

ROAD PRICING IN SINGAPORE AFTER 30 YEARS

Gregory B. Christainsen

Traffic congestion continues to be a serious problem in major cities around the world. Congestion results not only in time lost while sitting in traffic jams. It also constitutes a disruption to company supply chains and the general flow of commerce. Idling vehicles contribute as well to air pollution.

Congestion thus reduces the quality of life, but government efforts to limit it have been, for the most part, woefully inadequate. Indeed, in many metropolitan areas people take for granted the fact that helicopters will patrol thoroughfares in order to inform drivers about locations where traffic problems are particularly severe.

Since 1975 Singapore has priced vehicle entry into its central business district (CBD). The main purpose of this pricing has been to manage traffic volumes rather than the collection of revenue. Prices have been adjusted as traffic conditions have changed.

Tolls for roads, bridges, and highways have a long history around the world, but the tolls collected have been used mostly to help pay for transportation infrastructure. Charges for “hot lanes” on highways in Southern California, which help to smooth out traffic flows, have been the exception and not the rule.

The city of London introduced congestion pricing in part of its downtown area in 2003. The pricing has succeeded in reducing traffic

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Gregory B. Christainsen is Professor of Economics at California State University, East Bay campus (formerly known as the Hayward campus). The author is grateful to Brian Gothberg, Daniel Malick, Tony May, Stephen Shmanske, and Dirk van Wijk for useful discussions. Gopinath Menon, formerly Senior Manager, Land Transport Authority of Singapore and a member of the original 1975 working group that recommended road pricing to reduce traffic congestion, was particularly helpful in supplying data and clarifying Singapore’s policies. Piotr Olszewski of the Centre for Transportation Studies at Nanyang Technological University, Singapore, was also helpful. Jack Opiala, formerly of Wilbur Associates, Hong Kong, and now International Director, Intelligent Transportation Systems for Hyder Consulting in Wellington, New Zealand, was invaluable in updating the author on research regarding the possible use of satellites for road pricing.

volumes by about 15 percent, and average traffic speeds have increased about 22 percent (*The Economist*, 9 June 2005). It is possible that road pricing will be instituted on a nationwide basis in the years ahead.

The idea of road charges remains politically contentious, with prominent politicians vowing to stop them. The Dutch government made elaborate plans for more than 10 years to introduce widespread road pricing, but when the time came to implement the proposal in 2001, politicians could not summon the will to do so.

In Singapore, by contrast, there is no doubt about the long-term survival of pricing as a means to control traffic volumes. Such pricing has already existed for three decades. Much can be learned from Singapore's experience.

It should be emphasized that road pricing is viewed in Singapore as only one part of an eclectic approach to transportation management, and even in Singapore—where one political party has dominated the government—there are some political barriers to effective pricing. The introduction of superior technology for toll collection is also a sensitive matter. Nevertheless, Singapore has clearly been road pricing's world leader.

The Economics of Road Pricing

Elementary economics teaches us that an excess demand for a good or service can be eliminated if its price is raised sufficiently high. The demand for roadway use is no exception. Chronic traffic congestion indicates that there is an excess demand for roadway use, but in most cases, there is no explicit price charged for driving on streets and highways.

Gasoline taxes may mildly discourage driving, but they do not charge vehicles according to time and place. Roadways may be mostly free of vehicles at some times and places, but they may be extremely congested at other times and locations. Moreover, traffic patterns may change over the years. Road pricing offers the possibility of targeting specific thoroughfares at specific times for more intensive traffic control.

If the prices charged bear a reasonable relationship to the supply and demand for roadways, there are also payoffs with respect to information about driver preferences and road construction. In response to a higher price, for example, some travelers may choose to carpool, change the time of their travel, or use an alternative form of transportation. The higher price signals to people that they should consider changing their behavior, but the people involved make the decisions based on their own information about circumstances of time

and place (Hayek 1945). Some people may have close neighbors who commute to the same general area at about the same time and may prefer to carpool. Others may not know their neighbors very well, or their neighbors may commute to other locations. In the presence of a higher price, some people may prefer another form of transportation, and some people may not. Some people may continue to drive, but can take another route. Others cannot. In the long run, some people may even change where they want to live. Others would prefer to stay put.

By contrast, a decision by a public authority to set aside a highway lane for carpools during rush hours presupposes that a certain amount of carpooling is an appropriate response to the existence of traffic congestion. In fact, the carpool lane may be underutilized, and the congestion problems of the other highway lanes may actually worsen because most drivers are now denied access to one of the lanes.

The central issue is thus whether it is better to rely on the information available to a relative handful of public officials, who then make decisions for everyone else, or to just establish a market price to which thousands of people can respond on the basis of their own information.

Excess Demand for Roadway Use and the High Fixed Costs of Road Construction

As far as road construction decisions are concerned, the use of charges provides information as to whether additional roadway capacity is desirable, or whether in fact roadway construction in a particular area has already gone too far. If road charges—which could even involve a surcharge to help control air pollution—can more than cover construction, maintenance, and congestion costs (e.g., the value of time lost in traffic jams and the pollution caused by idling vehicles), it may be advisable to expand roadway capacity. If, on the other hand, charges cannot cover construction, maintenance, and congestion costs, the area may already be overbuilt with respect to roadways.

Construction of roadways involves very high fixed costs that do not depend on the volume of traffic. However, the expense necessary to offset the wear and tear to a roadway from one additional vehicle is rather low. If people's use of a roadway prevents others from reaching their destinations in a timely fashion, there are additional (congestion) costs associated with each vehicle-trip.

From the standpoint of neoclassical economics (e.g., Allen et al. 2005: 472–80), the basic user charge should correspond to the amount necessary to cover the costs of one additional vehicle-trip—

that is, the *marginal* cost of a vehicle-trip. As long as drivers are willing to pay at least an amount that would cover the maintenance and congestion costs associated with additional use of the roadway, it is economically desirable that additional use occur.

Construction costs are costs above and beyond the marginal cost. If the basic user charge also included the construction costs (averaged over the total number of vehicle-trips), the charge would be too high. In the jargon of neoclassical economics, we should have marginal-cost (MC) pricing, not average-total-cost (ATC) pricing (unless ATC happens to equal MC).

How to Cover the High Fixed Costs of Constructing Roadways

The standard ways by which businesses can effectively price activities involving high fixed costs, but relatively low marginal costs, include price discrimination and the use of set-up charges to supplement the basic charge for actually using the good or service. If there is both a set-up charge and a user charge, economists speak of “two-part” pricing.

Price discrimination involves charging some users more than others for the same good or service. The surplus revenue collected from some customers can be used to help cover fixed costs. As long as the price paid by marginal users corresponds to the marginal cost, this pricing can be efficient.

Examples of set-up charges include cover charges (e.g., at some bars), charges for joining clubs (without having as yet used any facilities), and installation fees (e.g., for fixed-line telephone service). For each of these, the set-up charge is not for actual consumption (e.g., of a drink, a round of golf, or for the making of a telephone call), but instead covers fixed costs (of constructing a bar, a golf club, or a telephone network).

With respect to roadways, Singapore practices both price discrimination and two-part pricing. Different types of vehicles pay different charges for using priced roadways, and charges vary by location and time of day. The charges have covered the costs of the road-pricing infrastructure—including gantries and administrators—as well as being a tool for controlling congestion.

Set-up charges in this context involve the collection of annual road taxes—and related fees for vehicle ownership—in addition to user charges. The road tax that a vehicle owner pays is independent of the amount of driving done. It depends instead primarily on the engine size of the owner’s vehicle. For example, a car with a 2,000 cubic centimeter engine (and which is less than 10 years old) pays the

equivalent of about \$US1,000 per year in road tax.¹ This tax defrays the fixed costs of roadway construction, and in the case of Singapore, maintenance costs as well.

The revenue from congestion charges has been high enough to finance an annual rebate on road taxes in addition to covering the costs of the road-pricing infrastructure. This rebate was granted each year for five years ending in August 2003. The rebate was also independent of the amount of driving that an individual did, and it helped somewhat to make the whole road-pricing scheme more salable politically. Rebates amounted to \$US100–200 per year and varied by vehicle type and year.²

The Sometimes Surprising Implications of Transaction Costs

The transaction costs of road pricing—the costs of toll collection itself—are not trivial, at least at this point, and have very important implications. For example, if tolls are collected simply by having vehicles stop at a booth to hand someone bills or coins, or drop coins in a collection bin, toll collection itself can cause congestion. Vehicles may have to queue up to pay the tolls.

In Singapore the gantries used to scan vehicles as they use key thoroughfares are not inexpensive, and the administrators who run the system command white-collar salary levels and fringe benefits. For key thoroughfares carrying significant road charges, the revenues collected—and the reduction in congestion—may more than justify the costs of the system. For marginal thoroughfares, however, the costs that would have to be incurred to build and monitor additional gantries may not be economically justifiable. Nevertheless, there may in many instances be traffic problems on streets outside the CBD.

In the presence of high transaction costs, the argument thus begins to turn in favor of physical or quantitative controls to reduce congestion. We have previously noted the attractiveness of prices in terms of decisionmaking that involves information that is scattered among thousands of people. In the presence of high transaction costs, however, pricing may not always be practical.

So it was that in 1990 the government announced a ceiling on the total number of vehicles to be allowed in the city-state. People must bid for rights—represented by “certificates of entitlement” (COEs)—to buy a limited number of new vehicles each year, with the number of new vehicles permitted being related to the scrap rate for older

¹See www.onemotoring.com.sg/publish/onemotoring/en/lt/enquiries/road_tax_calculator.html.

²See http://app.lta.gov.sg/corp_press_content.asp?start=488.

vehicles plus an allowed net rate of increase. The economic argument for this quantitative measure is that, at least in the context of the technology in use, the transaction costs of implementing congestion pricing throughout the entire country would be too high, and that even though it is not sensitive to circumstances of time and place, a limit on the total number of vehicles has benefits in terms of general traffic control that outweigh the welfare loss that it otherwise entails.

With a limited supply of vehicles available to buy, Singaporeans pay what appear to be exorbitant prices for cars. For example, the total cost of a new Honda Accord, including the COE, can be more than US\$50,000. The downside of this policy has been lessened by a provision that allows people to purchase rights to operate additional vehicles (beyond the aggregate limit that would otherwise exist), if they agree to drive them only after normal business hours and on weekends. These vehicles carry a special license plate. If someone is detected driving such a vehicle during business hours, the driver is subject to a stiff fine.

In the presence of technology that would make possible comprehensive road pricing with much-reduced transaction costs, it should be stressed that the economic argument for a limit on the number of vehicles vanishes.

Traffic Control in Singapore: A Chronology

Singapore is a city-state of about four million people. In 1972, policies to address worsening traffic problems started coming to the fore. In that year, the import duty on motor vehicles was raised from 30 to 45 percent. A separate registration fee equal to 25 percent of a vehicle's market value was introduced. However, those measures had little impact on traffic volumes.

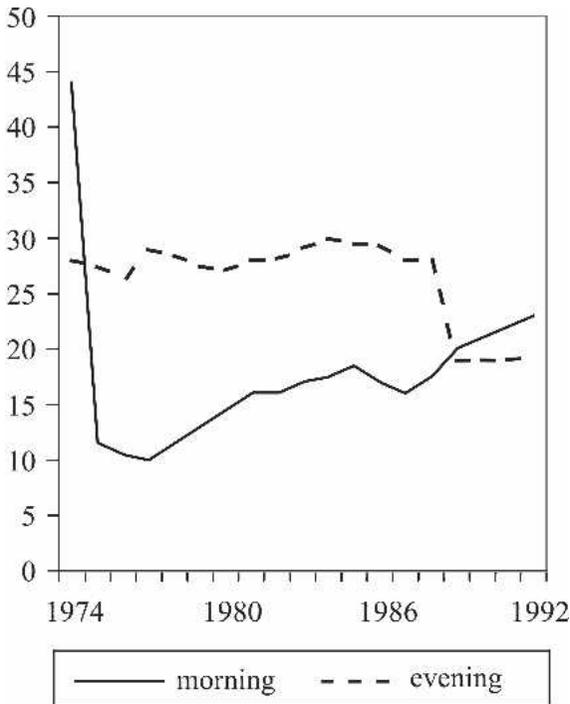
In 1975 the special registration fee was increased to 55 percent of a vehicle's market value, with the owner being eligible for a discount if an old vehicle was being scrapped. An interministry working group assisted by the Public Works Agency (now subsumed under the Land Transport Authority) was asked by Prime Minister Lee Kuan Yew to come up with additional proposals. The government ultimately ratified a policy that cars entering the CBD during the morning rush hours be charged three Singapore dollars (S\$3) per day, more than double the bus fare for those commuting in from outside. (Today, one Singapore dollar is about 61 U.S. cents. In terms of purchasing power, S\$3 in 1975 was equivalent to more than US\$3.50 today.) A driver was originally exempted from the charge if there were at least four people in the vehicle as it entered the CBD.

As shown in Figure 1, the traffic volume was cut by more than 50

percent when pricing was introduced. Average traffic speeds in the CBD doubled to 36 km per hour (*The Economist*, 3 September 1998). A vehicle owner had to purchase a sticker and place it on the inside of his front windshield if he wanted to drive into the CBD during the priced (peak) hours. Enforcement officials sat in booths at checkpoints to see if a vehicle had the required sticker for the day in question.

In 1989 pricing was applied to the late afternoon rush hours as well. Less than two years before, the government set up a company to provide state-of-the-art subway service, with subway lines running north, south, east, and west. In 1990, after the government announced a limit on the total number of vehicles to be allowed in Singapore, there were also ongoing discussions about adopting a method for charging vehicles electronically for their use of roadways.

FIGURE 1
THOUSANDS OF CARS AND TAXIS TRAVELING IN SINGAPORE'S
RESTRICTED ZONE DURING PEAK HOURS



SOURCE: Polak, Olszewski, and Wong (1994:325).

Under manual road pricing with stickers (or what Singaporeans call paper licenses), a motorist could travel in and out of a priced area several times in a day without having to pay multiple charges. With electronic pricing, it is feasible to charge a motorist every single time he enters a priced area.

Singapore considered two types of electronic pricing systems: passive and active. Under a passive system a vehicle is identified at a control point, and the motorist is billed. He must pay his bill by the time a deadline is reached. In the case of London, motorists are billed on a daily basis. They need not pay on the spot, but must pay up by late in the day—or face a fine. Video cameras take pictures of the license plates of vehicles that enter the priced zone.

However, this type of system requires a significant bureaucracy to monitor nonpayers. Singaporean officials considered billing motorists on a monthly basis. In addition to the bureaucratic burden, however, Singaporean officials feared a “credit card syndrome” under which motorists would just pay monthly statements without devoting much attention to the specific charges involved. The fact that a motorist was paying a price for every trip into certain areas would not register strongly in his mind—or so it was argued.

With an active system the idea is that every trip into a priced area results in an immediate deduction from the balance on a prepaid smart card, and the driver sees the amount subtracted flash in front of him (every time). Drivers must also regularly top up their smart cards with cash in order to finance their next set of journeys and must habitually check to see if their smart cards are inserted into an in-vehicle unit (called a “transponder”). They will have to pay extra if they pass a control point without having inserted their smart card in the in-vehicle unit.

Thus, an active system constantly reminds motorists that they are paying for the use of priced roads. Motorists’ sensitivity to prices may therefore be higher than it would be under a passive system. In economic terms, an active system is claimed to result in greater price elasticities of demand. Singapore remains unique in its use of smart cards for road pricing.

Competing consortia vied for the job of implementing electronic road pricing in Singapore. Ten consortia were originally involved, with 3 of the 10 then invited to participate in a more extensive competition. The authorities decided that it was not sufficient for the government just to buy technology off the shelf and devise a more elaborate road pricing system. Instead, each remaining consortium was asked to come up with a detailed, customized proposal for Singapore’s CBD and expressways. The Singapore government paid the

consortia to conduct extensive field tests at Tuas, in the far west of Singapore, and consortia submitted bids for carrying out the customized proposals. In the end, the proposal of a consortium led by Mitsubishi and Philips Electronics was accepted. The proposal involved the charging of vehicles as they pass under the now-familiar gantries.

There was still much work to be done in constructing the gantries and determining the precise places to install them. The public had to be educated about what was to come. Signboards had to be made to inform drivers of the relevant charges before they entered the CBD or priced expressways.

A vehicle owner who wanted to use priced roadways would have to get a transponder to be mounted on the inside of his windshield. Cost: S\$80 (about US\$50 in 1998). A smart card (“CashCard”) would have to be inserted into the transponder. As the vehicle passes under a gantry, the motorist hears one beep to inform him that he has just been charged. Several beeps are heard if the balance on the smart card is then below S\$5. These beeps warn the motorist that his balance is low and that he should consider topping it up. The balance on a card can be topped up at an ATM machine by downloading funds from the driver’s bank account.

A driver who has no transponder, fails to insert his CashCard into the transponder, or fails to maintain a cash balance sufficient to pay a particular charge, automatically has the rear of his vehicle photographed as he passes under a gantry. Such drivers were originally issued a court summons and had to pay a fine of S\$70. Now, however, they pay only an administrative charge of S\$10.

Hundreds of thousands of vehicles had to be outfitted with transponders before widespread electronic road pricing could begin. In 1998 a pilot program was launched under which electronic road pricing was introduced on the inbound lanes of the East Coast Parkway. Full-scale electronic road pricing in the central business district and on the inbound lanes of two other expressways began later in the year. CBD pricing became electronic in September that year.

From a technical standpoint the system has performed almost flawlessly. Recently, billing errors have occurred in less than 0.050 percent of all transactions, with more than 3.5 million transactions occurring on a typical day (Menon and Chin 2004: 63). Prices for entering the CBD currently range from zero to S\$2.50, depending on the time of day.³

The demand to use various roadways would have been higher were

³For updates on prices, see www.onemotoring.com.sg/publish/onemotoring/en/traffic/erp_rates/passenger.html.

it not for the limit on the total number of vehicles, and the charges for using priced roadways would then have been higher as well. The limit on the total number of vehicles has been relaxed somewhat with the expansion of the priced area. The total number of registered vehicles was 674,000 in September 1998. Within 5 years the number had grown to 709,000, an increase of 5 percent (Menon and Chin 2004: 63). There is no doubt that electronic methods have reduced transaction costs compared with the old sticker system and improved the efficiency of road usage in Singapore.

Improving the System

Pricing

The charges for taxis, which often go in and out of the CBD several times in a single day, were phased in over a three-year period. The charges for goods vehicles and buses were phased in over a four-year period. Vehicles other than ordinary cars are priced according to the “passenger car unit (pcu) equivalent.” An ordinary car is 1 pcu. Taxis and light goods vehicles are also 1 pcu. A motorcycle is 0.5 pcu, a heavy goods vehicle is 1.5 pcu, and a bus is 2 pcu. Thus, if the charge for an ordinary car is S\$1, a bus must pay S\$2. Vehicles are not charged according to distance driven or the amount of time spent inside the CBD.

After the introduction of widespread electronic road pricing, the authorities found that, in order to avoid the charges levied in the CBD, drivers were making greater use of the semimajor roads just outside of it. Congestion on those roads increased and gantries were then added on some semimajor roads. The price charged for passing under one of these secondary gantries is not as high as the price for entering the CBD—since the demand for use of CBD roads is particularly intense compared with their supply.

Another problem was that prices were initially set over discrete half-hour periods. For example, if a rather high price was set from 8:30–9:00 a.m., some drivers would race to pass under a gantry before 8:30 a.m., or pull over to the side of the road at 8:58 a.m. and wait until 9:01 a.m. to proceed into the CBD.

Signs have been put up to advise waiting drivers that they will be detected by surveillance cameras and fined. Moreover, in cases where the charge per pcu is scheduled to increase during the next half-hour by at least S\$1, the price is now increased by a lesser amount during the first five minutes of the next half-hour. After five minutes, the price is increased by an additional amount. This graduated pricing helps to smooth out traffic volumes.

If a price is scheduled to decrease (rather than increase) by at least S\$1 from one half-hour period to the next, the price is already decreased by a lesser amount five minutes before the start of the next half-hour. The newer gantries display the time of day in light of the fact that drivers' watches and vehicle clocks are not always accurate.

Prices are adjusted on a quarterly basis based on the Singapore government's view regarding "optimal" traffic speeds. The optimal average traffic speed on expressways is said to be 45–65 km per hour (28–40 mph). The optimal average traffic speed on other streets is said to be 20–30 km per hour (12–19 mph). These speeds are said to maximize "throughput," which refers to the number of vehicles that can travel from one point to another during a given period of time.

A very high price can result in low throughput if it deters a large number of vehicles from using a roadway. A very low (or zero) price can also reduce throughput if it encourages so many vehicles to use an area that gridlock occurs.

If the average traffic speed for an area is below the optimal range as defined by the Singapore government, it indicates that the area is excessively congested. The government will then raise the price per pcu at one or more of the nearby gantries by S\$0.50 so that fewer vehicles will enter the area. The average traffic speed will then presumably increase. On the other hand, if the average traffic speed for an area is too high, it indicates that the roadways in question are underutilized. The price per pcu for the area will then be decreased by S\$0.50 so that more vehicles will enter it. The average traffic speed will then presumably decrease.

The Singapore government's definition of the optimal traffic speed is not necessarily the same as optimality from the standpoint of neo-classical welfare economics. The Singapore government's version is a physical, or one could say, an engineering concept. Economists tend to think more in terms of the values attached to different outcomes. For example, if a relatively small group of drivers put a very high value on a fast journey from point A to point B, and were thus willing to pay a very high price for it, while others did not mind using carpools or other forms of transportation, it could be economically optimal to charge a quite high price to use a roadway even if throughput would not then be maximized.

Short-term price elasticities for driving into the CBD from 7:30–9:30 a.m. on weekdays have recently been estimated to be in a range between 0 and -0.42 (Menon and Chin 2004: 65). The elasticity estimates for expressway use during the morning rush hours have ranged from -0.16 to -0.44 . These estimates have not been obtained via an elaborate econometric model, but by simply measuring the

traffic volume before and after price changes affecting half-hour periods.

To add some perspective, consider a price increase of S\$0.50 on top of a previous price of S\$2—a 25 percent increase in the price. An elasticity estimate of -0.40 would then imply a fall of 10 percent in the traffic volume.

The Central Expressway (CTE), which runs north and south, has been the most difficult to manage, with average traffic speeds sometimes being as low as 25 km per hour (15 mph)—well below the government's target range. Early on after pricing became electronic, a second gantry was added on the inbound lanes of the CTE, and a gantry has since been put up on the outbound lanes as well, with hours of operation from 6–8 p.m. on weekdays. CTE commuters who live in the northern part of Singapore may thus have to pay three charges in a single day.

A new northeast-southwest subway line began operation in 2003. This subway line was constructed in part to help reduce congestion on the CTE. A 12 km (7 mile) underground highway, which will also run from northeast to southwest, is currently under construction. It should be ready by 2007. This highway should further alleviate traffic volumes on the CTE and will itself be priced.

Use of Singapore's Roads by Foreigners

Foreign vehicles can enter Singapore only from Malaysia and only at two points: Tuas and Woodlands (in the far north of Singapore). If these vehicles are to use priced roads, they have three alternatives: (1) buy a transponder near the border; (2) rent the transponder; or (3) drive on priced roads to an unlimited extent without a transponder and be flagged as a “violator.” When the vehicle leaves Singapore it is then charged S\$10 per day for the days priced roads were used.

Electronic Road Pricing as an Investment

It is difficult to quantify the environmental impacts (e.g., reduced air pollution) from road pricing, let alone their dollar value. Some people have complained of “gantrification” and “visual pollution” as the number of gantries has increased, but there is no clear impact on the associated real estate values. Insofar as road pricing has made Singapore a more livable city-state than it otherwise would have been, it may have helped to support real estate values.

From a somewhat narrower perspective, road pricing has been a huge success. Not only has it helped to control traffic volumes, it also has earned a very healthy rate of return.

The infrastructure for electronic road pricing, including all motorists' transponders, cost about S\$200 million in 1998. The annual revenues have recently been about S\$80 million, and the annual operating costs have been about S\$16 million. Even in the early years of electronic road pricing (ERP) there was an operating profit on the order of S\$60 million.⁴ With the installation of new gantries there have been some additional capital costs and revenues.

If one just considers the up-front capital costs of S\$200 million and an operating profit of S\$60 million, and if the operating profit were to continue indefinitely, the net present value (NPV) of the system, viewed from 1998, would be given by:

$$\text{NPV} = -200 \text{ million} + \sum 60 \text{ million}/(1 + R)^t,$$

where R is the annual rate of return and t is time, with the number of years involved being potentially infinite. By setting NPV = 0 and solving for R, we can calculate the so-called internal rate of return. In this case, the average annual rate of return is seen to be 30 percent per year, a very good return compared with the return available on other capital investments. By just looking at the annual operating profit, one can readily see that the up-front costs of the infrastructure have been already been recovered quite easily.

From a pure investment point of view these results suggest that, even without considering a possible upgrade of the technology used for road pricing, it should be worthwhile to continue expanding the system for the next several years. It is economically worthwhile to expand the system as long as the rate of return for additions to the system exceeds the return that could be had on other investments of similar duration and risk.

There were originally 27 gantries forming a cordon around Singapore's central business district. There were originally 5 other gantries on expressways and related roads. The long-term plan is that a whole new cordon around the original cordon will eventually be completed, with the outer cordon consisting of 22 gantries. More than half of the 22 gantries have by now been installed and put into operation. Thinking even further into the future, one can imagine a series of concentric rings around the downtown area. The greater the number of rings through which a vehicle would have to pass to get into the central business district, the more the vehicle would have to pay. It is

⁴The data were supplied by Gopinath Menon, formerly Senior Manager, Land Transport Authority of Singapore. The Land Transport Authority itself does not make public the data necessary for a detailed assessment.

conceivable that whole new business centers will emerge over time, each with its own toll rings.

Technology

The technology used for ERP in Singapore was regarded by some commentators as outmoded even before the system became operational (Malick 1998). The system relies on microwaves to identify transponders as vehicles pass under gantries. Gantries must be added, subtracted, or moved as traffic conditions warrant. Outmoded or not, the technology's reliability has been established. Vehicles can proceed at high speed in a multilane environment. Photographs of vehicles without transponders or smart cards, or whose smart cards have insufficient cash balances, arrive at a control center within 15 minutes.

However, the capital-intensity of the system cannot be denied and its desirability over larger geographic areas is open to question. Europe, for example, contains dozens of cities, many of which have congestion problems. Would it be appropriate to put up thousands of gantries all over Europe? Austria alone now has 800 gantries.

While some observers could unflinchingly support the idea of a far-reaching gantry approach, others believe that the time is ripe for satellite-based road pricing. GPS—Global Positioning Systems, or “Global Navigation Satellite Systems” in European parlance—rely on Low Earth Orbit Satellites to monitor vehicles, which would again be outfitted with transponders. The beauty of a satellite approach is that not only could the road-pricing infrastructure be amortized over literally hundreds of millions, instead of hundreds of thousands, of vehicles, the system also could be expanded at any time without any (or very much) additional infrastructure. Indeed, road pricing could potentially be done all over the world. Satellite systems have other uses as well—navigation systems, the finding of stolen or abandoned vehicles, and the tracking of ships. Wildlife migrations are now sometimes tracked with satellites (Christainsen and Gothberg 2001).

In Hong Kong a consulting firm, Wilbur Associates, conducted field tests to see if a satellite system, under a proposal sponsored by a consortium led by General Electric, could perform as reliably as the Mitsubishi-Philips Electronics technology, which involves gantries. The satellite approach performed well and may indeed be more economical over large geographic areas, but this conclusion comes with some caveats.

In urban areas satellite signals are sometimes reflected in misleading ways by the glass sides of buildings. Buildings may also cut off signals in cases where satellites are low on the horizon. However, in

cases where some satellites are low on the horizon others may be more directly overhead. The problems tend to be more severe the farther one moves away from the equator. There can also be problems in heavily wooded areas with an overgrowth of trees above vehicles.

In cases where signals are lost or are of questionable reliability, the satellite system needs to be supplemented with an “inertial navigation system” (INS). Moving vehicles may in most cases be tracked reliably by the satellite system, with updates every second. Based on the tracking trend, the next point to be occupied by a vehicle can be forecast with a reasonable degree of confidence. The INS calculates the next likely point as well. If the satellite system then receives a signal that is quite inconsistent with the forecast, it disregards it and the INS’s forecasted point is used for pricing purposes. Reliable signals are typically received again by the satellite system just seconds later. In the tests conducted in Hong Kong—one of the most difficult places on earth to track vehicles because of a very high population density and numerous skyscrapers—the results of a satellite system, in combination with INS, were more than 99.2 percent accurate and were actually slightly better than those of the competing gantry system, but the difference was not statistically significant.⁵

In Singapore the gantry/satellite issue is political as well as technological and economic in nature. If a change were made from a gantry approach to a satellite approach, a whole new public discussion would be necessary on optimal system design and pricing. If the capital costs and transaction costs of road pricing could thereby be lowered, there would then be pressure not only to do more pricing, but also to allow more vehicles in the city-state. Recall that the argument in favor of a limit on the total number of vehicles was that it is too costly to conduct road pricing on outlying streets and roads under the current technology. If satellites make pricing feasible almost anywhere, this argument no longer has any merit—at least on efficiency grounds.

Allowing a greater supply of vehicles in the CBD would bring down vehicle prices and increase the demand for roadway use. Satellites could make the pricing of previously unpriced areas feasible, but pricing those areas would be a sensitive political matter. Given a greater quantity of vehicles on the road, the optimal road prices for the CBD and other high-demand areas would increase as well—which would also be a sensitive matter from a political point of view.

⁵Personal communication with Jack Opiala, formerly of Wilbur Associates and now with Hyder Consulting. Opiala’s title is International Director, Intelligent Transportation Systems.

As Mah Bow Tan, one of Singapore's top policymakers stated, "If we rely on ERP charges alone . . . we are looking at a scenario of S\$20 per entry or S\$20 per day. I don't think that's palatable."⁶

It may be the case that the political party that has ruled Singapore since independence, the People's Action Party (PAP), can cope with the political pressures more easily than can politicians in Western democracies, but the PAP is not omnipotent and must handle these issues very carefully.

Conclusion: The Political Economy of Road Pricing

In most American cities, road pricing as a dramatic anti-congestion measure would appear to be a distant prospect. Recent experiments with toll roads in Southern California have mostly failed in political terms. Congestion pricing has attracted interest in the European Union, but formidable political obstacles remain.⁷ Even if congestion pricing gains more acceptance, it is very difficult to set up a regime under which anything close to optimal pricing is practiced. Congestion pricing has been called the idea that economists love, but that ordinary people hate.

Singapore has handled the politics of road pricing very well, but has not been completely unaffected by political pressures. The Central Expressway, for example, has not always been priced according to the government's own principles. It is noteworthy that decisions to change prices must be approved at the ministerial level. In other words, price changes are not just a minor technical matter to be left to functionaries. Expansions of the priced areas and the number of vehicles allowed are also troublesome politically. From the mid-1980s to the 1990s, the portion of tax receipts accounted for by the various charges for motor vehicles rose from about 5 percent to more than 20 percent (*The Economist*, 3 September 1998), which is not to say that there is any proof that the revenues received determine what the policies are. On the other hand, transponders are now viewed as standard equipment for motor vehicles.

In broad, political economy terms, road pricing as it is typically proposed by economists or some transportation specialists is an ex-

⁶*The Straits Times* (2 September 1998: 29). Mah Bow Tan is Singapore's Minister for National Development. He was formerly Minister of Communications. The Land Transport Authority, which conducts road pricing in Singapore, is under the Communications Ministry.

⁷See www.vtpi.org for updates on toll roads in Southern California and road pricing programs in the European Union.

ample of market socialism. The market aspect is the proposal that prices be set so as to balance the supply and demand for roadways. The socialist aspects are that, under most of the proposals, roadways remain a nationalized—or at least a public—industry, and prices are the responsibility of a government authority.

While Hayek ([1940] 1948) in particular exerted a lot of effort in critiquing the original proposals (e.g., Lange and Taylor 1938) for market socialism, his greatest contribution to economics was probably his analysis of “The Use of Knowledge in Society” (1945) and the extent to which all socialist proposals make use of the information possessed by a relatively small number of people (whereas capital markets and other markets in a free market system make use of information scattered among thousands or even millions of decision-makers).

Hayek paid far less attention to issues of modern public choice theory—the economics of politics (e.g., Buchanan and Tullock 1962). In Hayek’s *The Fatal Conceit* (1988), for example, the argument against socialism is still couched mostly in terms of the discovery, use, and transmission of knowledge, and not so much on the incentives of players in the political arena. Even the third volume of Hayek’s *Law, Legislation, and Liberty* (1979), while it rails against the undue political influence of interest groups, makes very little use of concepts in public choice theory.

Singapore after 1965 has been rightly called an economic miracle. It earned its place as one of four Asian “tigers”—along with Hong Kong, Taiwan, and South Korea. Given real per capita GDP growth of 6 percent per year, average living standards increased nearly eight-fold in the following 36 years. While nothing in the real world of political economy is perfect, including Singapore’s road pricing system, the country’s development has been phenomenal.

However, what merits as much discussion in this context as the economics of development is Singapore’s political miracle—especially when one considers the country’s racial and cultural diversity. In other countries, roads, medical care, housing, and many other goods and services are systematically underpriced insofar as their prices are controlled by government. They are underpriced in the sense that the prices charged result in excess demand—or require large subsidies in order to avoid excess demand. The underpricing is systematic in the sense that it almost does not matter who is in power—the underpricing goes on and on.

Singapore essentially broke the mold with respect to roadways, and the precise political conditions under which such breakthroughs occur, and endure, deserve more research on the part of political

scientists as well as economists.⁸ With respect to roadways, one can only speculate whether those conditions are now close to being met in additional cities around the world.

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⁸In Western-style democracies, the most far-reaching economic reforms of modern times were probably New Zealand's from 1984–96. For a discussion of the economic and political factors that made these reforms possible, see Christainsen (1996).