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Congestion Pricing:

International Experiences and Implications for China

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Congestion Pricing: International Experiences and Implications for China

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Abstract

This research presents the economic theory of congestion pricing. Making commuters pay a toll to internalize externality helps to correct market failure and mitigate urban traffic. A number of countries and regions have implemented congestion pricing, including Singapore, USA, and Europe. The international experiences demonstrate very positive consequences, such as significant traffic reduction, time savings, air quality improvement, and revenue generation. With the sound economic theory and successful international practices, congestion pricing in China could become a reality. In fact, China could have a better feasibility of implementing congestion pricing in major cities due to less regressive congestion charges and fewer institutional barriers.

1. Introduction

Since 1990, China has been experiencing rapid urbanization and fast income growth, with its urban population increasing from 301.95 million in 1990 to 606.67 million in 2008 and per capita GDP increasing from 1,634 RMB in 1990 to 22,640 RMB in 2008, respectively. One consequence is a dramatic growth of private vehicles. In 1990, China had 5.5 million private vehicles. This number swelled to 41.73 million in 2008, a 7.59-fold increase in 18 years. The growth of private vehicles in major cities is even faster. In 2008, for example, Beijing had 2.48 million private vehicles (NBSC, 2009). No question, China sees severe traffic congestion on its urban roads, which not only wastes tremendous amount of time of urban commuters but also causes many fatal traffic accidents.

Like most countries, China mainly depends on supply-side policies to mitigate urban congestion, such as through expanding network capacity and improving traffic management. For instance, Shanghai constructs light transit system which covers most of the city area; Beijing builds more subways; and many other cities increase the number of buses in services. Unfortunately, supply-side policies are not effective to reduce urban traffic congestion because better roads induce more demand and urban commuting is subject to the theory of "triple convergences" (spatial, time, and modal convergences). In an attempt to control traffic, regulatory instruments have also been applied in some Chinese cities. In Beijing, for example, starting from April 11, 2009, private passenger vehicles are required to stay off roads one day every week, from 7AM to 8PM, with the date determined by the license numbers and being rotated quarterly. Beginning on April 12, 2010, Beijing staggers work schedule to spread peak hour trips in the morning and evening, with working hours from 9AM to 6PM for all employees in city's public sectors (*People's Daily*, April 13, 2010). Such regulations, however, leave fewer choices and cause a lot of inconvenience for commuters.

Therefore, it is important to propose and implement demand-side policies to mitigate traffic congestion, such as adopting congestion pricing. As shown below, congestion pricing is to correct the market failure by internalizing negative externalities in urban commuting. Such price mechanism not only reduces congestion but also generates toll revenues for governments to provide better transportation network.

This study has three main objectives. First, it presents the economic theory of congestion pricing and determines the optimal toll rate and revenue. Second, the study investigates international experiences of congestion pricing, including those in Singapore, USA, and Europe. Third, the study derives implications for China, aiming to provide policy recommendations for China to better deal with its urban congestion problems.

2. Congestion Pricing: the Economic Theory

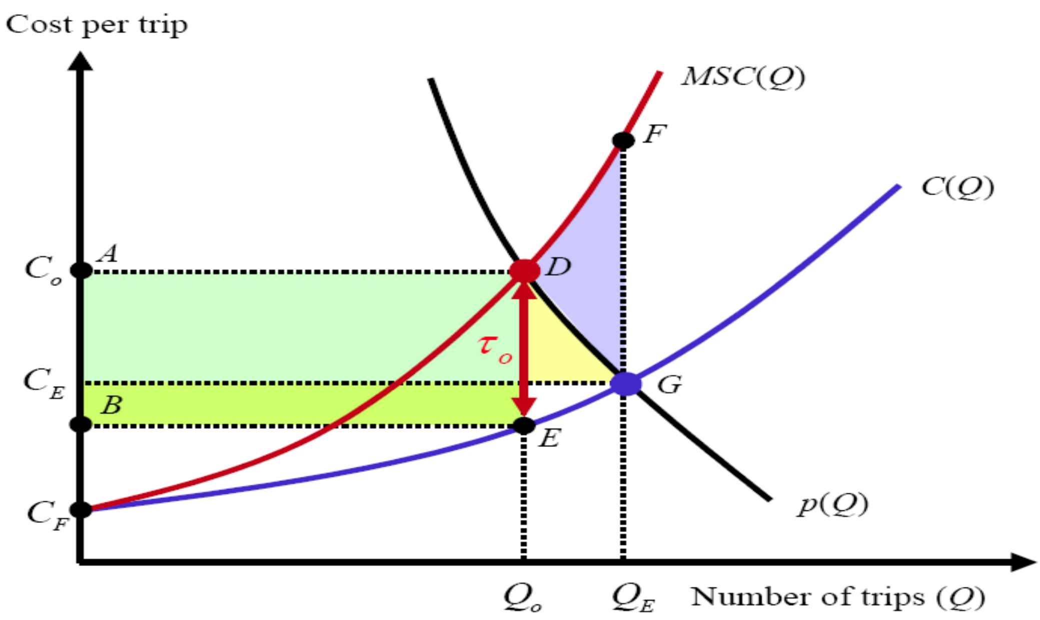
Travel is a derived demand. People travel because they need to go to work, shop, or do other things. In making travel choices of route, time, or modals, travelers compare their own costs and benefits. Put it differently, they will travel as long as the benefit is greater than the cost. They ignore how much delay they cause on other travelers but only pay attention to how much it costs them to get to their destinations. Therefore, the equilibrium numbers of commuters for routes and modals are reached when the benefit equals to the cost, which is not socially optimal, as shown theoretically below.

For each route or modal, let Q be the traffic volume and C be the average commuting cost. This gives the total commuting cost CQ and the marginal social cost (MSC),

$$MSC = \frac{d(CQ)}{dQ} = C + Q\frac{dC}{dQ} = C + EC$$

where EC is the externality cost. If the average commuting cost increases with the number of commuters, like the case on congested urban roads, EC is positive and marginal social cost (MSC) will be higher than the average private cost (C). Consequently, the equilibrium travel volume (Q_E) will be larger than the social optimal traffic volume (Q_O), i.e., too many commuters are on the roads. Q_E is determined based on the private average cost while Q_O is calculated based on the social marginal cost, as shown in the Figure 1 below. When no congestion exists, commuters do not affect each other. In this case, MSC equals to C and EC becomes zero.

Figure 1: Economics of Congestion Pricing



To reach social optimization, externality should be internalized. In the case of congested urban roads, this suggests a toll of $\tau_o = Q\frac{dC}{dQ} = EC$, to be charged on commuters. Because $Q\frac{dC}{dQ}$ depends on traffic volume and the relationship between travel time (speed) and traffic volume, the toll should be higher for more congested roads or periods than the ones for less congested roads or periods. The optimal toll revenue equals to $Q^2\frac{dC}{dQ}$ and it is determined by the area of *ABED* in Figure 1.

Two issues are worth mentioning. First, congestion pricing is not to eliminate congestion, but to reduce the number of travelers on the roads and thus mitigate the congestion level. It is to correct the market failure by asking travelers to pay their full cost of travel, so externality would be internalized. A certain level of congestion suggests an efficient use of road network, as long as the social marginal cost does not exceed the social marginal benefit. Theoretically, externality cost should include not only the time delay caused by additional commuters but also the increased emission and traffic accidents. All such externalities need to be internalized in the optimal toll and paid by travelers.

Second, relative to the original equilibrium outcome, commuters enjoy a smaller consumer surplus by paying a toll and driving less. Part of the lost consumer surplus goes to the government, with the amount determined by the area of *ABED*, as an income redistribution. The remaining lost consumer surplus is shown by the area of *DEG* (above the *C* curve but below the demand curve between Q_O and Q_E). The lost consumer surplus of *DEG*, however, is significantly smaller than the savings of social cost, which is determined by the area of *DEGF*, generating a net efficiency gain of area *DFG* (above the demand curve but below the *MSC* curve between Q_O and Q_E). With congestion pricing, fewer people travel during peak hours. Commuters thus drive faster and spend less time. This time saving, plus the reduced air pollution and traffic accidents, produces a significant net saving to the society. This second point helps to explain why congestion pricing is politicians' nightmare but economists' dream.

3. Congestion Pricing: the International Experiences

Because the general public usually perceives tolls as a new coercive tax, congestion pricing was considered an economists' dream but politicians' nightmare (Small, 1992). However, in recent years, congestion pricing is becoming more popular in practice and receiving more public support. It also has been implemented in a number of cities in different countries. This section presents the various congestion pricing programs in Singapore, Europe, and the USA.

To implement congestion pricing, some principles need to be followed (Santos, 2005).

1. Charges should relate closely to road usages.
2. Charges should vary with location, time, and modes, which are readily ascertainable.
3. The incidence of the system upon motorists should be fair.
4. In advance and automatic payment should be possible.
5. The drivers' privacy and rights should be protected.
6. The pricing system should be easy to understand.
7. It should be reasonably free from the possibility of fraud and evasion.
8. Equipment should possess a high degree of reliability.
9. Occasional users and visitors should be accommodated rapidly and at low cost.

The above principles help to determine charges that reflect the true social cost of driving under various conditions, recognize the regressive nature of congestion pricing which charges the same for the poor and the rich, increase time efficiency, allow drivers to check for their records and prevent from abuse, promote transparency, reduce evasion, ensure reliability, and provide flexibility.

3.1 Congestion Pricing in Singapore

The best-known and comprehensive example of a successful congestion pricing program is the Area Licensing Scheme in Singapore (Keong, 2002). In June 1975, to slow growth and use of motor vehicles in the central business district (CBD), Singapore implemented a toll system in its 2.0 square-mile restricted zone (RZ) with initially 24 vehicular entry points manned by human monitors. The government's goal was to dissuade private cars and taxis during morning peak hours by instituting a manual area licensing scheme (ALS) on the basis that vehicle use, not ownership, causes traffic congestion. With the ALS, all vehicles were required to purchase and display a mountable decal license costing S$3 per day or S$60 per month (company registered vehicles cost double) for entry into the RZ between 7:30AM to 9:30AM Monday through Saturday. A Park-and-Ride shuttling system was developed which provided low-cost parking in several newly constructed garages located on the RZ fringes. Taxis, buses, motorcycles, and carpooling vehicles carrying 4+ persons were exempted from ALS compliance (Keong, 2002). Violations were identified at the entry points and citations were sent to vehicle owners by mail. On December 31, 1975, the daily ALS fee for private vehicles was increased from S$3 to S$4, and then to S$5 on March 1, 1980 (again twice as much for company owned vehicles).

Singapore's initial goal was to reduce traffic volumes by 25-30 percent in the RZ but the early ALS results observed a 43 percent decrease because motorists shifted trips to before or after the restricted hours and morning peak hour traffic took new routes to bypass the RZ. In addition, even though morning traffic volumes dropped significantly, evening peak hour congestion did not decrease as anticipated (the so-called mirror image). Congestion had been shifted in location and time (Phang and Toh, 2004).

On August 1, 1975, Singapore revised the ALS in an effort to optimize efficiency by extending the morning peak hours to 10:15AM. The total number of motor vehicles entering the RZ during the extended restricted hours fell from a March 1975 (pre-ALS) daily average of 74,000 to an October 1975 (post-ALS) daily average of 41,500, a 44 percent reduction in the total traffic, much more than the targeted 25 to 30 percent reduction (Phang and Toh, 2004). According to Bhatt et al. (2008), the pricing resulted in shifts to HOV 4+ and public transit, with HOV 4+ share increased from 8 to 19 percent and bus share increased from 33 to 46 percent. Congestion inside the RZ was virtually eliminated. Speeds inside the RZ during the morning peak hours increased by 20 percent (including buses). On most congested streets, the speeds went up from 15-18 kph to 30 kph. There was also a 10% increase in speeds on inbound radials leading to the RZ. However, along with these improvements, the speeds on the bypass route dropped by 20 percent.

To address the evening peak hour congestion conditions, the ALS was expended on June 1, 1989 to impose a toll for the RZ entry between 4:30PM and 7:30PM, which later got shortened to between 4:30PM and 6:30PM, Monday through Friday. With the extension of hours, toll went back to S$3, but carpools, commercial vehicles, and motorcycles were also charged. Scheduled public buses and emergency vehicles are the only ones exempted (Keong, 2002). Results again revealed inbound traffic reduced by 44 percent during evening hours within the first year of implementation.

In May 1991, Singapore announced that the average speed during peak hours in the CBD had reached 35 kph, up from 19 kph in 1975. In January 1994, to smooth out the peaks and troughs, the Whole Day ALS was introduced, covering 7:30AM to 6:30PM Monday through Friday and 7:30AM to 3:00PM (later shortened to 2:00PM) on Saturday. In addition, part-day licenses were introduced for S$2 for entry between 10:15AM and 4:30PM Monday through Friday and 10:15AM to 3:00PM on Saturday. Results from the Whole Day ALS revealed an increase in morning traffic from 49,000 to 60,000 vehicles, a decrease in afternoon traffic from 168,000 to 143,000 vehicles, and an increase in evening traffic from 28,000 to 34,000 vehicles. According to Phang and Toh (2004), this was the first real evidence that it is possible to smooth out peak and valley congestion through an appropriate congestion pricing scheme.

The ALS was expanded to include a road pricing scheme (RPS) introduced on the East Coast Parkway in June 1995 in which all vehicles were required to purchase and display a S$1 daily or S$20 monthly license for entry during 7:30-8:30AM on all non-holiday weekdays. The RPS resulted in a decrease in traffic volumes from 12,400 to 7,300 vehicles with an increase in speed from 29 kph to 64 kph during restricted hours within the first four months of implementation.

Both ALS and RPS were found to be very successful financially for Singapore. Dramatic changes were achieved from the minimal capital investment of S$6.6 million for the original ALS plus an astonishingly low cost of S$0.17 million for the revised ALS in 1989. Revenues from license sales totaled S$47 million with the operating expenses reaching only 9 percent of the total revenue (Phang and Toh, 2004). Bhatt et al. (2008) found that the revenues from the

ALS scheme were about 11 times the costs. Santos (2005) suggested that the annual net revenue of ALS were roughly five times of the annual operating costs. In addition, by shifting modality, public transportation cost had decreased because ridership had more than doubled (an increase from 33 percent to 69 percent) and parking rates in the RZ decreased 30 percent (Phang and Toh, 2004; Bhatt et al., 2008).

Although the ALS and RPS were successful in reducing congestion, manual licensing and the enforcement of 16 different pricing schemes proved challenging to citizens and management alike. According to Keong (2002), there were about 60 enforcement personnel constantly required at the gantry points and another 60 offices at the dedicated license sales booths. Extending the schemes to other points would need even more people to run them. Also, a license offered a vehicle unlimited number of entries to the RZ or passage through the ALS/RPS control points. Furthermore, there was always a rush to enter the RZ just before or after the restricted hours, causing sharp and short peaks of entering traffic volumes.

After extensive field tests during 1995-1997, Singapore introduced an electronic road pricing (ERP) system between April and September 1998 at an initial cost of S$197 million. Of which, about S$100 million covered the initial supply of in-vehicle unit (IU) transponders given to motorists for free during a 10-month period of grace. For less than S$300 per vehicle, IU was custom fitted (Phang and Toh, 2004). The remaining amount of S$97 million was for the design, development, supply, installation and one-year warranty of ERP equipment, including the gantries and central computer system. The system is designed to support up to 100 ERP points, and by 2004, there were 45 gantries on the road (Santos, 2005).

The IU accepts prepaid smart debit cards before each trip and is debited at the antenna-equipped gantry locations found near the RZ. Vehicles are charged without having to slow down and no central processing agency is needed. The ERP system is linked to controllers who check for potential violations such as insufficient balances or no smart cards installed when a violation is spotted, a camera image of the rear license plate is taken and submitted to the user with an S$10 administrative fee. The ERP charge point locations as of 2005 are shown in Figure 2.

Figure 2: Singapore ERP in 2005 [CBD priced zone (Inset) and Expressways (Red)]

Source: Bhatt et al. (2008)

All vehicles (excluding emergency services) are levied on a per use basis and rates vary according to vehicle type, time, and location. Vehicle-type charges are based on a passenger car unit (PCU) measurement calculated from the amount of road space occupied. For example, motorcycles have a PCU of 0.5 while a large truck may pay twice as much given its PCU of 2.0.

Initially, the ERP gantry locations mirrored the toll and RZ entry points in the ALS and RPS, though the new system charged between S$0.5 and S$2.5, less for small PCU vehicles. By 2003, the ERP system had 45 gantries covering the RZ, each operating Monday through Friday from 7:30AM to 7:30PM plus gantries on four expressways and four major arterials operating between 7:30AM and 9:30PM, Monday through Friday. In more recent years, the charge period in the central RZ is in effect from 7:00AM to 7:00PM, Monday through Friday, and charge rates vary from zero to approximately US$2.00 per crossing at a charge point. On expressways, the prices are in effect weekdays from 7:00AM to 9:30AM (with additional PM outbound charges on one of the freeways). The rates vary from zero to about US$4.00. Also, a few of the arterial streets are priced weekdays from 7:00AM to 9:30AM and the prices vary from zero to about US$0.80 (Bhatt et al., 2008).

Results indicated that traffic in the RZ decreased about 10-15 percent during operating hours, as compared to the ALS scheme (Keong, 2002). Traffic speeds in the CBD remained in the optimum of 20-30 kmh (Santos, 2005). In late 1998 the ERP was expanded to include seven additional gantry locations. The major difference is that the ERP charge is applicable for each passing, while the ALS charge allowed multiple entries for that day. Hence, the ERP had influenced particularly the behavior of those who made multiple trips to the CBD. Further, with the ERP system, traffic was better spread out during the day, with the expressways and arterial roads carrying close to their designed capacity (Goh, 2002; Phang and Toh, 2004).

Financially, the ERP system proved successful. According to Santos (2005), as of 2004, the annual operating cost of the system was about S$16 million. The average gross revenues from 2001-2003 were S$80 million per year.

As argued by Goh (2002), the ERP system demonstrates several advantages. First, it rations vehicle flow efficiently because it charges directly and can be easily adjusted to charge more during peak hours. Second, the charges per entry are more efficiently allocated than the daily permits with multiple entry privileges. Therefore, motorists are made more aware of the true cost of driving as charges are levied on a per-pass basis and can vary according to the congestion levels. The road user can better recover the full cost of the transport infrastructure.

Starting from April 1999, Singapore implemented the quarterly rate review system which adjusts congestion prices based on the target speed ranges between 45 and 65 kph for expressways and between 20 and 30 kph on arterial roadways. These ranges were set based on road capacities and the level of service E ratings, i.e., the speed-flow curves. Hence, it is a "pay as you drive system." Rates will fluctuate throughout the day depending on the time of travel and the specifications that are programmed into the IU, with charges being the highest during the morning peak periods. Based on this principle, if a road has less than optimal traffic, the charge is decreased to encourage higher traffic volumes. On the other hand, if a road experiences over optimal traffic congestion, the charge is raised in hopes of deterring people from using that route. This system has been accepted by the public (Goh, 2002). In February 2003, the ERP charges were further fine-tuned to discourage motorists from waiting on road shoulders for price adjustments or from speeding to avoid toll charges. Positive result of the ERP system's convenience and flexibility not only allows for responsive traffic volumes and road utilization but it also reduces road taxes and vehicle registration fees and allows for increases in Singapore's motor vehicle quota scheme.

Table 1. Summary of the Singapore Experience

Date of implementation	Implementation	Policy	Impact
June 2, 1975	Morning peak hours manual area licensing scheme (ALS) Windshield license 24 entry points A Park-and-Ride shuttling system on the RZ fringes	S$3/day or S$60/month Company registered vehicles cost double Taxis, buses, motorcycles, and carpooling vehicles were exempted 7:30 - 9:30AM M-Sat	43 percent decrease in the traffic volume in the morning peak hours No mirror image for the evening peak hour congestion
August 1, 1975		Extended to 10:15AM	44 percent decrease in traffic volume in the morning peak hours
December 31, 1975		S$4/day	
March 1, 1980		S$5/day	
June 1, 1989	Evening peak hours ALS	4:30-6:30PM, M-F S$3/day Carpools were charged	Traffic reduced by 44 percent during evening hours
January 3, 1994	Whole Day ALS	7:30AM-6:30PM, M-F and 7:30AM-3:00PM, Sat. S$2 for 10:15AM-4:30PM M-F and 10:15AM-3:00PM Sat.	Smooth out congestion through pricing
June 1995	Road pricing scheme (RPS) on the East Coast Parkway	S$1/day or $20/month 7:30-8:30AM	41 percent decrease in the traffic volume An increase in speed from 29 kph to 64 kph
April-September 1998	Electronic road pricing (ERP) system	S$0.5 - S$2.5, less for small vehicles	Traffic in the RZ decreased about 10-15 percent during operating hours
Late 1998	The ERP was expanded to include seven additional gantry locations		
By 2003	The ERP system had 45 gantries covering the RZ plus gantries on four expressways and four major arterials	7:30AM to 7:30PM for the 45 gantries and 7:30AM to 9:30PM for the expressways and arterials, M – F	
Starting from April 1999	Pay-as-you-drive system	The quarterly rate review system adjusts congestion prices based on the target speed ranges between 45 and 65 kph for expressways and between 20 and 30 kph on arterial roadways	10 mph increase in average speed, 25 percent fewer traffic accidents, 45 percent reduction in traffic, 20 percent increase in use of public transportation, 176,400 fewer lbs of CO_2 emitted (www.edf.org/)

Note: Compiled by the author from various sources.

3.2 Congestion Pricing in London

Congestion pricing has also been implemented in Europe. The Greater London Authority was granted the power to charge for road use in 1999. After three years of planning, assembling, and sufficient financial leverage, on February 17, 2003, London implemented road pricing to combat congestion in Central London. As argued by Litman (2006), central London is a strong candidate for congestion pricing, given its limited road space, densely populated CBD, and heavy road congestion.

Figure 3: The Central London Congestion Charging Zone

Source: Benko and Smith (2008)

The scheme involves a standard per-day charge for vehicles traveling within a zone bounded by an inner ring road. The system covers an eight square mile area (1.3 percent of Greater London); it was almost doubled in size in early 2007 when it was extended westward to include Kensington and Chelsea. Between 7:00 AM and 6:30 PM (modified in 2007 to 7:00AM-6:00PM), excluding public holidays, motorists are required to pay a daily fee of £5 during the week. Exemptions from this payment exist for cab drivers, roadside help, disabled people, and two wheelers. Area residents are subsidized with a 90 percent discount. Payment can be made in several different manners through internet payment sites, text messaging payment, retail outlets, and local payment machines. Periods of payments can be weekly (£25), monthly (£110), or annually (£1,250). In July 2005, the daily charge was increased from £5 to £8. This was done to achieve additional reductions in congestion as well as to fund further public transit improvements. There are several methods of payment. During the first year, 36 percent sales are paid via retail, 19 percent via the call center, 26 percent via the Internet, 19 percent via the short message service on mobile phones, and less than one percent by post (Santos, 2005).

This cordon pricing system is run by Transport for London (TfL), the unified agency responsible for carrying out the Mayor's transit strategy. The system works through an intricate network of cameras placed at the 174 entry points to the central business district, as well as approximately 50 cameras throughout the zone. The video cameras record the license plate numbers of vehicles and match them with paid motorists through an intricate optimal character recognition (OCR) system. Due to privacy concerns, license plate images are erased from the system each evening. Vehicles that do not match any records of payment are fined in the sum of £80. This fine is reduced to £40 if paid within two weeks and increases to £120 if not paid after a month. Ken Livingstone, then the Mayor, made the remarks， only half-jokingly that, if a driver declined to pay fines, the city would relentlessly track his car down, clamp it, tow it away and crush it – “with or without the driver inside” (*New York Times*, 20 April 2003, by Randy Kennedy).

Congestion pricing program brought significant improvements in traffic congestion to Central London, although various studies present different findings. According to Litman (2006), within the first few months of implementation, traffic was reduced by 20 percent or around 20,000 vehicles per day. In the first year, Nash (2007) found the number of vehicles entering the zone dropped by 14 percent. Leape (2007) showed that in the first year of the charge, traffic delays in London dropped by 30 percent, journey time reliability increased by 30 percent, and average speeds rose 17 percent. The charge also changed who was using the roads: private car trips dropped by 34 percent, but bus, taxi, and bike trips all rose sharply. Inbound bus passenger numbers increased 37 percent in the first year, about half of whom had previously traveled by car. Leape argued that a key reason for the surge in bus passenger numbers to the “virtuous circle” for bus transport. The higher cost of rush-hour car trips and increased bus travel speeds result in increasing passenger numbers and falling average costs. In turn, it leads to improved service levels and lower fares that stimulate further shifts to public transport and additional reductions in congestion. According to the findings of Bhatt et al. (2008), after the first year of operation, traffic circulating within the charging zone was reduced by 15 percent during charging hours. The number of vehicles entering the charging zone was reduced by 18 percent. Traffic delays were cut by 25 percent. Travel speeds increased by 30 percent in the zone. Bus use increased by 40 percent. Santos and Shaffer (2004) found that over the first year congestion decreased by 30 percent, traffic level within the charging zone fell by 16 percent, speed for car travel increased by more than 20 percent, and bus travel became more reliable. Santos (2005) stated that an 18 percent drop in the traffic volume was recorded for the first two years of the program. Data from surveys from the project reveal that the average speed has increased by 37 percent, from an average speed of 8 mph to 11 mph.

There was a concern at the start of the program that traffic congestion would be diverted to different routes, causing inefficient and lower capacity roads to be filled with more drivers. However, the traffic spillover proved to be minimal. A key lesson in the London experience is that traffic has not overflowed onto neighboring roads. After a short adjustment period, free rings have traffic levels comparable to 2002 levels (http://www.edf.org/page.cfm?tagID=6241).

According to Santos (2005), the capital costs of the congestion pricing were approximately £200 million at 2002 prices, most were provided by the central government. The total annual cost £130 million included £5 million for administration, £90 million for operation, £20 million for additional bus costs, and £15 million for charge-payer compliance costs. In the first year, the program generated net revenue of £68 million, less than an original estimate of £120 million, probably due to too many exemptions, high discount, and higher levels of evasion. Revenues collected from congestion pricing, with £97 million in net revenues in the 2004/05 budget year, for instance, have been used to improve public transit and roadway system, such as adding subway stations, buses, and bus lanes. As results, bus congestion delays declined 50 percent, bus ridership increased 14 percent, and subway ridership increased one percent (http://www.tfl.gov.uk/tfl/cclondon/pdfs/thirdannualreportfinal.pdf). Transport for London (2006) estimated that the congestion pricing program raises a surplus of £122 million per year.

Bhatt et al. (2008) summarized the TfL's reports that showed congestion pricing also improved air quality within and alongside the Inner Ring Road boundary of the zone. Levels of NOX fell by 13.4 percent between 2002 and 2003, CO_2 by 15 percent, and particulates (PM10) by 7 percent. Between 2002 and 2003, Beevers and Carslaw (2005) found that the total NOX emissions in the charging zone reduced by 12.0 percent, PM10 emissions reduced by 11.9 percent, and CO2 emissions reduced by 19.5 percent.

A final measure of London's success is the satisfaction of those involved. Seventy-eight percent of people who pay to enter the cordon area are satisfied with the system, and reinstatement of the system is scheduled for August 2007. Initial public skepticism has turned into support, with the level of acceptability of road pricing increasing from about 40 to above 50 percent before and after the introduction, respectively. In June 2004 London's Mayor Ken Livingston enjoyed popular re-election after adopting the charge (CURACAO, 2007; http://www.edf.org/page.cfm?tagID=6241).

Table 2. Summary of the London Experience

Date of implementation	**February 17, 2003**
Implementation Policy	● Per-day charge for vehicles traveling within the Central London ● Video cameras optimal character recognition system ● £5/day, £25/week, £110/month, or £1,250/year ● 90 percent discount for area residents ● Taxi drivers, roadside help, disabled people, and two wheelers are exempted ● 7:00AM to 6:30PM Monday – Friday
Impacts	● 30 percent average drop in congestion; 37 percent average increase in traffic speed; 12 percent drop in particulate matter and nitrogen oxides; 20 percent decrease in fossil fuel consumption and CO_2 emissions ● Within the first few months of implementation, traffic was reduced by 20 percent. ● In the first year, the number of vehicles entering the zone dropped by 14 percent ● In the first year of the charge, traffic delays dropped by 30 percent, journey time reliability increased by 30 percent, and average speeds rose 17 percent, private car trips dropped by 34 percent, inbound bus passenger numbers increased 37 percent. ● After the first year of operation, traffic was reduced by 15 percent during charging hours, traffic delays were cut by 25 percent, travel speeds increased by 30 percent, bus use increased by 40 percent. ● For the first two years of the program, traffic volume dropped 18 percent, average speed increased by 37 percent. ● £97 million in net revenues was collected in the 2004/05 budget year. ● Between 2002 and 2003, levels of NOX fell by 13.4 percent, CO_2 by 15 percent, and particulates (PM10) by 7 percent.

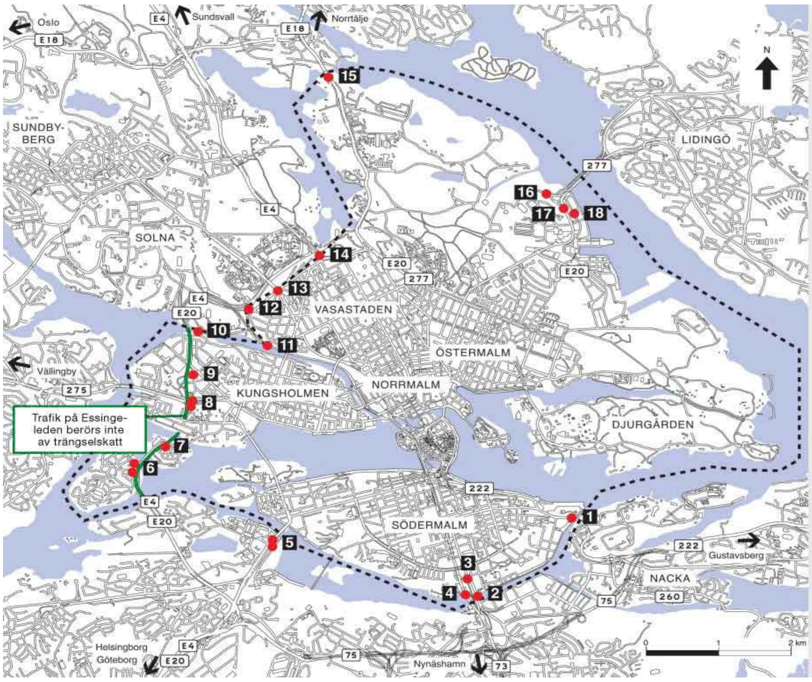
Note: Compiled by the author from various sources.

3.3 Congestion Pricing in Stockholm

The election in 2002 resulted in social-democratic governments backed by the Left and Green parties, both at the national level and in the City of Stockholm. The newly-elected announced to introduce a full-scale congestion pricing program. The law authorizing congestion taxes was enacted in 2004, with the stated goals of reducing congestion, enhancing public transportation to increase accessibility, and improving the environment (CURACAO, 2007; Bhatt et al., 2008).

Stockholm initiated a trial period of cordon pricing for its central city between January 3 and July 31, 2006 (Decorla-Souza, 2006; http://www.edf.org/page.cfm?tagID=6241; Eliasson, 2008). The central city area of approximately 20 square miles was designated as the priced zone (Figure 4).

Figure 4: Stockholm Priced Zone Cordon with Charging Locations



Source: Benko and Smith (2008)

The project was preceded by transportation improvements including 197 new buses, 16 new bus lines and more trains at peak hours. The charges were effective weekdays from 6:30AM to 6:30PM and the price was set at 10, 15 and 20 SEK (about US$1.33, 2.00 and 2.67 at 2006 rates) for off-peak, shoulder (7:00-7:30AM, 8:30-9:00AM, 3:30-4:00PM, 5:30-6:00PM) and peak period (7:30-8:30AM, 4:00-5:30PM), respectively (Eliasson, 2008, Table 1). The charges were collected when entering or exiting the zone at 18 barrier free "control points" encircling the city center. The daily maximum charge, for multiple crossings was set at 60 SEK (about US$8.00) (Bhatt et al., 2008; http://www.transalt.org/campaigns/congestion/international). About 30 percent of vehicles entering the priced zone were exempted from charges, including taxis, hybrid cars, buses, foreign cars, handicap tagged cars, diplomats and police and emergency vehicles. Vehicles traveling through the priced zone without stopping were also exempted.

Three overhead gantries at each charge point electronically identified the passing vehicle if equipped with On-Board Transponder Unit (OBU) and allowed automatic charge deductions from pre-set accounts. License plate photos (front and rear) were captured for all vehicles with and without OBU. Vehicles without pre-set accounts or those without transponders had until noon time the next day to post payments that could be made on the web, at retail outlets, banks and kiosks. Fines for non-payment were set at 70 SEK (US$10) for the first reminder and went up to 500 SEK (US$70) for the second reminder (Bhatt et al., 2008).

According to Bhatt et al. (2008), overall traffic to and from the inner city declined by 10 to 15 percent and vehicle miles traveled in the charged zone decreased by 14 percent. Public transportation use increased by six to nine percent. A significant portion of car users who gave up trips during the charge period shifted to transit. Few changed time of departure. No significant increase was observed in cycling, carpooling or telecommuting. Recent data show that the permanent charging program, reintroduced in 2007, appears to have reduced traffic by 18 percent. The proportion of exempted “green” cars has risen to nine percent. Eliasson (2008) found that traffic across the charging zone decreased by around 30 percent during the first week, before settling down at a surprising stable decrease of around 22 percent less traffic than corresponding periods of 2005. When charges were abolished on August 1, 2006, there was a remaining traffic decrease of around five to 10 percent compared to the 2005 level. When charges were reintroduced in August 2007, traffic once again decreased around 20 percent compared to the 2005 level. The number of vehicle kilometers driven in the inner city decreased by around 16 percent. According to the Environmental Defense Fund (EDF) website (http://www.edf.org/page.cfm?tagID=6241) , Stockholm's successes show a 15 percent reduction in traffic, a 10-14 percent drop in CO_2 emissions, and preventing 30 premature deaths by reducing NOX.

The total start-up cost of the system was 1,900 million SEK, including information campaigns and extensive system tests. The yearly operational cost of the system (220 million SEK) includes not only running costs but also necessary reinvestments and maintenance such as replacement of cameras and other hardware. In terms of economic welfare, Eliasson (2006) estimated that the trial program would have produced a net annual benefit of nearly 700 million SEK ($90 million) against the investments and annual operating costs listed above. These data would suggest a payback period of about four years. Eliasson (2008) showed that the Stockholm system yielded a large social surplus, well enough to cover both investment and operational costs. A permanent congestion-tax system is calculated to yield an annual social surplus of about SEK 650 million (after deducting operating costs).

As in London, positive results led to an increase in support. CURCAO (2007) provides a summary of the public attitudes toward Stockholm congestion pricing scheme before and after the six-month trial in 2006: "In autumn 2005, about 55 percent of all county citizens believed that it was a "rather/very bad decision" to conduct the congestion-tax trial. Since the congestion tax was introduced in January 2006, this percentage has continuously fallen. In April and May 2006, 53 percent of all citizens believed that it was a "rather/very good decision" while 41 percent believed that it was a "rather/very bad decision". Significantly, even those traveling by car to/from the inner city during the charge period in the most recent two 24-hour periods have become more positive by several percentage units. In May 2006, car drivers were about equally for and against the road pricing trial. Two months after the trial, on September 17, 2006, 51.7 percent of voters passed a referendum to reinstate the charge, effective July 2007. The congestion pricing system enjoys broad support from liberal and conservative political groups (Eliasson, 2008; http://www.transalt.org/campaigns/congestion/international). Eliasson (2008) argued that Stockholm charging scheme is successful because of its working technical system, effective information campaign, visible congestion reduction, extensive and scientific evaluation, and clear objectives.

Table 3. Summary of the Stockholm Experience

Date of implementation	January 3 and July 31, 2006
Implementation Policy	● Weekdays from 6:30AM to 6:30PM ● Charge per entry, with 10SEK for off-peak, 15SEK for shoulder (7:00-7:30AM, 8:30-9:00AM, 3:30-4:00PM, 5:30-6:00PM), and 20SEK for peak period (7:30-8:30AM, 4:00-5:30PM) ● Daily maximum charge of 60 SEK for multiple crossings ● About 30 percent of vehicles entering the priced zone were exempted from charges ● Preceded with public transportation improvements ● On-Board Transponder Unit allows automatic charge deductions from pre-set accounts ● 70 SEK fine for the first reminder and 500 SEK for the second reminder
Impacts	● Overall traffic to and from the inner city declined by 10 to 15 percent. ● Vehicle miles traveled in the charged zone decreased by 14 percent. ● Crossing traffic decreased about 20 percent. ● Public transportation use increased by 6 to 9 percent. ● 10-14 percent drop in CO_2 emissions ● Prevented 30 premature deaths by reducing NOX ● Produced net annual benefit of nearly 650 million SEK ● Significant improvement in public support

Note: Compiled by the author from various sources.

3.4 Congestion Pricing in the USA

Scholars in the United States have done a tremendous amount of theoretical research on congestion pricing (e.g., Decorla-Souza and Kane, 1992; Giuliano, 1992; Small, 1992; Poole, 1992; Arnott and Small, 1994; Lee and Gordon, 2006; Small et al., 2006). In practice, a number of congestion pricing projects have been implemented in the USA (Harrington et al., 1998; VDOT, http://www.virginiadot.org/info/resources/congestion_pricing/cp_in_us.pdf). For example, high occupancy toll (HOT) lanes are currently under development on the I-495 corridor in Northern Virginia. A toll is required for solo drivers and low-occupancy vehicles that want to use high-occupancy vehicle lanes, while carpoolers, vanpoolers, motorcycles, buses and emergency vehicles could use the lanes free of charge. A 2-lane-8-mile reversible facility was constructed in the median of I-15 in San Diego, California in 1996. Solo drivers could use these HOV-3 lanes if they purchased monthly "ExpressPass" permits for $70. In 1998, a fully automated dynamic pricing pilot project was implemented to deduct per-trip fees from pre-established accounts as opposed to charging a monthly flat fee. To accommodate the changing price, the ExpressPass was replaced by electronic transponders (FasTrak) that could be affixed to drivers' car windshields. Today a posted schedule informs drivers of the highest toll they should expect to pay during the hours of operation. Tolls typically vary from $0.50 to $4 depending on the level of congestion. In Lee County, Florida, variable pricing was established in 1998 on the Cape Coral and Midpoint Bridges. To encourage drivers to adjust their travel times, these bridges offer half-price tolls in the time period just before and just after peak travel periods. Typical tolls cost between $0.50 and $1. Only drivers who have a pre-paid account with LeeWay—Florida's Electronic Tolling system—are eligible for the discount. The I-394 MnPASS Express Lanes (HOT Lanes) opened in Minneapolis, Minnesota in 2004. Drivers could use these lanes if they obtained an MnPASS electronic transponder. Preliminary evaluations have proven that congestion pricing is an effective traffic management tool that ensures free-flowing speeds for transit and carpoolers, helps vehicles better utilize HOV-lane capacity, and even provides congestion relief for non-MnPASS lane users. In Houston, Texas, a congestion pricing project named QuickRide was established in 1998 on an existing 13-mile HOV lane stretch of the I-10. It allows a limited number of carpools with only two riders (HOV-2) to buy into the reversible HOV-3 lane during peak travel periods. During this time, participating HOV-2 vehicles pay a $2 per trip toll, while HOV-3 vehicles continue to travel free of charge. Solo drivers are not allowed to use the HOV lanes. To avoid causing congestion for HOV-3 riders, the number of HOV-2 vehicles permitted to travel on these lanes is limited. Like the I-15 project in San Diego, QuickRide is also automated using windshield-mounted transponders and overhead readers.

A better known US example is the State Route (SR) 91 Freeway in Southern California (Figure 4), the world's first high-occupancy toll (HOT) or express toll lanes, which was opened in December 1995. A private consortium, operating under a 35-year concession, added four lanes to SR 91, one of Southern California's most congested freeways. Carpools with three or more passengers could use the new lanes at half price; all other cars (no trucks were allowed) would pay a toll set high enough to ensure high-volume but uncongested traffic flow at all hours.

Figure 4: California State Route 91 Express Lanes (The segment in red)

Initially, the combination of added capacity on SR 91 and the fact that many vehicles switched to the new lanes brought significant reductions in peak-period congestion on the regular or general-purpose lanes (in addition to free-flow conditions in the express lanes). But after about five years, enormous growth in traffic in this commuter corridor led to the return of serious congestion in the general-purpose lanes. The concession agreement included a rigid noncompetition clause, preventing the addition of any more general-purpose capacity. This situation proved politically untenable, leading to the purchase of the express lanes by the Orange County Transportation Authority (OCTA) seven years after they had opened to traffic.

Recognizing that correct pricing was the only way the lanes could deliver the promised benefit of a reliable, uncongested trip, the OCTA created an algorithm that uses measured traffic density in the express lanes, hour-by-hour, seven days a week. For any one-hour time block during peak travel times, where set traffic conditions are at risk of becoming more congested, as measured over a 12-week period, the toll rate for that time block is increased accordingly. The adjustment process also checks for under-use and permits automatic downward adjustments. Appendices A-D show the toll policies, the adjustment processes, and the recent toll schedule.

Empirical evidence shows that congestion pricing has worked very well on SR 91. Not only did it reduce toll-payers commuting time by 20-30 minutes and make trips more time reliable, but it also significantly improved road efficiency. As traffic engineers know, under severe congestion, freeway vehicle throughout can be drastically reduced. Pricing ensures that freeway operational efficiency is not lost due to excess demand. According to Paniati (2006), in the peak hours, the average speed on the free lanes is about 15 mph, while it is about 65 mph on the HOT lanes. Each of the HOT lanes on SR 91 carries twice the number of vehicles that the adjacent toll-free lanes do. Since each vehicle on the HOT lanes carries more people on average, the difference is even greater with regard to the number of persons.

It could be interesting to mention an unsuccessful effort of the City of New York in promoting congestion pricing (http://en.wikipedia.org/wiki/New_York_congestion_pricing). New York congestion pricing was first proposed on April 22, 2007 as one component of New York City Mayor Michael Bloomberg’s plan to improve the city’s future environmental sustainability. It was a proposed traffic congestion fee for vehicles traveling into or within the Manhattan CBD. On August 14, 2007, the U.S. Department of Transportation awarded from the Urban Partnership program $354 million to New York City, of which, $10.4 million is allocated for launching the congestion pricing program. The idea of congestion pricing was endorsed by the then Governor Spitzer and Senate Majority Leader Joseph Bruno. On January 31, 2008, the New York City Traffic Congestion Mitigation Commission approved a plan for congestion pricing, which was passed by a vote of 13 to 2. On March 31, 2008, the proposal was approved by the New York City Council, by a vote of 30 to 20. However, despite an extraordinary majority of New Yorkers supported congestion pricing, on April 7, 2008, after a closed-door meeting, the Democratic Conference of the State Assembly decided not to vote on the proposal. The State Assembly Speaker Sheldon Silver opposed the plan, claming that commuters would choose to park in neighborhoods just outside the pricing zone and the installation of cameras for tracking purposes might have raised civil liberties concerns. Some other opponents called the proposal a "regressive tax" on the poor and the middle class. Shortly after April 7, most of the federal grant that was to have gone to New York City was awarded to Chicago for bus-only lanes and Los Angeles for HOT lanes.

4. Implications and Conclusions

Once being implemented, the above international experiences suggest that congestion pricing could be quite successful in reducing traffic levels, saving time, improving air quality, generating net revenues, and even increasing public acceptability. Technology is no longer an issue of congestion pricing implementation. However, for several reasons, it remains a challenge for the general public to accept the concept. First, the public perceives that congestion toll simply as a new tax, in addition to taxes they have paid to finance the transportation network. Freeways are not free anymore. Second, such a fee could be regressive because it charges the same for the poor and the rich. Hence, the poor is paying a higher proportion of their income, while high-income commuters would not be turned off from the road by paying the charges. Third, commuters dislike congestion fees because they perceive them coercive, in that they often have few practical alternatives to paying the fee.

A number of studies have examined political acceptability (Giuliano, 1992; Small, 1992; Harrington et al., 1998; King et al., 2007; Eliasson, 2008). Some found that political feasibility and public acceptability depend on who receives the toll revenue. For example, Harrington et al. (1998) conducted a survey of Southern California residents. They found that a promise to offset the imposition of congestion fees by other taxes could result in a seven percentage point increase in support for congestion pricing policies, and the restriction of congestion pricing to a single lane on a freeway attracts from 9 to 17 percentage points of additional support. King et al. (2007) argued earmarking the toll revenue can make congestion pricing politically successful. Unlike previous studies which conventionally mean earmarks for specific programs and purposes such as public transit or road improvements, they discussed earmarking the revenue for places and people. “The first goal of any toll revenue distribution must be to secure the initial approval of congestion pricing. For this reason the path to congestion pricing does not go through transit agencies or highway bureaucracies, and it does not involve efforts to buy off motorists. Rather it involves igniting the self-interest of cities. Only when it offers concentrated benefits to strong political forces will anyone rise to fight for congestion pricing” (King, et al., 2007). Accordingly, the authors argued that congestion pricing on freeways will have the greatest chance of political success if the revenue is distributed to cities, and particularly to cities through which the freeways pass. In Los Angeles, where potential congestion toll revenues are estimated to be almost $5 billion a year, distributing toll revenue to cities with freeways could be politically effective and highly progressive. Eliasson (2008) investigated the Stockholm congestion charging trial in 2006. The author found that during the trial public opinion gradually changed from a large majority opposed to the charges to a small majority in favor of them, and a referendum resulted in the charges being reintroduced in 2007.

With the successful international experiences and expected significant improvement in urban traffic, China may have a strong incentive to experiment congestion pricing in some Chinese cities. As mentioned in the introduction section, in 1990 China had 5.5 million private vehicles. This number skyrocketed to 41.73 million in 2008, a 7.59-fold increase in 18 years. The growth of private vehicles in major cities is even faster. In 2008, for example, Beijing had 2.48 million private vehicles (NBSC, 2009). No question, China sees severe traffic congestion on its urban roads, which not only wastes tremendous amount of time of urban commuters but also causes many fatal traffic accidents.

Some possible candidates for congestion pricing projects could include the rings in Beijing, the above-ground roads in Shanghai, and the major arterials in some other Chinese cities. If space permits, construction of additional lanes for congestion pricing could be most popular. In this case, no existing lanes will be converted. Motorists see improved capacity and thus are more likely to support the concept of congestion pricing. Even if no space available for additional lanes, converting existing lanes into HOT lanes could be effective. As evidenced by the case of SR 91 in Southern California, during peak hours, each of the HOT lanes carries twice the number of vehicles than the adjacent toll-free lanes do. As traffic engineers know, under severe congestion, freeway vehicle throughout can be drastically reduced. Pricing ensures that freeway operational efficiency is not lost due to excess demand.

To have an efficient congestion pricing program, the nine principles mentioned earlier need to be applied. Specifically, toll should vary depending on traffic levels, charging a higher rate during peak hours and a much lower or even zero rate during other time periods. The bottom line is to ensure free traffic flow and thus maintain the maximum of the capacity usage. Given the regularity of commuting patterns during weekdays and weekends, traffic level for various time periods tend to be quite stable, so should be the congestion tolls. Of course, like the practices in Southern California and Singapore, the fee structure needs to be reviewed and adjusted, such as quarterly or annually, to reflect the changes of urban commuting.

Technology should not be an issue for congestion pricing implementation. However, initial capital investment could be a challenge and a barrier for some local cities and governments. For this, provincial authorities or the central government may provide support, like the cases in London, Stockholm, and most applications in the USA. It is also possible for a government-private partnership in financing the initial capital investment, like the case of SR91 in Southern California. China had some successful experiences of government-private partnership in financing freeway projects in rural areas. It could be more attractive for the private sector to get involved into congestion pricing programs in urban areas.

Public perception about congestion pricing could be more favorable in China than in other countries. First, privacy is not concerned by most Chinese commuters as much as those in Western countries. Second, car travelers in China include only middle or higher income people. Hence, the regressive of congestion charges tends to be much smaller in China. Third, freeways in China are mostly not free. A fee is collected from every vehicle traveling in the freeway.

Hence, charging a fee for using transportation facility is not a new concept, especially for those that are newly constructed. Last, most of Chinese urban workers still commute via public transit. With congestion pricing, toll will be collected from those who are relatively richer and revenue will be used to improve transportation facility such as adding more buses and expanding subways. Therefore, the majority of Chinese urban residents would see direct benefits from congestion pricing.

China could have a better political feasibility of implementing congestion pricing. First, with the rapid increase in private vehicles, local officials feel urgent to find effective solutions to mitigating the worsening urban congestion. Expanding facilities has been proved an unsustainable solution. They have to seek some other instruments that could better influence commuting behavior and reduce traffic levels. International successful experiences of congestion pricing would encourage Chinese policy-makers to implement similar programs. Second, unlike cities in the US where a metropolitan area have many political cities and these cities have to cooperate to make decisions on regional policies, transportation or economic cities are basically the same as political cities in China. Hence, there are many fewer institutional or political barriers to overcome in transportation planning and implementations. Third, as mentioned above, most of Chinese urban workers still commute via public transit. With congestion pricing, a significant portion of toll revenue would be used to improve public transportation, benefiting the majority of Chinese urban residents. In turn, it enhances political support. Fourth, the Chinese government seems to have more financial means for public project investment. It also enjoys more control over resources such as urban land. Last but not the least, like Singapore, China sees many more government-oriented projects. Congestion pricing can certainly be a new government-led project.

With the sound economic theory and successful international practices, congestion pricing in China could become a reality. In fact, China could have a better feasibility of implementing congestion pricing in major cities due to less regressive congestion charges and fewer institutional barriers. Congestion pricing, which used to be a Western economists' dream but politician's nightmare, could be a dream of both Chinese economists and policy makers.

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Appendix A: 91 Express Lanes Toll Policy

Adopted July 14, 2003

(Source: http://www.91expresslanes.com/generalinfo/tollpolicy.asp)

Goals

The goals for the 91 Express Lanes toll policy are to:

- Provide a safe, reliable, predictable commute for 91 Express Lanes customers.
- Optimize vehicle throughput at free flow speeds.
- Pay debt service and maintain debt service coverage.
- Increase average vehicle occupancy.
- Balance capacity and demand to serve customers who pay tolls as well as carpoolers with three or more persons who are offered discounted tolls.
- Generate sufficient revenue to sustain the financial viability of the 91 Express Lanes.
- Ensure all bond covenants are met.
- Repay the Orange County Transportation Authority's (OCTA) internal borrowing and provide net revenues for Riverside Freeway/State Route 91 corridor improvements (As allowable under Assembly Bill 1010).

Definitions

Cash Available for Debt Service - for any Period, the excess, if any, computed on a cash basis, of:

1. the amount *of 91 Express Lanes cash receipts durin*g such Period from whatever source, including, without limitation, toll receipts, transponder revenues, amounts paid to OCTA under the Facility Agreements, and investment earnings, excluding:
   - proceeds of insurance,
   - proceeds of the debt service letter of credit or other amounts held in or disbursed from the payment account, the debt service reserve account, the coverage account and the major maintenance reserve account, and
   - the proceeds of any Additional Senior Bonds or Subordinated Bonds, over
2. All Operating and Maintenance Costs incurred during such Period and not deducted in the computation of Cash Available for Debt Service in a prior Period. In computing Operating and Maintenance Costs for any Period, an appropriate prorating will be made for expenditures such as insurance premiums and taxes that would be prorated if the computation were to be made in accordance with GAAP

Consistently - Any six weeks of twelve consecutive weeks, excluding any week that includes a Holiday or major traffic pattern anomaly caused by an accident or incident.

Debt Service - for any Period, all payments of principal, interest, premiums (if any), fees and other amounts made (including by way of prepayment) or required to be made by OCTA during such Period under the Bond Documents (debt service payments related to OCTA's internal subordinated debt borrowings are to be excluded from these calculations). In computing Debt Service for any Period prior to the issuance of the new bonds, OCTA will give pro forma effect to the transactions contemplated by the Bond Documents and the use of proceeds of the new bonds. In computing Debt Service for any prospective Period, OCTA will estimate in good faith such payments on the basis of reasonable assumptions. Such assumptions will include the absence of any waivers of or amendments to any agreements and the absence of any optional or extraordinary mandatory redemption of the bonds.

Debt Service Coverage Ratio - for any Period, the ratio of Cash Available for Debt Service for such Period to Debt Service for such Period.

Fiscal Year - July 1 to June 30

Holiday - Any of the following holidays that occur or are recognized any day between Monday through Friday: New Year's Day, Memorial Day, 4th of July, Labor Day, Thanksgiving and Christmas.

Inflation Factor (Included in the present 91 Express Lanes Operating Agreement and subject to change with any new contractor agreement):

1. 0.75 times the product of (A) the hourly toll for the immediately preceding fiscal year, times (B) a fraction, the numerator of which shall be the Labor Index Adjuster for June of the prior fiscal year and the denominator of which shall be the Labor Index Adjuster for June of the year immediately preceding such fiscal year, plus
2. 0.25 times the product of (A) the hourly toll for the immediately preceding fiscal year, times (B) a fraction, the numerator of which shall be the CPI Index Adjuster for June of the prior fiscal year and the denominator of which shall be the CPI Index Adjuster for June of the year immediately preceding such fiscal year.

Maximum Optimal Capacity - 3,400 vehicles per hour, per day, per direction in the 91 Express Lanes facility Non-Super Peak - Hourly period that is not Super Peak.

Operating and Maintenance Costs - all reasonable and necessary expenses of administering, managing, maintaining and operating the 91 Express Lanes and in accordance with the Bond Documents and the Facility Agreements.

Period - the most recent twelve complete months.

Super Peak - Hourly period, per day, and per direction with traffic volume use which meets or exceeds the Trigger Point.

Trigger Point - 92 percent or more of Maximum Optimal Capacity (3,128+ vehicles per hour, per day, and per direction).

Week - 12:00 a.m. Sunday to 11:59 p.m. the following Saturday.

Super Peak Hours

The toll adjustment goals are to: a) reduce the likelihood of congestion by diverting traffic to other hours with available capacity; b) maintain free flow travel speed in the 91 Express Lanes; c) maintain travel time savings; d) accommodate projected growth in travel demand and; e) ensure that the toll road generates sufficient revenue to effectively operate the toll lanes and maintain a strong debt service position.

The toll for use of the 91 Express Lanes during a Super Peak hour shall be determined as follows:

1. Hourly, day, and directional traffic volumes will be continually monitored on a rolling 12 consecutive week period basis.
2. Hourly, day, and directional traffic volumes of 3,128 or more will be flagged for further review.
3. If the hourly, day, and directional traffic volume is Consistently at a level of Super Peak then the toll rate for that hour, day and direction may be increased.
4. The toll for that hour, day, and direction shall be increased, based on the average vehicle volume of the flagged hour, day, and direction identified per Section 2 above, as follows:
    a. if the average flagged vehicle volume is 3,300 or more, then the toll shall be increased by $1.00.
    b. if the average flagged vehicle volume is between 3,200 and 3,299, then the toll shall be increased by $0.75.
    c. if the average flagged vehicle volume is less than 3,200, then the toll shall not be changed.

Six months after a toll increase, the most recent 12 consecutive weeks (excluding weeks with a Holiday or a major traffic anomaly caused by an accident or incident) shall be reviewed for the hour, day and direction that the toll was increased. If the traffic volume is less than 2720 vehicles per hour, day, and direction in six or more of the weeks then the traffic volumes for that hour, day and direction for the 12 consecutive weeks shall be averaged. If the average traffic volume is less than 2720 then the toll shall be reduced by $0.50 to stimulate demand and encourage 91 Express Lanes use.

OCTA's Board of Directors and customers will be informed of a toll adjustment 10 or more days prior to that toll adjustment becoming effective.

Non-Super Peak Hours

All Non-Super Peak tolls shall remain fixed at November 2001 levels except for an annual adjustment for inflation (see Exhibit IV). The Inflation Factor shall be identified and applied beginning July 1, 2004 and at the beginning of each fiscal year thereafter to all Non-Super Peak and Super Peak hours that were not adjusted in the previous 12 months. All tolls shall be rounded up or down to the nearest 5-cent increment.

Discounts

Vehicles with three or more persons (HOV3+), zero emission vehicles (ZEVs), motorcycles, disabled plates and disabled veterans are permitted to ride free in the 91 Express Lanes during most hours. The exception is Monday through Friday 4:00 p.m. to 6:00 p.m. in the eastbound direction when these users pay 50 percent of the toll. The exception that these users pay 50 percent remains in effect until such time as the Debt Service Coverage Ratio - inclusive of senior and subordinated debt - is projected to be 1.2 or greater for a six month period. At that time, HOV3+ users will ride free all day, every day.

Financing Requirements

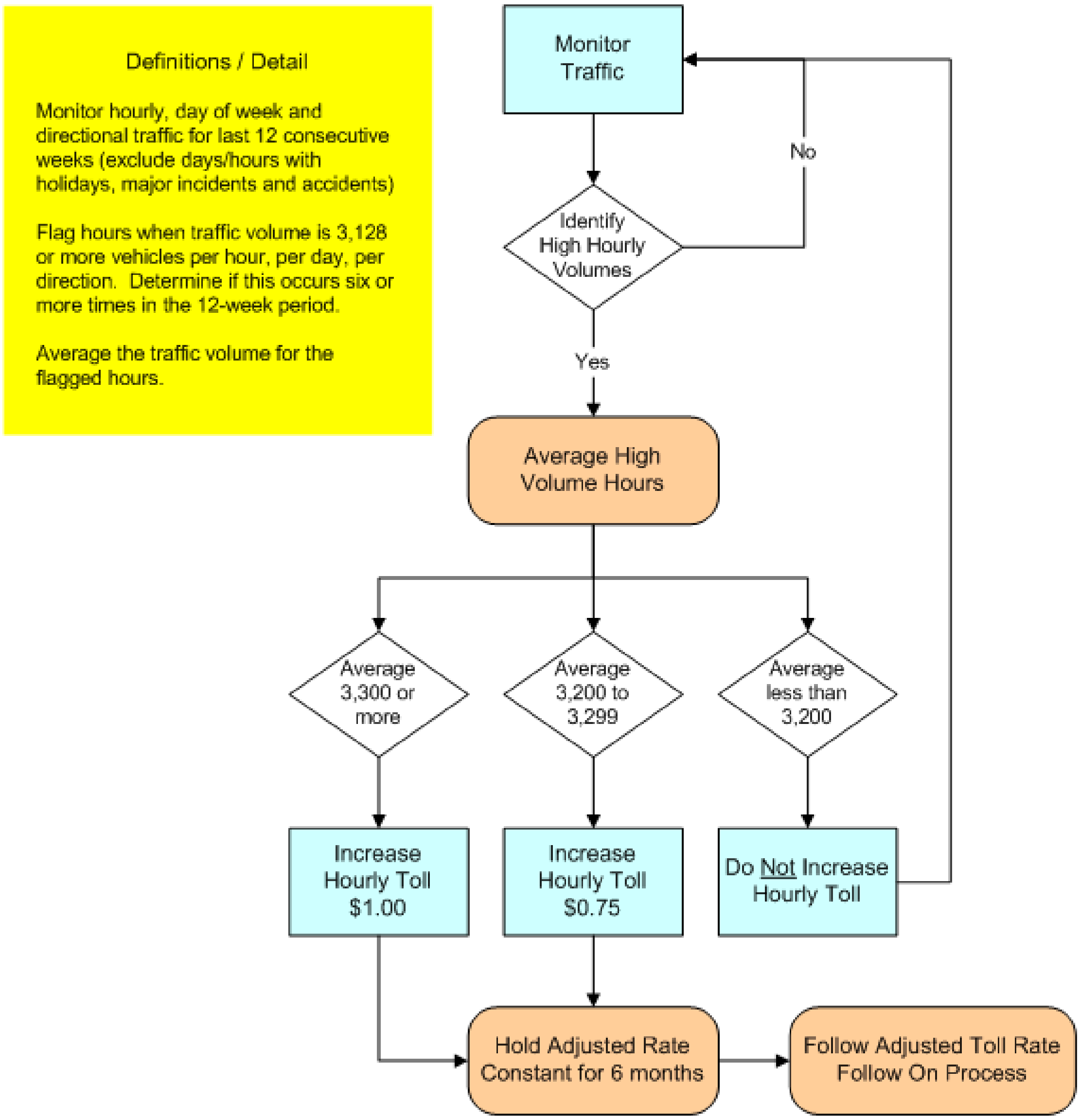
OCTA shall charge and collect tolls that generate enough revenue to maintain the Debt Service Coverage Ratio to be at least 1.30 to 1.00. OCTA recognizes that it must maintain a strong debt service position in order to satisfy the existing taxable bond covenants as well as the bond covenants in the proposed taxexempt refinancing documents.

Holiday Toll Schedules

All existing holiday toll schedules shall apply. Existing holiday toll schedules are identified on Exhibit V and shall be adjusted by the inflation factor at the beginning of each fiscal year beginning July 1, 2004 in a similar fashion as with Non-Super Peak Hours.

Appendix B: Toll Policy Decision Process

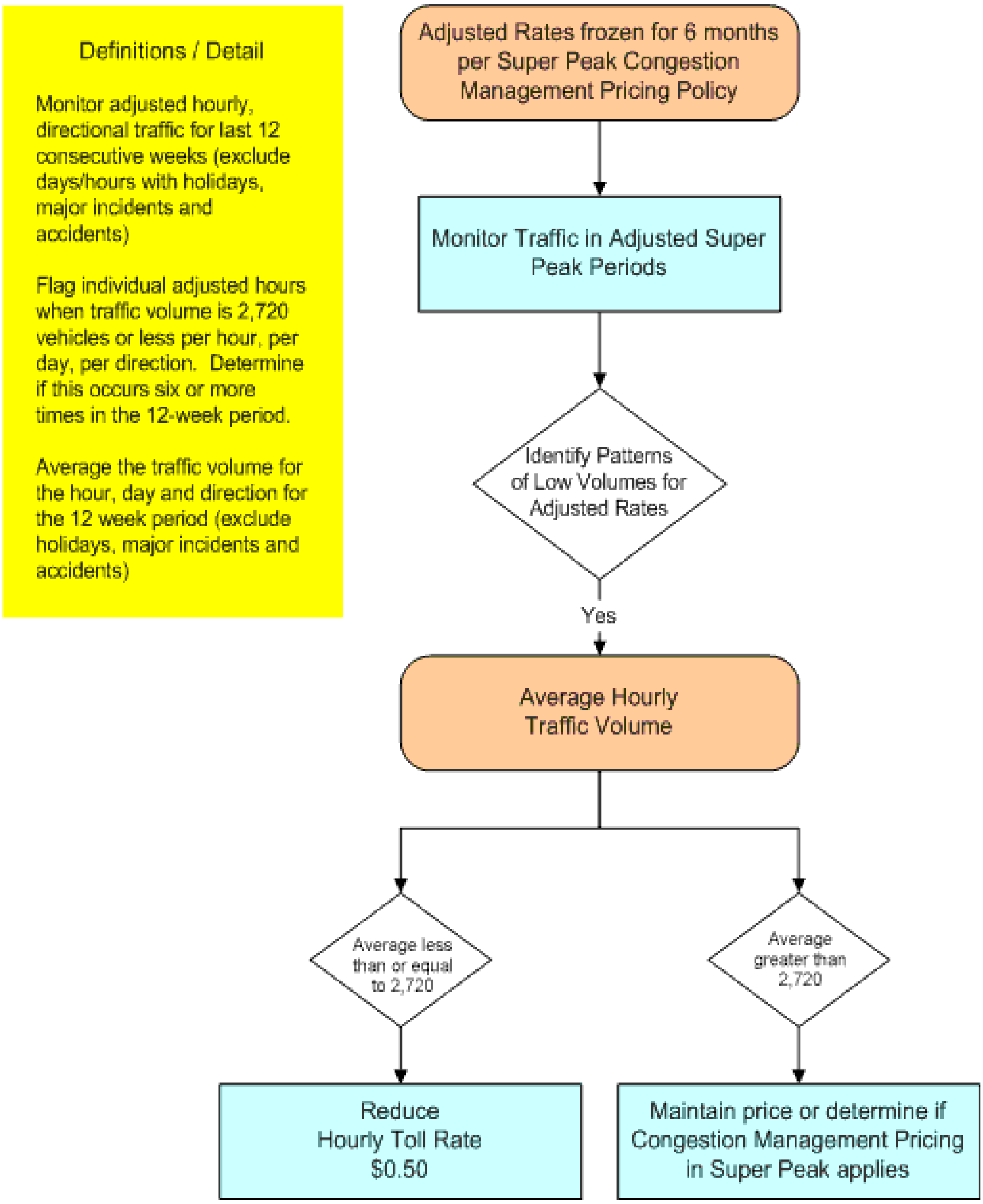
(Congestion Management Pricing in Super Peak)



Source: http://www.91expresslanes.com/generalinfo/tollpolicy.asp

Appendix C: Adjusted Toll Rate Follow On Process

(Super Peak Adjusted Rates Only)



Source: http://www.91expresslanes.com/generalinfo/tollpolicy.asp

Appendix D: Toll Schedules

(Effective January 1, 2010)

Toll Schedule — *Effective January 1, 2010*

Eastbound — *SR-55 to Riverside Co. Line*

	Sun	M	Tu	W	Th	F	Sat
Midnight	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
1:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
2:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
3:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
4:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
5:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
6:00 am	$1.30	$2.05	$2.05	$2.05	$2.05	$2.05	$1.30
7:00 am	$1.30	$2.05	$2.05	$2.05	$2.05	$2.05	$1.30
8:00 am	$1.65	$2.05	$2.05	$2.05	$2.05	$2.05	$2.05
9:00 am	$1.65	$2.05	$2.05	$2.05	$2.05	$2.05	$2.05
10:00 am	$2.50	$2.05	$2.05	$2.05	$2.05	$2.05	$2.50
11:00 am	$2.50	$2.05	$2.05	$2.05	$2.05	$2.05	$2.50
Noon	$3.00	$2.05	$2.05	$2.05	$2.05	$3.10	$3.00
1:00 pm	$3.00	$2.85	$2.85	$2.85	$3.10	$4.85	$3.00
2:00 pm	$3.00	$4.05	$4.05	$4.05	$4.15	$3.60	$3.00
3:00 pm	$2.50	$4.35	$3.70	$4.95	$5.90	$9.50	$3.00
4:00 pm	$2.50	$5.55	$7.75	$8.25	$9.90	$9.30	$3.00
5:00 pm	$2.50	$5.35	$7.25	$7.75	$9.05	$7.25	$3.00
6:00 pm	$2.50	$4.35	$4.10	$3.60	$4.90	$5.25	$2.50
7:00 pm	$2.50	$3.10	$3.10	$3.10	$4.45	$4.90	$2.05
8:00 pm	$2.50	$2.05	$2.05	$2.05	$2.85	$4.45	$2.05
9:00 pm	$2.05	$2.05	$2.05	$2.05	$2.05	$2.85	$2.05
10:00 pm	$1.30	$1.30	$1.30	$1.30	$1.30	$2.05	$1.30
11:00 pm	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30

Toll Schedule — *Effective January 1, 2010*

Westbound — *Riverside Co. Line to SR-55*

	Sun	M	Tu	W	Th	F	Sat
Midnight	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
1:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
2:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
3:00 am	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
4:00 am	$1.30	$2.40	$2.40	$2.40	$2.40	$2.40	$1.30
5:00 am	$1.30	$3.95	$3.95	$3.95	$3.95	$3.80	$1.30
6:00 am	$1.30	$4.05	$4.05	$4.05	$4.05	$3.95	$1.30
7:00 am	$1.30	$4.50	$4.50	$4.50	$4.50	$4.35	$1.75
8:00 am	$1.75	$4.05	$4.05	$4.05	$4.05	$3.95	$2.05
9:00 am	$1.75	$3.25	$3.25	$3.25	$3.25	$3.25	$2.50
10:00 am	$2.50	$2.05	$2.05	$2.05	$2.05	$2.05	$2.50
11:00 am	$2.50	$2.05	$2.05	$2.05	$2.05	$2.05	$2.90
Noon	$2.50	$2.05	$2.05	$2.05	$2.05	$2.05	$2.90
1:00 pm	$2.90	$2.05	$2.05	$2.05	$2.05	$2.05	$2.90
2:00 pm	$2.90	$2.05	$2.05	$2.05	$2.05	$2.05	$2.90
3:00 pm	$2.90	$2.05	$2.05	$2.05	$2.05	$2.50	$2.90
4:00 pm	$3.05	$2.05	$2.05	$2.05	$2.05	$2.50	$3.05
5:00 pm	$3.05	$2.05	$2.05	$2.05	$2.05	$2.50	$3.05
6:00 pm	$3.05	$2.05	$2.05	$2.05	$2.05	$3.00	$2.50
7:00 pm	$2.50	$1.30	$1.30	$1.30	$1.30	$2.05	$2.05
8:00 pm	$2.50	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
9:00 pm	$2.50	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
10:00 pm	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30
11:00 pm	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30	$1.30

Source: http://www.91expresslanes.com/tollschedules.asp