Congestion Charging: Challenges and Opportunities

THE INTERNATIONAL COUNCIL
ON CLEAN TRANSPORTATION

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EXECUTIVE SUMMARY

Surface transportation congestion is an urgent and growing problem in many urban areas. Congestion contributes to frustrating and costly delays for drivers, urban and regional air pollution, national energy security concerns and global climate change. Congestion charging addresses these issues by charging drivers for operating vehicles at highly congested times and locations to reduce travel times, improve air quality and decrease greenhouse gas emissions.

This paper presents a brief overview of several congestion charging systems in use, reviews the benefits and challenges of the strategy and presents best practice recommendations for policy makers and planners globally who are considering congestion charging. It considers congestion charging experiences in London, Singapore and Stockholm, as well as a Hong Kong pilot program that did not lead to full-scale implementation. In addition, it describes the results of an ICCT-sponsored study of the potential for congestion charging in Santa Clara County, California, an area representative of less concentrated development patterns.

Key observations include the following:

- **Congestion reductions of 13 to 30%, greenhouse gas reductions of 15 to 20%** and significant reductions of ozone and fine particulate pollution have been achieved from implementing congestion charging systems in London, Singapore and Stockholm (based on empirical data), and similar benefits would be expected in Santa Clara County (based on a travel model). Public health benefits may be compounded by increased walking and cycling. Discounts for low-emission vehicles can encourage a transition to cleaner transportation but must be weighed against congestion reduction goals.

- **Cost-benefit results can be favorable. In the two cases where monetized time** savings calculations were available, Stockholm and Santa Clara County, time savings were higher than operating costs by a wide margin. While these are not the only costs and benefits, they likely represent the largest portion of each and thus provide an indicator of overall costs and benefits. Studies found no difference in economic growth inside the charging perimeter compared to surrounding areas in London and no effect on retail sales in Stockholm.

- **Multiple technologies have been proven in congestion charging or closely** related road pricing applications, creating flexibility in implementation. These include camera-based recognition, radio-frequency identification, dedicated short-range communications, and global positioning satellite systems combined with cellular radio communications.

- **Initial public acceptance can be difficult to secure, and implementation of** congestion charging can require time to build consensus. London first studied the concept of congestion charging in the mid-1960s. Singapore used these studies and concepts to implement its first Area Licensing Scheme in 1977. In London and Stockholm - the two most recent examples covered in the paper – initial public opposition did not prevent implementation of congestion charging, and public support increased after the program began. In Hong Kong, uncertainty and local political opposition helped stop an initial 1983-1985 congestion charging technology pilot test from resulting in full implementation though the idea has since been reconsidered. Because some drivers will perceive a net loss from the charge, effectively communicating overall benefits is very important, as is addressing concerns about privacy and the concerns of business owners about possible economic impacts.

- **Upfront investments in public transit may be necessary to absorb increased** ridership and to provide affordable mobility for low-income populations. These investments can also help create confidence that implementation of a congestion charging system will provide tangible benefits. Congestion charging systems are more effective when they provide net benefits for the majority of travelers through reduced driving times and improved transit access and reliability.

- **Net revenue generated by congestion charging can be used for transit** enhancements and other benefits. Providing increased transit can enhance the effectiveness of congestion charging. After funding transit improvements, revenue may also be available to make improvements for pedestrians, cyclists and drivers. Some targeted revenue recycling back to area residents or for other purposes may also be viable. Public confidence that revenues will be used for transportation improvement is an important element of any congestion charging strategy.

- **Convenient, flexible payment systems are important components to facilitate** congestion charging implementation as well as shifts to public transport. Existing congestion charging systems in Singapore, London, and Stockholm have various convenient payment options. In addition, these areas and Hong Kong have introduced various smart/debit card systems for commuters of all forms of public transport.

I. *Introduction*

The United Nations estimates that urban areas are currently home to 50 percent of the world's population, and predicts that figure will reach 70 percent by 2050 (United Nations Expert Group, 2009). Growing urbanization provides both opportunities and challenges from the perspectives of transportation mobility, climate change and air quality. Higher population densities generally support greater levels of transit and can make destinations more easily accessible by walking or cycling, thus providing increased mobility while allowing reduced usage of passenger vehicles.

At the same time, urbanization leads to higher competition for space on roadways and tends to increase surface transportation congestion. In the United States, congestion costs were estimated at $63.1 billion annually in 2000 and $87.2 billion annually in 2007, with approximately 28 million tons of carbon dioxide (CO_2) emitted per year due to fuel wasted from inefficient vehicle operation due to congestion (Shrank, 2009). In China, sharply escalating vehicle ownership rates (Figure 1) have led to increasing congestion in recent years. The cost of congestion in terms of traveler delays and air pollution (including CO_2) in Beijing is estimated at approximately 50-101 billion RMB annually (US $7-15 billion) (Creutzig, 2009).[i]

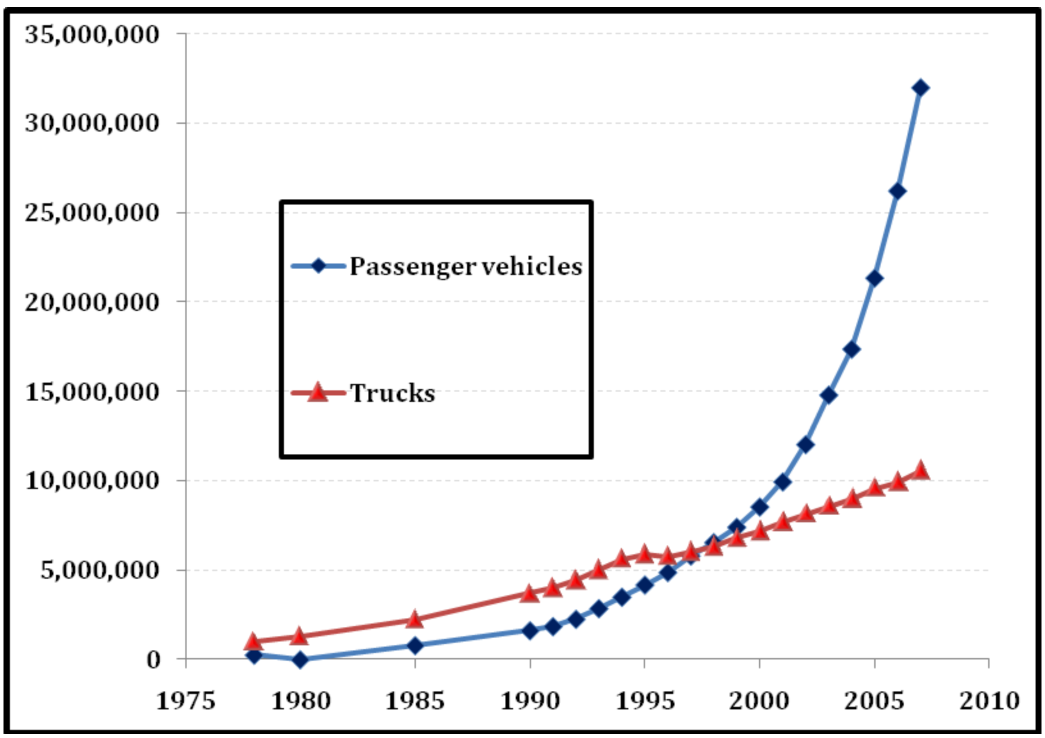

Figure 1: China's Civilian Vehicle Population
(Source: China Statistics Yearbook 2008, Table 15-27)

The concentration of both emissions sources and exposed populations in urban areas creates a significant challenge for air quality regulators seeking to protect human health.

Efforts to reduce congestion through road building frequently fail to keep pace with transportation demand and are likely to generate additional vehicle traffic, which can worsen air quality and create further demand for road building. While economic downturns may temporarily moderate the sharp upward trend of private automobile use, the twin challenges of surface transportation congestion and air pollution will remain. Congestion charging addresses these issues by charging drivers for operating vehicles at highly congested times and locations to reduce travel times, improve air quality and decrease greenhouse gas emissions. Policy-makers and planners around the world may find congestion charging to be an important strategy to increase livability and reduce pollutant emissions in their cities.

This paper begins by evaluating congestion charging programs in three cities where it has been successfully implemented: Singapore, London, and Stockholm.[ii] Appendix A contains a table comparing a number of features for these three examples. Next the paper considers Hong Kong, where a pilot trial did not lead to full and permanent implementation. Finally, the paper summarizes a study sponsored by the International Council on Clean Transportation (ICCT) of the potential use of congestion charging in the United States. The paper concludes with best-practice recommendations based on these examples.

II. *Congestion Charging Example: Singapore*

Singapore was an early leader in adopting congestion charging. Following a one-year public dialogue in 1975, Singapore implemented a paper system of daily licenses for vehicles entering the central zone during peak traffic periods. The system was implemented as part of an overall strong focus on restraining traffic, including increased vehicle and parking taxes, land-use planning and enhanced public transit (Keong 2002). Two types of licenses were sold, one valid all day and one valid for midday.

Figure 2: Electronic Road Pricing Gantry in Singapore (Copyright © 2005 Mailer Diablo)[1]

Traffic entering the zone dropped by 44 percent after implementation, while travel speeds increased from 11 mph to 21 mph (Keong 2002, EDF 2006). More than 10 years later (1988), traffic levels remained 31 percent below original levels even as employment in the city had increased by a third and vehicle ownership by 77 percent (Keong 2002). Bus ridership increased about 20 percent due to congestion charging, transit improvement and related policies.

The system was significantly overhauled in 1998 with the introduction of Electronic Road Pricing (ERP). In-vehicle units (IUs) were permanently installed in 680,000 vehicles at no charge to the user (they can now be purchased for approximately 156 Singapore dollars, S$, or $110 in U.S. currency) (Keong 2002, Singapore Land Transportation Agency 2008). The units communicate with overhead gantries (Figure 2) at charging points and deduct the appropriate charge from a smart card (which can also be used for other transactions such as parking and public transportation) inserted into the IU. The transaction occurs onboard as a debit on the smart card rather than through a central processing system. As long as the vehicle has a valid IU and smart card, no information collection is needed at the charging point, avoiding privacy concerns. In addition, the government has committed to erasing bank transaction records within 24 hours (Keong 2002).

If a vehicle does not have an IU installed or the smart card does not have an adequate balance, enforcement cameras on overhead gantries photograph the vehicle in order to assess a fine. The fine, which can be discounted by paying online or through other automatic methods, is S$10 ($7 U.S.) for failure to carry a sufficient balance and much higher for driving without an IU. Foreign drivers entering the charging zone can choose to rent or purchase an IU. Otherwise, they pay a flat fee (Singapore Land Transportation Agency 2008).

The peak fee for passenger cars was dropped to about S$4 (approximately $3 U.S.) with ERP, but a flat daily rate was eliminated in favor of a charge imposed for each entry into the charging zone. Motorcycles and heavy vehicles were also added to the system (with different tolling rates). Rates are graduated to avoid spikes just before and after charging periods.

Traffic levels are reviewed every three months to determine appropriate toll levels—for instance Saturday tolls have been dropped as a result—and the possibility of predictive pricing to account for anticipated traffic levels is under study to potentially replace the current practice of looking backward at the recent past. Since 2008, it is official policy to adjust fee rates at each of the 70 charging points as needed to ensure traffic moves at uncongested target speeds 85 percent of the time or more. For example, when average travel speed on highways is observed below 45 kilometer per hour (kph) or above 65 kph, the rates are increased or decreased respectively.

Operating costs are 10 percent or less of the revenue collected through the system. Initial capital expenses were approximately 40 percent of initial annual revenue (European Conference of Transport Ministers, 2006). Net operations revenues are not earmarked for transportation. At the same time, the government has taken a number of steps, such as dropping the Saturday charge, to demonstrate that the system is not primarily motivated by revenue generation. A 2008 expansion that was projected to raise an additional S$70 million ($49 million U.S.) was coupled with a larger drop in vehicle ownership taxes, as well as additional bus service in the expanded zone (Lim, 2008).

Raymond Lim, Singapore Minister for Transport, January 30, 2008

"Of all the different measures to deal with congestion, ERP is the only one that addresses the problem directly by requiring individuals to take into account the costs of congestion caused by their driving to others… Without ERP, Singaporeans would be spending many hours in traffic snarls, just like people in Tokyo, Los Angeles and many other US cities, who pay for congestion, not with their wallets, but with the time that they have lost, stuck in traffic gridlock."

III. *Congestion Charging Example: London*

The London congestion charging system was implemented in 2003 to cut traffic and air pollution with the strong support of then-mayor Ken Livingston. The system was initially implemented in a highly congested 21-square-kilometer (8.4-square-mile) area containing about 200,000 residents and five times as many jobs. Public support for the system grew after it was implemented and the zone was doubled in size in 2007 with the addition of the western extension, as shown in Figure 3. After he was elected Major of London in 2009, Boris Johnson announced a plan to reconsider whether to continue the extension (London Mayor's Press Office, 2008). A final decision has not yet been made.

The system uses overhead cameras to recognize license plates. This data is processed centrally to apply charges to the appropriate account. A number of different payment options are available including retail stations, online, text messaging and phone. The initial charge of 5 British pounds (£) for entering the charging zone was increased in 2005 to £8 (about $12 U.S.), with the expectation that the change would further decrease congestion and provide additional bus system revenue (TfL 2006).

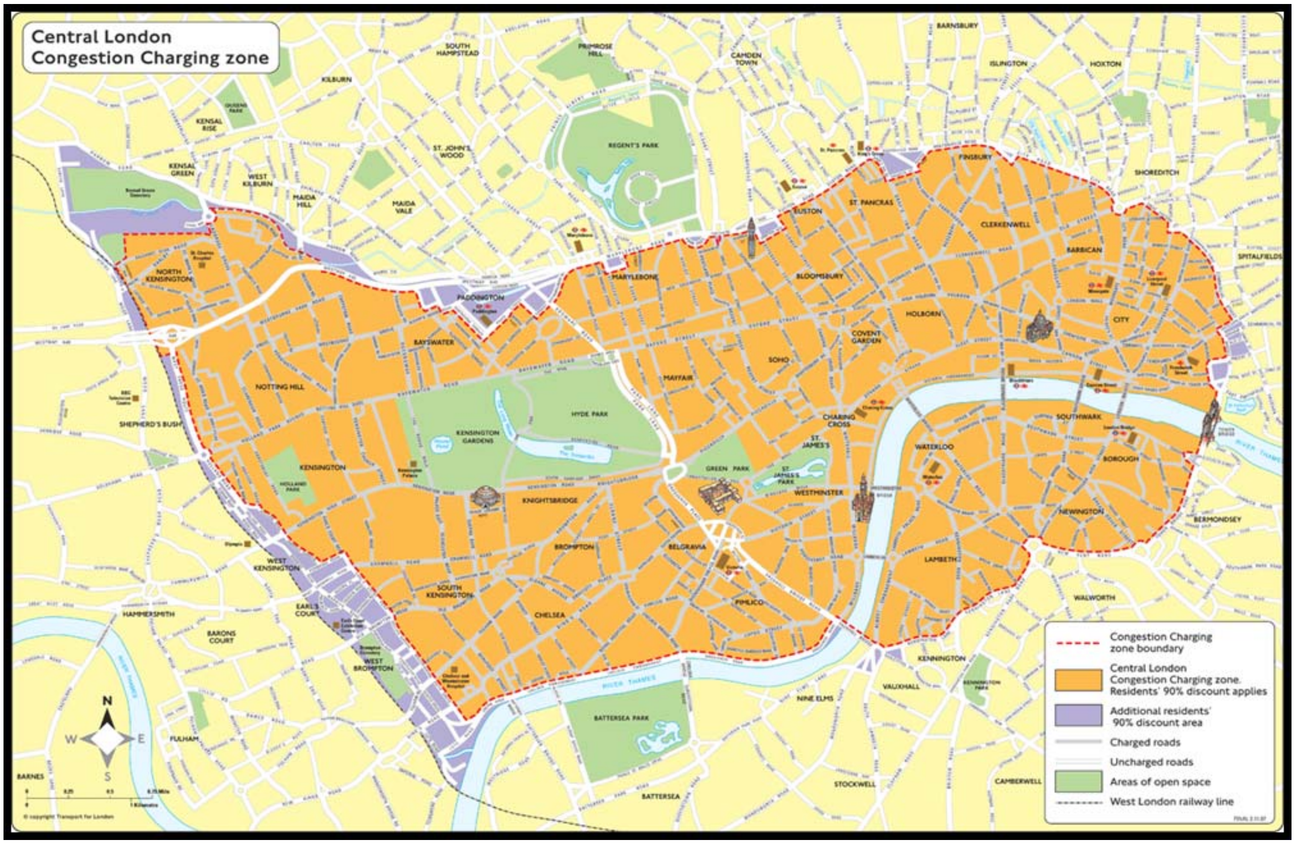

Figure 3: London Congestion Charging Zone (Source: Transport for London)

The London program has cut congestion from the original cordon by 20 to 30 percent (70,000 fewer cars per day), and by 14 percent in the western extension (30,000 fewer cars per day). There has been a 6 percent increase in bus ridership and a 12 percent increase in cycling journeys into the western addition during charging hours; and a 66 percent increase in cycling within the charging zone since it was introduced (Transport for London, 2009). As private vehicle traffic has dropped, some road space has been dedicated to transit and other purposes. Transport for London (TfL) announced that construction-related delays and changing use of road space contributed to increasing traffic congestion in the charging zone back to pre-charging zone levels, but that the number of vehicles was still significantly lower and that construction-related delays would have been worse without the congestion charging zone in place (Mail On-Line, 2008). Many of these delays appear to be temporary, although some alterations to roadways to promote alternative forms of transportation are permanent.

Carbon dioxide emissions dropped 15 to 20 percent, and fine particulates and nitrogen dioxide dropped 10 percent according to the Central London Congestion Charging Impacts Monitoring Sixth Annual Report (TfL, 2008). This is especially important because London currently exceeds European standards for nitrogen dioxide (NO_2) and fine particulates (PM_{10}). Transportation is the largest sources of both, including tailpipe emissions and brake and tire wear (Mayor of London, 2009). Congestion charging can compliment tailpipe vehicle standards while also reducing particulates from brake and tire wear. Electric vehicles and low-emission alternative fuel vehicles are exempt from the charge in order to promote environmentally friendly vehicles. The number of these types of vehicles registered for the exemption increased from 11,000 in 2005 to 18,000 in 2007 (TfL, 2008).

TfL analyzed effects on business indicators such as sales, profitability, new business formation and rents based on four to five years of data in the central zone. Employment increased within the charging zone during that time period, consistent with broader economic growth trends. The report states, "Overall, five years after the event there is no general evidence of any measurable differential impact from the central London congestion charging scheme on business and economic activity, at the aggregate level, based on analysis and surveys conducted by TfL."(TfL, 2008)

By law, net revenue must be dedicated to transportation and has been used to fund bus improvements at the level of £112 million ($170 million U.S.) in the fiscal year 2007/2008, with similar investments the prior year as well as £4 million ($6 million U.S.) funding for cycling and pedestrian facilities. These investments are necessary both to provide the capacity for travelers to shift modes and to enhance the accessibility of alternative travel options in order to further encourage switching. Additional revenues are spent on road safety and other transportation purposes.

Low Emission Zones

- London has operated a Low Emission Zone (LEZ) in parallel with the congestion charging zone since 2008. The LEZ covers a broader geographic area to combat the regional impacts of air pollution.
- The LEZ covers vehicles greater than 3.5 tonnes (2500 kg), with a €220 ($320) charge for vehicles that do not meet emission standards.
- Milan has also implemented a LEZ for passenger vehicles, resulting in emission reductions of PM_{10}, NO_x and CO_2 by 14 to 23 percent.
- Berlin and Beijing ban passenger cars with inadequate emission controls. Germany also charges variable truck per-mile tolls based on emission control levels.

(Sources: Transport for London website; Agenzia Milanese Mobilità Ambiente (2008-Dec-09); "Monitoraggio Indicatori ECOPASS. Prime Valutazioni" Comune di Milano(in Italian))

Operating costs consumed nearly half of revenue raised by the system in the 2007/2008 fiscal year. System managers are investigating the potential for cost saving measures such as switching to a "tag and beacon" system similar to the systems used in Canada and the United States for toll bridges and roads (TfL, 2008). In these systems, relatively inexpensive on-board transponders placed in vehicles are detected at charging points and the corresponding accounts are debited.

Revenues are also decreased due to the discounts or exemptions offered to 60 percent of vehicle movements within the congestion zone, including large discounts for residents of the charging zone. One unexpected cost has been the theft or counterfeiting of license plates, resulting in an estimated 300 evasions daily and the need for a police program to detect vehicles using stolen plates (Sheth 2007).

IV. *Congestion Charging Example: Stockholm*

The Stockholm experience is unique because the system was turned off after an initial six-month trial during the first half of 2006. During the trial, the system reduced traffic volumes by about 20 percent, with vehicle speed increases of the same amount or more, and transit ridership growth between 6 and 9 percent (U.S. Federal Highway Administration, 2008). When the trial ended, traffic rebounded by a similar amount.

This correlation was likely responsible for a significant shift in public opinion. In autumn 2005, before the trial took place, about 55 percent of all Stockholm residents viewed the congestion charging scheme negatively. After the trial 53 percent of Stockholm city residents viewed the idea favorably, while 41 percent viewed it unfavorably, providing enough public support for the system to be implemented permanently (Stockholmsforsoket 2006).

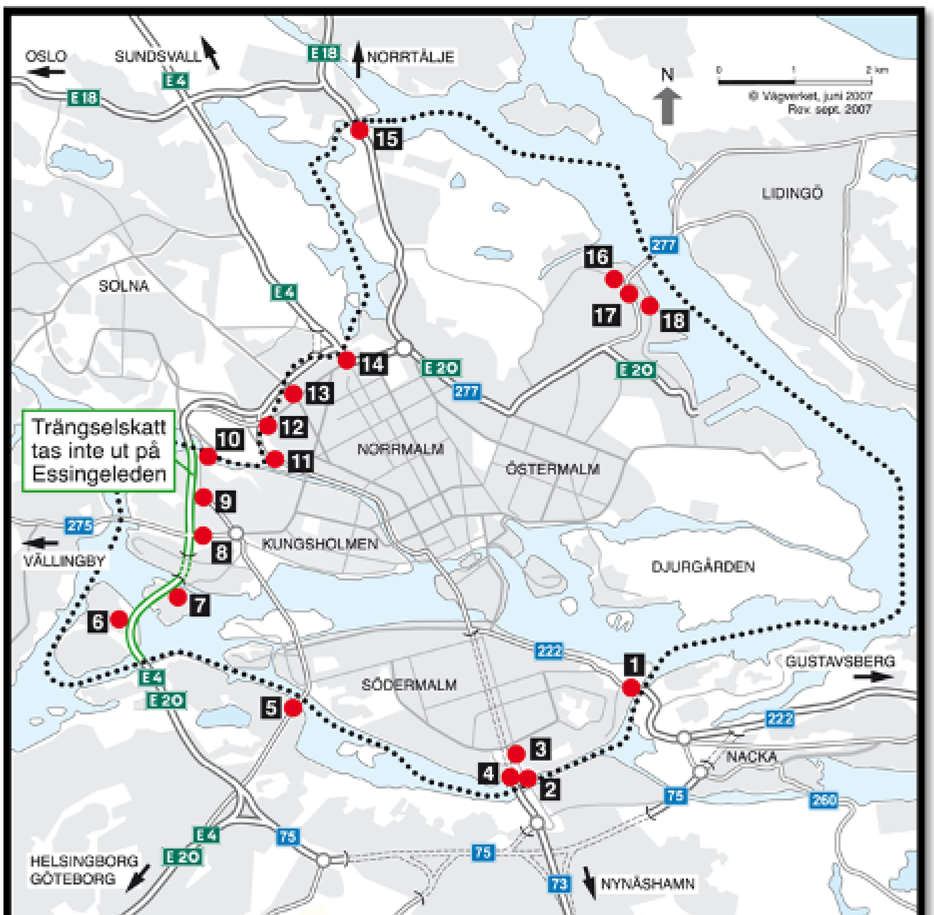

Figure 4: Stockholm System
(Source: Swedish Transport Agency)

The system covers 34 square kilometers (21 square miles) with a charge up to 20 Swedish Krona (SEK) or approximately $3 U.S. to vehicles passing one of 17 charging points while entering or leaving the city's central area (Figure 4) with a daily maximum of 60 SEK,

($8.50 U.S.). There are about 345,000 daily passes (Lamba 2008). System implementation was initially based on detecting vehicles with a combination of automatic license plate recognition (see Figure 5) and transponders, although the system has since shifted primarily to cameras that automatically detect license plates (Stockholmsforsoket 2006). Payment options include automatic account debiting, online payment, and in-person payment including at shops and banks.

Figure 5: Stockholm congestion charging station
(Source: Mats Halldin)

The system was found to be extremely cost-effective, with the primary benefits being shorter travel times valued at 600 million SEK ($85 million U.S.) annually, increased road safety valued at SEK 125 million ($18 million U.S.) and health and environmental benefits valued at SEK 90million ($13 million U.S.) (Stockholmsforsoket 2006). Operating costs are 25 percent of annual revenues (Replogle 2008b). Upfront investments included $300 million U.S. in buses, transit and park-and-ride lots, plus $200 million US in system operations. No effect on retail sales was observed (Jenstav, 2007).

In addition, CO_2 emissions were reduced by about 15 percent, with reductions in other pollutants such as nitrogen oxides (NO_x) and PM_{10} as well (EDF 2007).

An expert panel identified the following beneficiaries among transportation users:

- Public transit users who benefit from more options and faster travel speeds;

- Drivers who value their time savings more than the charge or who receive the benefits of reduced traffic without passing the cordon and paying a charge;

- Cyclists who benefit from an improved traffic environment; and

- Commercial drivers who benefit from an improved work environment.

Transportation users who may be negatively affected include:

- Drivers who pay the charge rather than choosing alternatives and value their time savings less than the cost;

- Drivers who forgo a trip due to the charge; and

- Public transport users who encounter more crowded conditions due to increased ridership (Stockholmsforsoket 2006).

V. *Congestion Charging Pilot and Study: Hong Kong*

Hong Kong is an example of an area that also considered congestion charging due to growing urban congestion and environmental concerns. Hong Kong first addressed electronic road pricing (ERP) in 1983-85; again in 1997-2000; and, more recently in 2004-2006. The government is still considering its options but has not decided to implement the system to date. This experience offers additional evidence of the challenges facing planners and policy-makers in regions that consider implementing a congestion charging system.

In the 1980's, Hong Kong had experienced a dramatic increase in traffic and congestion due to a doubling of vehicle ownership over the prior decade. In response, Hong Kong implemented a 21-month congestion charging pilot from July 1983 to March 1985 (while also dramatically increasing vehicle taxes for initial and annual registration fees). A congestion charging study estimated aggregate benefits of up to HK $1.25 billion (roughly U.S. $160 million) in 1990, and options were identified that would achieve the majority of these benefits with an average charge of HK $8 to HK $10 ($1-$1.30 U.S.). Though the pilot demonstrated the economic and technical feasibility of the concept and studies showed that the system would be cost-effective, it was not permanently implemented for a number of possible reasons:

- Diminished urgency due to lessened traffic congestion at the time the pilot expired. This was due to construction of two major public transportation infrastructure projects, a severe recession, doubling of the First Registration Tax and tripling of the Annual License Fee (Government Secretariat Transport Bureau, Hong Kong 2001);

- Newly create local council government bodies were not consulted and did not support the trials;

- Missed opportunities to develop stakeholder support and address concerns about the financial viability of the system through a lack of transparency and stakeholder outreach;

- The agreement between China and the United Kingdom on the transfer of Hong Kong back to the Chinese Government complicated the political landscape; and

- Citizen concerns about whether the government would follow through on promises to reduce other vehicle taxes and privacy concerns about the system information were not successfully addressed (Hau, 1990)

While transit use remained high, vehicle usage and traffic increased as income levels rose[iii] resulting in consideration of options to limit congestion. A study of Electronic Road Pricing (ERP) began in 1997 with a view that technology and system effectiveness had improved over the last decade. The study objective was examining the practicability of implementing an ERP system in Hong Kong and assessing the need for such a system to meet transport objectives.

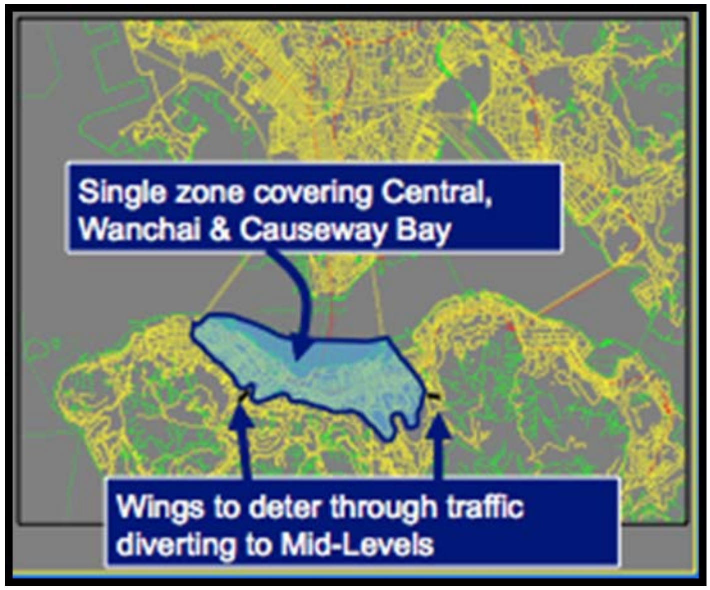

Figure 6: Potential Hong Kong Congestion Charging Zone

Two options were selected for field evaluation, namely the Dedicated Short-Range Communications (DSRC) System and the Vehicle Positioning System (VPS). The VPS would levy a charge by using the satellite-based Global Positioning System (GPS) to communicate with the in-vehicle units (IU) and determine the location of the vehicle. No roadside equipment was required at charge points but violation enforcement stations would be required at strategic locations. A wireless data communication network between the vehicles and the control centre would process transaction data transmissions and enforcement verification. VPS technology offered greater flexibility for system implementation and additional navigation and other Intelligent Transport System (ITS) services to drivers than a DSRC system. The DSRC is limited to communicating with IU when a vehicle passes a fixed charging point. Although the cost of VPS was higher than DSRC at the time by a factor of five, the projected cost of VPS was projected to drop at a faster rate than that of DSRC. Thus, the study determined that VPS technology was the best-balanced choice for ERP in the longer term for Hong Kong.

An overall concept of the entire system was designed in the study. Its major highlights were:

- Charging Method - A cordon-based charging scheme was preferred in comparison with distance-based, time-based and congestion-based for its simplicity in both operation and enforcement, and technology readiness. Directional charging, i.e. charging on entering in the morning and exiting in the afternoon, was preferred to charging both directions.

- Charging Zone – The zone would only cover the areas that are perceived to be the most congested and are well served by public transport to provide opportunities for road users to change mode of travel. A single zone encompassing Central, Wan Chai and Causeway Bay as shown in Figure 6 was preferred to multiple charging zones that would add complexity to the scheme.

- Charging Period - Charging periods were considered in terms of their overall economic benefits according to traffic volume at different times of the day. Charges would be highest during peak hours (with a lower 30 minute “shoulder” charge to reduce the problem of "bunching"), and no charge was envisaged for the overnight period from 7:30 pm to 7:30 am or on Sundays and holidays.

- Charging Rate - Charges needed to meet the target speed range on 20 km/hr ranged from HK $8 to HK $31 ($1-$4 U.S.) depending on the period of the day and the traffic demand growth scenarios.

- Exemptions - ERP provides the flexibility to differentiate charges by vehicle type and to exempt a particular vehicle type from charge. However, exemptions other than for emergency vehicles must be carefully considered because all trips contribute to congestion. Any potential exemption should be evaluated against the basic principles of equity, efficiency and public acceptability. Discounts rather than exemptions were proposed, which could be administrative tailored or phased-out if appropriate. (Opiola, 2010)

The study estimated that this possible ERP design would divert 40% of car trips in the morning peak to public transport and may change travel time for an additional 10%. The remaining 50% would be subject to the charge while benefiting from higher travel speeds and less congestion. Transport operations such as bus services would benefit from increased speed and increased utilization. Improved service times and greater reliability for delivery vehicles would benefit businesses. Complementary measures were incorporated to facilitate increased transportation usage. (Opiola, 2010)

The economic benefits derived from reduced traffic delays accrued to all road users and to the community at large. The estimated net economic benefit resulting from journey time savings and lower vehicle operating cost was about HK $2 billion/year ($260 billion U.S.). On the other hand, the estimated cost for the proposed ERP scheme was $1 billion ($130 million U.S.) including the cost of in-vehicle units for existing vehicles with an annual recurrent cost of HK $200 million ($26 million U.S.). ERP was forecast to generate annual gross revenue of HK $0.4 to HK $1.3 billion ($50-170 million U.S.) for transport infrastructure investment. (Opiola, 2010)

The environmental benefits include reduced vehicle emissions and reduced exposure to traffic noise inside the charging zone. However, the environmental conditions of other areas, especially the by-pass routes and areas surrounding the charging zone would witness some deterioration due to the overall redistribution of traffic. ERP therefore would assist in the overall improvement to the environment, but was not seen as the sole solution to the complex issue of air quality and noise abatement. The overall improvements in the charging zone were estimated to be approximately 12% to 16%. (Opiola, 2010)

Figure 7: Santa Clara County congestion afternoon peak levels, with red indicating worst levels (source: Valley Transportation Authority "2008 Monitoring and Conformance Report")

The major findings of the study were:

- Both DSRC and VPS technologies can be adopted for a possible ERP system in Hong Kong. VPS was considered to offer the best-balanced choice in the longer term because of its adaptability, flexibility and better integration with ITS applications.
- ERP could generate transport operation, economic and environmental benefits.
- ERP and other alternative traffic management measures such as parking charges and taxes are not mutually exclusive.
- Reducing the number of vehicles on the roadway would delay or eliminate the need to build more infrastructure.

The updated study results occurred at the same time that an economic downturn and new infrastructure reduced congestion, similar to the historical background after the release of the 1985 study. However the study predicted that congestion would increase once the economy bounced back, and recent traffic increase along with environmental concerns has led to further consideration in Hong Kong.

VI. *Study of an Area-Wide Congestion Charge in California*

The ICCT commissioned an analysis of the potential benefits and costs of implementing a congestion charging system in Santa Clara County, California. Santa Clara County is a region of the San Francisco Bay Area that has less concentrated development than the cities examined earlier and is among the ten most congested areas of the United States. The county has a total population of 1.8 million, including most of Silicon Valley and the city of San Jose, where the average driver experiences 53 hours of travel delay annually. Because Santa Clara County is highly developed but less concentrated around a single urban center, it offers a good opportunity to study whether congestion charging could be applied on a regional basis.

As seen in Figure 7, congestion hotspots are widespread in the county. The red zones represent the most congested areas during the afternoon peak travel period, when uncongested green zones are mostly nonexistent on major freeways and highways.

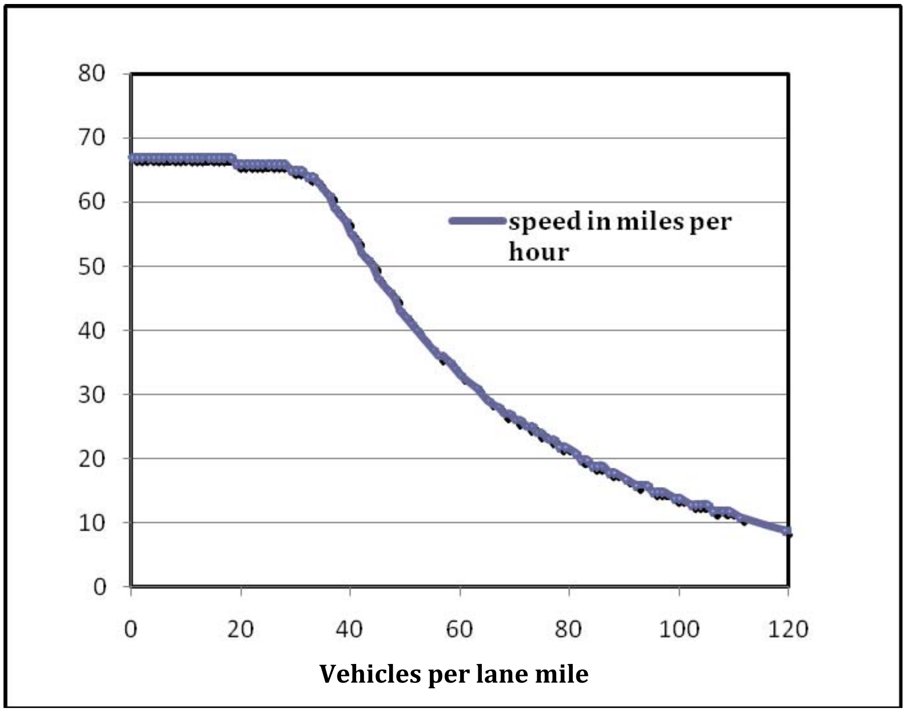

Figure 8: Vehicle Speed vs. Traffic Density (source: ICCT analysis of data from Valley Transportation Authority "2007 Monitoring and Conformance Report")

The study was designed by ICCT and Komanoff Energy Associates (KEA) and implemented using a KEA spreadsheet model. A per-mile charge was assessed on highways (colored to match their congestion levels) and expressways (in white) shown in Figure 7 to target widespread congestion.[iv] The model also allowed different scenarios to be tested in order to tailor the timing and amount of the congestion charge. Figure 8 illustrates a key relationship between vehicle density and travel speeds that was applied in the model. This relationship shows how reducing vehicle density can lead to dramatic time-savings. For a short summary of the model and inputs, please see Appendix A.

A per-mile charge over a wide area is an alternative to a cordon approach, in which a vehicle is charged upon entering a defined central urban area. The cordon approach has been used by every city that has thus far implemented congestion charging, is under consideration in San Francisco and has been considered by other cities. However, as vehicle ownership continues to rise around the world, congestion levels are also likely to rise in more regions outside core urban areas that have less concentrated development. These regions could potentially benefit from this type of a per mile congestion charge.

The ICCT-KEA study found that the societal benefits of a congestion charging system that targets areas and periods of high congestion in Santa Clara County would be several times larger than the costs (Table 2). The largest predicted benefits are 22 million hours per year in time-savings from avoided congestion and $250 million in gasoline savings. Reductions in air pollution and greenhouse gas emissions added significantly to the expected net societal benefits. Estimated greenhouse gas emissions reductions of over 600,000 tons of CO_2, representing an approximately 17 percent reduction from baseline weekday CO_2 emission rates, are comparable to the reductions achieved in London and Stockholm. Reduced accident costs were expected but not quantified. These benefits are for the year 2012, while the model predicts even greater benefits for the year 2020.

Vehicle travel reductions	2 billion km (1.3 billion miles)
CO_2 reduction	600,000 metric tons
Gasoline savings	260 million liters (70 million gallons)
Time savings	22 million vehicle-hours

Table 1: Santa Clara County study estimated benefits

Costs were estimated by KEA at $150 million for system operation and about $120 million in decreased convenience for drivers who decide to forgo a trip that they would otherwise have taken by driving (about 10 to 15 percent of the benefits of time savings).[v] The $860 million in estimated annual tolls would more than cover system administration costs, resulting in a net balance of close to $700 million annually. Technology options for an area-wide congestion charge could include GPS-based technology, which has been used in Germany since 2005 to toll trucks over 12,000 kilometers (7,500 miles) of roads along with overhead gantries (Kossak 2007). Transponders with overhead tolling gantries are another technology option for area-wide systems and are used to toll trucks on approximately 3,000 kilometers (1,800 miles) of roads in Austria and the Czech Republic (Czako 2007).

Predicted Benefits	
Time savings	$738,000,000
Gasoline savings	$255,000,000
Pollution reduction (ozone, fine particulates)	$27,000,000
CO_2 reduction	$30,000,000
Total Benefits (excluding charging revenue)	$1,050,000,000
Predicted Costs	
System administration	$150,000,000
Vehicle travel reductions - lost amenity/convenience	$114,000,000
Total Costs (excluding charging revenue)	$264,000,000
Tolls paid by drivers and received by implementing agency	$862,000,000

Table 2: Estimated monetized benefits & costs

While there are uncertainties in these estimates, a large amount of net tolling revenue is expected. Net toll revenue was not considered a cost or benefit in this comparison, as it could be returned to residents or drivers directly as a "dividend" or used to augment transit operations and other mobility options. Congestion charging works best when alternate transportation options are available. Public transit may require funding from net congestion charging revenue or other sources to provide capacity expansions and accommodate higher demand, and to provide options for travelers less able to afford the charge. Expanded service and improved bicycling and pedestrian facilities would provide additional choices and further increase the effectiveness of the congestion charging system.

Congestion charging study for Beijing
Congestion charging studies have also been conducted for other areas. A study by Creutzig and He includes an analysis of a potential congestion charge for Beijing (Creutzig 2009). The study estimated congestion benefits of 11 billion RMB ($1.6 billion U.S.) with opportunity costs of 4 billion RMB ($0.6 billion U.S.) from a charge of 1 RMB /km ($0.24 U.S./mile). Similar to the Santa Clara study, congestion reductions are the largest benefit and air quality improvements are a significant additional benefit. The Beijing study also found that bus riders would enjoy significant time savings (which was not evaluated in the Santa Clara study). Shenzen China is another example of an area where congestion charging is under evaluation.

In the Santa Clara example, additional surplus revenues may remain after funding transit and other traveler mobility options. Policy makers could choose from a number of options, such as land-use planning that further reduces congestion and pollution while providing travelers with additional choices.[vi] Revenues could also be used for road maintenance, safety and/or other public purposes. Per capita dividend or sales tax reductions would be options for policy makers to consider for addressing concerns about higher impacts on local residents and/or mitigating concerns that the charge is a "tax" that would increase overall taxation rates.

VII. *Status of Congestion Charging Efforts in California*

The California Air Resources Board (CARB) has identified congestion charging as an option for achieving California greenhouse gas emissions reductions required by the California Global Warming Solutions Act of 2006. A related law (Senate Bill 375) also sets vehicle travel reduction goals (CARB 2008). CARB has noted that the California state legislature needs to provide authority for local jurisdictions to implement congestion charging, and in some cases federal authority may also be needed.

The San Francisco County Transportation Agency (SFCTA) is completing a detailed congestion charging study for the San Francisco area that is scheduled for release in early 2010. The proposal under study focuses on a cordon approach, with fees levied for entering a defined region (San Francisco Country Transportation Authority 2010). Most options focus on the most densely developed downtown core, which is a compact area that draws a large number of trips during congested times. Other local areas in California are also considering road-pricing options, although some focus on charging single-occupancy drivers to pay for driving in carpool lanes.

The reduction of traffic due to the economic downturn in California has temporarily reduced the need for congestion relief, but traffic volume can be expected to rise once the economy rebounds. Figure 9 from Santa Clara County illustrates the rebound in congestion following recovery from the 2001-2002 recession. About 60 percent of lanes achieved free-flow traffic (Level of Service or "LOS A," in green) during the last recession. Once the recession ended, virtually every lane was moderately or severely congested. The 2009 Urban Mobility report examined past recessions in California, the Northeast and Texas and found that "in every case, when the economy rebounded, so did the congestion problem" (Shrank 2009).

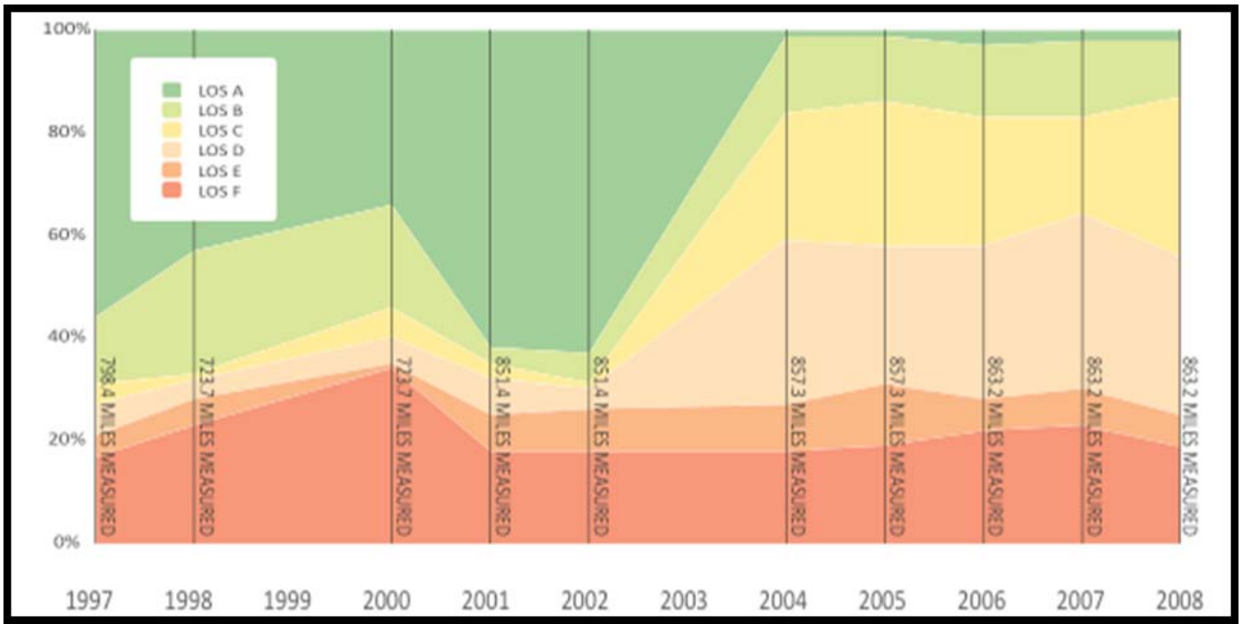

Figure 9: Santa Clara County congestion trends (source: Valley Transportation Authority "2008 Monitoring and Conformance Report")

VIII. *Equity Issues*

Addressing equity issues may be important to preserve mobility for disadvantaged groups and avoid a potential point of public concern, depending on the location. Most U.S. households, even at lower income levels, own a private vehicle and thus would potentially be subject to a congestion charge (Bureau of Labor Statistics, 2008). In China, on the other hand, only 9 percent of all households own a private vehicle and car ownership is typically beyond the reach of lower income brackets (National Bureau of Statistics China, 2009).

Ecola and Light reported that most studies analyzing the payment of congestion charges (which tend to focus on developed countries) found these systems slightly regressive. Studies that consider revenue usage "suggest that the way in which toll revenues are spent can have a large effect on who benefits and who loses from congestion pricing" (Ecola 2009). Transit enhancements tend to be progressive, especially in areas with the greatest access to transit resources for low-income groups. Revenue redistribution on a per capita basis or income-based discounts are also options to address potential impacts to low-income residents, including those that do not use transit. Other forms of equity concerns, such as regional equity, should also be taken into consideration for any revenue redistribution.

Environmental impacts are another aspect of equity. One study of the London congestion charging system found that "the scheme appears to have led to a modest reduction in socioeconomic inequalities in air pollution exposures and associated mortality." The study predicted benefits of 183 fewer years of life lost per 100,000 people in areas with a congestion charge (Tonne, 2008).

IX. *Conclusion and Best Practice Recommendations*

Traffic congestion is a persistent and growing problem in metropolitan regions worldwide. As passenger vehicle population and usage grows, most dramatically in rapidly developing countries such as China and India, local governments will require innovative solutions such as congestion charging to maintain the flow of traffic and reduce transport emissions. Congestion charging has significant benefits as well as noteworthy challenges as summarized below in Figure 10. Though it may not be appropriate in all cases, a review of its application in Singapore, London and Stockholm shows that congestion charging has increased mobility in densely populated urban areas and studies in Hong Kong suggest it would provide the same benefit in that city as well. A modeling study of Santa Clara County, California, suggests it can offer solutions on a regional scale as well. From a fiscal standpoint, these congestion charging systems have provided greater savings in the form of decreased travel time than they cost to implement.

Congestion charging can also provide additional benefits in the form of reduced emissions of CO_2 and local air pollutants such as ozone and fine particulates, and compliment other efforts such as vehicle emission standards. Environmental improvements may be supplemented by additional public health benefits due to decreased traffic accidents and increased walking and cycling.

Potential Congestion Charging Benefits:

- Reduced travel times and improved reliability for drivers, buses, taxis and deliveries
- Potential source of funds to improve transit frequency and coverage; for bicycle and pedestrian improvements; and to increase road safety and cover road maintenance
- Reduced emissions of greenhouse gas and local air pollutants
- Does not restrain (and may encourage) economic growth
- Public health benefits due to increased cycling/walking and potentially lower accident risk due to decreased private vehicle use
- Can encourage use of the cleanest vehicles through discounts to the charging system

Potential Congestion Charging Challenges:

- Securing public acceptance
- Need for upfront investment in transit
- Ensuring low income populations realize improved mobility
- Addressing public concern over privacy issues
- Allaying business owner concerns
- Designing the system to meet technical and cost-effectiveness criteria
- Assuring net benefits for most drivers in the form of reduced congestion and/or improved transit

Figure 10: Summary of Potential Challenges and Benefits

However, realizing these benefits requires careful design, planning and public outreach. While congestion charging systems must be tailored to local circumstances, the following best practice recommendations provide principles to address a number of common key issues:

System Design:

Geography, traffic patterns, and other local factors are important considerations for choosing the charging strategy and the most cost-effective system for implementing that strategy. The geographic scope should be designed to target areas where congestion reduction benefits will be maximized while also taking into account practical issues such as political boundaries.

A single charging rate offers simplicity and is most appropriate for areas without a sharp morning or afternoon congestion peak. Systems (such as London) where the consumer pays in advance or the day after will likely work best with flat rate pricing so that consumers don't lose track of the amount they need to pay. Flat-rate systems will likely impose the least constraints on system technology options. Areas such as Santa Clara County, where weekday peak traffic delays are severe but midday traffic is not highly congested, may benefit by adjusting charging levels throughout the day. Variable charging levels for these types of areas would likely work best with automatic payment options, such as the smart cards or transponders with automatic debit used in Singapore and Stockholm and used by many drivers for toll bridges in the Santa Clara County area.

Targeted Discounts:

Discounts or exemptions for disabled persons, emergency vehicles and others should be considered. Discounts for residents of the charging zone may be important to improve public acceptance, but should be weighed against potentially higher operating cost ratios (due to losses on the revenue side of the equation) and potentially diminished effectiveness of congestion charging systems.

Discounts or exemptions for zero-tailpipe emission or low-emission vehicles can enhance the environmental benefits, and caps or periodic reviews of such discounts can ensure that congestion reduction goals are still achieved. Regions with significant variations in vehicle air pollution emission rates can also consider charging rates that vary based on vehicle emission rates, as Milan, Italy has done (as noted earlier under low-emission zones).

Up-Front and On-going Investments in Transit and Transportation:

Transit demand is likely to increase significantly, leading to the need for up-front investment in additional capacity to serve existing routes as well as additional routes to further increase the benefits of the congestion charging system.

Once the congestion charging system is in place, revenues from congestion fees are a potential source of funding for continuing transit improvements and other transportation projects including pedestrian and bicycling facilities to provide improved mobility options. Indeed, a key to public acceptance likely lies in showing the public that new congestion charges will lead to better system performance with less congestion and better travel choices (Replogle, 2008a).

In some regions, net revenue after system administration costs may be sufficient to provide for potential uses in addition to improved transportation. For regions that choose to redistribute net revenue to make the charge revenue neutral, Singapore's example of adopting policies up-front are likely to maximize public acceptance. Congestion charging will be more likely to succeed if fees are not perceived as a tax increase on drivers.

Privacy and Equity Concerns:

Effectively addressing privacy concerns without creating an overly costly or complex system requires careful consideration. Some tolling agencies allow drivers to use a transponder or smart card with no record of the user's identity as long as the charge is paid.[vii] Systems can also be set up to delete user-specific information once payment has been processed such as in Singapore.

As noted earlier, perceptions of equity can also influence political acceptability. While specific equity issues will vary based on local circumstances, a planning process to identify potential equity issues and responses is an important first step. This can be followed by outreach to improve public education and provide meaningful consultation with potentially affected groups. Monitoring actual impacts for specific groups of concern, such as the low income and disabled persons surveyed in London, can help educate both policy makers and the public about actual effects.

Public Outreach:

Public acceptance is a major challenge. While existing systems have generally been accepted once in place, they have sometimes had to overcome intense initial resistance (Lamba 2008 and Replogle 2008a).[viii] Costs may seem more immediate and tangible than some of the benefits such as improved health from better air quality. An effective public outreach and education strategy is likely to be essential for any new system in addition to addressing the issues above. In Singapore, London and Stockholm officials have garnered support with extensive efforts to demonstrate the public benefits of congestion charging. Stockholm followed an especially dramatic course by turning off the system after a temporary trial to demonstrate its effectiveness. In Hong Kong, by contrast, the failure to communicate benefits and address fiscal and privacy concerns may have created roadblocks during initial consideration of a congestion charging plan. Key outreach topics include each of the best practice topics highlighted above in this section.

While technical and public acceptance challenges are significant, they can be addressed for areas that wish to implement congestion charging. Economic downturns may temporarily reduce congestion and public pressure for policies to address congestion, but the long-term need will continue to grow. In conclusion, congestion charging can often play an important role in reducing the negative effective of congestion while providing environmental and other additional benefits.

ENDNOTES

[i] On the other side of the world, the Australian government found that the cost of road congestion in Australian cities, if left unchecked, could grow from $9.5 billion in 2005 to $20.4 billion Australian by 2020. (Infrastructure Australia, Major Cities Unit, 2010. "State of Australian Cities 2010" available at http://www.apo.org.au/research/state-australian-cities-2010)

[ii] A number of other cities have also implemented congestion charges (Replogle, 2008a).

[iii] In Hong Kong there are less than 50 private cars vehicles per 1,000 population, half as many as Singapore and Seoul. Only about 11 per cent of daily person trips at the time were made by private cars vehicles while 89 per cent use public transport; however, this percentage had rapidly declined from 91 percent in the previous two years due to the high discretionary capital of a booming economy.

[iv] While the model contains the capability to assess a toll on local roads, that option was not included in this assessment. A lesser toll on intermediate-level roads will reduce pressure on local roads, and tolls are assumed to be set low enough to discourage shifting traffic onto the most local roads; which are generally low speed residential streets with frequent stops. In addition, any shifting to local road would be offset at least in part by the local portion of trips avoided due to the congestion charges and improved transit service.

[v] Costs are estimates based on the Puget Sound Regional Council "Traffic Choices Study" Appendix 21, which used a GPS-based system. Guests could obtain a flat-fee license similar to the Singapore ERP system. Another option would be "tag and beacon" such as the "Fast-track" system used in Southern California (https://www.thetollroads.com/home/pdf/F10_visor_map_6_22_09.pdf) for a system that monitors about three dozen intersections or other charging points and is also used in the San Francisco Bay Area for bridge tolls and tracking vehicle travel time for informational purposes.

[vi] Some potential options include new transit service, telecommuting choices, pilot projects for mileage-based automobile insurance, and planning efforts that decrease the separation of homes, jobs, and goods & services.

[vii] Singapore uses on-board "smartcards" that do not require the collection of data outside the vehicle if the charge is properly paid using an on-board "smartcard." Toronto RT 407 users can set up a cash account with no identification on request. In Singapore banking transaction data is promptly deleted.

[viii] Ecola and Light also reference Glaister and Hugosson finding that implementation has improved after implementation.

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APPENDIX A: Comparison of Singapore, London, and Stockholm Congestion Charging Systems

	Singapore	London	Stockholm
Key Objectives	Reduce congestion and encourage shift to transit and off-peak driving	Reduce congestion and air pollution	Improve mobility and reduce congestion
Date Introduced	1975	2003	2007
Congestion Reduction	13%	30% for original zone; 10% for western extension	25%
Size of Area Covered	Original area was 7.25 sq km (4.5 sq mii); additional charging locations added in 2008	Original zone of 22 sq km (8 sq mi); 2007 expansion to 24 sq km (15 sq miles)	34 sq km (21 sq miles)
Motor Vehicle Trips Into Zone (Weekday)	235,000 daily entries into charging zone	292,000 daily entries into charging zone	345,000 passes including both directions
Discounts	Emergency vehicles are exempt	Emergency vehicles, residents, vehicles used for disabled persons, alternate fueled vehicles, are exempt	Emergency vehicles, taxis, environmental vehicles, and foreign registered vehicles.
Current charge amount	S$0.35-4.0 ($0.25-2.90 US)	£8($12 US)	10-20 SEK, 60 SEK/day max ($1.40-$2.80 US, $8.50 max)
Technology	Implemented on-board unit in 1998 with smartcard instantly debited; camera enforcement	Payment via text message, phone, internet or pay stations; camera enforcement	most payments direct debit; transponder with camera enforcement
Mode split	40% transit when initiated; 60% transit mode split today	40% of weekday inner London trips via public transportation; 31% via walking; 29% via private vehicle	Originally 75% transit on-peak; 34% car & 41% transit off-peak; transit split increased 4.5% due to charge
CO_2 Reductions	Not available	15-20%	15%

(Sources: EDF 2006;GTZ 2009; Keong 2002;London Travel Demand Survey Supplement 2007; Luk 1997; Reuters 2007, Söderberg 2008; Swedish Transport Authority 2010, Tfl 2007; TfL 2009; Yam 2005)

APPENDIX B

Summary of California Congestion Charging Study Methodology and Inputs

The study developed a speed-traffic density relationship that is linked to dynamic modeling of the effects of road charging on traffic volumes. The model includes effects based on both price and time elasticities, i.e. the effect of increased dollar cost and decreased time cost on the number of auto trips. The model allows the user to model results for either 2012 or 2020, and is designed to estimate aggregate results consistent with the limited scope of this project. The model assesses both benefits and disbenefits – including lost convenience for trips foregone due to the road charge. The model includes the "rebound effect" of drivers attracted to take more trips by shorter trip times. It does not include the benefits of travelers that further reduce driving due to increased transit availability or other enhancements that could be funded by net congestion charging revenue, nor the potential benefits of reduced accidents and noise as they were outside the scope of this study. Carbon monoxide reductions were calculated but not monetized as the cost-effectiveness estimates used for the study do not include carbon monoxide, and calculating air toxics benefits was not within the scope of the study.

The average tolling rate during congested times was set at $0.18/mile, compared to an average fuel price of $0.15/mile at 25 mpg. This figure is based on a $3.75 gallon fuel price in effect when the analysis was conducted, and lower fuel prices would likely increase benefits because baseline congestion levels would be higher. All freeways (102 miles) and expressways (86 miles) in congested areas (70 % of Santa Clara County) were charged in the analysis. Freeways charges were set at $0.40-$0.50 per mile during peak congestion times (5 hours), $0.15 mid-peak (8 hours), and no charge was imposed off-peak (including all weekends and holidays). Charges for limited-access expressway (typically with speed limits of 45 miles per hour) were set 25% lower. The average tolling rate was $1.74 per trip.

The study also varied inputs, including price elastiticity, and found that congestion charging results in net societal benefits under low, high, and mid-point price elasticities varying from -0.2 to -0.8, with the primary scenario using a price elasticity of -0.5 based on a recent pilot study by the Pugeut Sound Regional Council (http://www.psrc.org/projects/trafficchoices/index.htm). Time elasticities, i.e. willingness to change the time of a trip to avoid or reduce toll costs, were included in the model and can be varied by the user. For more details, the technical appendix for the technical is available on request.

Readers interested in an example of a spreadsheet model applying these same principles to a potential future New York City cordon fee can also download that Komanoff model for New York City at http://nnyn.org/index.html.