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Curbing Urban Traffic Congestion in Singapore: A Comprehensive Review

One of the most pervasive and frustrating of modern transportation problems is urban traffic congestion. For example, the average vehicular speed during peak hours is 11 miles per hour in Stockholm, 10 in Hong Kong, 7 in London and Manila, and only 6 in New York and in Bangkok (where two-hour one-way commutes on congested streets are not uncommon).¹ Many cities around the world have considered or implemented some form of traffic restraint.² Singapore is no exception.

Singapore is a small island city-state, about 250 square miles in area, strategically located at the crossroads of commerce and tourism at the southern tip of the Malaysian Peninsula. With a 3.4 million resident population, it has a very high population density of 13,600 persons per square mile, compared to 75 in the United States. Located only three degrees north of the equator, the country is hot and humid, creating a heavy demand for air-conditioned private transportation. Singapore now has 350,000 cars (95 percent privately owned) out of 650,000 registered motor vehicles traveling on 1,900 miles of roads, resulting in a linear density of about 340 motor vehicles per mile. This very high motor vehicular density compares with only 100 in the United Kingdom, 69 in Japan, and 44 in the United States.³ More to the point, there are 44 cars per 100 households in Singapore, about two-and-a-half times higher than in Hong Kong, a comparable city-state.

A major reason for Singapore's love affair with the car is that economic growth has been nothing short of phenomenal, averaging 8 percent over the last 30 years. Singapore's per capita gross national product in 1996 was S\$37,000 or approximately US\$26,500 (where

S\$1 = US\$0.71), comparable to the United States and exceeding most western countries. Cars are very expensive in Singapore. The popular Honda Civic (1,600 cc automatic) retails for about S\$149,000 or about US\$106,000, approximately seven times the cost in the United States, with an accompanying annual registration fee (road tax) of S\$1,440 or close to US\$1,000, about four times what it costs to license a compact car on U.S. roads. Furthermore, in addition to paying a fortune to buy a new car in Singapore, the owner has to decide in advance when and where to drive, what size car to purchase, and whether it should be registered as a private or corporate car. Then one bids for a license to own a car, waits for the results of the auction, and if successful, pays US\$100,000 for a compact car, installs a smart card reader on the dashboard to pay for a soon-to-be-implemented system of automatic tolls, and then goes through the experience all over again in ten years (or whenever one wishes to purchase a new car).

THE AREA LICENSING SCHEME

The problem of urban traffic congestion in Singapore reached a peak in 1975 when during the morning and evening rush hours, traffic in the Central Business District (CBD) crawled at an average speed of only 12 miles per hour, prompting the authorities to discourage the entry of cars into the CBD by instituting an area-wide system of tolls. Singapore's world famous Area Licensing Scheme (ALS), the most comprehensive of its kind in the world, was implemented in June 1975, defining a Restricted Zone (RZ) of slightly more than two square miles in the CBD with initially 22 vehicular entry points (now expanded to 33) at its boundaries. All vehicles except those in the exempt categories had to possess and display a special decal costing S\$3 per day or S\$60 per month (double for company registered cars) to enter the RZ during the restricted times, from

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7:30 a.m. to 9:30 a.m. Monday through Saturday. It was hoped that the morning restrictions would have a "mirror image" effect on the evening return flow.⁴

Since its inception, the ALS has undergone numerous changes to the restricted hours, fees, and categories of restricted vehicles. Today, the ALS operates from 7:30 a.m. to 7:00 p.m. weekdays and from 7:30 a.m. to 2:00 p.m. on Saturdays, except on public holidays, with police, emergency vehicles, and scheduled buses exempted. There are now two types of ALS licenses: Whole-Day, which costs S\$1 for motorcycles and S\$3 for other vehicles and valid for all hours of operation, and Part-Day, which costs S\$0.70 for motorcycles and S\$2 for other vehicles and valid from 9:30 a.m. to 4:30 p.m. on weekdays and 9:30 a.m. to 2:00 p.m. on Saturdays. Monthly licenses cost 20 times the price of daily licenses, and company vehicles pay a double rate because the fees are tax deductible.

As a result of the implementation of the ALS, affected motorists shifted their trips to just before and after the restricted hours to avoid paying the fee. Note that part-day licenses were successfully introduced as a form of shoulder pricing to help even out the peaks and valleys in traffic patterns.⁵ In addition, morning and evening peak hour traffic has been diverted to new "escape corridors" that bypass the RZ. An immediate result of the introduction of the ALS in June 1975 was to reduce the traffic volume by 45 percent during the morning peak hours, far exceeding the original target of 25 to 30 percent, and average speeds went up from 12 to 22 miles per hour.⁶ The introduction of evening ALS from 4:30 p.m. to 7:00 p.m. and the extension of restrictions to goods vehicles and motorcycles had a similar effect, reducing inbound evening traffic by 44 percent with traffic speeds now averaging 20 miles per hour.⁷ The introduction of the ALS also led to a modal shift from private to public transportation, the latter of which increased its share from 33 percent to 69 percent.⁸

The theoretical foundations of road congestion pricing for allocative efficiency were first proposed by Pigou⁹ in 1920 and Knight¹⁰ in 1924, and were advocated by the famous Smeed Report¹¹ for use in the United Kingdom in 1960. Walters in 1961, Thompson in 1962, Roth in 1967, Vickrey in 1967, Solow in 1973, Pines and Sadka in 1985, and Morrison in 1986

developed the concepts further.¹² In 1992, a World Bank economist provided a comprehensive review of the theory of road pricing and optimal tolls¹³ and in 1994, two researchers surveyed international practices in road pricing.¹⁴

Essentially, economists argue that traffic congestion arises because the marginal user of a crowded road takes into account only his or her private cost and ignores the fact that his or her vehicle slows down and inconveniences others. Thus the marginal social cost exceeds the marginal private cost of congested road usage. Neo-Classical welfare theorists therefore argue for a Pigouvian toll on the use of congested roads to increase the individual cost of usage by an amount equal to the external diseconomies imposed by one commuter on all others in order to equate marginal social cost with marginal social benefit.

As we have seen, the ALS succeeded in curbing urban road congestion, but perhaps only too well, since the initial 45 percent reduction in traffic volumes far exceeded the intended target of 25 to 30 percent, leading to underutilized roads and a rationing of road infrastructures that were no longer scarce. In one of the earliest articles on the ALS that was published in 1977, the first author, examining the changed pattern of drastically reduced traffic flows, had demonstrated mathematically and by diagrammatic analysis that the ALS fees were too high, leading to underutilized roads.¹⁵ At the much lower traffic volume, the marginal private cost curve is horizontal with zero cost elasticity, and since there is no divergence between the marginal social cost and marginal private cost, there are no external diseconomies, thus paradoxically invalidating the very toll that brought about the situation. Since then, other studies (using 1975 data) on the ALS have come to the same conclusion.¹⁶ More troubling, the congestion shifted to just before and after the restricted hours and to the peripheral ring roads,¹⁷ and those who had switched to buses contributed to increased travel times for all bus riders, leading to a decline in social welfare.¹⁸ However, these problems have been reduced, given the significant increases in ring road capacity and the number of buses, and the opening of a state-of-the-art Mass Rapid Transit system.

In spite of shortcomings, the ALS has been very successful in curbing road congestion, thus it was extended. A linear Road Pricing Scheme (RPS) was introduced on the East

Coast Parkway in June 1995 and on the Central Expressway and Pan Island Expressway in May 1997. Motorists pay S\$2 and motorcyclists pay S\$0.70 to use these highways from 7:30 a.m. to 9:30 a.m. Mondays through Fridays, excepting public holidays. Again, the monthly license is 20 times the daily cost, and a valid Whole-Day or Part-Day ALS license can be used as an RPS license. The allowable dual usage of the licenses for both the ALS and RPS created a congestion problem, especially on the Central Expressway. Thus on July 1, 1997, motorists using the Central Expressway during the restricted period from 7:30 a.m. to 9:30 a.m. and then entered the CBD had to purchase a Whole-Day license, effectively making dual usage more expensive. As a result, the number of motor vehicles using the Central Expressway fell from 13,000 to 9,000 and traffic speeds improved from an average of 18 mph to 40 mph.

GENERAL PRICE RESTRAINTS

The very high initial tolls and drastic reductions in peak hour traffic in the CBD reflected a longstanding policy of restricting the growth of car usage in Singapore. As early as the 1970s the government had embarked on an aggressive policy of restraining the rapid growth of cars by increasing the cost of ownership and operation. The system of taxation and fees on cars is rather complex, generally depending on the value and engine capacity of the car. For illustrative purposes we will consider one car model.

The Open Market Value (OMV) or destination price c.i.f. on a new Honda Civic (1,600 cc automatic) is about S\$22,000. Singapore imposes an ad valorem customs duty of 41 percent on all imported cars with a Goods and Services Tax (GST) of 3 percent. On top of this, there is a high Additional Registration Fee (ARF) equal to 150 percent of the OMV.

Dealer markups in Singapore are exceptionally high. In a previous comprehensive work on urban transportation in Singapore published in 1992, the second author had estimated that the dealer markup on new car sales in Singapore averaged about 80 percent, but could be as high as 305 percent for the Maserati Biturbo 220.¹⁹ However, in a consultant's report to the Automobile Association of Singapore prepared in 1995, the first author discovered that the average dealer markup on new car sales in Singapore had dramatically gone up to about

124 percent because of the increased cost and risk associated with selling new cars (more about that later).²⁰ The main reason that the average markup on new cars in Singapore is about ten times more than in the United States is that cars in Singapore are sold by *sole* distributors at *fixed* prices, and the top five corner 63 percent of the new car market.²¹ Note that although the sole distributors allow independently owned branches to sell their makes, the distributors control the retail prices. One dealership, with four independently owned branches, revealed to one of the authors that the names of potential customers who initiate negotiations are keyed into the computer system so that no other retail branch can negotiate with the customer for two weeks (one month for commercial customers), thus the high sustainable markups on cars because of the total absence of competition within models. Then there is a one-time registration fee of S\$1,000, an annual road tax of S\$1,400, insurance of S\$500, and a Certificate of Entitlement (COE) quota premium of S\$54,000, which constitutes the May 1997 auction price of a license to own a car in that engine capacity category (to be discussed later).

Summarizing, for the month of May 1997, the cost components of a privately licensed new Honda Civic in Singapore would be approximately as follows:

OMV	S\$22,000
Import tax (41 percent of OMV)	9,000
GST (3 percent of OMV plus import tax)	1,000
ARF (150 percent of OMV)	33,000
Dealer markup (124 percent of OMV)	27,000
Registration fee	1,000
Road tax	1,500
Insurance	500
COE	54,000
Total	S\$149,000

Note that of the total price of S\$149,000 on the Honda Civic, the government collects about S\$100,000 in taxes and fees, or about two-thirds the retail price of the new car.

Given the high taxes on new cars to discourage increased car ownership to help curb traffic congestion in Singapore, one would expect people to switch to one of the world's best systems of public transportation,²² or at least to purchase small "inexpensive" stripped-down cars. In 1996, the Mercedes Model E, which costs S\$300,000, overtook the Honda Civic to become the best selling new car model in Singapore. This rather paradoxical turn of

events can be explained by the Third Law of Demand (the Alchain and Allen Theorem), which postulates that where there is a dramatic change in relative prices (the luxurious Mercedes Model E is now only twice as expensive as the humble Honda Civic), the substitution effect predominates. That is to say, whereas the Mercedes Model E used to cost three times as much as the Honda Civic, since the former is now “only” twice as expensive as the latter, the Mercedes becomes a good buy.

A peculiar system of tax rebates called the Preferential Additional Registration Fee (PARF) has been in existence since 1975. Concerned that high prices for new cars would encourage motorists to keep their cars for longer periods, consequently increasing the average age of cars on the road leading to more frequent traffic-slowing breakdowns, the government offered car owners a percentage reduction (up to 65 percent in one instance) on the ARF on new privately owned cars if an old car in the same engine capacity group or larger is scrapped or reexported before the end of its tenth year. This created an instant market for scrap cars, and as the price of new cars rose steadily with inflation, accompanied by a rise in the value of the Japanese yen and coupled with a rise in the ARF rate itself, the value of the discounted PARF associated with scrap cars rose correspondingly. In one instance, the Mazda 929 (which falls within the engine capacity group of 2,001 cc to 3,000 cc) cost S\$31,000 in 1979. Ten years later in 1989 the same car could be sold for scrap at a price of S\$44,000 to get the PARF on a more expensive Mercedes. In no other country in the world is a car an appreciating asset (incidentally, this creates an actuarial nightmare for insurers and leasing companies). This perverse unintended anomaly led some people to purchase cheap cars with large engine capacities from Russia and Eastern Europe for their ultimate speculative scrap value.²³ For this reason and others, the PARF system went through many changes. But as it now stands, for cars registered after November 1, 1990, the lump sum value of a PARF rebate is equal to 80 percent of the OMV of the old car at the time of its registration, and this can be used to offset the ARF on any new car. Cars that are ten years old or older are required to pay a surcharge on the road tax equal to 10 percent a year beyond ten years, up to a maximum of 50 percent—once again as an inducement to

get older cars off the road.

To discourage car usage, Singapore imposes either a 50 percent *ad valorem* tax on gasoline or a duty of US\$1.60 per U.S. gallon, whichever is higher, so that the retail price of gas is around US\$3.30 per U.S. gallon. To discourage Singaporeans from driving north to Malaysia to refill their tanks with cheaper gas, the government passed a law called the “Half-Tank Rule,” which requires Singapore registered cars to have at least half a tank of gas (later changed to three quarters) when leaving Singapore and before entering Malaysia. Later on the same day, Parliament passed another law making it illegal to drive a motor vehicle with a faulty fuel gauge.

To further discourage car usage in the restricted zone, parking rates in the CBD were periodically increased so that today, the rates are \$0.90 per half hour between 8:30 a.m. and 5:00 p.m., and half the amount during nonpeak hours. Outside the CBD where there is less congestion, the parking rates are S\$0.45 per half hour during enforcement hours, from 8:30 a.m. to 10:00 p.m.

As we have seen, Singapore has aggressively used pricing policies to discourage both the ownership as well as the usage of cars.²⁴ Thus today, 51 percent of all motorized trips are by public transport, 3,000,000 by bus, and another 700,000 by the Mass Rapid Transit system. However, in spite of the significant shift to public transportation, with little tolerance for traffic congestion in a country built on commerce and dependent on tourism, the government decided that high prices were insufficient deterrents to the use of private motor vehicles. For instance, in 1989, because of a high economic growth rate (9.6 percent), there was a 9 percent increase in the number of cars over the previous year, much in excess of the long-term average growth rate of 4.2 percent, and very much greater than the average 1 percent annual growth in the number of miles of roads in Singapore. Reporting to the Parliamentary Select Committee on Land Transportation, the second author had computed the income elasticity of demand for cars to be around 1.0, whereas the price elasticity was only -0.45, meaning that the demand for cars in Singapore is driven more by increasing incomes than deterred by increasing prices.²⁵ Partly based on this discovery, the Committee concluded that in view of Singapore’s land constraints and robust econo-

my, the number of motor vehicles had to be controlled and kept below the level that the then existing ineffective pricing mechanism would permit. The Committee then went on to recommend a quota on the maximum annual increase in the number of motor vehicles.

THE QUOTA SYSTEM

The quota system on new cars (the only one of its kind in the world²⁶), implemented on May 1, 1990, has been extensively discussed and analyzed in previous studies by both authors working independently.²⁷ All motor vehicles except scheduled and school buses and emergency vehicles are subject to fixed allocations. Two systems of allocating the quotas were considered—by free balloting as in a lottery, and by silent auction. It was felt that while balloting is more equitable, motor vehicles would not necessarily go to people who need them most. An auction was considered more desirable on efficiency grounds, because the vehicles would be allocated to owners who are willing to pay the most for them, thus maximizing social welfare. The Quota System, like most other measures to curb traffic congestion in Singapore, has undergone numerous changes. As it now stands, anyone who wants to buy a new motor vehicle must bid at an auction (held once a month) for a Certificate of Entitlement (COE) to own a car for ten years, in line with the existing limit for PARF benefits.²⁸ If the vehicle is scrapped or re-exported before the ten-year period expires, the owner receives a pro-rated rebate of the paid quota premium. If the owner chooses to keep the vehicle beyond ten years, he or she will not be required to bid for a new COE, but will have to pay the prevailing quota premium (based on the moving average of the past twelve months) for the appropriate category of vehicles in order to revalidate the entitlement for another ten years (the fee is halved for a five-year extension). To prevent those who can afford bigger cars from outbidding those who can afford only smaller cars, there are four categories for cars of different engine capacity groups, one category for goods vehicles and buses, one for motorcycles, and an open category to allow some leeway for market forces to determine the vehicular mix.

The quota for each of the seven categories is announced in advance. Bidding is done electronically by sealed tender accompanied by a

returnable deposit equal to half the tendered amount. But instead of charging successful tenderers what they had bid, thereby appropriating all consumer surplus through perfect price discrimination, it was decided that everyone on the high side will pay the *lowest* successful tender price, referred to as the “quota premium,” for the respective vehicle category.²⁹ Again, company cars must pay twice the amount because the quota premiums are tax deductible.³⁰

Upon implementation of the Quota System, speculative activity soon became rampant because of ever increasing quota premiums. Between May 1990 and July 1992, 86 percent of new cars were registered using COEs (which were originally good for six months and transferable only once before being used to register a vehicle) purchased in the secondary market. Today, each individual can submit only one bid in each tender exercise, firms can make any number of bids, but car dealers cannot, and COEs for the car and motorcycle categories are now nontransferable. Although technically barred from participating in auctions, car dealers in Singapore continue to submit bids on behalf of their customers. A potential buyer will put up S\$5,000 to bid for the COE that the dealer will tender on his or her behalf, advancing the tender deposit. If the bid is successful, the deal goes through, otherwise the dealer will try again in the next tender exercise. Prices of cars were quoted inclusive of the prices of COEs. If the quota premium was below the contract amount, there is usually a rebate, but if it was above the contract amount, the dealer will usually split the difference evenly, thus assuming some risks, not unlike selling short on the stock market. Dealers also bid through proxies, paying relatives and friends between S\$50 and S\$100 to use their names, register the cars under their names, and then arrange for the transfer of car ownership when it is actually sold after paying a transfer fee of 2 percent of the car's value. This practice came to be known as “double transfer” in the trade, and accounted for about one third of all new car sales between January and September 1994.³¹ Altogether in one way or another, the 28 sole distributors in Singapore controlled more than two-thirds of all the bidding, and therefore could more or less predict what the quota premiums would be for each category of vehicles. They routinely traded, lent, or borrowed COEs from one another.

Having cornered the market for COEs, the dealers were also selling cars as "investments," since the price of the COE kept going up.³² Because of ever increasing demand for cars, by late 1994 and for two categories of vehicles, the quota premium exceeded S\$100,000. The point bears repeating. Singaporeans were willing to pay upwards of US\$70,000 for the right to own a car for ten years.

On February 19, 1995, in order to discourage double transfers and to break the stranglehold of the car dealers on the market for COEs, the government banned the transfer of cars within three months of first registration, among other things. Using multiple input transfer function noise and lag polynomial models, the second author discovered that with the new curbs, speculators were less able to corner the market for windfall gains.³³

When the Quota System was first introduced in May 1990, the quota premium for a Honda Civic (considered a medium-sized car) was a mere S\$1,800. By May 1997, seven years later and in spite of all the measures taken by the government to minimize speculation and monopoly, the quota premium had gone up to S\$54,000, since on average the number of bids tendered is about twice the allocated quota of approximately 3,500 cars a month. Quota premiums fluctuate with demand, which in turn depends on the state of the growing economy, the price of imported cars, additional restraints on vehicular ownership and usage imposed by the government, consumer psychology, and speculative activity. In previous studies, both authors working independently showed that by introducing the quota system, Singapore has achieved certainty in the maximum number of new motor vehicle registrations each year, but at the expense of the public's anxiety over fluctuating prices.³⁴ In other words, the problem of uncertainty has not been solved—it has merely been shifted. A priori, which kind of uncertainty causes larger welfare losses cannot be determined.

PARALLEL IMPORTS AND COOPERATIVES

Frustrated with the high dealer markups and their stranglehold on the COE market, independent dealers have started to engage in what has been called "parallel imports" of cars into Singapore to challenge the sole distributors' monopoly. This had an immediate downward

effect on the retail price of targeted models. For instance, prior to the parallel importation of the subcompact Nissan March (1,000 cc), the sole distributor was selling the model at S\$76,000 inclusive of COE. But with parallel imports of that model, the price dropped to S\$69,500, despite higher COE prices, while the parallel importers were selling it at between S\$65,900 and S\$66,800.³⁵ Sole distributors have threatened to retaliate by cornering the market for COEs by bidding them up through their prospective buyers (by May 1997 the quota premium for small cars at or below 1,000 cc reached a peak of S\$36,000). They have also tried to frighten off purchasers of parallel imports by implying that cars made for Japan and Europe are unsuitable for the tropics, and that they will not service these cars, which can be singled out by their vehicle identification numbers. Meanwhile NTUC Income, a trade union insurance company, plans to help its policy holders import their own cars and assist in arranging for freight and insurance. Furthermore, it intends to parallel import small cars to be used in an experimental car sharing cooperative in two housing estates starting in June 1997, along the lines of those found in Germany, Switzerland, and Britain. Each cooperative will have about 75 to 100 members sharing five cars and paying a one-time entrance fee of S\$100, S\$100 in annual subscriptions, and a rental fee of S\$9 per hour for the use of a car. If the scheme proves popular, it will be extended to other housing estates. This is a very significant development, because 85 percent of Singaporeans live in very dense high-rise housing estates, and Singapore may be the most ideal country in the world for jointly owned and operated car cooperatives. Parallel imports and car cooperatives represent the first incursions into the monopolistic stranglehold of the sole distributors. Finally, the rules of the game have been changed.

WEEKEND CAR SCHEME

In May 1991, Singapore implemented an unusual program called the Weekend Car Scheme to encourage the use of private cars during off-peak hours. Motorists were given financial incentives such as a 70 percent discount on the annual road tax and rebates on the registration fee, import duty, and COE quota premium up to a maximum of S\$15,000 if they

register their new cars as weekend cars, which can be used only from 3:00 p.m. on Saturday and the whole of Sunday and public holidays, as well as from 7:00 p.m. to 7:00 a.m. on weekdays. The cars are identified by red license plates fixed with tamper-proof special screws and coded seals and accompanied by stiff fines (in the thousands of dollars) for usage violations. To accommodate emergencies, each weekend car is given five free daily coupons per year and additional coupons can be purchased for S\$20 each.

Although the Weekend Car Scheme was implemented in response to popular public demand and was well intentioned, it became a public relations embarrassment because of its unintended effects. As it turned out, many of the weekend cars were either luxury cars enjoying the 70 percent discount on the high annual road tax and the other financial incentives, or the second or third cars belonging to affluent households. Also, the owner of a Porsche 911 (3,600 cc) would enjoy a S\$4,400 savings on the annual road tax, which alone would pay for a lot of daily licenses. In July 1994, the newly introduced Weekend Car COE cost S\$27,000 while the COE for a car in the large category (2,001 cc and more) was S\$65,000. Thus a person registering a large car as a weekend car could save \$38,000 on the COE quota premium and also enjoy the maximum rebate of S\$15,000 on import taxes, etc. The upfront savings of S\$53,000 on a luxury car were enough to purchase ten years of S\$20 daily coupons. The redistributive effects were widely perceived to be unfair to the less wealthy.

Responding to public dissatisfaction of rich people purchasing luxury weekend cars for daily use, the government revamped the scheme in October 1994. The new Off-Peak Car Scheme with the same hours of restriction offers the same tax incentives regardless of car engine capacity: a flat S\$17,000 rebate at the time of registration, and a flat \$800 discount on the annual road tax. The specially created Weekend Car COE category was removed. Rich and poor are now treated equally.

ELECTRONIC ROAD PRICING

As we have seen, despite the pent-up demand for cars, the ALS/RPS has succeeded in curbing urban traffic congestion in Singapore. But the schemes are manually operated and have become more complicated over time, with four-

teen types of licenses (Whole-Day ALS, Part-Day ALS/RPS, and daily and monthly licenses for three categories of restricted vehicles, privately and company owned). Motorists must figure out what type of license to buy, and visual enforcement by the police has become very difficult as vehicles are not obliged to slow down as they approach the gantry (entry) points. Moreover, the different licenses can be illegally switched among vehicles and enforcement in this regard is by the honor system. The ALS and RPS are also very labor-intensive, requiring more than 120 personnel to manage the system. But perhaps the most important drawback of the ALS/RPS from the perspective of allocative efficiency pertains to the unlimited number of entries into the RZ, resulting in under-penalized contributions to traffic congestion, and making it difficult to equate marginal social costs with marginal social benefits. Thus the need to switch to Electronic Road Pricing (ERP).

As early as 1989, anticipating advances in smart card technology, the government announced plans to introduce ERP and invited firms to submit tenders for a viable "active" system. (A "passive" system involving detailed monthly bills giving breakdowns of toll sites crossed that was tried in Hong Kong on an experimental basis from July 1983 to March 1985 had proven to be unpopular because of privacy concerns and was rejected.³⁶) Numerous trials were conducted, and after successive rounds of demonstrations and tenders, in October 1995 the government awarded the S\$197 million ERP construction contract to a consortium comprising Philips Singapore, Mitsubishi Heavy Industries, Miyoshi Electronics, and CEI Systems and Engineering. The consortium will also maintain the system for five years for another S\$39 million. An efficient, almost fail-proof system is expected to be in place by early 1998.

A detailed, technically illustrated description of the technology involved can be found in a recent joint study by the authors.³⁷ Briefly, each type of motor vehicle (car, taxi, commercial vehicle, and motorcycle) will be fitted with a small color-coded In-Vehicle Unit (IU) on the bottom right corner of the windscreen or the center of the motorcycle's handlebar, with the IU connected to the motor vehicle's battery. The IU will debit the toll from a Cashcard (ubiquitously available and launched in 1996 at a cost of S\$40 million to help turn Singapore

into a cashless society) every time the vehicle passes under a set of gantries. The IU has a liquid crystal display that will indicate the card's stored-value balance and confirms every transaction with a beep. It also alerts the driver whenever cash balances are low or the smart card is faulty. The IUs will be permanently affixed so they cannot be swapped among different categories of vehicles, which will be charged varying rates to reflect vehicle size. Foreign motorists (mostly from Malaysia) may rent temporary IUs or install permanent ones if they visit Singapore regularly.

Entry point gantries will work in pairs. The first gantry will have antennas which, using radio frequencies, will check the validity of stored-value Cashcards in approaching vehicles after mutual verification, after which it will execute debiting instructions to the IU. The second gantry has a set of optical vehicle presence detectors which pinpoints the location and type of the vehicle. A second set of antennas on the second gantry verifies if the correct deduction has been made by identifying the type of vehicle passing through. An outstation controller located by the roadside links the information from the antennas and vehicle presence detectors to check for possible violations. If violations are detected, enforcement cameras mounted on the first gantry record the image of the rear license plate of the violating vehicle, then forward it to a central computer with the transaction record for a fine.

Note that the ERP system to be implemented does not have toll booths or lane dividers and does not require vehicles to slow down. This requires the system to be able to handle cluttered vehicles traveling up to 75 miles per hour in a multilane traffic pattern with consecutive passings and lane changes as well as very close parallel passings with motorcycles in between. Since it takes 0.4 seconds for the algorithm to be completely sequenced, the set of two gantries must be placed at least 17 yards apart. The permissible error rate is set at 1 error per 100,000 passings. Every attempt will be made to ensure that the errors are not of the false identification kind in order not to erode public confidence in the system. It is expected that initially, ERP will exactly duplicate the present ALS and RPS, but eventually, ERP is expected to be progressively extended to first cover check points along expressways and then to congested arterial ring roads by the year 2000.

From the welfare perspective, the greatest advantage of ERP is that charges *per entry* are more allocatively efficient than timed interval licenses with multiple entry privileges. Every time a vehicle enters, exits, or reenters the RZ, it contributes to road congestion and generates external diseconomies which should and will be penalized. In this respect, the ERP is a definite improvement over the ALS and RPS. Furthermore, it has been suggested that toll charges can be made to vary with time, area, or distance traveled to reflect varying levels of road congestion.³⁸ With ERP, it is also easier to introduce gradually tapering shoulder prices to even out traffic flow, as was achieved with the two-tier Whole-Day and Part-Day ALS. Ultimately the vehicle detectors can help in determining traffic volume, level of congestion, and adjust the optimal tolls accordingly to achieve Pareto optimality in road allocation. Furthermore, the proposed ERP system in Singapore has some built-in efficiencies in that, unlike toll booths in other parts of the world, cars will not have to slow down, saving on time and gas. In other words, the ERP system in Singapore will be operationally non-intrusive. Also, the depleted Cashcards can be topped up at banks and automated teller machines, and can be used for almost everything else eventually. The system is almost fool-proof and fraud-proof. People will not be accidentally caught with the wrong license used at the wrong time or place, and permanently fixed IUs are not removable or interchangeable, unlike present area licenses. The cameras will provide documentary proof of violations, and at a maximum false positive error rate of 1 in 100,000, protestations of system error will not be terribly persuasive.

Realizing that the legitimate car owning aspirations of middle class Singaporeans should not be unreasonably curtailed,³⁹ the government has announced that with the implementation of ERP in March 1998, the annual quota of about 40,000 new motor vehicles will be increased by 9 to 12 percent. We believe that this is a wise move because ownership does not cause congestion, only usage does. And because of its flexibility, ERP can take Singapore to the first-best world of Pareto optimality in allocating scarce road space. But the government has intimated that the state-of-the-art ERP system will be in place for only ten years, and then it will be dismantled in favor of an even more sophisticated automatic monitoring and collection system

using satellite technology.

SUMMARY AND CONCLUSION

Since 1975, Singapore has introduced a relentless series of traditional and experimental measures to slow down the growth of the motor vehicle population and to control its usage. We have seen that while some of the measures have been somewhat successful, some of the problems were shifted or were substituted. The ALS led to a shifting of the problem in time and place while the quota system has substituted uncertainty in quantity with uncertainty in price. Furthermore, the PARF system and the Quota System had the unintentional effect of creating an appreciating asset market for motor vehicles encouraging speculation, while the well intentioned Weekend Car Scheme resulted in some undesirable redistributional effects. Despite the shortcomings, because Singapore had taken such bold measures to tackle the problem of urban traffic congestion, officials from Brunei, China, Hong Kong, Japan, Malaysia, the Republic of Korea, Taiwan, and the United Kingdom (among others) have come to study Singapore's road transport policies. Academics from all over the world and the World Bank have written scores of learned articles on the measures undertaken by Singapore to curb congestion. Although there are clear lessons to be learned from the successes and mistakes, it is important to bear in mind that many of these measures to curb road congestion are implementable in Singapore only because it is a small island with a transportation grid almost totally insulated from foreign motorists, has a strong unwavering government committed to solving the problem, and an obedient, law-abiding citizenry. In this respect, Singapore is almost unique. The draconian measures that Singapore has taken to curb urban traffic congestion cannot be implemented in the United States for obvious political reasons.

Until very recently, both of the authors had been *independently* studying and writing on the problem of urban traffic congestion in Singapore for a long time. While the second author found that the income elasticity of demand for the *ownership* of cars was 1.0, the first author found that the price elasticity of demand for the *usage* of cars was -2.54 .⁴⁰ Thus whereas an increase in the price of cars will not

seriously discourage their purchase, a nationwide system of automatic tolls will seriously discourage their usage. Since usage and not ownership causes congestion, we are now *both* of the opinion that ERP is the ultimate solution to Singapore's road congestion problem because it is flexible, efficient, operationally nonintrusive, and most importantly, effective in putting Singapore in the first-best world of Pareto optimality. In the meantime, the world waits and watches to see the results of this bold and interesting experiment conducted on an unprecedented scale.

ENDNOTES

¹ See Brian G. Field, "Road Pricing in Practice," *Transportation Journal*, Fall 1992, p. 8.

² See J. Fraser, "Auto Clogging of the Arterials Evident in Capitals of Europe," *Toronto Globe and Mail*, October 31, 1986, p. 8; J.A. Gomez-Ibanez and G.R. Fauth, "Downtown Auto Restraint Policies: The Costs and Benefits for Boston," *Journal of Transport Economics and Policy*, Vol. 14, 1980, pp. 133-153; Thomas J. Higgins, "Road-Pricing Attempts in the United States," *Transportation Research*, Vol. 20A, No. 2, 1986, pp. 145-150; J. Tagliabue, "Cars Face Rush-Hour Ban in Central Rome," *The New York Times*, February 22, 1987, p. 6.

³ See Winston Lee, *Quota System and the ARF/PARF Scheme*. (Singapore: Singapore National Printers, 1991.)

⁴ This never happened because those who took circuitous routes to their destinations during the restricted hours added to the cross town traffic in the evening, prompting the extension of the ALS to the evening peak hours as well in 1989.

⁵ For a detailed discussion of the success of differential shoulder pricing, see Sock-Yong Phang and Rex S. Toh, "From Manual to Electronic Road Congestion Pricing: The Singapore Experience and Experiment," *Transportation Research E: The Logistics and Transportation Review*, Vol. 33 No. 2, June 1997, pp. 97-106.

⁶ See A.P.G. Menon, S.H. Lam, and H.S.L. Fan, "Singapore's Road Pricing Scheme: Its Past, Present, and Future," *ITE Journal*, December 1993, pp. 44-48.

⁷ See A.P.G. Menon, S.H. Lam, and H.S.L. Fan, *ibid*

⁸ See A.P.G. Menon, S.H. Lam, and H.S.L. Fan, *ibid*.

⁹ A. Pigou, *The Economics of Welfare*. (London: Macmillan, 1920).

¹⁰ F.H. Knight, "Some Fallacies in the Interpretation of Social Costs," *Quarterly Journal of Economics*, Vol. 28, 1924, pp. 522-606.

¹¹ Ministry of Transport, *Road Pricing—The Technical and Economic Possibilities*. (London: HMSO, 1960.)

¹² See A.A. Walters, "The Theory and Measurement of Private and Social Cost of Highway Congestion," *Econometrica*, Vol. 29, 1961, pp. 676-699; J. Thompson, "Calculation of Economic Advantages Arising from a System of Road Pricing," *Transport and Road Research Laboratory Report No. PRP8*, 1962; G. Roth, *Paying for Roads: Economics of Tragic Congestion* (City: Penguin, 1967); W. Vickrey, "Optimization on Traffic," *Journal of Transport Economics and Policy*, "Vol. 1, 1967, pp.123-

136; R.M. Solow, "Congestion Cost and the Use of Land for Streets," *Bell Journal of Economics*, Vol. 4, 1973, pp. 602-618; D. Pines and E. Sadka, "Zoning First-Best, Second-Best, and Third-Best Criteria for Allocating Land for Roads," *Journal of Urban Economics*, Vol. 17, 1985, pp. 167-183; Steven A. Morrison, "A Survey of Road Pricing," *Transportation Research*, Vol. 20A, No. 2, pp. 87-97.

¹³ See Timothy D. Hau, *Economic Fundamentals of Road Pricing Policy: A Diagrammatic Analysis*, Transportation Division, Infrastructure and Urban Development Department, The World Bank, December 1992.

¹⁴ See J.A. Gomez-Ibanez and K.A. Small, *Road Pricing for Congestion Management: A Survey of International Practice*. (Washington, DC: Transport Research Board, National Academy Press, 1994.)

¹⁵ Rex Toh, "Road Congestion Pricing: The Singapore Experience," *The Malayan Economic Review*, October 1977, pp. 52-61.

¹⁶ See A.T. Armstrong-Wright, "Road Pricing and User Restraints: Opportunities and Constraints in Developing Countries," *Transportation Research*, Vol. 20A, No. 2, 1986, pp. 123-127; P.L. Watson and E.P. Holland, *Relieving Traffic Congestion: The Singapore Area Licensing Scheme*, World Bank Working Paper No. 281, Washington, DC; Paul W. Wilson, "Welfare Effects of Congestion Pricing in Singapore," *Transportation*, Vol. 15, 1988, pp. 191-210.

¹⁷ See Brian G. Field, *op. cit.*, pp. 5-14.

¹⁸ Using the Nash function as well as the Bentham and Sen measures coupled with World Bank data, Paul Wilson (*op. cit.*) showed that all three measures indicated a decline in overall social welfare.

¹⁹ S.Y. Phang, *Housing Markets and Urban Transportation*. (Singapore: Mc-Graw Hill Co., 1992).

²⁰ Rex S. Toh, *The High Cost of New Cars in Singapore: The Role of Dealer Profits*. A Consultant's Report to the Automobile Association of Singapore, January 1995.

²¹ Information provided to one of the authors by the Registry of Vehicles in Singapore.

²² See Sock-Yong Phang, 1992, *op. cit.*

²³ For a thorough discussion of the unintended effects of the PARF Scheme see S.Y. Phang, Wing-Keung Wong, and Ngee-Choon Chia, "Singapore's Experience with Car Quotas," *Transport Policy*, Vol. 3. No. 4, 1996, pp. 145-153.

²⁴ For a detailed discussion of general pricing restraints, see Rex S. Toh, "The High Cost of Motoring in Singapore," *Business Horizons*, March-April 1994, pp. 68-74.

²⁵ S.Y. Phang and Anthony Chin, "An Evaluation of Car-Ownership and Car Usage Policies in Singapore," *Report of the Select Committee on Land Transportation Policy*, presented to the Seventh Parliament of Singapore, 2 January 1990, pp. B105-117.

²⁶ Japan has a sort of "quota system" by requiring aspiring car owners to have parking spots (fixed in the short run).

²⁷ See S.Y. Phang, 1992, *op.cit.* and Rex S. Toh,

"Experimental Measures to Curb Road Congestion in Singapore: Pricing and Quotas," *The Logistics and Transportation Review*, Vol. 28, No. 3, September 1992, pp. 289-317.

²⁸ If the vehicle is scrapped or re-exported before the ten year period expires, the owner receives a pro-rated rebate of the paid quota premium.

²⁹ This method of setting the price had been successfully used to allocate textile and chlorofluorocarbon (CFC) quotas in Singapore.

³⁰ At this juncture, it should be pointed out that the doubling of fees and taxes on company cars is a historical anachronism. The double charge was quite reasonable when the corporate tax was a flat 40 percent. But now that the corporate tax has been reduced to 26 percent, companies should be over assessed by a factor of $1/(1-.26) = 1.35$ times the amount paid by private individuals, for maximum allocative efficiency.

³¹ According to the Committee to Discourage Double Transfers, *Report on Implementation of Measures to Discourage Double Transfers of Vehicles*, submitted to the Minister of Communications, 4 May, 1996.

³² For instance, while collecting data for the Automobile Association of Singapore, one dealer told the first author that a 1992 Saab which used to cost S\$160,000 in 1992 could be resold for S\$170,000 in 1994.

³³ See Sock-Yong Phang, Wing-Keung Wong, and Ngee-Choon Chia, *op. cit.*, pp. 150-151. A fuller version of these analyses was presented by the second author to the Committee to Discourage Double Transfers. See Appendix IV of the committee's report (previously cited).

³⁴ See S.Y. Phang, 1992, *op. cit.*, Chapter 8 and Rex S. Toh: 1992, *op. cit.* pp. 302-310.

³⁵ "Competition Has Lowered Car Prices," *The Straits Times*, February 15, 1997.

³⁶ See J.A. Gomez-Ibanez and K.A. Small, *Road Pricing or Congestion Management: A Survey of International Practice*. (Washington, DC: Transport Research Board, National Academy Press, 1994) and T.D. Hau, "Electronic Road Pricing: Developments in Hong Kong 1983-1989," *Journal of Transport Economics and Policy*, Vol. 24, No. 2, May 1990, pp. 203-214.

³⁷ See Sock-Yong Phang and Rex S. Toh, *op. cit.*

³⁸ Joseph Yee and A.P.G. Menon, "The Need for Advanced Technology in Road Pricing—The Singapore Experience," *Proceedings of the International Conference on Advanced Technologies in Transportation and Traffic Management*, Singapore, 18-20 May, 1994.

³⁹ The 1990 *Report of the Select Committee on Land Transportation Policy* (previously cited) cautioned that "The situation acquires social and political dimensions as increasing numbers of Singaporeans view the ownership of cars as an integral part of middle class aspirations." It continued to warn that the problem will worsen as incomes rise to levels comparable to Japan and the advanced Western countries.

⁴⁰ See Sock-Yong Phang and Anthony Chin, *op. cit.* and Rex Toh, 1977, *op. cit.*

