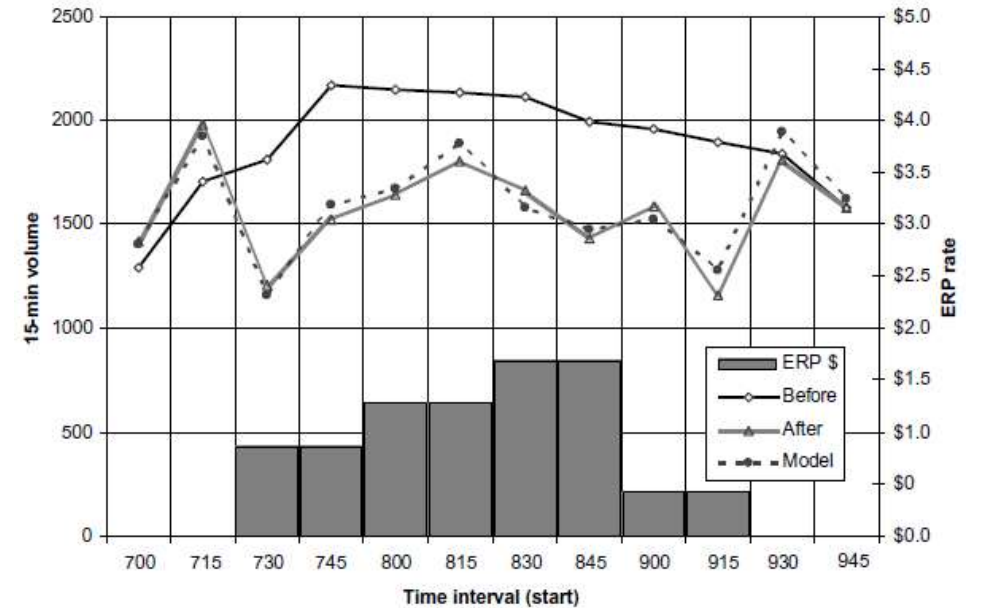


Fig. 2. Traffic pattern at AYE ERP gantry.

ERP Pricing Policy Considerations

- While ERP system pricing in principle only targets optimal traffic flow, some policy decisions in practice reveal that other considerations matter.
- ERP extended in August 2005 to charge motorists for home-bound evening peak trips on Central Expressway.
 - Highly controversial! Policymakers responded by announcing they would exercise greater flexibility before triggering ERP rate increases for evening outbound trips.
 - Suggests value of time / reliability does differ by time of day / purpose of trip.
- ERP extended in October 2005 to include Orchard Road shopping corridor.
 - Significant concerns expressed by retailers. Policymakers argued that pricing intended to deter through-traffic rather than shopping traffic.
 - Agarwal et al (2015) find that ERP price hikes appear to reduce retail property values.

ERP Prices and Finances in Perspective

- Road user charges have continuously declined in real terms since ALS in 1975.
 - Initial ALS day license in 1975: \$3.00 (\$7.23 in 2019)
 - Maximum ALS day license in 1980: \$5.00 (\$9.55 in 2019)
 - Maximum initial ERP CBD entry fee in 1998: \$3.00 (\$3.74 in 2019)
 - Real GDP per capita is six times higher in 2019 compared to 1975.
- Road user charges form a very small proportion of Government vehicle-related revenue.
 - ERP has generated about \$150M a year in early 2010s.
 - ERP generated 20% less than ALS in early 2000s due to lower ERP charges compared to ALS.
 - Vehicle ownership taxes generated \$2.623 B in 2018; Vehicle quota premiums generated \$3.616 B in 2018.
 - Vehicle taxes and premiums formed 8.5% of Govt operating revenue in FY 2018.

Considerations for the Next-Generation ERP System

- Distance-Based Pricing?
 - Little known about how regular motorists respond to distance charges.
 - Ong, Riyanto and Theseira conducted behavioural experiments for Land Transport Authority in 2013 to test whether presenting the same charge as point-based, distance, or hybrid resulted in changes in motorist behaviour.
 - Motorists perceive a point-based toll (\$2 to drive on a 2-km tolled expressway) to be more psychologically costly than the same charge specified in distance-based terms (\$0.10 per 100 meters).
- Motorist behaviour management through technology?
 - OBUs can be used to guide motorists, offering different priced alternatives.
 - Some research conducted on OBU interface, but unclear if this included pricing.
- Welfare effects of ERP?
 - Little research besides early studies on ALS.
- More research is needed!