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WORKING PAPER

STUDY ON INTERNATIONAL PRACTICES FOR LOW EMISSION ZONE AND CONGESTION CHARGING

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EXECUTIVE SUMMARY

China's rapid urbanization and motorization have caused severe air pollution and traffic congestion in the country, which in turn has led to a sharp increase in social costs. In Beijing, vehicles account for 31.1 percent, 33 percent, and 50 percent of total emissions of fine particles (or particulate matter 2.5, PM2.5), volatile organic compounds (VOCs), and nitrogen oxides (NOx), respectively, making vehicles the leading pollution source in the city. Growing traffic congestion also imposes high socioeconomic costs. In September 2013, Beijing released the Beijing Clean Air Action Plan 2013–2017, and the Work Plan for Vehicle Emissions Control 2013–2017, in an important effort to tackle transport emissions problems. One of the key elements of the plans is to study the low emission zone and congestion charging (LEZ/CC) scheme. This scheme is also being considered as a local policy option by other cities in China.

Cities adopting the congestion charging (CC) scheme collect a surcharge on congested sections of road. The aim is to alleviate congestion through curbing travel demand without increasing infrastructure supply. This action has had a positive influence in London, Singapore, Stockholm,

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and Milan. Low emission zone (LEZ) refers to a dedicated emissions control area established to reduce vehicle pollutants. The LEZ policy is created mainly to solve air pollution problems caused by vehicle emissions. LEZ has been implemented in cities all over the world, and is particularly important in Europe.

This report was developed based on interviews with experts in LEZ/CC policies, and observations made during study tours in London, Singapore, and Stockholm. The report is intended to help readers understand how LEZ/CC policies work to alleviate air pollution and greenhouse gas (GHG) emissions. The report addresses the following questions:

- What are the main challenges to introducing the LEZ/CC scheme?
- What are the main concerns expressed by stakeholders?
- Are there any complementary measurements to support the LEZ/CC scheme?
- How can public acceptance be improved through public communication?
- What are the main factors to consider when selecting LEZ/CC enforcement technologies?
- What are the benefits generated by the LEZ/CC scheme?

Table ES-1 shows the key features of the LEZ/CC policies implemented in the cities of London, Singapore, and Stockholm, and their results so far.

Table ES-1 | **Comparison of LEZ/CC Schemes in London, Singapore, and Stockholm (I)**

Features	London	Singapore	Stockholm
Policy	LEZ and CC	CC	LEZ and CC
Summary	Legal safeguards from national government, and political commitment from local government Clear policy objectives, and thorough consideration of details Comprehensive public consultation, with open and transparent public communication Well-designed complementary measurements for transport sector Effective management and continuous improvement	Thorough consideration of policy results, while balancing theory and public acceptance Highly controlled technology development and management Emphasis on social equity and not-for-profit Focus on public communication and public participation	National law on taxation Effective communication between government and citizens Successful system trial Strong technology support Transparent revenue allocation
Timeline	CC in 2003 (less than 3 years' preparation) LEZ in 2008	Area Licensing Scheme (ALS) in 1975 and Electronic Road Pricing (ERP) in 1998 (with 13 years of preparation) GPS-based ERP (stage II) in 2017	LEZ in 1996 CC in 2007 (4 years' preparation)
Prerequisites	Initiated by national government and mayor	Initiated by government	Trial Referendum
Exemptions	Multiple Exemptions, including ultra-low emission discount	No Exemptions, except for emergency vehicles such as police cars, fire trucks, and ambulances	Multiple Exemptions

Table ES-1 | **Comparison of LEZ/CC Schemes in London, Singapore, and Stockholm (II)**

Features	London	Singapore	Stockholm
Charging Hours	7.00 am–6.00 pm Monday to Friday	7:30 am–8:00 pm, Monday to Friday 12:30 pm–8:00 pm on Saturdays 7:30 am–1:00 pm for public holidays (differs at some road sections)	6:00 am–6:30 pm Monday to Friday
Rate	Daily Flat Rate £11.50 (about USD 14.2)	Charging on passing gantries. Rates vary from 0 to SGD 12 (about USD 8.4), depending on vehicle type, time, and location	SEK 35 (about USD 3.8) charged on passing gantries during rush hours Daily Maximum of SEK 105 (about USD 11.3)
Revenue Allocation	Dedicated to improving transport system of London during the first 10 years of implementation	Revenue to national government, no dedicated usage	Dedicated to infrastructure development in Stockholm Details of revenue allocation shown on tax bill
Challenges	Impacts on low-income groups, and overall economy Issues created by traffic diversion and compulsory enforcement Technical feasibility	Privacy of vehicle owners Safety of cash cards Charging of non-local vehicles System reliability	Theft of vehicle license plates Public boycott Blocking or changing of vehicle plates to escape charging Charging system malfunction Privacy of vehicle owners
Concerns from Stakeholders	Decreased business activities in zone Increased cost of transportation to logistics suppliers Dividing charges between taxi drivers and passengers	Over-charging of taxis with multiple entries to charging zone Indirect negative influence on business activities in the zone Financial pressure on low-income groups	Negative influences on retailers within charging zone Business relocation from downtown area, causing recession within the zone Large number of complaints from public
Complementary Measures	Improved public transportation service Alternative detour plan Optimized traffic signal timing Exclusive parking zone for residents around charging boundaries	Reduced vehicle registration fees Introduction of carbon emissions-based vehicle scheme Revised certificate of entitlement for vehicles "Free Pre-Peak Travel" on MRT	Extension of public transport services Improved bicycle lanes and sidewalks

Table ES-1 | **Comparison of LEZ/CC Schemes in London, Singapore, and Stockholm (III)**

Features	London	Singapore	Stockholm
Public Communication Strategies	National government released Road Charging Options for London Promotion of CC policy during election campaign Professional surveys of public and key stakeholders Open access details of the policies in newspaper, radio, television, and other media Road shows and community meetings to communicate with residents	Land Transport Authority Gallery, and reader-friendly brochures Open-to-all traffic information Community partner teams to understand traffic within communities, and to promote policies Social work Alerts on charging rate adjustment Use of congestion charging rather than road tolls to emphasize congestion alleviation	Public inquiry to collect feedback and understand public expectations Emphasis on environment charges during promotion Pioneer of congestion charging trial project Frequent and accurate disclosure on policy implementation Easy-to-understand communication materials
Selection of Technology	Automatic Number Plate Recognition (ANPR): • Verified technology • Quick to set up (completion within mayor's term) • Influences on cityscape	Dedicated Short-Range Radio Communications (DSRC): • Stable • Intelligent • Environmentally friendly • Flexible • Easy to use • Affordable	Early stages: ANPR+DSRC Now: ANPR • Labor and construction cost • Recognition rate • Installation of cameras for policy enforcement as required by law
Policy Results	CC policy (within one year of policy becoming effective): • Number of private vehicles entering charging zone dropped by 30% during charging hours, with level of congestion dropping by 30% • Number of buses and coaches entering the central area increased by 20% • During morning rush hours, the number of bus passengers entering the charging zone increased from 77,000 to 106,000 LEZ policy (by June 2013): • Over 95% of vehicles entering the zone have met the corresponding emission requirements • Concentration of particulate matter (PM) dropped by ~2.46–3.07% within the zone, and by 1% outside the zone	• The number of vehicles in Singapore has continuously increased, but traffic volume in the restricted zone has remained unchanged • Ideal speed has been reached in restricted road sections • Temporal-spatial redistribution of traffic flow during rush hours • Share of public transport increased to 66% during rush hours	Trial implementation of CC policy: • ~10–15% vehicle emission reduction in inner city • ~10–14% reduction in air pollutant concentrations • 21% reduction in traffic volumes LEZ policy: • PM emissions from heavy-duty vehicles across the city decreased by 40% 4 years after introducing LEZ

Based on the experiences of these three cities, we conclude that the key factors in successful implementation of congestion mitigation and emission control policies include: legal safeguard[i] from national government; strong policy objectives from local government; a comprehensive feasibility study; equity and transparency during policy implementation; reliable technologies; effective public communication; and sound complementary measures. City authorities are the decision-makers regarding LEZ/CC policies in China, while national governments play an important role in policy promotion. This report proposes the following recommendations for decision-makers on the basis of combining experiences from London, Singapore, and Stockholm, and unique features of China.

National Government

- *Legal Safeguard:* the national government should combine the objectives of local LEZ/CC schemes with national transportation strategies in a clear and consistent manner. National government should also support the implementation of local congestion mitigation and emissions reduction policies through favorable legislation, regulation, and policies.

Municipal Government

- *Strong Policy Objectives:* the municipal government should set clear and strong objectives before implementing the LEZ/CC scheme. Strong objectives are the starting point for developing an effective scheme, and can help to ensure consistency throughout policy preparation, implementation, operation, management, and monitoring. Consensus on objectives and the implementation process should be reached early, because multiple local government agencies will be involved during policy development and enforcement.

- *Comprehensive Feasibility Study:* local government should conduct comprehensive studies focusing on implementation details, such as charging fees and targets. Modeling and scientific analyses are important to evaluate different scenarios and provide support to decision-making.

- *Equity and Transparency in Policy Implementation:* the allocation of revenues from congestion charging is critical to policy implementation outcomes. We recommend that revenues be dedicated to transportation system improvements, and that the process be transparent, which helps to increase policy acceptability among the public.

- *Reliable Technologies:* innovative and advanced technologies are not necessarily the right choice when selecting technological systems. Field-proven technologies that are appropriate to local circumstances offer the greatest chance of successful implementation.

- *Effective Public Communication:* Public communication is one of the key elements in ensuring policy acceptability. Communication strategies should be effective, and updated to take account of public feedback and enable public communication to serve its purpose of improving policy acceptability.

- *Sound Complementary Measurements:* the LEZ/CC scheme should be considered as an effort to improve transportation and the environment. A complete set of complementary measurements that offer viable alternative travel options and mitigate potentially unwelcome impacts of the scheme should be developed before implementation.

INTRODUCTION

Rapid urbanization in China has resulted in severe congestion problems and great social costs, thus becoming a prominent public issue. Meanwhile, various environmental effects of congestion have imposed a heavy burden on urban daily life. In 2013, emissions of PM2.5, volatile organic compounds, and nitrogen oxides (NOx) from vehicles accounted for 31.1 percent, 33 percent, and 50 percent, respectively, of the total amounts of these air pollutants in Beijing (Beijing Municipal Environmental Monitoring Center 2014). Congestion alleviation and emissions reduction are becoming two of the most pressing issues for China. The pressures and challenges faced by Chinese cities during the process of the rapid urbanization and mobilization, while distinctly Chinese in some ways, have nevertheless been experienced more generally by cities in developed countries as well. This gives China the advantage of being able to learn from their experience when problem solving. Low emission zone (LEZ) and congestion charging (CC) schemes are among the more effective measures that are often adopted by cities to tackle congestion and high levels of vehicle pollution.

Cities adopting a CC policy collect a surcharge on congested sections of road. The policy is an attempt to alleviate congestion through curbing travel demand without increasing infrastructure supply. Congestion charging is aimed at marginal consumers, rather than all travel groups, who do not show strong preferences among travel modes, but are keenly sensitive to travel cost. These marginal consumers' attention to travel cost makes it possible to channel their choices on travel modes through the CC policy. Three international cities—London, Singapore, and Stockholm—have successfully launched CC policies.[2] Low emission zones (LEZs) are dedicated emission control areas set up to limit vehicle pollutants with the aim of improving regional air quality. LEZs are widely implemented globally and have become an important measure to improve air quality, especially in cities and regions of Europe.

In September 2013, Beijing announced the city's decision to conduct research on the LEZ/CC scheme in the *Beijing Clean Air Action Plan 2013–2017*, and the *Work Plan for Vehicle Emissions Control 2013–2017* (General Office of the People's Government of Beijing Municipality 2013; People's Government of Beijing Municipality 2013). This was an important effort to tackle transport emissions problems. Other cities in China, such as Shanghai, Hangzhou, Chengdu, Qingdao, and Suzhou, are also considering the LEZ/CC scheme as a policy option.

This report explores actions that can be adopted by China to alleviate congestion and reduce vehicle emissions. The main focus is on discussing proven practices in London, Singapore, and Stockholm regarding the LEZ/CC scheme, from the preparation stage to implementation planning, selection of technology, public communication, implementation, and management.

RESEARCH METHODOLOGY AND FRAMEWORK

This report has selected London, Singapore, and Stockholm as case study subjects for the LEZ/CC scheme. The selection was made on the basis of comparing the outcomes of scheme implementation in different cities, and the requirements of the Beijing Municipal Commission of Transport. The practices and problem-solving skills demonstrated by these three cities while promoting the LEZ/CC scheme can be of assistance to similar efforts in China.

World Resources Institute (WRI) and Beijing Transport Institute (former Beijing Transportation Research Center and Beijing Transport Energy and Environment Center) undertook a combined study tour to London, Singapore, and Stockholm between May 2014 and July 2014. The study tour took the form of interviews with experts and field trips that emphasized policies related to the LEZ/CC schemes. A total of 40 field experts from 18 organizations, including Department for Transport of United Kingdom, Transport for London (TfL), Land Transport Authority of Singapore, Stockholm Storstockholms Lokaltrafik AB(SL), and Stockholm Environment Institute, contributed to our research. In addition, more than 700 photographs and video segments and over 1,300 minutes of interviews were collected during the tour.

This report analyzes the LEZ/CC practices in the case study cities in the areas of policy launch, public communication, policy implementation, and policy outcomes. The analysis is presented separately for each city, with the aim of creating a comparative point of view that highlights each city's particular features (see Figure 2-1). The analysis for Singapore focuses only on the city's CC scheme because Singapore has yet to introduce an LEZ policy. The lack of an LEZ in Singapore is partly due to the fact that air pollution is not a key concern for government authorities, and, more importantly, policies that can achieve similar results already exist. For example, the cost of owning and using vehicles is very high in Singapore, thanks to the requirement for a certificate of entitlement (COE) for vehicles. Singapore has applied tighter diesel emissions standards to reduce vehicle emissions and related pollution, so to avoid increasing costs for enterprises and households, which is always a possible downside of establishing LEZs (Lianhe Zaobao 2013).

Figure 2-1 | **Research Framework**

LONDON CASE STUDY

London Overview

London is the capital city of the United Kingdom (UK). It is the most populous city in the country and one of the largest metropolises in the world. Globally, London is also one of the leading political, economic, cultural, and entertainment hubs. The population of the Greater London area reached 8.54 million in 2014, with the population density being 5,432 persons per square kilometer (UK Office for National Statistics 2015). The transport mode share in London in 2014 was 45 percent public transport, 32 percent private transport, 2 percent cycling, and 21 percent walking (see Figure 3-1) (TfL 2015). Car ownership was 2.592 million, that is, about 329 cars per 1,000 persons (London Department for Transport 2015).

Travel demand in London is high, though road capacity is quite limited. Vehicle trips during rush hours before the LEZ/CC scheme came into force were 388,000 into the city and 377,000 out of the city; total distance traveled was 150,000 kilometers (TfL 2003). The average vehicle speed in the city center was 14 km/hour in 2002, and travel time was doubled due to congestion (TfL 2003). The large vehicle volume and severe congestion led to increased vehicle emissions. Emissions of NO_x and PM10 from vehicle exhaust generated in the city center (which is only 1.4% of the area of Greater London) accounted for 4 percent and 6 percent, respectively, of total emissions of these gases from vehicles on London's roads.

In their own words...

Each day in 2006 there were almost 70,000 fewer vehicles entering the charging zone compared to the number that had been entering each day before charging began . . . The amount of traffic entering central London during charging hours has been cut by around 20 percent . . . It has contributed to the growth of cycling, with more people than ever before travelling by bike—there has been a 72 percent increase in the number of cyclists on the capital's major roads since 2000."

—Former London Mayor Ken Livingstone (Weaver 2007)

Since the establishment of the Greater London Authority (GLA) in 2000, the Mayor, together with GLA and Transport for London (TfL), have been actively committed to improving the transport system to reduce travel time and costs for residents, and to reduce environmental pollution caused by the transport sector. The Central London CC policy and the LEZ for Greater London are two of the most prominent transport strategies.

Figure 3-1 | **Transport Mode Share in London**

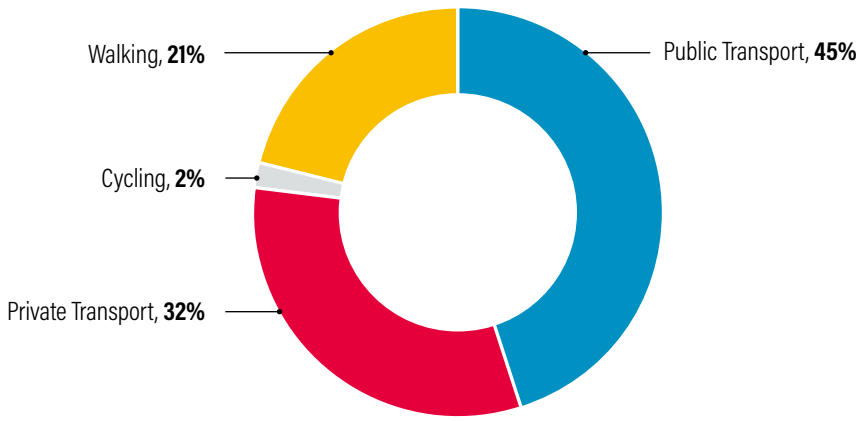
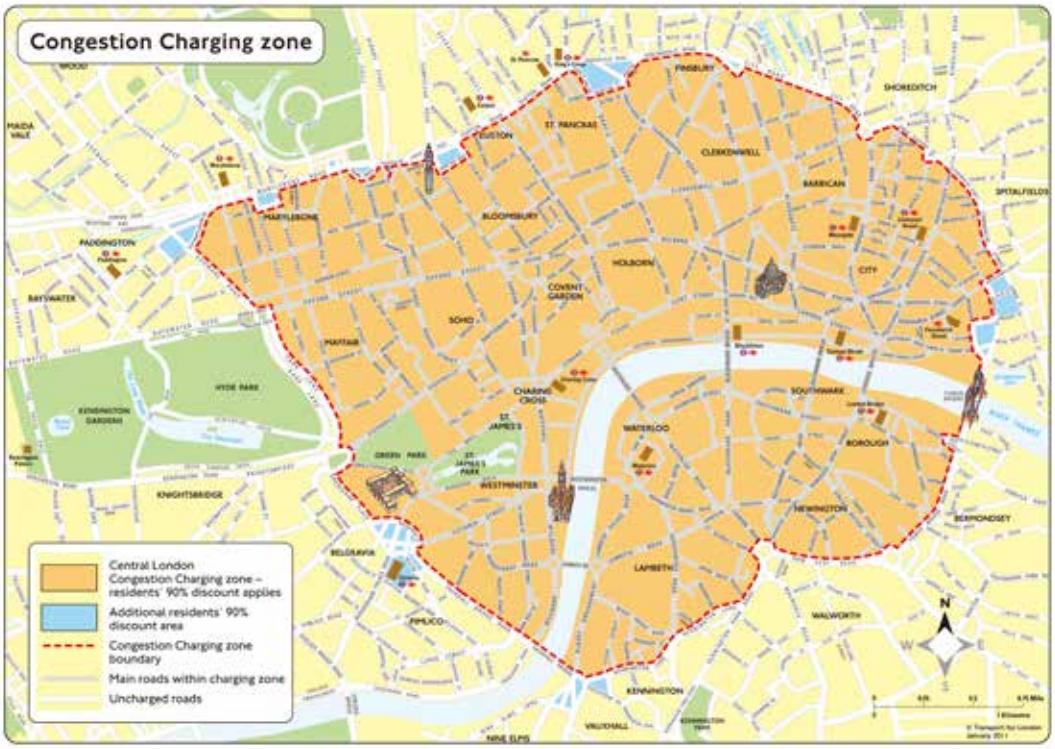


Figure 3-2 | **Congestion Charging zone in London**



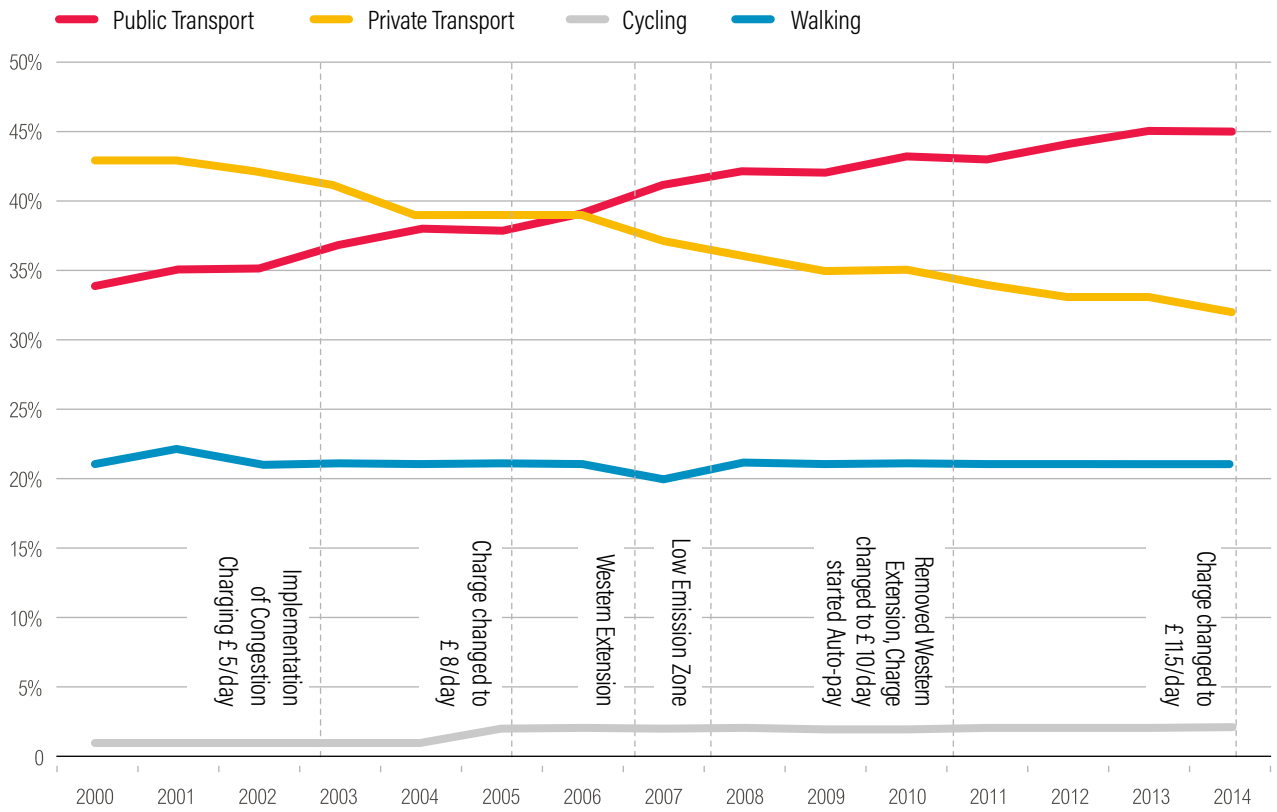
Source: TfL, 2014

Congestion Charging

In February 2003, London initiated the CC policy for the central area with the specific aim of reducing the level of traffic congestion. Many travel means such as bus, underground (metro), taxi, bicycle, and walking are available in addition to vehicles as alternative modes of transport. This made Central London quite suitable for the introduction of CC. As shown in Figure 3-2, by 2015, the charging zone covered 21 square kilometers inside the Inner Ring Road of Central London (not including the Inner Ring Road), with the daily charge being £11.50 (about USD 14.2). The charging period is between 7:00 am and 6:00 pm from Monday to Friday, excluding other time intervals from Monday to Friday, weekends, public holidays, and the period between Christmas and New Year. Within the CC zone, all motor vehicles are subject to the charge, with certain exceptions depending upon vehicle type, intended use, and the residential address of registered users. It is worth mentioning that, since July 1, 2013, vehicles that are either pure electric or emit no more than 75 grams of carbon dioxide per kilometer (g/km) and meet the Euro V emission standard are qualified for complete exemption from the congestion charge (TfL 2013b).

The CC policy has undergone a series of complex developments and evolutions such as price adjustment on a number of occasions since its introduction. The addition of the Western Extension and its subsequent removal, the transition from telephone as main payment channel to automatic account-based payment, and changes in the categories of charged vehicles, among other developments of the past 13 years, are shown in Figure 3-3. In 2003, when the CC scheme was first implemented, the charge was £5/day (about USD 6.2), and payment was made mainly by telephone. The charge was raised to £8/day (about USD 10.0) in July 2005. In February 2007, the zone was extended westward, doubling the size of the original area, while the charge and types of vehicles exempted remained the same. In January 2011, the western extension was removed. In the meantime, the congestion charge had increased to £10 (about USD 12.5), and the AutoPay system was officially opened for use. Recently, in June 2014, the charge increased to £11.50/day (about USD 14.2).

Figure 3-3 | **Important Milestones for London Congestion Charging and Mode Split, 2000–2014**



Source: TfL, 2015

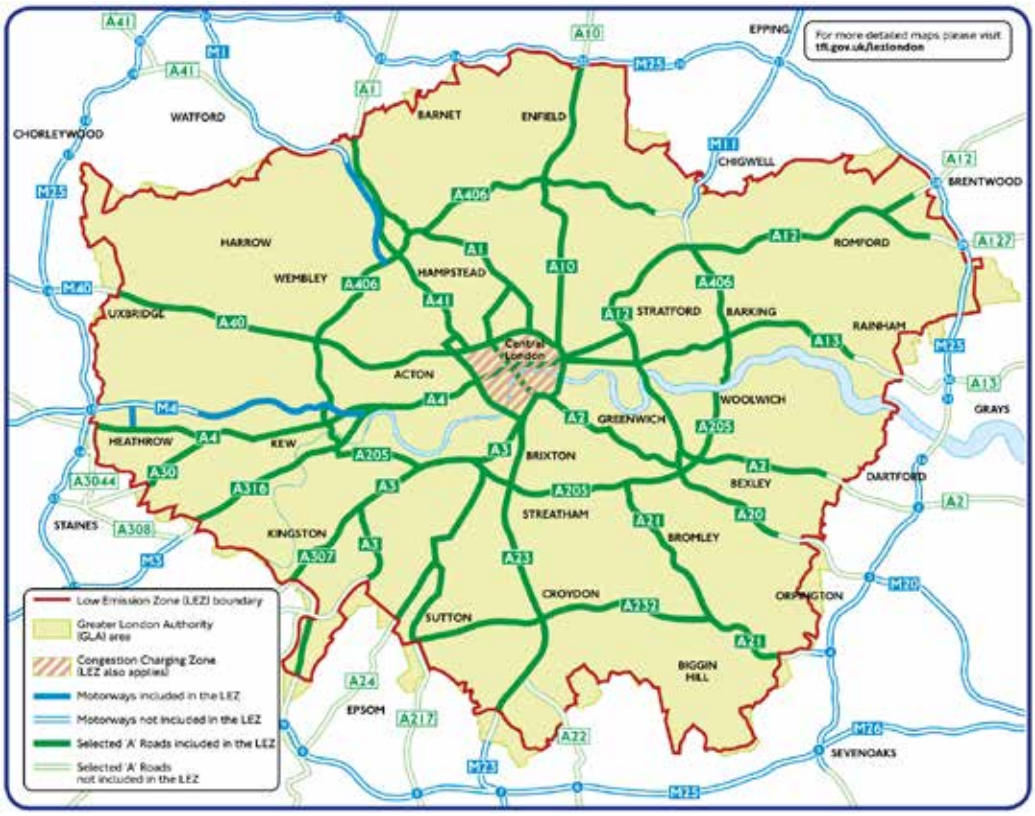
As shown in Figure 3-3, the share of journey stages by public transport across London increased from 37 percent in 2003 to 45 percent in 2014, while private transport dropped from 41 to 32 percent (TfL 2015). The changes in mode share of journey stages are closely related to implementation of the CC policy. Though CC policy has experienced complications and problems since its initiation, the implementation has generally been seen as effective in alleviating congestion, and the net revenue obtained from charging is also seen as an important source of capital for improving public transport services and non-motorized transport systems, transport infrastructure, and implementing other transport demand management (TDM) policies.

Low Emission Zone (LEZ)

The London LEZ was introduced to combat air pollution. The LEZ covers the entire Greater London area, with a total area of 1,580 square kilometers, as shown in Figure 3-4. The operation time is 24 hours per day, seven days per week. The LEZ was implemented with the aim of limiting the entry of highly polluting heavy vehicles into London and encouraging the upgrade of vehicles (especially diesel vehicles) in London to meet the tightened emission standards. The policy also aimed to promote cleaner vehicles, thus improving air quality in London and reducing the detrimental impact of emissions from the transport sector on public health.

There have been three important phases of implementation of the LEZ policy. In January 2008, when first introduced, vehicles over 12 tonnes were required to meet the Euro III standard. In June 2008, the standard was extended to include freight vehicles over 3.5 tonnes, and buses/coaches over 5 tonnes. In January 2012, the stricter Euro IV standard

Figure 3-4 | **Low Emission Zone in London**



Source: TfL, 2012

was applied for heavy freight vehicles, buses, and coaches. Vehicles that do not meet emission requirements are charged £200 (about USD 249.6) to enter the zone. In addition, other vehicles are subject to the Euro III standard, including minibuses below 5 tonnes, ambulances and RVs, vans between 1.205 and 3.5 tonnes, light-duty trucks, and trucks. An entry fee of £100/day (about USD 124.8) will be charged on these vehicles if they do not meet the Euro III standard. Vehicles reaching the appropriate standards may travel free of charge in the zone. Vehicles entering the zone illegally (attempting to avoid being charged) are fined between £250 and £1,000 per day (about USD 312.0-1247.8), depending on vehicle type and time of payment. Some vehicles are exempted from the charge such as agricultural or farm machinery and equipment, mobile cranes, road and building construction machinery, vehicles produced before January 1, 1973, and vehicles belonging to the Ministry of Defence.

Since the introduction of the LEZ policy in 2008, significant progress has been made in reducing vehicle emissions—a large proportion of vehicles have reached the emission standards. At the end of 2010, fewer than 40 percent of vehicles met the required emission standards; by June 2013, more than 95 percent of vehicles entering the LEZ met the emission standards corresponding to their class of vehicle (TfL 2013c).

The purpose of establishing an LEZ is to promote appropriate emissions standards for motor vehicles and encourage clean energy vehicles. Although charges and fines within LEZs are significantly higher than the CC, TfL has collected little revenue from the LEZ policy, indicating a high level of compliance.

Policy Background

The CC policy for London was approved thanks to a strong political background. Determination and strong political will were key factors in the successful implementation of CC in London.

Greater London Authority and the Greater London Authority Act 1999

From 1986, when Conservative Prime Minister Margaret Thatcher abolished the Greater London Council (GLC), to 1997, when Labour Leader Tony Blair was elected Prime Minister, there was no London-wide elected body with administrative and representative political capacity. London residents were limited to borough (local) voting rights in the affairs of the city, and the resulting urban segmentation and service dispersal led to lower efficiency of urban management and operations in many areas, including transport.

Prime Minister Blair fulfilled his promise to recreate a London-wide elected body. Under the Blair administration, the Greater London Authority (GLA) was established with the passing of the *Greater London Authority Act 1999* (the Act). In the Act, a unique strategic management form was created for London, with the elected Mayor exercising the power of decision-making on behalf of the GLA and a separately elected London Assembly having scrutiny powers over the Mayor. The GLA is responsible for a series of important issues, such as economic planning, public security, fire control, and transport. The Act also specified regulations on charging-fee allocation. In addition to the legislation, the Blair government also undertook an in-depth feasibility study of implementation of CC. It can be said that, before the CC policy was implemented, the national government had removed many obstacles and provided many of the legal powers necessary for its introduction.

An important piece of experience gained from the implementation of CC in London is the need for legal status (a safeguard or guarantee). Rather than a tax established by law, London's CC policy involves collection of certain fees within specified boundaries, which formerly was not protected by law. The *Greater London Authority Act 1999* provided legal status for the implementation of the policy, as well as for management and enforcement operations.

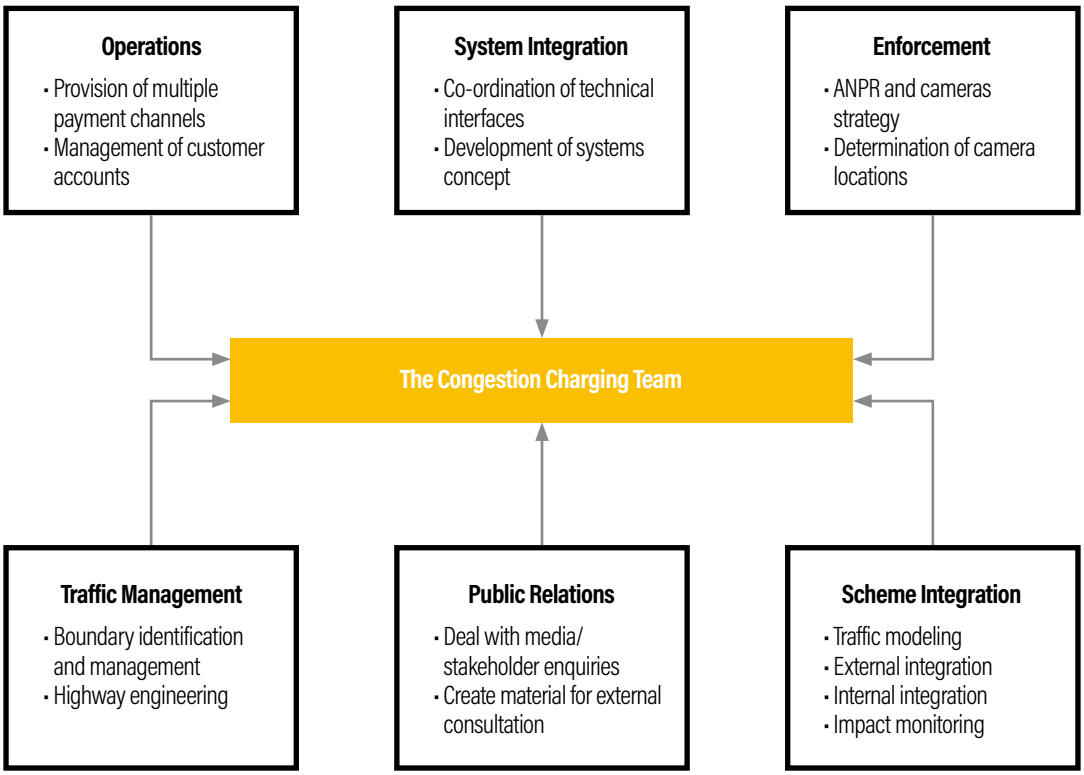
First Mayor – Ken Livingstone

Transport was an important issue during the campaign for the first Mayor of the Greater London area. Although CC was seen as a notoriously difficult policy to sell to voters, Ken Livingstone, an independent candidate, was courageous enough to propose it as the key measure to address London's transport problems, and promised to implement this policy within his first term, while other candidates ranged from outright opposition to CC to lukewarm support. Ken Livingstone was elected as Mayor of London in May 2000, indicating the public's expectations of improving transport system.

Mayor Livingstone actively promoted the CC policy during his term to fulfill his campaign commitment. He viewed CC as part of a package of integrated transport and social policies rather than a single, standalone policy. Complementary measurements to the CC policy included improving the public transport system, promoting sustainable transport, reducing the cost of commuting, and penalizing illegal parking and loading, among others. Implementation faced numerous and serious challenges, especially objections from a majority of the public, and the policy would have failed had it not been for the leadership of a strong and charismatic politician such as Ken Livingstone. Livingstone paid great attention to detail, which greatly encouraged the whole CC team to maximize their commitment to the project and "to walk the extra mile," engendering a very productive working environment among the transport professionals responsible for implementation of the scheme. With characteristic effort and determination, Livingstone successfully initiated the CC scheme before the end of his first term in office.

The most important lesson learned from London's practice of CC is that a strong and focused administrative team must be in place. Successful implementation of a CC policy is not possible without the resolution and continual efforts of political leaders. In the case of the UK, the Blair administration's work on legal and feasibility research prior to policy development helped clear many of political and legislative obstacles, while Mayor Livingstone's team showed great resolution and judgement in promoting the CC policy in London, despite controversial voices from different sides.

Figure 3-5 | **Scope of Responsibilities of Special Working Team for Congestion Charging**



Source: Dix, 2002

Transport for London (TfL)

After taking his post, Mayor Ken Livingstone quickly set up Transport for London (TfL) as the transport management agency. As the implementation authority of the CC policy, TfL is derived from a number of predecessor bodies—almost 16 separate transport service departments that include the Government Office for London (GOL), public transport operators, rail transit, light rail, trams, railway (currently the London Overground), transportation operation and management, traffic signal operation and management, major road construction, road safety, water transport service, taxi franchising, etc. TfL integrates multiple transport services and management under one roof, including construction of road infrastructure, traffic control, and law enforcement, thereby enabling efficient planning, implementation, and management of other complementary measures (e.g., improvement of public transport, road transformation, and re-organizing traffic flow to improve traffic speeds), which were important for the successful introduction of CC.

TfL also established a special working team for CC. The team was supported by a dedicated project management function and general procurement capability, as shown in Figure 3-5.

Preliminary Studies on Congestion Charging

In the early 1800s, discussing the use and management of public goods, British economists drew the public's attention to charging for road use as a possible solution to traffic congestion (Dupuit 1968). Economists, such as Pigou, considered that the cause of environmental pollution and traffic congestion was an imbalance of resource allocation in the market. His argument was based on the assertion that economic parties in the market failed to pay fully for the negative externalities arising from their consumption of public goods (Pigou 1920). Subsequent research on public goods consumption in a market economy led to widespread acceptance of the theories of charging for public goods consumption—for example, in the areas of energy, public

transport, and telecommunications—in cases of resource scarcity or instances of usage during peak periods. At a time when CC did not exist in London or anywhere else in the world, academia was confidently predicting that traffic conditions would be improved by means of charging road users.

The Smeed Report

The first major report on the feasibility of CC in London was produced in the 1960s, when the post-World War II growth in car ownership was beginning to create serious congestion problems. The Smeed Report, commissioned by the Department for Transport of UK in 1964, initially introduced the discussion on road-use management. The report explained that, according to the CC principle, "the road user should pay the costs that he imposes upon others," including the cost of road infrastructure, congestion costs, social costs etc. (Smeed 1964) However, political sensitivity blocked implementation of road pricing policy in any UK city and CC was set aside following a change of power in central government. The report did, however, highlight the potential of road pricing to the rest of the world, which helped to inspire the implementation of the Area Licensing Scheme (ALS) in Singapore in 1975, for example, where charging fees were designed based on time of day and congestion level. The economic and social discussion of the Smeed Report and principles of CC policy, despite the long delay before implementation in the UK, laid the theoretical foundation for future policy formulation.

Other Road Pricing Reports

Road pricing was discussed more widely in the UK following the release of the Smeed Report. Research on road pricing continued and reports published since 1995 include *The London Congestion Charging Research Programme* (UK Government and MVA 1995), which advocated CC using tag-and-beacon technology; Breaking the Logjam: The Government's Consultation Paper on Fighting Traffic Congestion and Pollution (UK Department of the Environment, Transport and the Regions[3] 1998), a government document comparing road pricing with workplace parking levies; *Road User Charging: A Proposal for Central London* (London First 1999), which discussed a paper-based traffic permit program in Central London; and Charging Ahead: Making Road User Charging Work (Adam Smith Institute and the Smith Group Business Consultancy 1999), which recommended the implementation of CC in London early in the 21st century. Most of the research publications agreed that charging was effective for TDM, and also had a beneficial effect in helping to ease traffic congestion and improve air quality. These reports, however, did not consider the wider implications of CC for low-income groups and the economy, issues that might result from traffic re-distribution and enforcement, and possible technical barriers at that time. The publication of these reports prompted relatively wide discussion in Parliament, academia, and among the public. Specifically, a consensus emerged that the local government should be granted the power of decision making and implementation of any CC schemes and that revenue from CC should be fully allocated to local government for transport system improvement.

Road Charging Options for London: A Technical Assessment

In order to study implementation of a CC policy in central London, the Government Office for London, promoted by the Blair administration, established an independent working group of experts in 1998. The team analyzed scaling, prices, and technology, as well as public reactions, and published the results in *The Road Charging Options for London: A Technical Assessment* (ROCOL Working Group 2000) (hereafter referred to as the ROCOL report).

When the ROCOL report was released, the *Greater London Authority Act 1999* had already granted the future London government the power of decision making and capital retention of revenues accrued from CC. As a result, the ROCOL report focused directly on analyzing the effect of implementing the charging program. Given that the Greater London Authority had not been established when the ROCOL report was issued, the charging program was actually developed with the support of the central government. Eugenie Turton, the chairperson of the working group of the report, wrote in the preface (ROCOL Working Group 2000):

> *"Each has contributed his or her professional views to a collective "illustration" of how the new powers might be used as part of a wider Transport Strategy . . . The term "illustration" is important, as the report neither offers formal guidance nor does it reach specific conclusions."*

Although the term "illustration" was used, the high degree of consistency between the "illustration" in the ROCOL report and the subsequent CC scheme implemented by Mayor Livingstone clearly indicates how important the

ROCOL report was as a template and reference document for the future London mayoral candidates to solve transport problems.

The ROCOL report was issued two months before the election of the first Mayor of London, providing the new Mayor and his traffic management team in TfL with a valuable initial study on the implementation of traffic congestion policy and the possible effects of the new policy. The report emphasized the importance of refining details in the CC policy, and provided analysis of areas on which to focus during enforcement, including the possible charging area, fee levels, hours of operation, penalties, exemptions, and policy benefits, which greatly contributed to the later public communications exercise. In addition, the report analyzed a series of technology options for the charging system, such as a paper license, an electronic road pricing (ERP) system with gantries, automatic plate number recognition technology, and so on. Although the report compares the details of different options, no specific scheme was advocated or recommended, allowing a great degree of freedom in decision making for the new Mayor and his traffic management team. The publication of the report and the resulting public communication provided Mayor Livingstone with a sound policy basis for the implementation of CC in his first term of office.

Public Communications

Due to the potential for significant public opposition to CC before implementation, the Mayor and his transportation team at TfL made great efforts to deal with various stakeholders and the public, using a number of public communication techniques.

Preliminary Communication

Public consultation without explanation of the details of CC could easily have led to public opposition. So if there were no definitive ways to show the impacts of the policy on their lives, the public might have opposed the policy out of fear of the unknown as much as informed objection to the policy. The mayoral election marked the turning point for policy communication. The campaign teams for Ken Livingstone promoted CC as the key campaign issue in the pre-election period, attracting much attention to the policy through extensive public communication. They promoted the policy framework using exactly the same information illustrated in the ROCOL report during the election campaign. Significantly, during the election campaign Ken Livingstone made the point that, if elected, he would proceed with plans to introduce a CC scheme without holding a further referendum on the subject. The promotional efforts based on the ROCOL report also resulted in a discussion about CC policy among the public. Londoners began to understand for the first time how the policy would influence their daily lives, which provided the basis for successful implementation of CC.

Mayor's Transport Strategy

Mayor Livingstone started to develop the Mayor's Transport Strategy after the success of his election campaign in May 2000. The central plank of the strategy was implementation of the CC policy, and especially to further define the charging vehicles, time, and fees. The Mayor's Transport Strategy opened in-depth discussion and communication of policy implementation among key stakeholders and ordinary citizens.

The Mayor of London issued Hearing London's Views in July 2000 to mark the beginning of formal consultations on the CC project, with 400 key stakeholders ranging from government agencies to city center business groups, logistics suppliers, motor manufacturers, and vehicle authorities, among others. The results showed that the number of supporting groups for CC in central London was six times greater than the number of opposed groups.

Mayor Livingstone issued the draft Mayor's Transport Strategy in January 2001, restating the great potential benefits of the CC program in central London in terms of reduced traffic congestion, greater attractiveness of the city, and the development of a society with a more pleasant quality of life. More than 8,000 written replies were received in response to the draft transport strategy and most of the citizens and related stakeholders supported CC. Livingstone published the final Mayor's Transport Strategy in July 2001, after revision based on the opinions collected, thereby laying the foundation for the issuance of detailed CC policy at the end of July.

Public Communication and Outreach Strategy

The CC policy came into force after just 18 months of preparation. Effective public communication strategies were key to successful kick-off and implementation. This process highlights three public communication strategies undertaken by Mayor Livingstone and his team.

Intensive monitoring of public opinion and timely adjustment. To understand the changes in public opinion between the development of the draft *Mayor's Transport Strategy* and the launching of CC, TfL employed a professional research company to send regular surveys out to the public and key stakeholders to monitor their thoughts on the policy. TfL then adapted the public communication strategy to reflect changes in public opinion and promote public acceptance.

The questions in the regular survey covered public attitudes to CC and people's understanding of the scheme's details, such as the location of the charging zone boundaries and charging targets, etc. Public opposition often results from misunderstanding and a lack of detailed knowledge about CC. In order to increase public knowledge and understanding of the scheme, TfL produced an intensive program of advertisements focusing on explaining on key issues such as the charging zone boundaries, charging targets, and vehicles eligible for discount or exemption. It was reported that public support for the policy increased due to this approach.

Targeted communication of policy impacts. Public transport accounted for about 85 percent of the trips entering the charging zone prior to the introduction of CC in London; therefore, the policy was expected to affect only a limited group of people, namely, those who drove into central London. Mayor Livingstone's public communication strategy focused on telling the public about the many people who would not be affected by the charging policy rather than the few who would. In addition, the charging area was scaled back to 21 square kilometers, one seventy-fifth of Greater London as a whole. Communication of these details helped many segments of the general public to realize that CC would have relatively little impact on their lives.

Full details of the CC policy were posted on TfL's website for the public to review and feedback was collected. Details of the policy were also published on a regular basis in citywide newspapers and local borough newspapers, and broadcast on public radio, television, and in other media. Staff from TfL and other involved agencies also conducted roadshows near the charging zone boundaries and in heavily populated areas to disseminate information on CC to the public. The staff also took an active part in community meetings close to the boundaries of the charging zone to communicate with the residents who would be directly affected. Thus, the limited public communication budget and resources were mostly allocated to influencing key groups of citizens.

Some key stakeholders expressed repeated and persistent opposition to the CC policy. It would have been of little or no use to allocate the limited public communication resources to these groups. The more tactical approach was to spend time and put effort into reaching the undecided and those who had shown continuous support for the policy during the process of public communication.

Open attitude and prudent decision-making. The implementation team for CC policy in TfL, led by Mayor Livingstone, maintained an open and receptive attitude to the opinions of key stakeholders and residents following the development of the *Mayor's Transport Strategy*. Although the Mayor had the right to make the final decision on whether to launch CC, smooth implementation of the policy needed active cooperation of the public. Although the CC policy later proved to be an effective measure to reduce traffic volumes, it was initially considered risky and aggressive, and could easily have failed because there was no previous experience on which policymakers could draw. Therefore, it was important to strive for public understanding and support. Through repeated discussions regarding vehicles to be charged or exempted with key stakeholders and citizens, TfL studied each exemption proposal carefully. All adjustments related to charging targets were made public, which not only showed an open attitude to information disclosure, but also reflected the transparent and inclusive style of communication adopted by the policymakers. All key surveys conducted regarding the public's attitude toward CC during the policy development phase showed that most citizens and stakeholders approved of the policy itself. Some residents just outside the boundaries of charging zone sought to obtain charge-free status for their vehicles, but TfL rejected their proposals because it was important that the boundaries should be as clear as possible. Allowing exemptions or partial exemptions to people living just outside the boundaries would have compromised the integrity of the scheme.

Nevertheless, special attention was given to people who lived just outside the zone boundaries because they were the people who stood to lose most through the scheme's

introduction. They were not eligible for the residents' 90 percent discount and they were likely to suffer from increased traffic volumes in their areas as traffic diverted away from the zone in order to avoid paying the charge. In order to defuse the potentially hostile reception of residents and businesses located just outside the boundaries, significant effort was made by the CC team to provide these people with mitigating complementary measures, which would reduce any perceived or real negative impact arising from the scheme's introduction. Many parking zones were created just for residents outside the zone boundaries only in order to eliminate the possibility of people driving to the boundaries' edge, parking their vehicles and then continuing their journeys by other modes of transport. A program of traffic management measures was implemented in these streets to deter their use by vehicles diverting away from the charged area. These included street closures, installation of width restrictions, creation of one-way streets, etc. All of these measures proved extremely popular with local residents and businesses in those areas.

Another feature of the communication strategies employed by TfL was the willingness to change or modify elements of the scheme both during the consultation stage and later, once the scheme had been implemented. Examples include the "pay-next-day" policy, which was introduced in 2006 following results of a survey indicating that many motorists incurred a penalty charge notice because they had simply forgotten to pay. By giving them an additional 24 hours to make the payment, the Penalty Charge Notice rate decreased significantly. Similarly, the AutoPay System was introduced in 2011 to streamline the payment process by introducing account-based post-payment, which greatly reduced the number of Penalty Charge Notices issued, thereby reducing operational costs. These adjustments made the public feel that attention was paid to their opinions, which helped to reduce natural aversion to the charging scheme.

Edinburgh and Manchester, two other cities that attempted to introduce a CC policy, did not succeed because of ineffective public communication. The City of Edinburgh Council, hoping to alleviate congestion and improve the environment, proposed a set of schemes regarding public transport improvement and transportation infrastructure upgrade in 2002, of which CC policy was an important component. The policy, however, was voted down by 75 percent in a referendum, mostly due to weak public communication on policy details. The lack of sufficient pre-communication caused unnecessary misunderstandings, for example, 38 percent of citizens overestimated the charge limit, which was £2 (about USD 2.5); 20 percent of citizens misread the policy as a tool to restrict their travel habits; and 37 percent worried that driving out of the charging zone would be charged, as well as driving in. Another factor that contributed to the strong opposition expressed in the referendum was a common misunderstanding of the full range of effects of CC. Many citizens focused only on the increased travel costs resulting from implementation. Benefits of the policy, such as reduced traffic and an improved public transport system, however, were ambiguous. Some of the opposing votes came from those who would benefit from a charging road system but failed to realize it. The city of Manchester also encountered multiple barriers when trying to launch a CC policy. In 2005, Manchester proposed the Greater Manchester Integrated Transport Strategy (Integrated Strategy) in preparation for the Transport Innovation Fund (TIF) bid that was raised by the Department for Transport of UK. The Integrated Strategy included the CC policy. The referendum on the Integrated Strategy showed that Manchester did not learn from Edinburgh's mistakes, though the city did put some effort into public counseling and public communication. Seventy-nine percent of voters opposed the Integrated Strategy. The CC policy received most media attention; while the TIF, a great benefit coming after policy, was largely ignored in media reports. A common belief among the public was that imposing charges on congestion would hit the local economy, though the Integrated Strategy would have brought immense investment opportunities for local public transport and infrastructure. Another common misunderstanding was that residents living near the charging zone boundaries would be charged for daily commuting, while the revenues would go only to Manchester city center. Lessons learned from Edinburgh and Manchester indicated that the key to acquiring citizens' support lies in continual tracking and quick reaction to media and public opinion; and effective communication on scheme details and likely benefits. London had shown good practices in both areas.

System Implementation

Since the CC policy was implemented in 2003, the charging area, charged vehicle types, charge times, and charging fees have been through multiple revisions to take account of public feedback. The political and public debates that occurred during the western extension of the

policy and the subsequent removal of the extension have provided lessons for other cities preparing their traffic policies. After more than 10 years of CC, London has gradually formed a unique operation and management framework with localized characteristics.

Determination of Congestion Charging Area, Fees, and Targeted Vehicles

The CC zone is located in central London within the Inner Ring Road and has an area of 21 square kilometers. There were two primary reasons for selecting the Inner Ring Road as the boundary of the charge zone. Firstly, this is a route with which most drivers are familiar. Secondly, the distance between the road and the central area is appropriate to clearly define an appropriately sized charge zone. When considering the area boundaries, the only significant debate was whether or not the River Thames could serve as the southern boundary of the zone. This, however, would have resulted in the creation of a number of problematic boundaries points and accompanying escape routes adjacent to the river. What was more, land use within the Inner Ring Road on the south bank is predominantly residential with low car ownership, unlike the areas north of the river inside the zone, which are predominantly commercial, governmental, and retail areas. TfL was keen to include a number of different demographic areas inside the zone, including residential areas. Considering the difficulty of setting boundaries and the diversity of land use inside the zone, TfL decided to designate the area within the Inner Ring Road on the south bank of the river as part of the CC zone. Meanwhile, a charge-free route was set alongside the boundaries and vehicles would have to pay the charge only if they crossed over the boundary route to enter the zone.

Although the initial charging fee was widely challenged because it was not determined by economic analysis, scholars have conducted extensive primary research on the CC fee level in combination with a traffic forecast model. The charging standard of £5/day (about USD 6.2/day) determined by Mayor Livingstone and his team had proved very effective in being both politically acceptable and successful in reducing traffic levels after implementation. It is worth noting that there was some discussion that the charge should be set at £7/day (about USD 8.7/day) at the very start of public consultation. The idea was inadvertently revealed to the media, and the media reported it as headline news. The official announcement of the £5 (about USD 6.2) charge was made to indicate that the media report was not always accurate and the final charge of £5/day (about USD 6.2/day) determined by TfL provoked less adverse reaction among vehicle owners.

Regarding the determination of vehicles to be charged and exempted, Mayor Livingstone's team negotiated with different stakeholders on many occasions, and some compromises were made. It is worth mentioning the concession to taxi drivers. When the scheme was first being developed, there was discussion as to whether taxis should be exempted from the charge. A particular concern was that taxi drivers could pass on the CC to their passengers; because each taxi would carry multiple passengers into the CC zone during a day, it would be hard to determine which passenger would be charged and how much (the charge is collected once a day, regardless of the number of times that taxis enter the charging zone). Therefore, a concession was made to the taxi industry, and taxis were included in the exempted vehicle list.

Exemptions and Penalties of Congestion Charging

The CC applies to vehicles entering the CC zone, with the following types of vehicles qualified for exemption:

- two-wheeled motorcycles and electric bicycles;
- emergency service vehicles, classified as 'ambulance' or 'fire engine';
- National Health Service vehicles which are not liable for vehicle tax;
- vehicles owned by physically challenged people and/or vehicles that serve physically challenged people that are exempt from vehicle tax and have a 'disabled' taxation class; and
- taxis and private hire vehicles (PHVs) licensed with London Taxi and Private Hire (TPH).

Some vehicles are eligible for the exemption under the condition of pre-registration. Examples of these vehicles include:

- certain categories of military vehicle;
- vehicles used by European Economic Area member states, HM Coastguard and Port Authorities, Royal Parks Agency and Breakdown organizations;
- key vehicles used by the London boroughs; and
- buses.

Some vehicles are eligible for a 100 percent discount from

the CC upon paying the annual registration fee of £10 (about USD 12.4). Examples of these vehicles include:

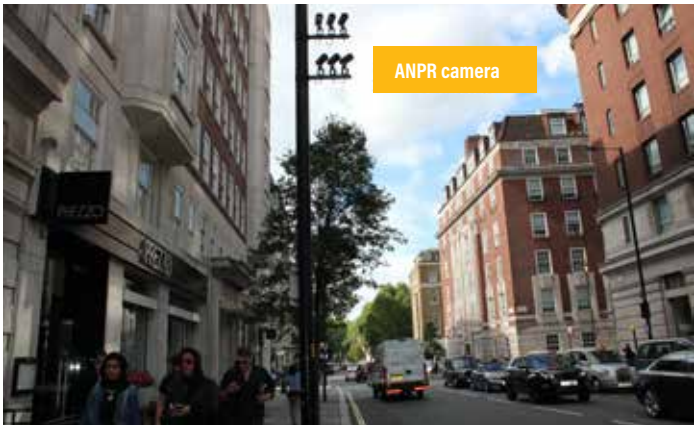
- cars or vans up to 3.5 tonnes which emit 75 g/km or less of CO2 and that meet the Euro V emission standard;
- motor tricycles not exceeding to one meter wide;
- buses and coaches (public service vehicles) with nine or more seats;
- vehicles in use to provide roadside assistance or recovery services operated by independently accredited organizations (e.g., Automobile Association, Royal Automobile Club, Green Flag); and
- people with Blue Badge.

Private vehicles owned by residents living within the charging zone boundaries are eligible for a 90 percent discount on the CC. Vehicle owners failing to pay appropriate charges are liable to a penalty charge of £130 (about USD 160.7). However, the actual amount is usually £65 (about USD 80.4) if paid within 14 days. If no payment or appeals are made within the first 28 days, the amount will be increased to £195 (about USD 241.1), which is enforced by the court. TfL also appoints a company to pursue vehicle owners from other European countries who owe unpaid fines. This company has collaborated with the several EU states, such as France, Belgium, and the Netherlands, and has access to their registered vehicle databases so that international vehicles traveling in central London are also liable to pay the charge.

Automatic Number Plate Recognition Technology

Selection of the technology that would be used for CC payment and an enforcement system was a complicated political effort, which required consideration of practicalities, as well as the need for consistency with the objectives and priorities of the transport strategy co-developed by the Mayor and the GLA. The Automatic Number Plate Recognition (ANPR) system was selected (as shown in Figure 3-6) because the technology platform could be ready for use within mayor's first term. This ensured a successful launch of the CC policy. Another reason was that ANPR has low visual impact on local urban planning and historical sites, and is therefore more suitable for London than large gantries that are difficult to install and unattractive in the cityscape. ANPR had been adopted in many other countries at that time, and had proven effective in the field, which further encouraged London to choose this system rather than other more advanced technologies.

Figure 3-6 | **Automatic Number Plate Recognition (ANPR) System**



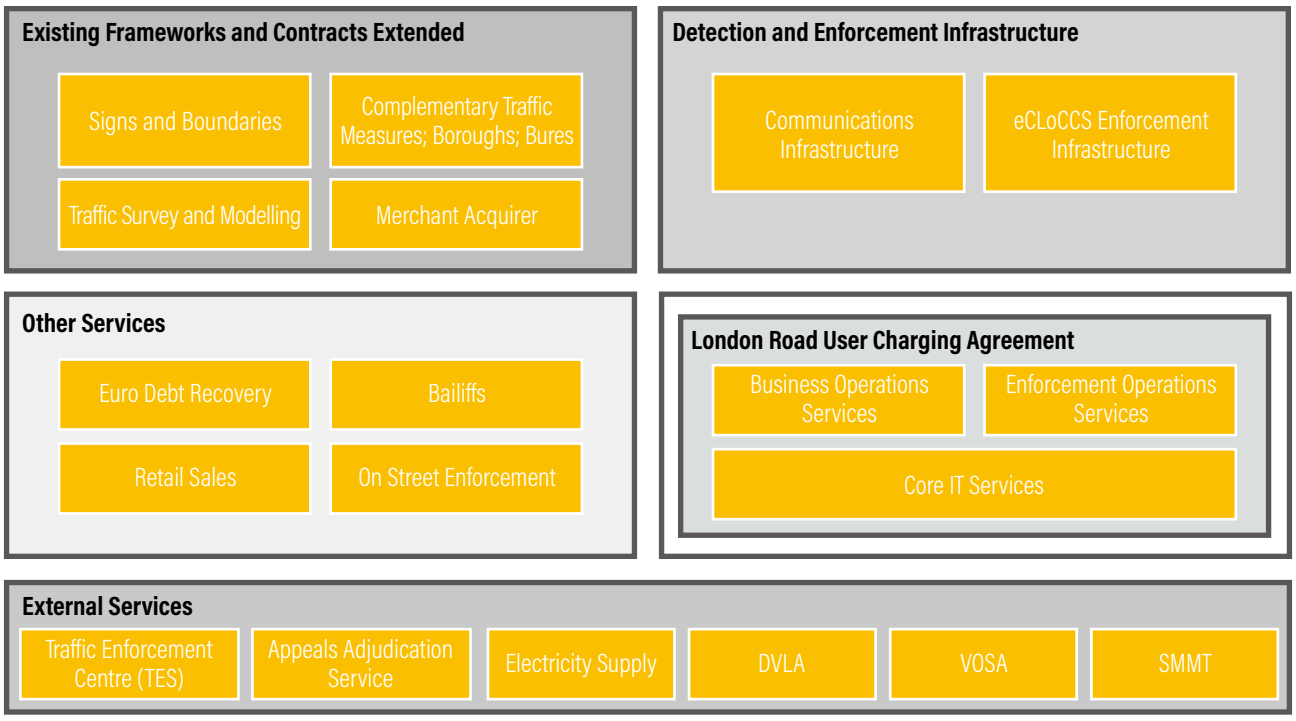
During the preliminary study of the Congestion Charging scheme, it was essential to communicate and negotiate with various stakeholders, and sometimes has to make compromises when balancing the interests of all parties. While choosing among different schemes, attention to details paved the way for London to implement the Congestion Charging policy in a short period of time. In selecting the enforcement technology, the most advanced technology was not automatically favored. In order to ensure successful implementation of the charging system, using field-verified technology was considered a preferable option rather than choosing a more ground breaking technological system.

Technology Placement and Management System

The operational cost of the CC scheme in London is relatively high compared with other cities—initial operational costs once accounted for 20–25 percent of revenue. This figure has now dropped to 17 percent, thanks to the AutoPay system. In Stockholm, the average charge per single vehicle is lower than in London, yet the system operating cost accounts for only 5–10 percent of revenue. There are two reasons for the difference. First, Stockholm's entire system is simple in design, with control points set up at only 18 locations on bridges connecting to the inner city. Second, TfL differs from other cities in the way it manages London's CC scheme. Where Stockholm contracts out all components of its CC system as one package, TfL adopts a modular system and is responsible for each component.

TfL is in charge of a variety of services, including management of the charging system, procurement and management of ANPR cameras, ANPR data analysis and

Figure 3-7 | **TfL's Modular Management System for Traffic Congestion Charging**



Source: Broughton, 2014

application, pursuit of delayed payments, etc. Each of these services is treated as a module and contracted out separately (see Figure 3-7). By contrast, Stockholm has a single contractual arrangement with IBM, which takes the form of a large comprehensive package including all system components of the entire charging system.

A further difference between TfL and urban transport management agencies in other cities is that TfL focuses more on the location and placement of CC technology, and pays more detailed attention to every aspect of system operation. Such specific requirements have made the operational cost higher than in other cities, although modular management keeps contracting of each module competitive and relatively low cost. The modular operation ensures high quality service and manageable operational cost when the charging system remains stable. However, when the main charging system undergoes major upgrade or changes, every module relating to operation also needs to be updated and adjusted, which increases the overall operational costs.

Another cause for the higher operating cost of London's CC system is higher expenditures on labor for enforcement. For example, each penalty charge notice is verified manually for details, such as registration number and make, model, and color of vehicle, before the notice is sent to the vehicle owner.

TfL always tries to find cutting edge technologies for the CC system to ensure that the quality of the operating system is as high as possible. For example, by applying infrared to assist number plate recognition, TfL

If the entire Congestion Charging service is packaged for tendering, as in Stockholm, bidders may treat equipment procurement and maintenance as the key working area, and pay less attention to other components, thus compromising the overall performance of the Congestion Charging system. Managing the system by individual modules ensures that qualified operators are contracted for each component. Although the challenge of coordinating between different modules may present risks to the overall system operation, TfL has kept this risk to a controllable scale by setting specific requirements for each module. Such an arrangement has proved to play an important role in maintaining high system performance.

significantly improved recognition at night and avoided attempts made by drivers to obscure their number plates. These additional efforts have increased operating costs, but have contributed to the successful operation of the system for a decade.

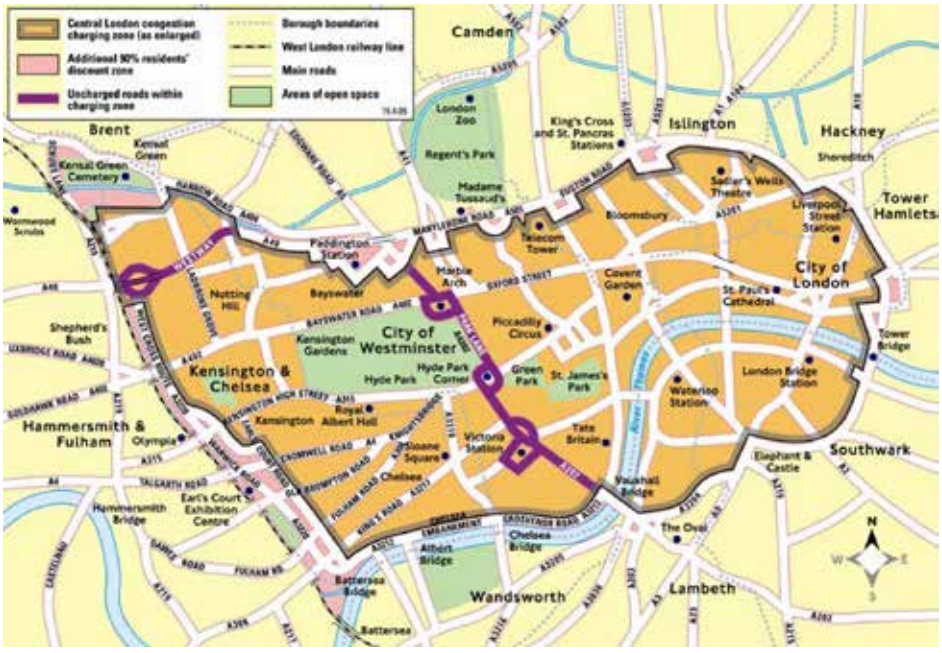
Western Extension and Removal of Extended Area

In November 2003, following the successful introduction of the original zone, Mayor Livingstone suggested that the CC area be extended toward the West. In February 2004, TfL formally started the public consultation procedure on the issue of the Western Extension. In August 2004, the result of public consultation showed that the Western Extension plan was opposed by most residents. However, after Mayor Livingstone was elected for his second term of office, he expressed the view that the consultation process on the Western Extension did not speak for all citizens. Instead, he insisted on the Western Extension proceeding, without taking any further measures to win public favor.

A number of other factors combined to stiffen public opposition to the Western Extension. First, there was a price increase. In July 2005, the CC in central London increased from £5/day (about USD 6.2) to £8/day (about USD 9.9). This action led to objections to the Western Extension from both residents and business owners. Second, as the traffic flow decreased over time in the original zone, TfL had shifted more highway space away from private vehicles toward green sustainable transport modes such as buses and bicycles, and prioritized pedestrians by adjusting traffic signals and installing more crossing facilities. While these actions helped to promote low-carbon transport, they were not appreciated by the public. (In fact, the reduced road capacity for private vehicles led to a slight uptick in congestion, according to a report issued in June 2006, reversing the downward trend following the introduction of CC).[4] Third, the local water company began a program to replace old water pipes in London, which created major large-scale road works and great inconvenience to drivers.

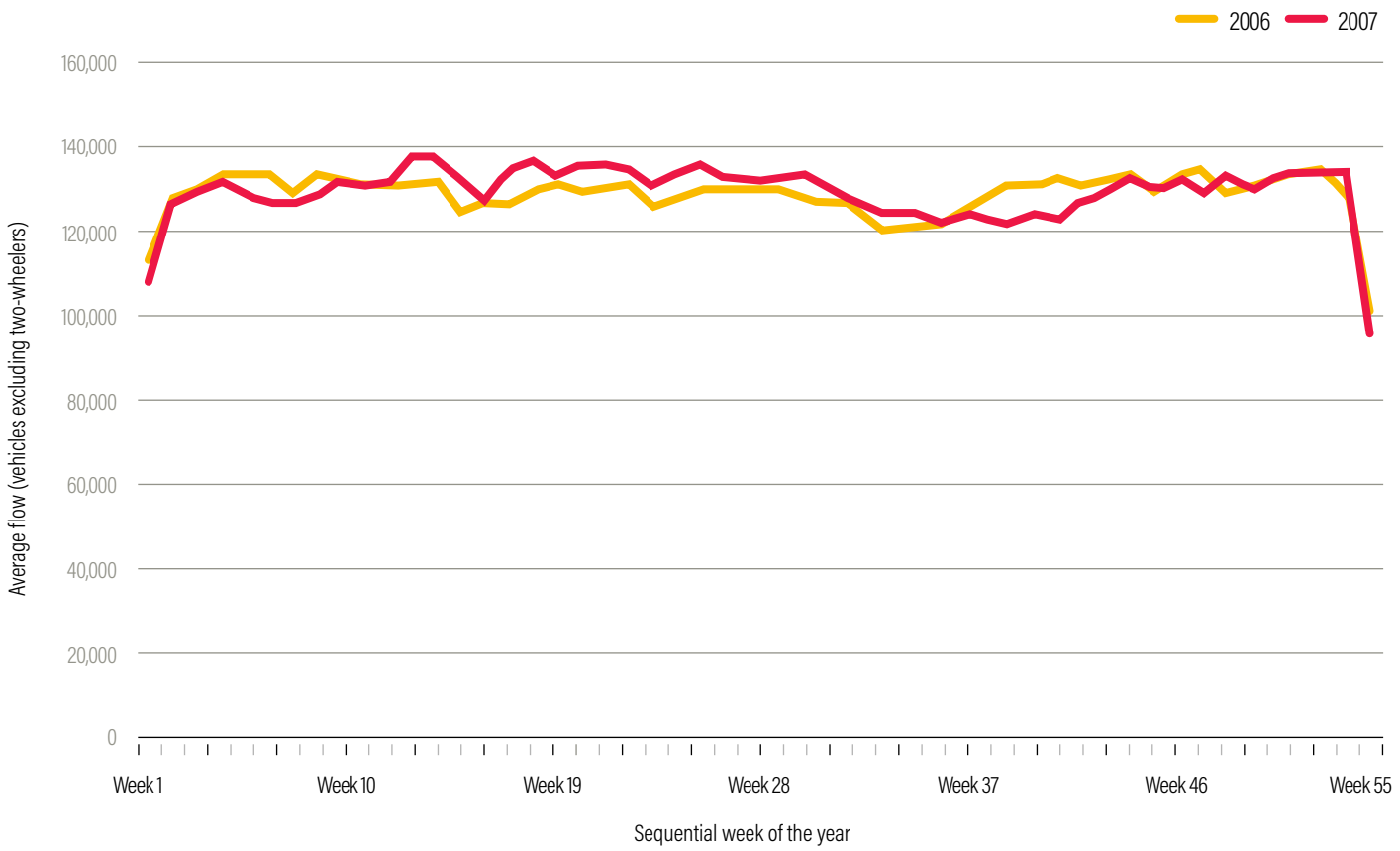
However, public objection to the Western Extension did not shake the determination of Mayor Livingstone and the new scheme went into operation in February 2007, at a cost of £123 million (about USD 152 million). The extended CC area included most of the Royal Borough of Kensington and Chelsea, and the City of Westminster (see Figure 3-8), covering an area of 19 km2. Charging levels and exemptions were implemented at the same levels as in the original zone.

Figure 3-8 | **Original Congestion Charging Zone and Western Extension**



Source: TfL, 2008a: 11

Figure 3-9 | **Average Daily Traffic Flow through Original Congestion Charging Zone**[5]



Source: TfL, 2008a: 42

Following the introduction of the Western Extension, there was a clear improvement in traffic conditions. According to TfL's fifth annual report, the number of vehicles entering the Western Extension zone daily dropped by 14 percent, and the vehicle kilometers traveled in the zone decreased by 10 percent (TfL 2007). Although the traffic volume along the boundaries of the Western Extension zone increased slightly, by 4 percent, the increment was within the scope predicted by TfL and it did not cause any severe traffic problems. Before the opening of the Western Extension zone, it had been predicted that large numbers of residents from the area would enter the original charging zone, causing negative traffic impacts. However, monitoring showed that, although the traffic flow increased slightly at first (5%), the situation normalized over time. Traffic flow from the Western Extension zone into Central London in 2007 was generally consistent with the volume before its implementation in 2006 (see Figure 3-9). Meanwhile, seem from a wider geographical perspective, traffic flow in and out of the Western Extension zone actually reduced, indicating that the Western Extension had favorably influenced regional traffic.

In spite of the apparent success of the Western Extension, it was removed by the newly elected Mayor, Boris Johnson, in 2011. The Western Extension scheme had brought improvements to London's traffic, but it was widely opposed by citizens, because road construction and infrastructure adjustments for the scheme caused inconvenience that overshadowed the benefits, and government authorities did not try to build public support beforehand. The public also displayed a natural aversion to increasing fees. Boris Johnson, as a candidate for the Mayoral office, proposed to remove the Western Extension, which won him support from many residents and stakeholders. The newly elected Mayor Johnson commissioned public consultation and an attitudinal survey on "keeping, removing, or improving" the Western Extension zone, which revealed that 67 percent

Figure 3-10 | **Public Opinion Survey Regarding the Future of the Western Extension Zone**

Source: TfL, 2008b: 9

of citizens and 86 percent of business groups preferred to remove it (see Figure 3-10) (TfL 2008b). The Western Extension zone was abolished by Boris Johnson after it had been operating for just four years.

System Performance

Economic and Social Performance

In order to evaluate the economic and social impacts of CC policy, TfL initiated a comprehensive program to monitor issues including transport operation, community activity, enterprise, public service, business activity, travel, and the environment. After implementation of the CC scheme, TfL also collected data and performed "before and after" analysis. One year after implementation, monitoring and survey data showed the following changes (TfL 2003):

- Private vehicles entering the charging zone decreased by 30 percent during the charging period, and congestion levels dropped by an average of 30 percent. Forty-one percent of residents in the charging zone thought that travel speeds had increased and travel delays had decreased. At the same time, traffic flows along the alternative routes for detoured vehicles remained stable. Overall traffic conditions in the charging zone improved.
- Compared with 2002, buses and coaches entering the central area increased by 20 percent during the charging period in 2003. During morning peak hours (7:00 am–10:00 am), the number of travelers entering the charging zone by bus increased from 77,000 to 106,000. Less congested road conditions, due to CC, led to more reliable ground public transportation; waiting times experienced by bus passengers throughout London decreased by 20 percent.
- Comparison of the economic performance of commercial businesses inside and outside the charging zone shows that CC did not have any negative impact on commercial activities. Meanwhile, because traffic volumes within the CC area decreased, safety and environmental conditions improved. CC is actually estimated to have contributed about £50 million (about USD 61.3 million) to London's economy (Santos and Shaffer 2004).

TfL staff cite the story of some London newspapers that held negative opinions on CC reserving six pages on the first day that CC went into effect in order to report the negative impacts. However, they had nothing to report because traffic was flowing freely from the first day of operation. In fact, it was surprising to see that the scheme achieved such positive results right from the beginning in a country where no road charges had ever been levied. TfL published annual performance monitoring reports on CC for six consecutive years, and finally combined performance analysis with their annual report, due to the steady performance of the charging scheme.

Revenue Allocation and Application

TfL has the authority to manage the allocation of revenues from CC, which are designated solely for improving the transport system. CC revenues are used to maintain various components of the transport system, including charging system operation, public transport upgrades, bridge and road construction, and non-motorized transport system maintenance (e.g., cycle lanes and pedestrian crossings). More than £1 billion (about USD 1.2 billion) has been raised by CC over the past 12 years, and used to improve sustainable modes of transport in London. TfL provides open-access information on all infrastructure and facilities maintained with CC revenues, which is an effective way of showing the public the benefits arising from the policy.

It is worth noting that, in order to meet the increasing demand for public transport, the Mayor and TfL have made great efforts in recent years to improve the public transport system. This was one of the key transport strategies of Mayor Livingstone. While CC provides revenue, the amount raised is far less than the total cost needed to improve London's public transport system. Most of the funding for public transport in the city comes from central government and bus fares. However, the fact the public sees that revenue raised by CC is being used to improve public transport and other sustainable modes of transport has been helpful in improving public perception of the scheme.

Low Emission Zone

As one of the supporting policies of the CC program, TfL implemented a Low Emission Zone (LEZ) in January 2008. The aim was to improve air quality in London by discouraging heavily polluting heavy goods vehicles (HGVs) from entering London, and encouraging motor vehicles in the London area, particularly diesel vehicles, to meet strict air pollution standards through vehicle retrofit or upgrade.

Air Pollution and Counter Measures

Air pollution in London is a recurring problem. In the 1950s, London was notorious for its dense smog, produced mainly by smoke dust and sulfur dioxide (SO_2) from domestic and industrial coal burning. Following the "Great Smog" of 1952, the UK government issued the Clean Air Act in 1956 and set a control zone to regulate smoke dust generated from industrial production. In the later 20th century, transport became one of the main sources of air pollution in London, as it has in other major British cities and urbanized areas in many parts of the world. Since January 1993, by law, all new vehicles sold in Britain have been equipped with catalytic converters to decrease the level of NOx emissions. In 1995, Britain passed the Environment Law, which tackled air pollution issues by creating national-level regulations. In the same year, Britain launched an Air Quality Strategy, stipulating that each city should evaluate air quality on a regular basis. In regions where national standards cannot be reached, local governments must designate air quality management zones and develop corresponding mitigation measures to meet the standards within a specified period. Since the end of 20th century, smog and SO_2 emissions in London have decreased significantly (Conlan et al. 2014).

Implementation of the Low Emission Zone Policy

In order to control pollution and improve air quality, the London Low Emission Zone was initiated in February 2008, covering almost the entire area of Greater London. This is the biggest emission zone of its kind in the world to date. As previously mentioned, implementation of the LEZ has experienced three stages (see Table 3-1)—adopted standards become stricter with each stage, changing from initial Euro III to Euro IV at present. Vehicles covered by the LEZ have been extended from HGVs to light-duty freight vehicles, buses, coaches, vans, and minibuses.

As with the CC policy, the enforcement technology adopted for LEZ is automatic number plate recognition (ANPR) technology. The main purpose of implementing LEZ is to prevent heavily polluting vehicles from entering London, rather than to collect fees or impose penalties.

Table 3-1 | **Emission Standards for London's LEZ**

Vehicle	February 2008	July 2008	January 2012
Lorries (trucks) over 12 tonnes	Euro III		Euro IV
Lorries (3.5–12 tonnes); buses; coaches over 5 tonnes		Euro III	Euro IV
Larger vans; 4x4 light duty vehicles; Pick-ups (1.205–3.5 tonnes)		Euro III	
Motor caravans; ambulances (2.3–3.5 tonnes)		Euro III	
Minibuses (below 5 tonnes)			Euro III

Compared to the CC zone, the camera coverage of the LEZ is much less concentrated, with only 350 cameras in the 1,580 square kilometers of the LEZ. TfL encourage vehicles to meet LEZ standards by the following methods:

- converting the engine to run on pure gasoline with a spark ignition;
- installing a certified exhaust filter; and
- purchasing only those second-hand or new vehicle that comply with exhaust regulations.

Implementation Outcomes of the LEZ Policy

Introducing the LEZ policy in London has promoted vehicle retrofit. By 2008, 31.9 percent of vehicles in London did not meet the Euro III emission standard, compared to 47.4 percent before implementation, meaning that the LEZ policy helped to phase out additional 20 percent of outdated vehicles (Ellison et al. 2013). The rate at which vehicles exited the fleet fell back to normal levels after 2008 (Ellison et al. 2012), which meant that authorities had to continuously raise emissions standards to maintain the desired policy outcome. By June 2013, 95 percent of vehicles entering the LEZ met the emissions standards (TfL 2013c). London's air quality improved significantly, even as the number of freight vehicles entering the zone continued to increase (Ellison et al. 2012). Studies show that the LEZ policy has had clear impacts on PM emissions, but relatively little effect on NOx emissions. Also, while PM concentration within the zone has been reduced by 2.5–3.1 percent, the reduction outside the zone boundaries is 1 percent (Ellison et al. 2013).

Relation to Congestion Charging Policy

CC and LEZ policies have both contributed to relieving traffic pressure and decreasing air pollution in London. As the goals of these two policies are different, the relationship between them is not straightforward (see Box 7). However, the GLA and TfL have made incremental moves to integrate LEZ and CC. Initially, alternative-fuel vehicles, such as hybrid and electric vehicles, were exempt from paying fees when entering the CC zone. In January 2011, TfL introduced the greener vehicle discount, which stipulated that all vehicles with CO_2 emissions less than 100 g/km were eligible to enter the CC zone free of charge. At the beginning of 2013, Mayor Johnson proposed the establishment of an ultra-low emission zone (the proposed area will overlap with most of the current CC zone; this initiative is expected be

The objectives of CC and LEZ are different: the first is to relieve congestion and improve traffic flow, while the second is to promote vehicle upgrades, reducing emissions, and improve air quality. CC is a road use fee, while the LEZ is designed to improve compliance through penalties. Thanks to European emissions standards, the entire vehicle fleet would eventually meet emissions standards due to the natural cycle of vehicle replacement, even if LEZ were not in place. However, the implementation of London's LEZ accelerates the vehicle upgrade and replacement process. It is particularly noteworthy that London integrated emissions reduction and vehicle upgrade into the CC scheme: clean vehicles both avoid LEZ penalties and earn reduced or free entry into the CC zone, which further encourages cleaner vehicle ownership by London's population and promotes improved air quality in the city.

launched in September 2020) to promote vehicle retrofit and upgrade in order to reduce air pollution. Consultation on the ultra-low emission zone is due to commence later in 2014. As a precursor, in July 2013, TfL implemented the ultra-low emission vehicle discount scheme, which replaced the previous greener vehicle discount scheme. This measure allows pure electric vehicles or vehicles with CO2 emission less than 75 g/km and meeting Euro V standards to enter the CC zone free of charge. Vehicle retrofit has been greatly accelerated by implementation of these measures.

London Best Practices Summary

The release of the Smeed Report in 1964 marked the beginning of research on road charging in London. By the time of actual implementation of the CC scheme in 2003 and LEZ in 2008, Londoners had experienced a long and at times painful learning process. China and other countries can observe the following best practices, which apply from the policy preparation stage to implementation:

- **Legal safeguard from national government and political commitment from local leaders**

Prescient politicians vigorously drove the congestion charge, which contributed greatly to the success of the policy. The national government, through legislation, granted the GLA and the Mayor the authority to develop and implement the CC policy even before it was put on the city's agenda. A preliminary study led by the national government investigated the details of CC schemes, which provided sufficient advance preparation. Another key factor for successful implementation was Mayor Livingstone's strong confidence in the policy, and his resolution to fulfill campaign promises. Decision-makers must have strong political will and determination during the early stages of policy implementation, if they are to prevail in debate with stakeholders, public confrontation, and challenges from the media. The CC policy has proved to be a fruitful measure, which is largely due to the Mayor's and other decision-making groups' hard work in fulfilling their political promises. It can be concluded that decision-makers' support and confidence is crucial to smooth policy implementation.

- **Clear goals for policy and thorough understanding of details**

Two goals were set for the CC policy for London—improving traffic flow by alleviating congestion, and raising funds for transport reinvestment. The goals were kept simple and clear, to guide policy development, and to help the public quickly understand policy outcomes and expected benefits. TfL made great efforts to refine policy details at the development stage in order to avoid both failure to meet desired objectives and creation of unintended consequences. Multiple scenarios were carefully studied, and close attention was paid to the interests of people who were likely to be most directly affected.

- **Active public consultation and transparent communication**

The GLA and TfL conducted extensive public consultation and communication to understand and shape public opinion on the CC policy. Discussions were held with different stakeholders in order to balance different interests, while the primary purpose of public consultation and communication was to share policy information. Information transparency was an important principle throughout the process of discussion and consultation, to allow informed feedback from the public on policy details, and eventually gain popular support.

- **Use of complementary transport measures**

London government authorities introduced a package of complementary transport measures, including improving public transport system, providing detour routes, improving the traffic signaling system, and securing parking for near-boundary residents. All these measures contributed to greater efficiency of the CC policy. In an area-based scheme, particular attention needs to be paid to residents and businesses located immediately outside the zone boundaries, because these are the parties who are most likely to be detrimentally affected. A comprehensive program of complementary measures including parking restrictions and traffic management schemes is necessary to mitigate the negative effects that can occur in such areas.

- **Efficient management and continuous refinement**

Effective management also contributed to successful operation of the CC policy. The modular management system adopted by TfL permits optimal operation of each system component. TfL sets specific requirements for each component based on evaluation of the general picture, to overcome poor coordination among components, which is an inherent risk of modular management. During policy implementation, TfL monitors component operation and management, and makes refinements and adjustments

as necessary to improve overall system performance. Key adjustment elements include boundaries of the charging area, charging methods, types of vehicle eligible for exemption; and system updates.

- **Integration of CC and LEZ policies for more effective environmental protection**

The purpose of the LEZ policy in London is not to collect fees, but to promote vehicle retrofit and replacement to meet higher emissions standards. The LEZ policy has played an important role in vehicle retrofit, emissions reduction, and air quality improvement when acting alone. London authorities chose to integrate LEZ with CC as a package, in order to further promote low-emission and alternative-energy vehicles by offering such vehicles exemption or discount from the congestion charge. By integrating CC and LEZ, and promoting vehicle retrofit through an economic instrument, the city has succeeded in facilitating air quality improvement.

SINGAPORE CASE STUDY

Singapore Overview

Singapore (the Republic of Singapore) is a city-state located at the southern tip of the Malay Peninsula, in Southeast Asia. Singapore has a land area of 719.1 square kilometers, with the central business district (CBD) area covering close to 100 square kilometers (km2), accounting for about 14 percent of the whole island. The population of Singapore is 5,469,700, with a GDP per capita of SGD 71,318 (about USD49,290.2) (Singapore Department of Statistics 2015). In 2014, the number of vehicles in Singapore was 972,037; approximately 44 percent of households own cars (Tan 2015).

Singapore has experienced rapid economic and population growth since it was established. The vehicle population has increased rapidly as well. The number of vehicles doubled during the 1960s alone, and the number of motorcycles tripled. By contrast, the public transport system fell behind (Dhakal 2002). In a city-state with limited land, congestion was the consequence, causing severe issues for Singapore, especially in the CBD. The congestion problem reached a peak in 1975, when the average speed during peak hours dropped to 19 km/hour (Dhakal 2002). Another alarming circumstance at that time was that the number of private cars continued to climb along with the population's prosperity. Traffic conditions in the CBD would surely have worsened without effective congestion management. Singapore launched a package of TDM measures, including the Area Licensing Scheme (ALS), to combat congestion and related issues.

In their own words...

It is not possible to build ever more roads to cater to private transport due to competing needs for our scarce land. Roads already account for 12 percent of our land area today, only a little under housing, which takes up 14 percent.

—Land Transport Authority 2013a: p4

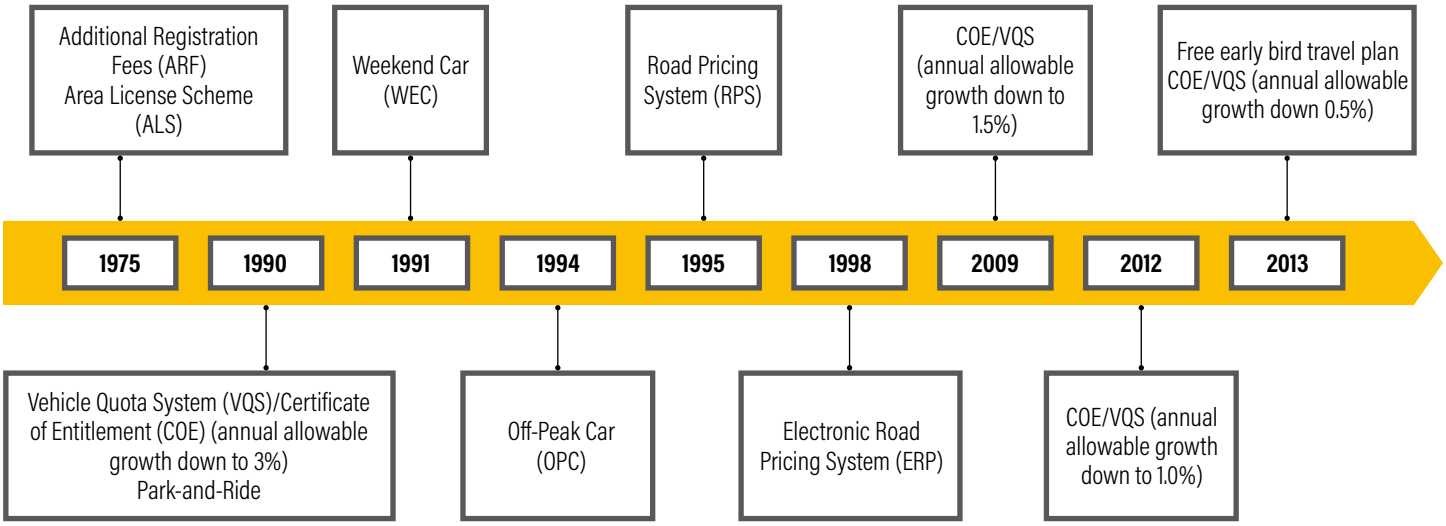
Road conditions in Singapore have since improved significantly. During the morning and evening peak hours (8:00 am to 9:00 am, 6:00 pm to 7:00 pm), the average vehicle speed on the expressway is 64.1 km/h, and 28.9 km/h on roads in the CBD and on arterial roads (Land Transport Authority 2015a). The average annual distance traveled by private cars can reach 17,500 km (LTA 2015b). In 2014, daily ridership was 3,750,000 for bus, 2,760,000 for the MRT, 140,000 for the LRT, and 1,020,000 for taxi (LTA 2015c).

Singapore is now a city with a highly developed public transport system, according to the mode share. Public transport takes the dominant share of the city's total trips, reaching 66 percent during peak hours in 2014 (Ministry of Transport 2014). According to the Land Transport Master Plan 2013, the Land Transport Authority (LTA) plans to increase the share of public transport during peak hours to 75 percent by 2030 (LTA 2013a).

Policy Background

The well-managed traffic system in Singapore has contributed to the prosperity of the urban area. Singapore imposes strict restrictions on urban transport and vehicle ownership. In 1975, Singapore began to introduce TDM policies to mitigate traffic congestion through controlling the ownership and usage of vehicles (see Figure 4-1). These TDM measures have promoted efficient traffic flow, boosted economic vitality, and preserved the livability of the city.

Figure 4-1 | **Development History of TDM Policies in Singapore**



From 1975 onward, Singapore has implemented a series of TDM policies such as additional registration fees (ARF), area licensing scheme (ALS), vehicle quota system (VQS), certificate of entitlement (COE), park-and-ride, weekend car (WEC), off-peak car (OPC), road pricing system (RPS), electronic road pricing (ERP), and free pre-peak travel on mass rapid transport (MRT). Most of the policies are intended to raise the cost of vehicle ownership and usage, so to curb travel demand through economic instruments, especially through ARF, VQS/COE, and ERP. In addition, there are complementary measures to promote green travel modes among the public.

1975: ARF

ARF, which was previously introduced by the colonial government in the late 1950s, is part of the tax imposed on newly registered vehicles. In the 1970s, this type of taxation was steadily increased and served as the principal measure to control vehicle ownership. In 1975, when the ARF increased to 100 percent of the market value of vehicle, the government introduced the preferential additional registration fee (PARF) as a supplement to offset the possible adverse effects that the high registration fee could have on replacement of the vehicles. In the 1980s, ARF became the primary source of government revenue from road transportation, which usually accounted for one-third of this sector revenue.

1975: ALS

In 1975, Singapore introduced ALS, which was the first successful CC strategy in the world. Singapore first introduced manual CC when government authorities became aware of the heavy traffic flow generated around the CBD area during peak hours, and wished to avoid the negative effects of urbanization, which had become obvious in many other metropolitan areas by that time. Twenty-seven entry points were set up in the 7.25 square kilometers of the restriction zone (RZ) (see Figure 4-2). During peak hours, vehicles had to purchase a license to enter the area, unless they had exemptions as emergency vehicles and public transport.[6] In 1989, the charging policy was expanded to cars, taxis, motorcycles, freight trucks, and buses; evening peak hours were also included in the charging period. The fee was SGD 1 (about USD 0.7) for motorcycles, SGD 3 (about USD 2.1) for private cars, and SGD 6 (about USD 4.1) for buses. The government also issued monthly permits with a price of SGD 60 (about USD 41.4) per permit. The charging period was expanded to the whole day in 1994 (Wang and Zhao 2008).

1990: VQS

Under the vehicle quota system, car buyers purchase a certificate of entitlement (COE) through public auction. The number of COEs (the quota) is set by the government and a certificate is valid for only 10 years. The quota of the COE has been tightened by Singapore's government since 1990,

Figure 4-2 | **Control Area of Area Licensing Scheme**

Source: Yap, 2005

and the annual allowable growth rate has been reduced from 3 percent in 1990 to only 0.5 percent in 2013. The rate was further restricted to 0.25 percent in February 2015.

1990: Park-and-Ride

In 1990, the Singapore government began to implement a park-and-ride plan, to reduce the impact of ALS on commuters. The government established 13 parking lots around the CBD restricted area; drivers can park their cars there at a very low fixed rate, and then ride the public bus to the CBD.

1991: WEC and 1994: OPC

WEC program began implementation in 1991, and was oriented toward people who hope to own a car but use it mainly in the evenings and at weekends. WEC cars have special license plates, which allow them to use the road freely from 7:00 pm to 7:00 am the next day on weekdays, after 3:00 pm on Saturdays and the five special holidays,[7] all day on Sundays, and all day on public holidays. OPC is the updated version of WEC with some slight adjustments to taxation incentive policies. The WEC policy was expanded to cover whole weekends and all public holidays in 2010.

1995: RPS

In 1995, Singapore introduced the RPS, similar to ALS, for its three arterial roads. The charging time was from 7:30 am to 9:30 am on weekdays, and it was also operated manually like the ALS system. Drivers had to purchase a special ticket to enter the three arterial roads during this period of time (Luo 2009). However, due to continuous area enlargement over 20 years, the two manual pricing systems (ALS and RPS) became overburdened. In total, 70 staff were employed to sell tickets, and 78 staff to supervise and provide enforcement. This level of manpower was still not enough to deal with the demand in the systems (Menon and Guttikunda 2010).

1998: ERP

The ERP system was put into operation in 1998; it applied to all the areas covered by the previous ALS. The system replaced ALS and RPS and became the modernized method for traffic congestion management in Singapore. All the vehicles passing the ERP gantry (the toll gate) must be equipped with an in-vehicle unit (IU), in which is inserted a multi-functional smart cash card. When the vehicle passes the ERP gantry during designated charging times, the appropriate ERP charge is deducted from the smart card automatically without the need for the vehicle to slow down.

2013: Free Pre-Peak Travel on MRT

The free pre-peak travel plan for MRT was introduced in June 2013, and is designed to end on June 30, 2017 (LTA 2016c). If commuters end their journey at one of the 18 designated MRT stations before 7:45 am, they will be able to travel free of charge. If they exit these stations between

Table 4-1 | **History of Singapore's Congestion Charging System**

Year	Events
1975	ALS first implemented in CBD
1984	Charging area expanded
1985	Singapore began to draw on electronic road charging experience of Hong Kong
1989	ALS expanded to evening peak hours
July 1989	Cabinet passed resolutions to begin ERP within five years
September 1989	Government called for tender of ERP system
February to April 1990	Study of electronic road charging systems of Dallas, New Orleans, Washington D.C., Paris, Florence, Trondheim, and Oslo
May 1991	Government increased requirements of ERP system and started re-tender of ERP system
September 1991	Government decided to use Smart Card system, replacing "passive charging mode" with "active charging mode"
1994	Introduction of two types of ALS certificate: whole-day access and partial access
June 1995	Manual pricing in the East Coast Parkway (ECP) road sections began
October 1995	Confirmed winning ERP tender
May 1997	Starting manual charging on Pan Island Expressway (PIE), and Central Expressway (CTE)
July 1997	Road taxation structure adjusted to make it more suitable for the ERP system
September 1997 to July 1998	Program of in-vehicle unit installation, with objective of completing installation in ten months Large-scale installation of gantries began
September 1998	ERP system began operation with 33 gantries in all
November 1998	Charging prices adjusted for the first time
April 1999	ERP congestion charges waived on Saturdays
June 1999	Penalty for overdue payment reduced
August 2001	Technology on gantries improved to prevent interference with Bluetooth signals
February 2003	Billing rules of the five-minute transition system came into effect
September 2003	Billing rules for foreign vehicles entering Singapore central area established
2005	Congestion charges reintroduced on Saturdays in some parts of the business district
July 2008	Benchmark for ideal speed promoted Number of gantries increased to 66 Price spread increased from SGD 0.5 to SGD 1 (about USD 0.3 to USD 0.7); Starting rate for new gantries raising from SGD 1 (about USD 0.7) to SGD 2 (about USD 1.4); Charges on Saturdays for certain areas
2009	Credit card payment mechanism introduced
2012-2013	Second generation of ERP based on GPS under full test
May 2015	Payment without cash card available
February 2016	Confirmation of winning tender for second generation of ERP; System to be updated and running in 2020

7:45 am and 8:00 am they receive a fare discount. The plan is targeted at those who travel earlier than peak periods because they live in more remote areas. To support this policy, Singapore MRT has increased its capacity in normal hours, and adjusted the working schedule of staff to meet the demands of every commuter to the greatest extent possible.

2014: Flexible Travel Plan Subsidy

A subsidy for the flexible travel plan came into effect on November 1, 2014. The subsidy is funded by the Singapore government. This measure aims to encourage enterprises to launch a flexible working schedule, so that employees can use public transport, ride bicycles, or walk to work during off-peak hours. Under the program, enterprises can apply up to SGD 80,000 (about USD 55,239.1) in subsidies every year toward improving or rebuilding facilities. If enterprises undertake some other activities to encourage employees to change their travel behaviors, they also can be granted up to SGD 80,000 (about USD 55,239.1) in subsidies every year. Meanwhile, the Singapore government also supports a "flexible trip planning reward" plan, that is, if employees take MRT between 6:15 am and 7:15 am or between 8:45 am and 9:45 am, they are eligible for bonuses.

Compared to other cities, Singapore road traffic is better organized and less congested, although the city has a high population density. This can perhaps be attributed to Singapore's great efforts on traffic congestion control, especially the road congestion charging policy. The CC system has undergone several adjustments, as shown in Table 4-1.

Public Communication

While implementing CC and other TDM policies, the Singapore government places great emphasis on public communication and education. Effective communication can inform the public about the purpose of the policy. The most important function is to educate the public about the social benefits of the policy and improve public understanding and acceptance of the policy. During implementation, the government provides the public with planning options in order to increase public acceptance of new policies. In addition, the Singapore government also uses a variety of media to educate and assist the public in selecting more environment-friendly and comfortable trip modes under existing policies.

Outreach to the Public

Singapore policy promotion has moved from a one-way to a two-way communication mode, which emphasizes interaction and public participation. In order to improve the public awareness of the urban traffic issues in a more comprehensive way, the LTA established a "Land Transport Authority Gallery" (LTA gallery) in 2008. The LTA gallery, which is an interactive media wall, shows the past, present, and future of Singapore's transport development. It also improves the public perception of the government's policy efforts on urban transport development. The LTA also circulates a large number of well-designed brochures to the public (see Figure 4-3) to promote its ideas and policies in a lively way.

Figure 4-3 | **LTA Gallery and Brochures**

The Singapore government tries to provide traffic information to the public through different channels. The LTA has established community partner teams to serve as contact points for the authority, and support public participation and social work. Responsibilities of community partner teams include: collecting residents' feedback and questions relating to transport, evaluating transport conditions within the community and proposing improvement suggestions; and helping ground-level organizations and residents get to know policies and measurements that affect their lives. The Government, with its community partners, provides and explains planned policy details (as well as the alternative options) to the public before policy is actually implemented in order to reduce unnecessary public confusion and gain public support towards the policy implementation.

The LTA set up a billboard in front of the ERP gantry to count down the days before the ERP scheme officially began. LTA also informs the public, via various channels, before the charging rate changes, despite the inconvenience this action can cause to decision-makers. When speaking about the policy, the LTA always uses the term "congestion charging" rather than "road pricing." It delivers accurate information to the public, making clear that the policy is a non-profit strategy intended to alleviate congestion, not to collect fees from road users. The ERP is a fair and equitable system—vehicles of government officials, and even the president and the prime minister, must pay the charging fee without any discount. In these ways, the government has won the trust and support of the public, and avoided some potential controversies.

The Singapore government communicates with the public about the details of the ERP system in innovative and transparent ways throughout the whole process, from preparation, to implementation, operation, and management, which results in a high degree of public acceptance of the policy and helps to build a good image of the government as well. During public policy development, the government tries to involve a wide range of public participation, expression, and dissemination mechanisms. The government is open to opinions expressed by all interest groups and these opinions are fully absorbed. The Singapore government also incorporates public participation into the entire process of public policy formulation, rather than adopting a top-down approach. The government stresses publicity and social communication for every strategy and policy stage, in order to raise public acceptance and avoid controversy.

Communication with Stakeholders

In addition to promoting public participation, the Singapore government also pays attention to the involvement of other stakeholders, such as public transport and taxi operators, bus and taxi drivers, public transport users, vehicle owners, urban planners, commercial companies, community organizations, and so on. All stakeholders play significant roles in the human-centered transport system. The Singapore government gives full consideration to relevant interested parties, collects opinions on the implementation of policies, and encourages people to participate in the development of the public transport system so as to get their support in the implementation of policies. The highly efficient urban transport system of Singapore is largely due to well-coordinated work of the government, stakeholders, and the public.

Some stakeholders (including taxi drivers, commercial tenants, and low-income families) also expressed their concerns about the ERP system.

- Taxi drivers believe the policy is unfair to them, because they usually enter the urban centers several times a day. LTA responds that the congestion charge is included in the taxi service fee and will be paid by the customers. In practice, the ERP system effectively prevents empty taxis from entering and driving around the urban centers.

- Commercial tenants think that the ERP system may restrict travel within the zone, thus indirectly impacting business within the restricted zone and leading to businesses moving out and relocating around the restricted CBD area. LTA (and academia) responds that the CC improves traffic efficiency and the accessibility of the CBD area, thus promoting business within the central area.

- The fairness of the CC policy is another controversial point because it ignores the income level of vehicle owners. While the charge may be insignificant to the rich, it can create severe stress for low-income drivers who have to enter the CBD frequently. Some citizens propose making the ERP fairer by using the ERP revenues for anti-poverty measures or providing subsidies to low-income groups for their public transport expenses. LTA responds that all the ERP revenue shall go into the central government and shall not be used for specific groups. In addition,

the government also provides other alternatives. For example, the metro is free of charge in the early mornings.

These opposing views are always delivered to the government by letter. The government then responds to these questions through media or spokespersons. In addition, the government also endeavors to improve the ERP system by taking these concerns into consideration in order to create a more efficient and fairer system.

System Implementation

In 1998, after 10 years of research and preparation, the ERP system officially replaced ALS as the system for managing traffic congestion in Singapore. The ERP system is the first large-scale and fully automated urban congestion charging system in the world. The system utilizes electronic gantries installed on roads to charge vehicles entering the congestion area.

The ERP has a very clear purpose, which is to use pricing to relieve congestion and improve vehicle speeds. All vehicles are treated equally without discrimination or favoritism; all vehicles using the road during peak hours must follow the "pay-as-you-use" principle. There are no exceptions for buses, new energy vehicles, embassy vehicles, or even the Head of State.[8] The only exceptions are emergency vehicles such as police cars, fire trucks, and ambulances. Such a clear purpose and fairness establish the credibility of the government to a certain extent, and avoid criticisms of unfairness from the public.

The following sections explain the operational features of the ERP system, including charging and pricing, enforcement and improvement, costs and benefits, interaction with other policies, and controversy and solution.

Charging and Pricing

Charging

The ERP system is based on a very important charging principle: "pay-as-you-use." Singapore installs an electronic charging gantry at every entrance to the specified area, and each vehicle is equipped with an in-vehicle unit (IU) that is attached to the windshield and powered by an in-vehicle power source (see Figure 4-4) (Menon and Guttikunda 2010). When the vehicle passes through the gantry, the system will deduct the appropriate charge automatically from the smart cash card in the IU. Unlike ALS, ERP does not offer a monthly pass. Usually, there is more than one gantry on the way to the CBD. Therefore, the greater the road use, the more gantries are passed, and the higher the total charge deducted from the smart cash card. The fee structure is based on the vehicle type and time period. The fees for private cars and taxis are twice those for motorcycles, HGVs and small buses pay three times as much as motorcycles, and very heavy goods vehicles and big buses pay four times as much. As of May 2016, the charging limit for cars entering a single gantry is SGD 6 (about USD 4.1) (LTA 2016a), and SGD 12 (about USD 8.3) for super HGVs (LTA 2016b). In this way the ERP system is considered fair to all because the charging bands are based on road usage (Luo 2009).

Pricing

In the ERP system, the charging rate of each gantry is calculated by comparing the ideal speed with the actual average traffic speed on the specific road during

Figure 4-4 | **Electronic Charging Gantry (left) and IU (right)**

school breaks. The rates are reviewed and adjusted (if necessary) quarterly by the LTA. Generally speaking, the ideal speed for the local road is 20–30 km/hour, and 45-65 km/hour for the expressway. The only reason for adjusting the charging rate is to achieve the ideal vehicle travel speed. If the actual speed for more than 85 percent of the three-month period is lower than the ideal speed, then the rate will be raised. Conversely, if the actual speed for more than 85 percent of the three-month period is higher than the ideal speed, the rate will be reduced (Menon and Guttikunda 2010). Singapore LTA presents this pricing principle openly to the public, and announces the new rates prior to the adjustments.

It should be noted that, in order to realize the ideal speed, the Singapore government also intentionally distributes traffic flow by adjusting charging rates in certain specific road sections. By doing so it can balance the traffic flow among different roads and improve efficiency throughout the entire network. For example, the CTE expressway that connects the northern and southern sections of the city is among the high-charging zones, because the traffic flow is heavy. Another two major expressways, ECP and PIE, connect Singapore's eastern logistics center with the western industrial zone. The ECP has the heavier traffic flow because it passes through the CBD area. In order to reduce the traffic passing through the CBD area during peak hours on the ECP, the charging rate set for ECP is much higher than that for PIE. By setting this rate difference, the government intentionally encourages some drivers to use the PIE instead of the ECP during the peak hours. However, as traffic on CTE from PIE increases, authorities raise the charging rate on PIE while lowering the rate on ECP to curb traffic on CTE.

Charging Hours

The ERP charging period for the CBD area is from 8:00 am to 10:00 am, and 12:00 pm to 8:00 pm, Monday to Friday; charging hours for Saturdays are between 12:30 pm and 8:00 pm. On New Year's eve, Lunar New Year, Christmas, Hari Raya Aidilfitri, and Deepavali, the charging period ends earlier at 1:00 pm. However, in the non-CBD areas, the charging time is much shorter—from 7:30 am to 9:30 am. Expressways with heavy traffic flow, such as CTE, will be under charging zones during evening peak hours, regardless of their location. Charging rates are adjusted for different hours. LTA adjusts the rate every half hour based on traffic flow, in order to redirect traffic from busy road sections.[9]

LTA improved the system in 2003 by establishing an interim rate for the five minutes before and after the exact time when the rate changes. The objective was to make the transition through charging prices more graduated and smooth, and discourage drivers from suddenly accelerating or decelerating in order to avoid charges.[10]

Charging Area

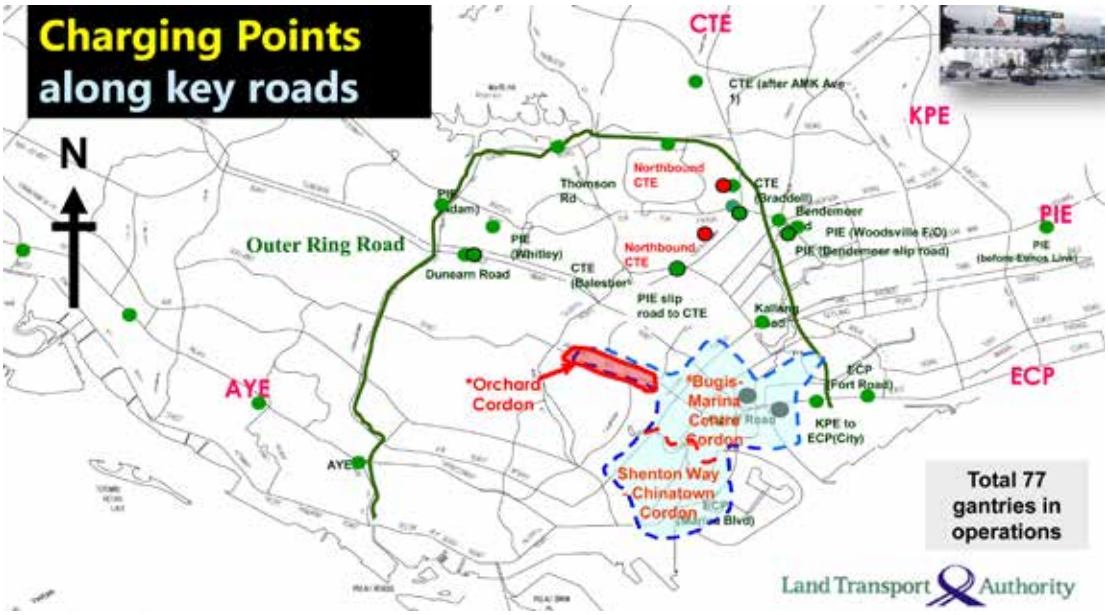
Unlike ALS, in addition to controlling traffic flow entering the CBD area during peak hours, ERP also controls and disperses traffic for the entire urban area because it is able to differentiate the charging rate at different charging locations. To balance traffic flow, the ERP gantries in Singapore are located mainly along the ring road in the central area and other parts of expressways. Early on, the ERP charging area included only the area surrounding the CBDs, which is called the first charging ring road. Later, due to the successful implementation of the system and further demands for relieving traffic pressure, Singapore constructed the second ring road around the first ring road. In 2016, there were 77 charging gantries in all of Singapore (see Figure 4-5).

Disclosure of Information

As mentioned, the charging rate is calculated based on vehicle types, times, and the locations of gantries. The pricing structure is very complex and difficult to remember. In order to convey clear charging information to the public, LTA and its affiliated agencies provide online information on charging rate for different time periods, locations, and vehicle types every three months. In addition, LTA has launched Traffic Smart, a digital version of the ERP system[11] (Figure 4-6). On this digital map, people can see the locations of the gantries with different rates for different times and vehicle types.

The ERP system in Singapore integrates two forms of charging: charging by city area (CBD and Orchard Road Business Area), and charging by road section (city expressways), reflecting the flexibility that is possible when implementing a CC scheme. In addition, through the use of variable pricing, the ERP system can encourage drivers to choose one road in preference to another, and achieve the redistribution of traffic flow, which greatly contributes to the dynamic balancing of demand and supply for road use.

Figure 4-5 | **Charging Area of Singapore's ERP system**



Source: LTA, 2015f

Figure 4-6 | **Digital Map of ERP in Singapore: Traffic Smart**

Source: LTA, 2016d

Enforcement and Improvement

During the 16 years of operation of the ERP system, various violations have occurred. LTA and the Singapore Attorney General's Chambers (AGC) work closely to ensure strict enforcement of the CC scheme.

There have been numerous attempts to avoid being charged, exploiting either policy formulation or technical weakness. For example, some motorcycle drivers turn off the engine intentionally (the IU will also be shut down)[12] and push the motorcycle through the gantry. Since the gantry cannot detect the IU, the motorcyclist is able to avoid being charged by the ERP. Some vehicle drivers reduce speed or even stop before passing the gantry, waiting for the rate to reduce or for the charging period to end. These action are not only illegal, they also create road safety issues. The Singapore government has considered removing the real-time charging information board (the LCD board) from the gantry, in order to discourage such behavior. However, considering the principle of "absolute disclosure and transparent information" to the public, this proposal was withdrawn by the government.

To strengthen the implementation of the CC policy, the government strengthened reinforcement and adjusted fine details of the policy. Manual supervision was upgraded by deploying a stronger police presence at specific charging points and during the periods when problems are most likely to occur. Another action was the improvement in 2003, noted above, of adding an interim charging rate five minutes before and after the rate shift. The purpose is to stabilize the pricing line, and discourage drivers from changing car speed to avoid charging.

The ERP system also strictly enforces the cash card payment system. When a vehicle is passing through the gantry, the system will automatically deduct money from the cash card installed in the IU. If no cash card is installed, or if the card balance is insufficient, the camera mounted on the gantry will automatically take a photo of the vehicle's license plate. The vehicle owner will receive an infringement notice within several days, and must pay the congestion charge and administrative fee of SGD 10 (about USD 6.9) within two weeks. The vehicle owner is free to select from various payment methods offered. However, the fee will be reduced to SGD 8 (about USD 5.5), if the owner chooses automatic payment paths, which include the LTA official online payment service, self-service facilities at post offices, the AXS self-service terminals,[13] ATMs, and Vpost.[14]

If the vehicle owner fails to complete payment within two weeks, a new notice will be issued, imposing a penalty of SGD 70 (about USD 48.3) that must be paid within 28 days. If the new notice is ignored, LTA will hand the case over to the court for legal action. The court verdict may include a penalty as high as SGD 1,000 (about USD 690.1), and imprisonment of one month in severe cases of violation.

The successful implementation of Singapore's ERP system can be attributed in part to strict law enforcement. Organized action against delays in payment, ranging from management by traffic regulations to court interventions, is evidence of a well-designed enforcement system that supports the operation of the ERP system. The ERP system is also user-friendly, making provision for convenient methods of payment.

Costs and Benefits

The Singapore government has invested SGD 200 million (about USD 138 million) in setting up the ERP system,[15] including the provision of free IUs for 670,000 vehicles. When first implemented, the annual income was SGD 80 million (about USD 55.2 million), while the operating cost was SGD 16 million (about USD 55.2 million). It took only three years for Singapore to recoup the investment cost of the ERP system (Luo 2009). According to the latest statistics of LTA, the current ERP annual income can be up to SGD 165 million (about USD 113.9 million), while the cost of system operation and maintenance is about SGD 21.6 million (about USD 14.9 million),[16] equivalent to 13 percent of total income.[17]

Importantly, the Singapore government has repeatedly stated that the ERP is a "dedicated congestion charging system" (improving the ideal speed is the only purpose) not a "road toll." Return on investment is not the primary concern; congestion alleviation is the purpose of this policy. It has the following features:

- Singapore government used a bidding process to hire private companies to develop the ERP system; all investment costs were borne by the government (Luo 2009). LTA is in charge of ERP system management

and operation. Prior to the implementation of ERP, the government provided free installation of IUs in 670,000 vehicles. All vehicles must be sent for installation of an IU as part of the requirements for receiving a license plate.

- The income of the ERP system is not dedicated to the road transport sector; instead, it is transferred to the national government as part of the nation's fiscal revenue. Although public transport in Singapore is in deficit, the ERP income is not used for this specific sector—investment in public transport is financed from general revenues.

- The government lowered the additional registration fees (ARF) to offset charges imposed on vehicle owners by the ERP system, to achieve a tax neutral balance between policy outcomes and overall taxation (see section 4.4.4).

Complementary Policies

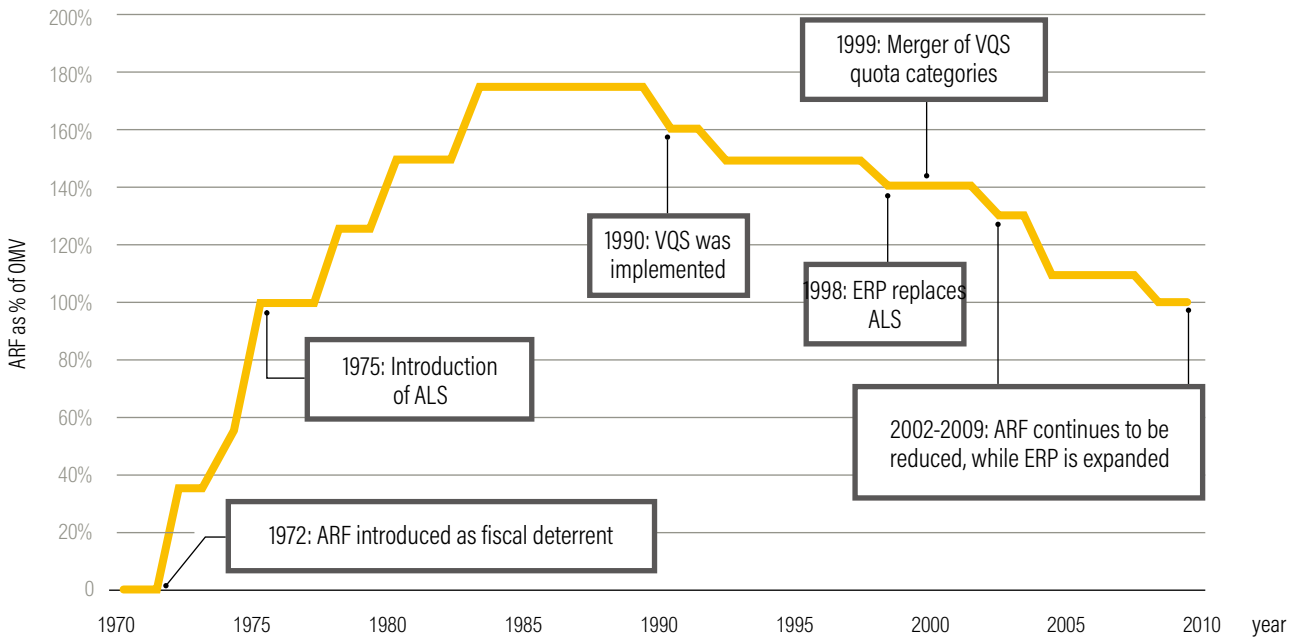
As the ERP system was unrolled, the Singapore government made corresponding adjustments to other TDM policies, so as to optimize the combined effect of the various policies.

- While implementing the ERP, the government lowered ARF for vehicles,[18] and did not add new items of taxation (such as road use tax). According to the statistics of LTA (LTA 2008), ARF has been reduced to 100 percent of the vehicle's open-market-value (OMV) since 2008. This measure cost the Singapore government close to SGD 310 million (about USD 213.9 million), which is much higher than the annual ERP revenue. This indicates that the goal of the ERP system is indeed to alleviate congestion through curbing vehicle use, not to increase government revenue (see Figure 4-7).

- Because the ERP system targets only congestion, the Singapore government introduced the carbon emissions-based vehicle scheme (CEVS). Low-carbon vehicles are eligible for an ARF discount of up to SGD 20,000 (about USD 13,802) if the vehicle was registered before June 30, 2015, and up to SGD 30,000 (about USD 20,703) if registered between July 1, 2015 and June 30, 2017 (LTA 2015e).

- It should be noted that the Singapore government did not weaken or cancel the COE policy with the introduction of the ERP. On the contrary, the COE quota has been reduced in recent years.

Figure 4-7 | **Interaction between ARF Rates and the ERP System**



Source: LTA, 2009a.

Controversy and Solution

Many issues have arisen with the implementation and improvement of the ERP system, which have caused doubts among the public. The Singapore government is trying to find solutions to the controversies, and to continue improving the ERP. The major concerns and solutions adopted are as follows:

- *Privacy security*. Many citizens worry that the ERP system may infringe on the privacy of vehicle owners; this has been the biggest concern since the system was first implemented. The Singapore government tries to mitigate this issue as far as possible. Charges are deducted from the cash card directly, and all transaction records will be deleted within 24 hours. In the case that payment is not completed, the system camera will take the picture of only the license plate on the rear of the vehicle, thus protecting the privacy of vehicle owners (Luo 2009). The government works hard on cultivating public's support through active communication and full information disclosure.

- *Cash card safety*. The cash card inserted in the IU is not linked to the vehicle owner, for privacy protection purpose—anyone can use the card in supermarkets and convenience stores.[19] However, this increases the risk of the card being stolen. The Singapore government is still exploring effective ways to prevent card loss. For now, the government has advised the public to be aware of the need for self-protection and to remove the cash card when leaving the vehicle.

- *Foreign vehicles*. Foreign vehicles (mainly from Malaysia) are also subject to the ERP charging system. Owners of foreign vehicles may either install a permanent IU in the vehicle, or rent a temporary IU device before entering Singapore. Alternatively, owners may choose to pay a fixed daily congestion fee of SGD 5 (about USD 3.5) during their stay in Singapore (Luo 2009).

- *System reliability*. The ERP system is able to detect and charge more than 98 percent of vehicles that pass through the gantries. The remaining 2 percent is missed by the system for various reasons, such as drivers tampering with their IU device. In this case the system will upload the vehicle license plate photo to the office for manual charging processing. Although manual charging is insignificant in percentage terms, the workload is enormous—a team of 10 staff is responsible for identifying 10 million charging cases per month. The reliability of the ERP system can reach 99.9 percent with the help of manual identification (Luo 2009). Each IU device has a quality warranty of five years. Vehicle owners who have problems using their IU devices can visit the LTA office for help with maintenance or updates, to avoid being charged incorrectly.

System Performance

The ERP system in Singapore is developed mainly for improving traffic flow and alleviating congestion. Additionally, the relative share of different travel modes has shifted, as the improved traffic flow has allowed better use of public transport, for example. It can be concluded that the ERP system has generated positive co-benefits in energy saving and emissions reduction.

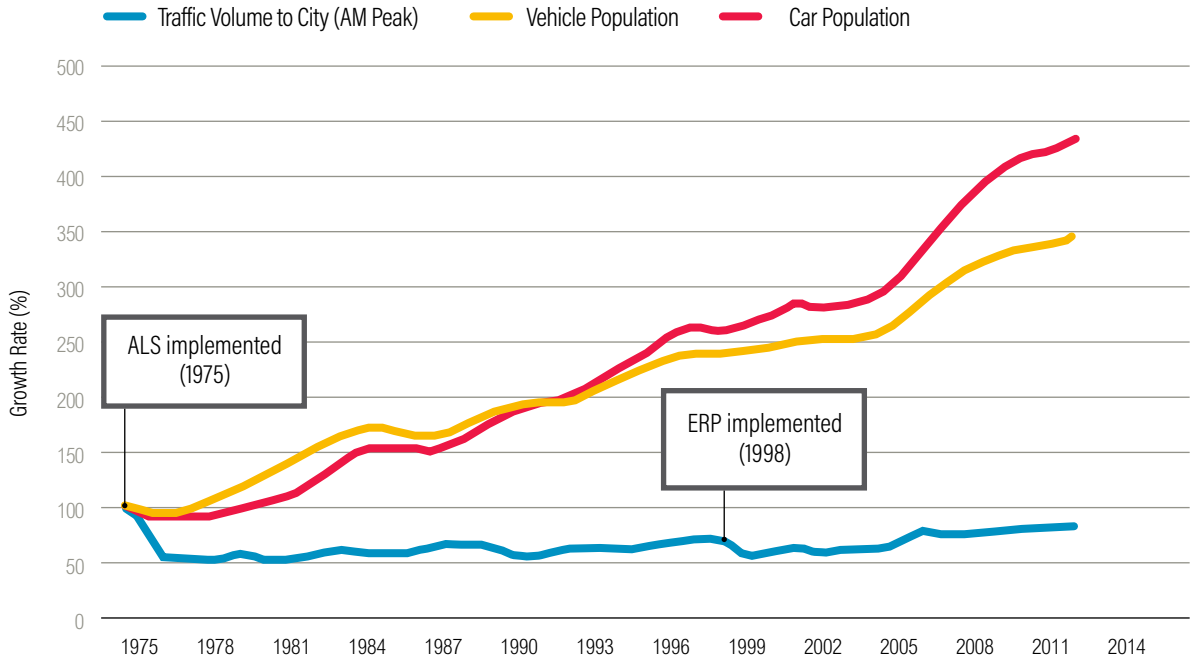
Influence on Traffic Flow

The ERP system began formal operation on September 1, 1998. According to the LTA, the ERP system reached the targeted result on the first day: the morning peak traffic flow on the expressway decreased by 17 percent, from about 16,000 to 13,400 vehicles (Goh 2002). Meanwhile, on the same day, 237 drivers did not comply with the new requirements—most of whom had either failed to insert the cash card in their IU, or failed to deposit enough cash on the card. However, the public quickly got used to the ERP, due to the government's continuous improvement of the system, and their previous experience with ALS (Goh 2002).

In the longer term, the ERP has proven to be effective in alleviating congestion. Since introducing ERP, traffic volume on expressways has decreased by 15 percent, with the average speed raised from 35 km/hour to 55 km/hour. The traffic volume in the restriction zone has decreased by 16 percent (Menon and Guttikunda 2010).

The number of vehicles in Singapore has risen continuously over the years. However, the traffic flow into the CBD during morning peak hours remains unchanged (see Figure 4-8). The ideal speed (20–30 km/hour for local roads, 45–65 km/hour for expressways) can be reached in each restricted road section. Although Singapore experienced booming development in these years, with rapid urbanization and increasing traffic volumes, no new roads have been opened in the CBD. This is further evidence that the ERP has a great effect on congestion alleviation (Luo 2009).

Figure 4-8 | **Growth Rates of Vehicle Population and Traffic Volume in Singapore, 1975–2014**



Source: LTA, 2013a: 45

The effects of ERP are not limited to decreasing the absolute traffic flow in the restriction zone; traffic flow can also be diverted with differentiated pricing, thus realizing temporal-spatial segregation of the traffic flow. Traffic volume in the trunk and branch roads increases half an hour before and after the charging period, indicating that people voluntarily adjust their travel timeframe to avoid the charge. This means the ERP system has obvious effects on flow diversion during the peak hours (Luo 2009). Throughout the day, the increased traffic flow during off-peak periods (such as noon time) shows that ERP has diverted traffic flow in a temporal dimension (Goh 2002). ERP also encourages drivers to choose road sections without heavy traffic, so to relieve the pressure on congested road sections. Upon implementing the policy, traffic volume on most of the expressways and normal road sections stayed within the maximum desired traffic volume capacity, and the congestion issue is largely relieved (Goh 2002). The implementation of the ERP has been influential on daily life in Singapore. More than 70 percent of vehicles in Singapore pass the ERP gantry at least once per month, and there has been an obvious decrease in vehicles entering the CBD multiple times (Menon and Guttikunda 2010).

Influence on Public Transport Mode Share

Passenger trips by public transport have increased significantly since the implementation of the ERP scheme, and bus speeds in the CBD have improved. Before ERP began operating, the share of private car and bus trips was 56 percent and 33 percent, respectively (Leitmann 1999). By 2014, 66 percent of citizens were using public transport for travel during peak hours (Ministry of Transport 2014). The annual growth rate of rail and bus trip shares is 10.1 percent and 2.8 percent, respectively (LTA 2015c).

Citizen travel behavior has seen interesting changes, due to the ERP scheme's discouragement of car travel. Normally, these kinds of change are not commonly seen in high-income countries (Olszewski 2007).

- Increased use of motorcycles: The number of motorcycles has been slowly increasing in Singapore, which is quite rare in a high-income country. This is possibly because motorcycles are more affordable and convenient to low-income groups.

- Increased use of taxis: Taxis are considered to be

convenient, cost-efficient, and easy to access because of the large number of cabs. They are well suited to one-way travel. The daily taxi ridership reached 870,000 in 2005, accounting for 11 percent of all trips in Singapore (LTA 2005).

- Increased chartered bus transport: This service provides customized point-to-point services, and accounts for 8 percent of the total trips in Singapore.

- Freight truck for illegal passenger transport: Some trucks are used for carrying passengers in Singapore because of their large capacity.

Co-Benefits to Energy and Environment

The combination of the ERP system with other TDM measures has greatly improved energy efficiency and environmental quality in Singapore. Since the implementation of CC, the public has been shifting gradually from private cars to public transport. The decrease in peak-hour traffic volumes and the shift of travel modes not only contributes to alleviating congestion in the city, but also to vehicle emissions reduction and air quality improvement, which can be summarized as the co-benefits brought by the CC scheme in Singapore.

ERP Technology

System Composition and Charging Technology

Singapore's ERP system utilizes dedicated short-range radio communications (DSRC) technology. DSRC, a type of wireless communication technology, is able to detect high-speed moving targets (with a typical range being a few dozen meters), and establish two-way communication in a short range, such as vehicle-road and vehicle-vehicle communication, and real-time transmission of images, voices, and data. Therefore, this connects vehicles with roads.

The DSRC system consists of an in-vehicle unit (IU), a roadside unit (RSU), and a dedicated short-range communication protocol. The system establishes communication by radio shortwaves.

- IU: Every vehicle in Singapore is equipped with an IU, which stores the physical parameters (such as vehicle type) of the particular vehicle. The IU can display the balance of the cash card and perform high-speed data exchanges between the IU and RSU.

- RSU: The RSUs are the communication and computer devices installed on ERP gantries. The RSUs are used for real-time high-speed communication with the IUs, executing auto recognition of the vehicle and photographing. An RSU consists of the control system, antenna, enforcement cameras, computer system, and other auxiliary equipment (see Figure 4-9, 4-10).

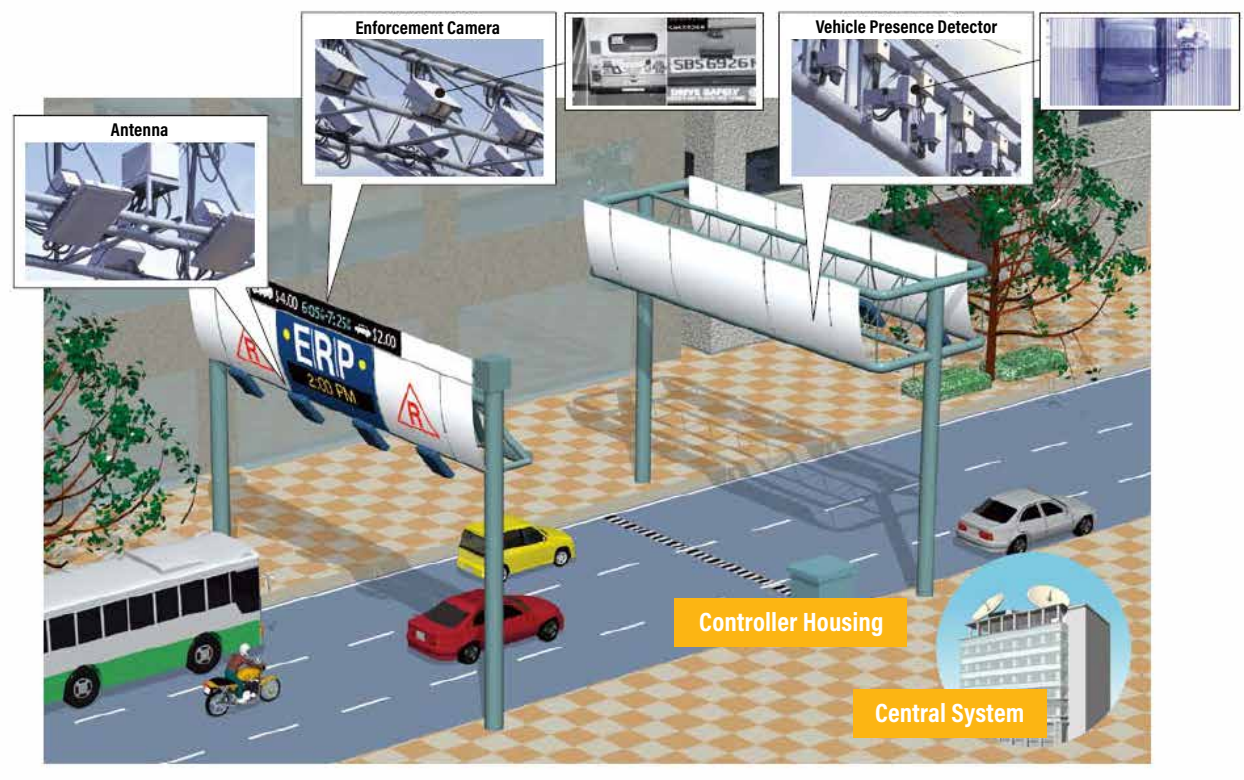
- Dedicated communication protocol: This is a dedicated protocol for communication between the IU and RSU. Each ERP gantry and control center exchange data by using the protocol via a dedicated channel provided by the telecom operator.

A two-way three-lane road is generally required for setting up the ERP system. The height of the gantry is 6.1 meters and the width is about 15 meters. The cost of each ERP gantry is SGD 1 million to SGD 3 million (about USD 0.7 million to USD 2.1 million), depending on the width of the road and gantry.

As shown in Figure 4-9, each ERP gantry set has two gates with width of 8 to 10 meters. The first sensor on the gate can utilize DSRC to automatically detect the validity of the IU within 10 meters of the approaching vehicle. By detecting the IU unique identity, the system can then identify the vehicle type to determine the charging rate. When the vehicle is in between the two gates, the IU automatically deducts money from the cash card. The optical sensor on the second gate confirms whether the transaction is successful or not, and shows the amount of the charge on the IU (Gopinath Menon 2000). In the meantime, the sensor captures passing vehicles. Information will be recorded in the local control system when the transaction is processed successfully. In case of unsuccessful transactions, the camera on the first gate will automatically take a photo of the number plate at the rear of the vehicle and record the reason (e.g., no cash on the cash card). All of the information (transaction data and digital images) is recorded in the local control system. The information is transmitted to the central controlling center regularly for further processing.

The ERP transaction records will be kept until the cash settlement is completed in the IU. Information on vehicles in violation will be kept for six months, serving as evidence of violations. Fire trucks, police cars, ambulances, and other emergency vehicles are also equipped with an IU; otherwise, they may be recognized as suspicious vehicles. However, the IUs in those vehicles are not required to

Figure 4-9 | **Structure of RSU for the ERP System**



Source: Mitsubishi Heavy Industries, 2015a

Figure 4-10 | **Charging System on ERP Gantry**

Gantry System

Antenna

Vehicle Detection And Classification

Enforcement Camera

Source: Mitsubishi Heavy Industries, 2015b

have a cash card. Even with such a card, no fee will be deducted (Zhang 2007).

The DSRC technology is able to charge vehicles in different lanes. This allows vehicle owners to drive and change lanes freely, even when passing the gantries (Mitsubishi Heavy Industries 2015c). This technology is thus ideal for multi-lane road sections.

DSRC System Testing

It took about 10 years for Singapore to establish the DSRC-based ERP system. The system design, research, and development, and installation were all outsourced to technology companies, which were selected by bidding procedure. See table 4-2 for system testing and bidding details.

Key technical indicators of the existing DSRC-based ERP system in Singapore are shown in Table 4-3.

In-Vehicle Unit

All vehicles registered in Singapore are required to install an IU, which may be removed and installed only by LTA-designated service stations. Unauthorized individuals are not allowed to remove the IU from vehicles. The IU was free when the government first introduced the ERP system. However, any vehicle purchased after September 1, 1998 is required to be equipped with an IU at the owner's expense. For foreign vehicles entering Singapore, an IU can be rented at the border; or a single payment may be made at customs. The fee is SGD 5 (about USD 3.5) per day.

The current IU cost is SDG 150 (about USD 103.5), which is normally included in the vehicle price. IU device for fire trucks, police vehicles, and ambulances are free of charge. Different IUs are designed for different types of vehicles (e.g., cars, taxies, light

Table 4-2 | **Testing and Bidding Process of DSRC System**

Time	Events
1991-1993	Bidding was initiated with three companies selected
Since April, 1993	Three companies conducted testing on the Tuas road section
Since May, 1993	Testing was conducted throughout Singapore. Cash cards were installed for testing
May 1995	A new round of testing was conducted with new IU installed
October 1995	MHI-oriented Philips Singapore group won the bid by providing extremely high system stability
1997	The Philips Singapore group began to conduct tests on highway

Table 4-3 | **Key Technical Indicators of DSRC-based ERP System**

Frequency	2.4 GHz (ISM band)
Maximum speed of free flow	180km/hr
Error rate	3 errors in 4.3 million charging/transactions (on-site testing)
Number of charges	2.3 million (August 2008)
Type of charging vehicles	• Car/light truck • Taxi • Motorcycle • Heavy-duty truck/mini bus • Extra-heavy truck/large bus • Special vehicle

Source: Mitsubishi Heavy Industries, 2015d

Figure 4-11 | **IU (left) and Self-Service Recharging Machine (right) of Cash Card**

Source: LTA, 2013b.

trucks, heavy trucks, buses, and motorcycles). The IU has the warranty period of five years. If there is any issue during the warranty period, the IU can be replaced after being tested by the service station appointed by the LTA. In Singapore, the in-car temperature can reach 85°C without air conditioning. Therefore, the designs of the IU and cash card are high-temperature resistant.[20]

The IU processes payment through an in-contact smart card[21] (see Figure 4-11). The cash card, also called smart card, is issued and managed by a specific institution formed by local banks. The cash card can be used repeatedly, and allows a maximum balance of SGD 500 (about USD 345.1); the balance can be assessed and recharged at ATMs and gas stations. When the cash card is inserted into the IU, the LCD screen on the device will display the balance and the charging price for ten seconds when the vehicle is passing through the ERP gantry. Different charging rates are applied to different types of vehicles. In order to prevent illegal exchange of the IU between different types of vehicles, the IU is generally installed on a bracket, which is fixed on the windshield with high-adhesive tape, or bolted on the handle of a motorcycle. If exchanged, they can be easily recognized (Zhang 2007).

In addition, the IU is a multi-functional device. It can be used both for the ERP system and at most parking places in Singapore. The IU-compatible parking system is called the electronic parking system (EPS).

At present, more than 500 parking lots in Singapore have adopted such compatible technology (Mitsubishi Heavy Industries 2015d). The basic charging technology of the EPS, which is also equipped with sensors and cameras for interacting with the IU, is similar to the ERP system. When driving through such a parking lot, the driver does not need to roll down the window for payment, or wait in line. As shown in Figure 4-12, the integration of congestion charging and parking charging systems enables more types of services for IU users, and enhances the overall acceptability of the system.

Figure 4-12 | **Sensor of the Electronic Parking System**

Moreover, Singapore has developed a new generation of IUs in recent years and made the following improvements:

- the size of the new IUs is 34–50 percent smaller than the previous generation, depending on the vehicle type;
- the new IUs are compatible with public transport cards other than the cash card;
- the new IUs support auto-recharging in case of insufficient balance; and
- the new IUs can differentiate taxi service fees from ERP charges.

ERP Gantry Design

The LTA has put great effort into the design of ERP gantries. The design aims to display the information clearly on the boards of the gantries while also considering aesthetics and minimizing the physical presence. As shown in figure 4-13, the information board on the gantry uses white wording on a blue background, and displays real-time charging information including the current time, charging time, and the rate for different types of vehicles. The symmetrically positioned letter "R" in a red triangle represents Restricted Zone. The frame of the gantry is all in white, ensuring the color consistency and the aesthetic standard of the whole facility. The gantries require regular maintenance to avoid rusting in the humid weather of Singapore.

Envisioning Future Technology: ERP II System

The LTA has been considering replacing the DSRC system with more advanced global navigation satellite system (GNSS) technology to make distance-based congestion charging possible. If successful, the new CC system supported by GNSS will be named ERP II. The ERP II system is currently being tested, and is expected to begin operation in 2017 or 2018. Moreover, several types of GNSS (e.g., GPS and Galilean system) are under consideration to be used in tandem to ensure the reliability and stability of the system. Meanwhile, the ERP II is required to be compatible with the existing EPS.

Advantages of GNSS

Figure 4-13 | **An ERP Gantry in Singapore**

The GNSS-based ERP II system has the following advantages:

- The existing DSRC-based ERP system is not flexible because the position of the gantries is fixed. The gantries can only collect fees at certain points on the road, and can influence the traffic only within a limited area. The GNSS-based technology enables distance-based charging, and provides flexibility and accurate charging rates. As a result, it can be more effective in managing road traffic.

- The GNSS-based ERP II system does not require the charging gantries. It requires only reliable communication between the satellite and the IU. Therefore, the ERP II system will have limited impacts on the urban landscape. The DSRC-based ERP system requires more space and other construction conditions, and the cost for system installation and maintenance is considerably higher. Although LTA has considered many permutations of gantry design, it still has concerns about the negative impacts of the gantries on the city's landscape.

- The ERP II system adopts the most advanced technologies. The current DSRC-based ERP system was developed in the 1990s. The technologies are outdated and some components are no longer in production. Therefore, expensive customized components are needed to maintain the system.

- The GNSS-based ERP II system provides efficient adjustments depending on real-time traffic situations. It takes one year to design and install the charging gantry for the existing ERP system. The real-time and dynamic charging rates are difficult to adjust in some unexpected situations, such as accidents.

- The GNSS-based ERP II system is more flexible and suitable for developing cities that are subject to constant road construction or modification—such as Beijing—because it can accommodate changing road planning and layout.

In general, when compared with DSRC, the GNSS technology is more intelligent, flexible, convenient, and cost-effective. Therefore, the replacement of DSRC with the GNSS-based ERP II system could bring substantial benefits for Singapore.

Challenges of GNSS

Despite the numerous benefits offered by GNSS technology, to date, it has been successfully applied in only a few countries in the context of inter-city long-distance transport charging. The ECOMOUV system in France is one example. Intra-city traffic is much more intensive, unpredictable, and complex than inter-city transport. It requires extremely high accuracy of the satellite positioning technology. There may be some technical challenges when introducing GNSS technology into the urban congestion charging ERP II system. Some of these issues have not been completely addressed by Singapore.

- **Signal:** GNSS technology requires stable communication between the IU and satellite. Unfortunately, tall buildings and trees in the city frequently block the transmission signal, resulting in system failure of real-time vehicle tracking. Satellite signals may also be disrupted by heavy rain and stormy conditions. For GNSS-based charging, the accurate driving path and mileage tracking are critical for determining the charging rates. Using the ERP II system, it will be difficult to manually track vehicle paths and mileage as the base for charging fees. Therefore, the technology needs to be further improved, for example, by installing signal-receiving devices in places where the satellite signal is blocked.

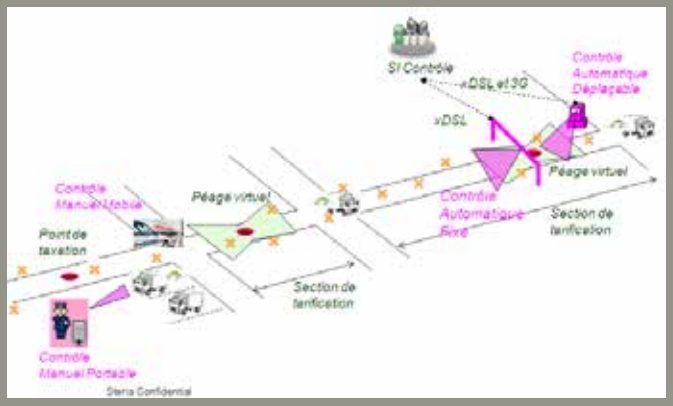
- **Rate calculation:** The GNSS-based charging system guides traffic flow by means of dynamic rate adjustments. However, figuring out how to determine the corresponding rate is a great challenge. The rate calculation methodology is extremely complicated. Various factors should be considered in terms of rate change and dynamic adjustment method. The LTA has been working on the solution to this issue.

- **Privacy:** The current ERP system captures only the identification of the vehicle when it passes through the gantry. It does not track the vehicle's driving path. Therefore, it constitutes a relatively limited invasion of privacy. The future GNSS-based ERP II system tracks and monitors vehicle paths, which many citizens may regard as too great an intrusion on personal privacy.

- **IU tampering:** When using the GNSS-based system, some users may turn off the IU devices and even disable them. As a consequence, anti-tampering

The ECOMOUV Program uses GPS technology to calculate and collect road taxes on heavy-duty trucks (over 3.5 tons) in France. It is a distance-based road tax. The on-board unit (OBU) on each truck communicates with satellites, transmits data to the control center, and calculates tax rates for the truck. There are currently 800,000 vehicles (600,000 in France and 200,000 in other countries) equipped with OBUs. There are 173 fixed check-points on the 15,000 kilometers of national and regional roads in Europe, with annual tax revenues of 1.2 billion Euros (about USD 1.27 billion). This system can also be used in other applications:

- Fleet management: real-time positioning, vehicle status, and driving time
- Energy-saving and emissions reduction: tracking driving behavior (excessive acceleration, emergency braking, etc.) and vehicle emissions data collection
- Vehicle insurance: determine the premium according to the driving patterns (e.g., no insurance premium for unused vehicles)
- Vehicle rescue: quickly locate vehicle, determine vehicle conditions, and rescue the vehicle in case of emergency



technology is required that is capable of recognizing tampering and/or malfunction of the IU devices.

ERP II Components

In the GNSS-based ERP II system, the on-board unit (OBU) detects the vehicle's position and its travel route, and automatically determines the charging rates. The system also recognizes violations, such as traveling without a smart card, and automatically sends photo evidence of the violation and charging information to the driver. Mitsubishi Heavy Industries has conducted the research on the GNSS-based ERP II system (see Figure 4-14).

The GNSS-based ERP II system consists of four components, namely OBU, central computer system (CCS), enforcement system (ES), and roadside unit (RSU) (see Figure 4-15).

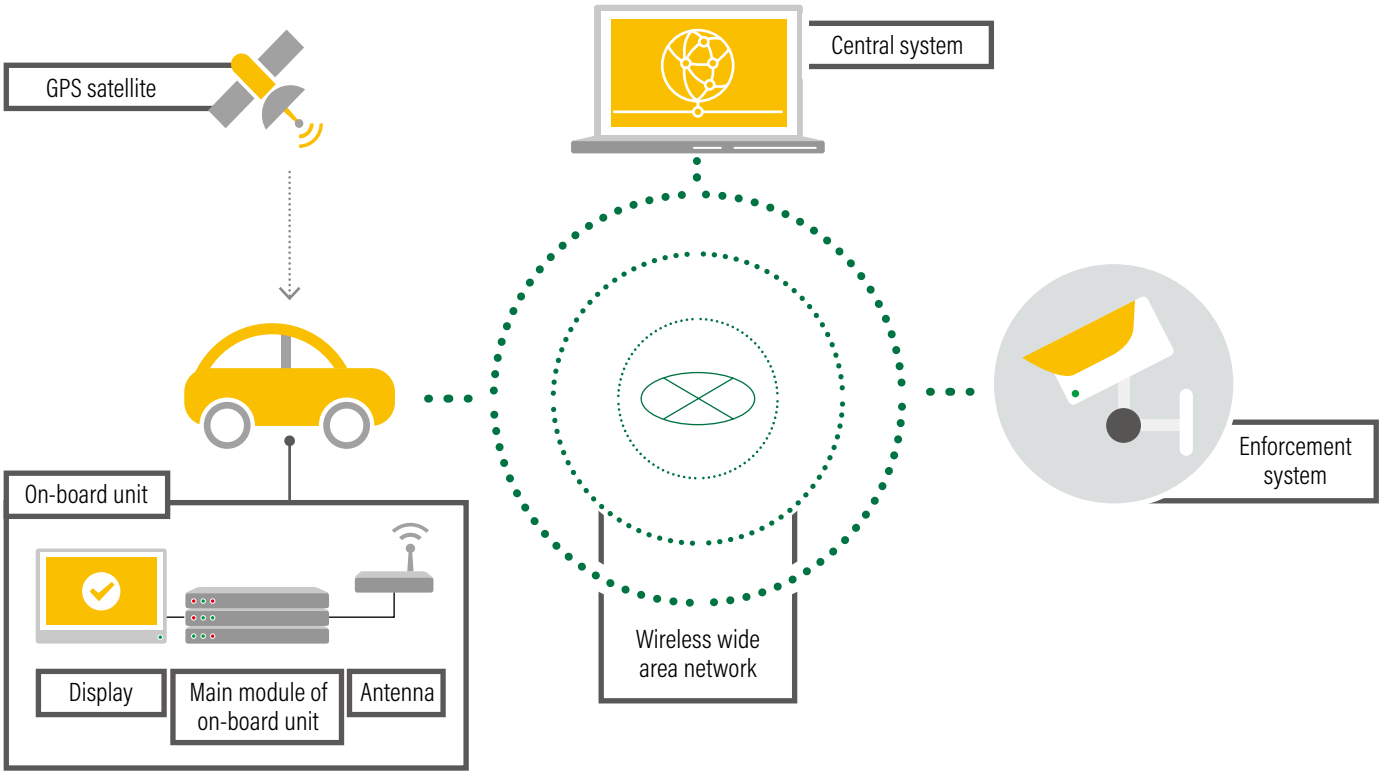
OBU

OBU is the device in the vehicle that independently executes the charge according to the positioning information. It is also capable of transmitting the charging information and vehicle position to the CCS. When the GNSS signal is unstable, the acceleration sensor and the gyroscope in the OBU can assist with positioning to ensure that information is accurate and charging is stable. This is known as the "dead reckoning" method. By using the positioning information obtained from map matching (technical positioning information and an electronic map are matched), the travel path and charging points can be confirmed through the map. The charging command will be executed after the confirmation. There is no delay before the driver receives the charging notice upon passing the charging point because the charging time is calculated by adding a time compensation of a few seconds, based on the actual vehicle position.

CCS

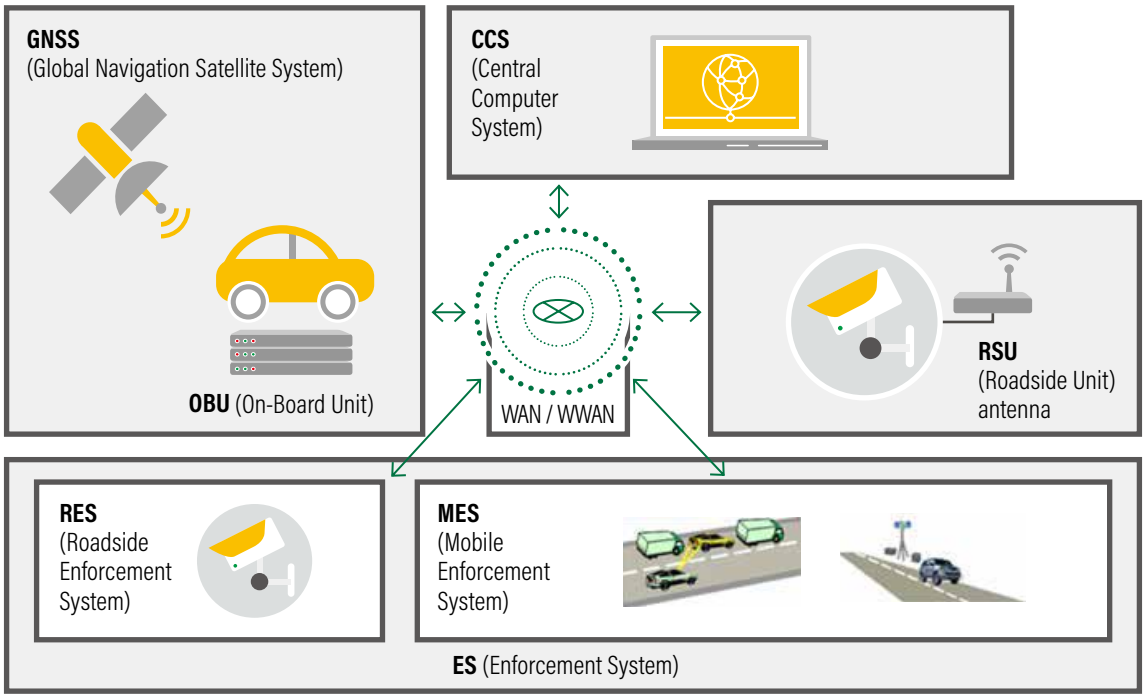
The CCS is a central processing system that transmits and receives information from each sub-system. It receives the charging rate information from the OBU and transmits the charging bill back to the OBU. The CCS receives the monitoring information through the ES to determine whether the charge has been executed successfully and whether there are any violations. In addition, through the RSU, the CCS collects information from the OBUs and sends traffic information back to each OBU to guide the

Figure 4-14 | **GNSS-based ERP II System**



Source: Mitsubishi Heavy Industries, 2012

Figure 4-15 | **Key Components of the ERP II System**



Source: Hiura et al., 2013

vehicle toward the less congested roads.

ES
There are two types of ES: a roadside enforcement system (RES), which is a fixed roadside monitoring system, and a mobile enforcement system (MES), a monitoring system installed on an enforcement vehicle or the equipment on the road shoulder. Both of them are capable of recognizing license plate numbers, exchanging information with OBU through DSRC, using the obtained information to determine the charging results, and detecting illegal behavior (e.g., failure to insert cash card into OBU).

RSU
RSU is a communication device installed at the side of the road to deliver traffic information and positioning information to passing vehicles. Its enhanced positioning signal is mainly used for providing OBUs with correct positioning and road information when tall buildings or trees in the city block the GNSS signal. RSU is used mainly for communicating with OBUs and collecting traffic information from OBUs.

Testing GNSS Technology

Singapore conducted a large-scale test of the GNSS-based ERP II system through 2012 and 2013. The test was first conducted on the system function. The test of the effectiveness of the GNSS system lasted five months on each road under varying conditions. The test involved more than 300 testing schemes, which focused mainly on the following aspects (Hiura et al. 2013):

- system compatibility with various types of vehicle;
- more than 100 combinations of driving patterns, driving speeds, and driving habits;
- possible delay in transmission of the OBU signal under real driving conditions; and
- system performance during night driving.

Results from the testing schemes show that the GNSS technology is able to meet the ERP II requirements under various conditions.

In addition, Singapore also conducted a two-month test on the reliability of the GNSS-based ERP II system. The test was conducted by installing ES on various road sections to see whether it could successfully distinguish vehicles with OBUs from those without, and whether the charging system was fully functional. The testing result shows that the new system is reliable.[22]

Singapore Best Practices Summary

From the ALS to the ERP (and the future ERP II), Singapore has 40 years of experience in CC policy. The Singapore government has gained much experience in policy implementation, technology design, and public communication over the decades. This section highlights some of these experiences.

Balance among policies, and trade-offs between theory and public acceptance

The Singapore government pays close attention to balancing ERP and other TDM policies. It optimizes the co-benefits of these policies by adjusting each individual policy. For example, it integrates the IU technology with ERP and parking pricing, thus combining CC and parking charging into one policy package. The best example is perhaps the balance among Singapore's key economic TDM policies. ARF, VQS, and ERP are the core of Singapore's TDM strategy (LTA 2014b). The three powerful economic instruments have led to significant changes in vehicle ownership and usage management in Singapore. Considering the overall impact of these policies on public life, and in an effort to shape public travel patterns through controlling vehicle usage, Singapore has reduced the ARF tax rate several times to offset the continual increases in the congestion charge.

Interestingly, the Singapore government seemed not consider the influence that combining the VQS policy and the ERP system might have on congestion alleviation. The VQS quota has tightened in recent years, in tandem with the rising COE price. While the government gave some consideration to a theoretical combination of a "loose VQS and strict ERP," it decided that the idea is not feasible in practice. The government believes that the strict VQS policy brings less public dissatisfaction than the strict ERP.[23] Therefore, the government made a trade-off between the two polices and retained its strict VQS policy after considering the issue of public acceptance.

The lesson is that governments must not only balance the effects of all TDM policies, but also consider the balance between what might theoretically be achieved by a new or

adjusted policy and the actual public acceptance of such policy changes.

Strict technology development and management

The CC system has gone through a lengthy process from development to testing and implementation; it also requires continuous improvement during the service period. The Singapore ERP system took 13 years from preliminary study to implementation. The research and development (R&D) and the assessment for the GNSS-based ERP II technology, which will replace the existing ERP in the future, have already taken about 10 years. Since the first ERP system was put into operation in 1998, the Singapore government has continued to adjust the technology and its charging policy, to correct flaws existing in technologies and policies at early stages. In terms of system operation, also, the government continues to improve management of the system, modifying the charge regularly based on traffic flow, and adjusting the rate seamlessly.

Emphasis on fairness and nonprofit

The Singapore government has always been focused on "absolute fairness" and "nonprofit" of the ERP system. This system is designed to relieve congestion and improve traffic speed, rather than to raise revenue, and all vehicles are treated equally. This absolute fairness principle applies to all vehicles, even buses, clean energy vehicles, and the cars of the head of state and embassies. These vehicles also occupy road space and contribute to traffic congestion. As a result, they should pay the congestion charge without subsidy or deduction. The only exceptions are emergency vehicles (e.g., police vehicles, fire trucks, ambulances). The nonprofit principle is reflected in the fact that all investment in the ERP system is the responsibility of the government and all ERP revenues are owned by the state. None of the revenues are earmarked for transport-related expenses.

Public communication and public participation

Good public communication is one of the key reasons for the success of CC in Singapore. Effective public communication improves the level of public acceptance. Policy and technology can also be improved through communication. A number of principles underpin public communication in Singapore:

- Establish a good public image for CC: emphasize to the public that the purpose of CC is to solve congestion, the ultimate beneficiary is the public, and the government does not seek profit from charging revenues. The government puts great effort into ERP gantry design to achieve a high aesthetic standard and provide the public with clear charging information.
- Emphasize fairness: with the exception of emergency vehicles, all vehicles driving on the road must be charged without discount, even the vehicle of the president.
- Disclose information: announce price adjustment information to the public in a timely manner, publicize it widely through the network and bulletin boards, and display the current charging price and charging time clearly on ERP gantries.
- Conduct outreach activities with the public through various media channels. Promote two-way communication, and emphasize interaction and public participation.
- Show responsiveness: during implementation of ERP, the government listens to the opinions of the public (and other stakeholders), and provides feedback and solutions promptly.
- Provide a variety of solutions: while implementing the ERP, the government offers the public a number of policies so that people have multiple choices. For example, the government introduced free subway in the early morning, park-and-ride, and off-peak car policies etc., to provide more options for people in selecting bus trips and off-peak trips.

STOCKHOLM CASE STUDY

Stockholm Overview

Stockholm, located on the western shore of the Baltic Sea, is the capital and the largest city in Sweden. Stockholm County extends over 14 islands (see Figure 5-1) with a population of about 2.2 million in 2014, of whom approximately 0.91 million live in Stockholm Municipality (Statistics Sweden 2015). In Stockholm, there are 465 cars and 34 motorcycles for every 1,000 people (Swedish Transport Agency 2014). Stockholm has an extensive public transport system, with a daily ridership of over one million person trips in the metro system, nearly 250,000 person trips in the commuting railway network, 100,000 person trips in the light rail system, and close to one million person trips in the bus network (Eliasson 2014).

The concentration of NOx in Stockholm reached its 1990s peak during the winter of 1995, due to cold weather and increased traffic (heavy-duty trucks in particular); the concentration in main streets of the city center exceeded the health limit (Johansson et al. 1999). Road traffic had become the leading source of pollution in the city. In 1996, the first LEZ strategy was introduced in Stockholm, focused primarily on traffic-related pollution. The strategy proved inadequate because it applied only to limited types of vehicles (high-emission trucks and buses), and failed to address other transport issues, including congestion.

In their own words...

Most of the benefits [from the congestion tax] are accessibility benefits, i.e., travel time savings and reduced travel time variability. From an economic point of view, it should be noted that it is these benefits that are translated into economic productivity and growth."

—Jonas Eliasson,
KTH Royal Institute of Technology, Sweden

Rising population, increased traffic volumes in the city center, and longer and more frequent travel all contributed to worsening congestion, which became a pressing issue for Stockholm after 2000. Just before the congestion tax was enacted in 2005, the vehicle count (crossing the boundary into the inner city area) during workday peak hours (7.30 am to 9:00 am) reached 36,000, while the average speed was 30.8 km/hour (Engelson and van Amelsfort 2011).

Figure 5-1 | **Geographical Setting of Stockholm**

Policy Background

Stockholm has implemented two measures to alleviate its traffic problems: the low emission zone (LEZ) policy, also known as the environment zone policy, and the congestion tax policy. These policies principally target poor air quality, serious traffic congestion, and the substantial costs of congestion.

The congestion tax was put on the agenda as part of an ongoing national party political struggle. In the late 1990s, a CC program was strongly favored as an environmental protection measure by the Green Party. In 2002, the ruling Social Democratic Party set up a commission to negotiate agreements on new infrastructure constructions in Stockholm. The commission planned to use road pricing as a funding source, but the idea was attacked by the Conservative Party.

To ease the tension, the Social Democratic Mayor of Stockholm publicly announced that no road tolls would be imposed in Stockholm during the next election cycle. However, to win both the national and the Stockholm elections, the Social Democrats needed the support of the Green Party. In return for their support, the Green Party demanded that a multi-year, full-scale "congestion charging trial" should be carried out in Stockholm. The Social Democrats agreed to the trial, but their wavering position resulted in an extremely fierce debate.

CC was unpopular from the very beginning and the breach of the Stockholm Mayor's election promise made implementation of the policy even harder. Opponents of CC suggested holding a referendum to accept or reject the charge—based on their assumption that a "no" vote would prevail. The Social Democratic Party welcomed the idea and saw it as a chance to put some distance between the government and the CC policy. Moreover, in order to win votes from the Green Party, it was decided that the referendum would be held after the trial, at the same time as the next national election scheduled for September 2006. This solution—in which a public referendum was held after, rather than before, a full-scale trial—is highly unusual. The trial (described in Section 5.2.1) was generally regarded as a success but it is worth noting that, in the referendum held on September 17, 2006, the residents of Stockholm Municipality voted "yes" to permanent implementation of the congestion charge but residents in the other—much smaller—14 municipalities of Stockholm County voted "no." However, the winning parties of the September 17 national election declared that the results from Stockholm Municipality were binding and CC was made permanent on August 1, 2007.

Congestion Charge Trial Period

To pave the way for the trial, the national government put forward a proposal on CC to the parliament in June 2003, which was approved by the latter. The law was formally proposed in June 2004, thus introducing a new congestion tax law as the legal basis and safeguard for Stockholm's congestion tax policy. After more than two years of system design, construction, and testing, Stockholm officially began its CC trial in January 2006, by introducing a time-differentiated toll within a cordon around the inner city. The seven-month congestion charging trial period ran from January 3 through July 31, 2006.

One of the major reasons for public opposition to CC was that residents did not believe that the measure would reduce congestion. In addition, many residents living in the peripheral municipalities of Stockholm County resented the fact that their voices would not be heard in the forthcoming referendum because only the votes from Stockholm Municipality would count. However, during the trial, traffic volumes across the charge cordon decreased by 20–25 percent during charged hours, and emission of pollutants within the cordon (CO_2, NOx and PM) dropped by about 14 percent (Swedish Transport Agency 2014). With the effects of the trial becoming more apparent over time, support from the public and media began to shift, particularly in the inner areas of Stockholm. The trial was a success in Stockholm Municipality, where 53 percent of voters supporting the continuation of CC in the referendum (Stockholm City 2007). The vote across all 15 municipalities was 51.3 percent in favor. Despite opposing votes from the outer municipalities, the Congestion Tax policy was officially implemented in August 2007, and is still in operation.

In Stockholm, the partisan struggle created a good opportunity for the introduction of the congestion tax policy, while the referendum provided the legal basis for its permanent implementation. The successful trial before the referendum proved the feasibility and effectiveness of the policy, thus putting an end to the 40-year-long debate about CC and laying a solid foundation for winning public support.

Legal Status of Stockholm's Congestion Charge

From a legal perspective, the congestion charges in Stockholm are not "charges" but national taxes. Under the Swedish legal system, municipalities cannot create new taxes, nor can they levy taxes on residents from outside their own municipal area. Stockholm's action on congestion management was first presented as a "charge" but was deemed by the national government to be a "tax" under Sweden's constitution and therefore the responsibility of the State. Therefore, even though Stockholm was in charge of designing the charging system and implementing the trial, it was the national government that could actually levy the tax and administer the charges through the Parliamentary resolution. The national government also has legal authority over revenue allocation. Although the Swedish government promised to refund the revenues to Stockholm, the local residents and politicians promptly raised objections to the revenue calculation method, the use of funds, and vehicle exemptions. Concerns were also raised over the amount of the charges or whether charges should be imposed in the case of inflation or economic growth. Like the public, political parties also raised doubts about the charge and the use of revenues. Those concerns could only be answered at the national level.

Use of Revenues

One of the key factors affecting public opinion regarding the CC system is the level of trust. Public trust in CC depends largely on whether government agencies will use the charge revenues openly, transparently, and fairly. To address this issue, the Ministry of Finance indicates the orientation of each expenditure on the bill of taxes. The congestion tax revenues are listed in the national fiscal budget, which is managed by Parliament, and allocated toward specific construction projects such as infrastructure in Stockholm and its municipalities. For example, one of the initial reasons for introducing CC was to build a 20-km road tunnel near the City of Stockholm, from Kungens kurva to Kista. This tunnel was funded in advance by loans from national project planning sectors, to be repaid with the charge revenues. The revenues from the congestion tax have funded parts of a major transport investment package, including urban planning, new bus lines and roads, reconstruction of signal lights and roads, public transport services in Stockholm, travel planning, smart park and ride (P+R) facilities, road auxiliary equipment, and evaluations of the effect of the congestion tax.

One of the major reasons for successful operation of CC system in Stockholm is that it is a tax policy at the national level, which confers the following characteristics:

Mandatory – When a municipal charges upgrades to a state tax, it has the force of law and becomes mandatory. Refusal to pay taxes is a violation of the law.

Empowering – A tax policy at the national level gives Stockholm the right to charge foreign vehicles for congestion, facilitating promotion and implementation of the policy.

Credible – As a tax, the income and expenditure of CC is transparent, which enhances the public's trust, and facilitates communication between the government and municipal political parties.

Parking Charges Considered but Rejected

Prior to implementation of CC, Stockholm also considered raising parking charges to alleviate traffic congestion, but did not put the idea into practice for the following reasons:

- parking is not the major reason for the traffic congestion in Stockholm;
- implementing a time-differentiated parking pricing policy is complicated, and the public would be forced to travel during periods with lower parking rates such as before 5:00 am, which would be inconvenient;
- Stockholm has many privately owned parking lots in the inner city, some of them free of charge, so a uniform parking pricing policy for all parking lots would be hard to impose; and
- drivers in Stockholm are already accustomed to parking charges, so a policy of raising parking prices would have less effects on congestion mitigation than CC.

5.3 Public Communication

Successful implementation of the congestion tax policy in Stockholm is closely related to the success of the public vote, in which public communication played an important role.

5.3.1 Public Inquiry

In Sweden, the introduction of any policy is subject to public inquiries, a necessary process mandated by the

country's legislative system. When a policy is proposed, the government publishes public reports about it, then collect comments from various stakeholders who study the proposal. The government then drafts a bill and submits it to the parliament. After debating, parliament will vote on the bill. Finally, if it is passed, the government will sign the bill into law. As stated above, Stockholm's CC policy is a national tax law, so the CC scheme began with a public inquiry. This involves a process of collecting advice and public demands, which paves the way for development and implementation of congestion tax policy, while balancing the interests of different stakeholders.

Public Communication Strategy

When promoting the CC policy, the tax was identified as an "environmental" charge. To the public, environment and health issues are more important than traffic congestion. Therefore, public support for the policy depended not only on the policy per se, but on its objectives. After Stockholm's congestion tax won acceptance as an environmental measure, the government emphasized the health benefits of reduced air pollution, making the charge more appealing to the public.

Public Trial of the Congestion Charge

There were debates over CC for Stockholm long before the congestion tax came into force, and the best estimates of its actual effect after implementation were only theoretical guesses. The trial of the CC in Stockholm, the first in history, invited the public to actually experience the system. Compared with Helsinki and Lyon, the much higher support rate for CC in central Stockholm was due to the trial period (Hamilton and Eliasson 2012). Although the public doubted that the charge would actually improve traffic flow, experience proved that the favorable effects were not merely theoretical. The regular release of system assessment reports, showing the continued positive impacts, also built long-term support for the policy.

Publicity Campaigns

CC changes every driver's travel experience. To build public support, the government made great efforts in the area of public communication. At the height of the public campaign for the policy, the Mayor of Stockholm attended radio and TV interviews twice a day, and held press conferences to disclose the latest updates. This practice effectively avoided the spread of rumors and unverified reports.

The Swedish Transport Agency also stressed the importance of simplifying the messages to minimize confusion. Four key messages to the public were summarized as follows:

- The charging time is from 6:00 am to 6:29 pm on weekdays
- The charge amount is SEK 10–20 (about USD 1.1-2.2), depending on the time of the day
- Vehicles passing the charging posts will be automatically recorded by the system with no need to stop the vehicle
- A tax bill will be sent to users

The public raised concerns over the uses of charge revenues. Since the redistribution of the tax was clearly specified in the constitution, the major part of the revenue was channeled to infrastructure construction. Tax revenue redistribution is strictly regulated. The City of Stockholm may not use the tax to build defense facilities, nor may the city use it for infrastructure or educational investments in other cities. Thus, the city, as well as the national government, also clearly explained how charge tax revenues would be used, using numerous channels; this played a key role in increasing public support.

Because the congestion tax policy is in the public interest, public communication is the key to its success. The government, especially the mayor, played a very important role, particularly in clarifying unverified information. Stockholm's experience also highlights the importance of a clear public communication strategy. Presenting the policy as an "environmental fee" rather than a "congestion charge" was helpful in removing the public's resistance to the conventional road charge. When communicating with the public, simplified information is vital to reduce confusion.

System Implementation

Risk Management

Before implementing the congestion tax, the government was concerned about the following risks:

- public complaints and opposition to the tax;

- thefts of vehicle license plates that could create confusion in charging;
- public boycott of the charge;
- illegal behavior to avoid the charge (e.g., blocking or hiding from the camera);
- technical malfunctions of the system;
- unauthorized use of the system to spy on drivers, thus causing invasion of privacy;
- adverse impacts on businesses within the charging zone, even bankruptcy; and
- depressed economy in the city center due to business relocation.

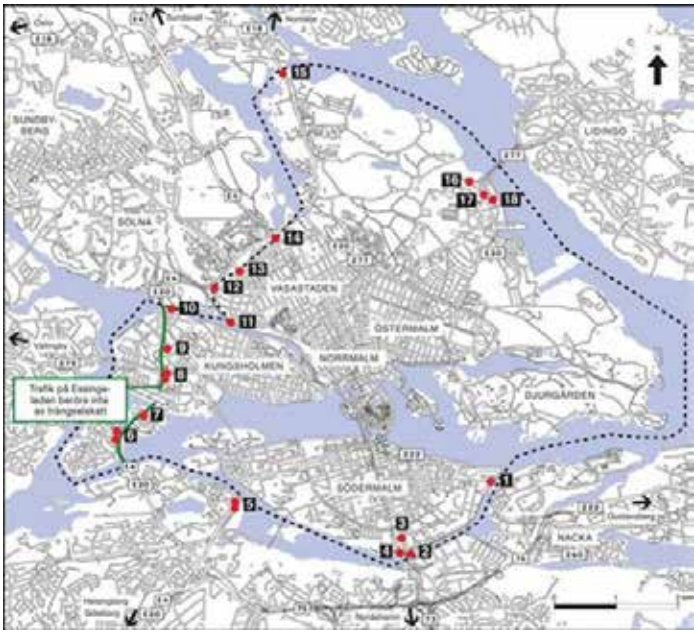
In view of these risks, the government and implementation teams took several precautions to "err on the side of caution." For example, in the event of technological system failure, the government would charge less to avoid any wrongful charges; in cases where the license plate is not captured well by cameras, the charge would be exempted. Any wrongful or unfair mischarge would quickly undermine public support for the system, whereas a few instances of exemptions and lower charges would have neutral or even positive impacts. These precautionary measures had the desired effect and the government avoided these risks once implementation began.

Implementation Scope

The delineation of the CC zone in Stockholm took into account geographical features, traffic patterns, and technical operational feasibility. Stockholm is a city surrounded by water, and the inner city is connected to the outer city mainly via bridges. Due to the long historic development of the city, the old inner city is where the city center is located and where traffic congestion is worst. The Stockholm government decided that the best solution would be to install monitoring equipment on the bridges and form a circle around the inner city as the charging boundary. This boundary contains 18 toll gates, which are the gateways to the CC zone, as shown in Figure 5-2.

The charging zone covers about 35 square km and was home to approximately 330,000 residents, of whom about 60,000 worked outside the zone in 2006 when the policy became effective. In addition, there were about 318,000 employees who worked inside the zone, more than two-thirds of whom commuted in from outside (Eliasson 2014).

Figure 5-2 | **The Congestion Charging Area in Stockholm**



Source: City of Stockholm, 2014

The CC zone in Stockholm took advantage of the natural geographical configuration of the city and installed charging equipment on the bridges to the inner city. This has greatly enhanced system operation and facilitated enforcement. This is a clear showcase for tailored policies that are respectful of specific local conditions and how they can simplify policy development and thus ease implementation.

Congestion Charge Rates

All Swedish motor vehicles are subject to the charge with the exception of five types of vehicles (as of May 2016). They are: buses over 14 tonnes, heavy-duty freight vehicles that are not used for freight transportation, ambulances, motorcycles, and electric bicycles.

Stockholm implements a bidirectional charging system with a daily upper limit. Vehicles are charged according to

the times of crossing the warning line (either entering or exiting the zone) and the time of day. The charging period is between 6:00 am and 6:30 pm from Monday to Friday (except for public holidays and the day before each holiday, and during July). When the scheme was first implemented, the rate for a single charge was between SEK 10 and SEK 20 (about USD 1.1–2.2) but the total daily charge could not exceed 60 SEK (about USD 6.6).

Stockholm adopted a new set of charging rates on January 1, 2016, and started charging on the Essingeleden road section. The highest rate for one entry or exit during peak hours is now increased from SEK 20 (about USD 2.2) to SEK 35 (about USD 3.8), and the daily upper limit is increased from SEK 60 (about USD 6.6) to SEK 105 (about USD 11.5).

Following Singapore and London, Stockholm is the third city to implement a CC. Therefore, the determination of the rate is based on the two precedents, and the city adopts a bidirectional charging system with a daily upper limit. This charging scheme avoids unnecessary traffic flow to/from the central area in the case of daily charges, while the upper limit reduces public discontent with the system.

Stockholm's CC is a tax and, per national legislation, congestion charges must be paid within three months. The first month is for verification of license plates and charges, and vehicle owners' obligations under the tax; the second month is for delivery of tax bills; the third month is for processing the charges by activating a direct debit system. If a driver's obligation has not been fulfilled in three months, a fine of SEK 500 (about USD 55.2) will be imposed. In cases where a tax of more than SEK 5,000 (USD 551.7) has not been paid for six months or more, the driver is subject to a possible ban on using the vehicle.

Selection of Vehicle Identification Technology

Stockholm compared the following three technological options for its congestion tax scheme.

London Model

The system in London is a pre-payment system. It is established based on drivers' liability. Drivers pay the charge either in advance or the next day, and the amount that is owed will increase if payment is delayed. The charge is a flat rate per day. For enforcement, the authorities use roadside cameras for random inspection. A vehicle that has not paid the charge after entering the CC zone will be fined.

A disadvantage of this system is that the charging scheme cannot be too complex. Complicated charge schemes would increase the workload. In Stockholm, the congestion tax is calculated based on the time of entering the zone, and the amount varies according to the time of day. If the London model were adopted, the driver would be required to check not only whether the vehicle was in the zone, but also what time the vehicle entered the zone. For example, if the first entry through the toll gate is made at 7:30 a.m., the driver will need to pay SEK 15 (about USD 1.7). However, many drivers do not know how much they should pay if they pass the toll gates again 20 minutes later. This may cause errors while paying. Overall, the technology would be very difficult to operate if the charging scheme is complicated.

GPS-based System

GPS is used to monitor vehicle travel routes, and verify whether the vehicle enters the charging area within defined charging times. This system is relatively expensive, because the system must be able to track vehicles at all times, even in areas where the signal is weak, in which case roadside monitoring equipment is required. Another reason for the high cost is that GPS devices must be installed in every vehicle. Most vehicles in Stockholm did not have GPS devices and, because vehicle inspection for GPS devices is labor intensive, the system is costly. The system has advantages in terms of enforcement and charging over a large area. It is relatively easy to monitor long-distance travel on highways. However, it is relatively difficult to set up a GPS-based system in a small confined area with a large number of vehicles like Stockholm, due to the limitation of the technology. The technology was therefore deemed inappropriate for Stockholm.

Gantry-based System

This system can be classified into two types: transponder-based dedicated short range communication (DSRC); and camera-based automatic number plate recognition (ANPR). At first, Stockholm used a combination of the two: transponder-based DSRC plus video identification. When a vehicle passes through the gantries (as shown in Figure 5-3), a micro-wave system activates the transponder mounted on the vehicle to register the entry or exit. In addition to the transponders, cameras are necessary to identify vehicles without transponders, to prevent owners from placing the transponders on other vehicles or intentionally blocking them.

Figure 5-3 | **A Congestion Charge Gantry in Stockholm**

Source: City of Stockholm, 2014

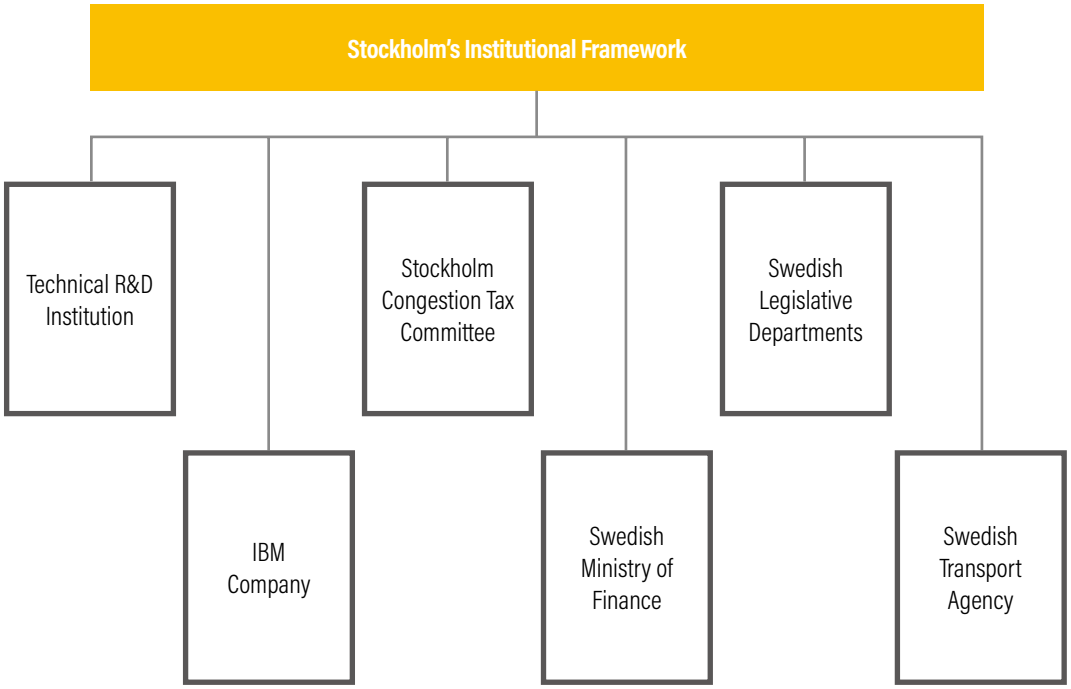
Stockholm chose to apply a gantry-based monitoring system that combines DSRC and ANPR mainly because of the very low identification rate of ANPR that was achieved during the system research stage in 2003. DSRC was employed with ANPR as scaffolding for vehicles without transponders. With improved identification technology, Stockholm can now rely on ANPR for vehicle inspection and recognition. An additional factor is that, under Swedish law, tax bills cannot be generated based only on DSRC; they require camera evidence as well. Combining the two sets of technologies simplifies implementation and enforcement because the charging zone is isolated and can be reached only via bridges. Finally, the system facilitates drive-through charging with multi-lane and free traffic flow features.

Institutional Framework

Successful implementation and operation of Stockholm's congestion tax policy is also attributed to a sound institutional framework, as shown in Figure 5-4.

- Technical Research and Development Institutions – responsible for early research on the congestion tax policy, including area selection and charge rates. The institutions also provide data for evaluation of the system post implementation. They are overseen by Stockholm's Congestion Tax Committee and support the decision-making entities.
- IBM Company responsible for design, construction, and adjustment of the first charging system.
- Stockholm Congestion Tax Committee – responsible for issuing assessment reports on the congestion tax policy, and public communication.

Figure 5-4 | **Institutional Framework for Operation and Management of Congestion Tax Policy**



- Swedish Ministry of Finance – responsible for management of the congestion tax and revenue redistribution for transport infrastructure investment.
- Swedish legislative departments – responsible for legislation and amendments to the congestion charge tax.
- Swedish Transport Agency – responsible for the technical system, payments and violations, communicating the policy to the public, and releasing related information to ensure that the charging process is understood by the public.

Complementary Measures

While Stockholm implemented the congestion tax policy, the government also invested heavily in complementary measures that responded to the changes in travel patterns resulting from the new congestion charge. Prior to the trial, the government had extended and improved public transport services. In part, this was necessary simply to meet increased travel demand that came with population growth. And in part, the political objective was to improve traffic conditions through combining the congestion tax and upgraded public transport. The extension of public transport services prior to implementation of the congestion tax provided extra service capacity that allowed residents to shift from private cars to buses.

Non-motorized transportation (bicycling and walking) has always been a focus in Sweden. Right after implementation of the tax, the government allocated significant funding to improving bicycle lanes, sidewalks, and bicycle parking facilities, promoting environmentally friendly travel, and encouraging people to shift from driving to cycling.

System Performance

The implementation of the CC policy has had obvious positive impacts on the environment, traffic conditions, and economy in Stockholm. The negative impacts about which the government was so concerned have so far not materialized. The public has experienced the benefits that were the intended outcome of the policy.

Environmental Impact

Improving the environment, especially air quality, was a major public concern. Because of this, the congestion tax was promoted as an environmental fee from the

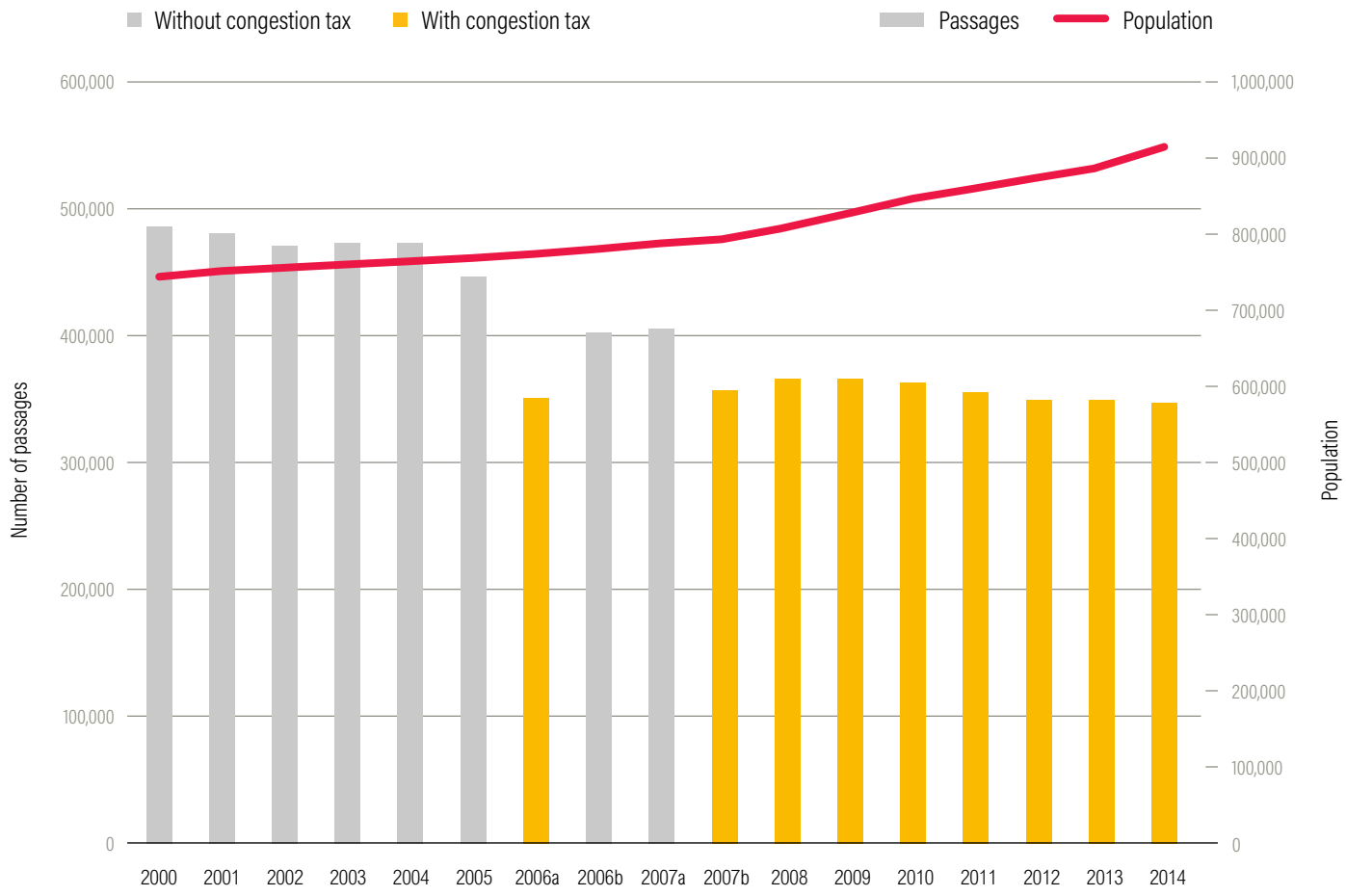
beginning. Emissions of pollutants are closely related to vehicle travel distance. After implementation of the congestion tax, vehicle emissions in the inner city have fallen by 10–15 percent (depending on the specific pollutant), and air pollutants have fallen by 10–14 percent due to reduced traffic volumes and travel distances (Eliasson 2014).

Effect on Traffic

One of the objectives of the implement CC in Stockholm is to reduce traffic volumes. As shown in Figure 5-5, traffic volumes across the boundary to/from the inner city have fallen dramatically, both during the trial in 2006 and after official operation began in 2007.

Before 2006, daily average traffic across the cordon was consistently above 450,000 vehicles. Several weeks after the trial began in 2006, traffic volume had dropped by about 22 percent. After the trial ended on July 31, 2006, there was a small increase in traffic volume, but to lower levels than those seen prior to the trial; in other words, the impact of the trial continued. This may indicate that some vehicle users developed their new travel habits during the trial and kept to them even after the trial ended. After the charging scheme was officially implemented in August 2007, the traffic volume fell back to the same level as during the trial period in 2006. In September 2012, due to cancellation of the exemption for vehicles using alternative fuels, the traffic volumes decreased further.

Figure 5-5 | **Average Traffic Volumes across Stockholm's Charging Boundary, 2000-2014**

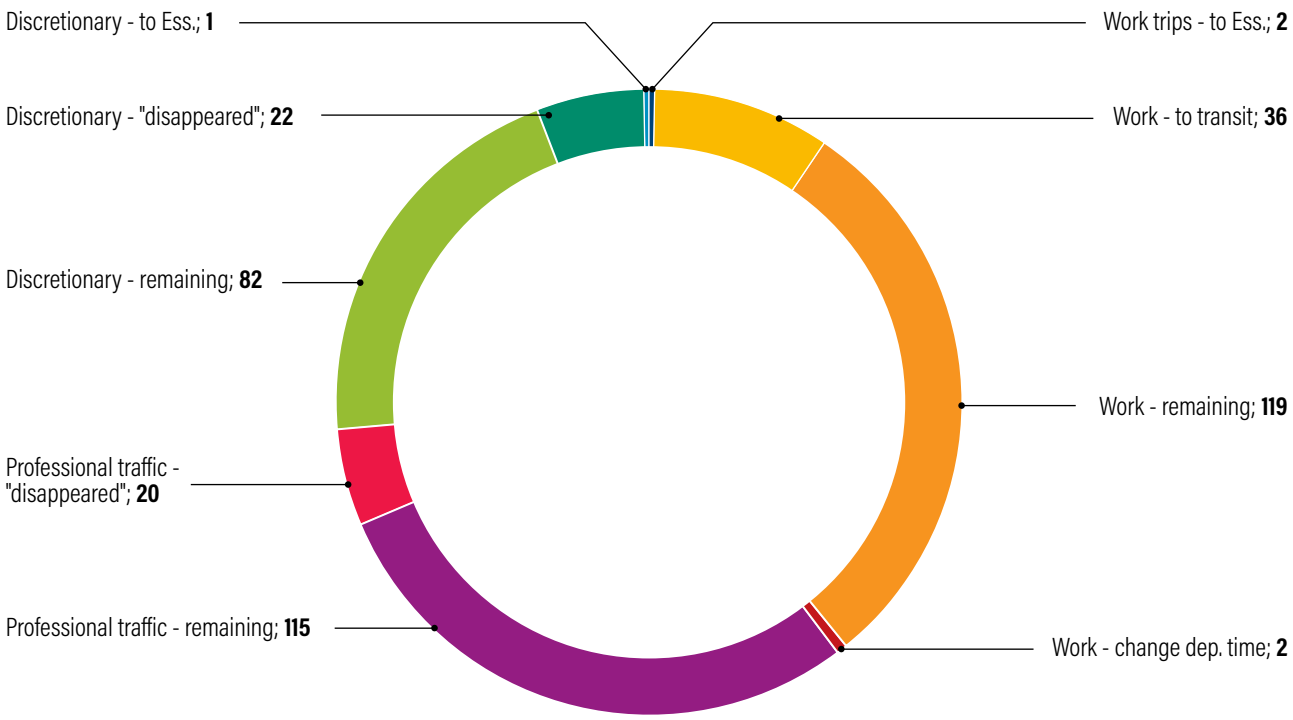


Source: City of Stockholm, 2014

Change of Travel Mode

Franklin et al. (2009) studied the change in travel modes resulting from the CC by analyzing variations in traffic volume across the charging boundary, as shown in Figure 5-6. This research classified travel into three categories—commuting (travel for work), discretionary travel, and professional traffic (e.g., freight transport, taxi). As shown in Figure 5-6, traffic volume across the boundary dropped by about 21 percent, from 399,000 vehicles before implementation to 316,000 after implementation. Of this reduction, 10 percent was accounted for by commuting traffic (9% shifted to bus, 0.5% selected the Essinge bypass, and 0.5% changed travel time); 6 percent was accounted for by discretionary travel (5.5% changed destination or reduced travel frequency, 0.5% selected another road), and 5 percent was accounted for by professional traffic (the specific direction was unclear). The research indicates that the CC policy had a significant influence on people's travel modes, changing commuting traffic especially.

Figure 5-6 | **Estimated Changes in Car Trips across the Charging Boundary during Charged Hours (in 1,000 trips)**



Source: Franklin et al., 2009

Low Emission Zone (LEZ)

The Stockholm government's policy of integrating the congestion tax with a LEZ enhanced the reduction in urban vehicle emissions in the city.

Standards and Enforcement of Low Emission Zone

The LEZ was set up in July 1996, and was defined as a 10 km by 10 km area centered on Stockholm's city center, as shown in Figure 5-7. Trucks and buses that are not in compliance with the emission standard are not allowed to enter the zone. Since 1996, when this policy was implemented, the vehicle emissions standard has been continually raised. The latest restrictions are as follows:

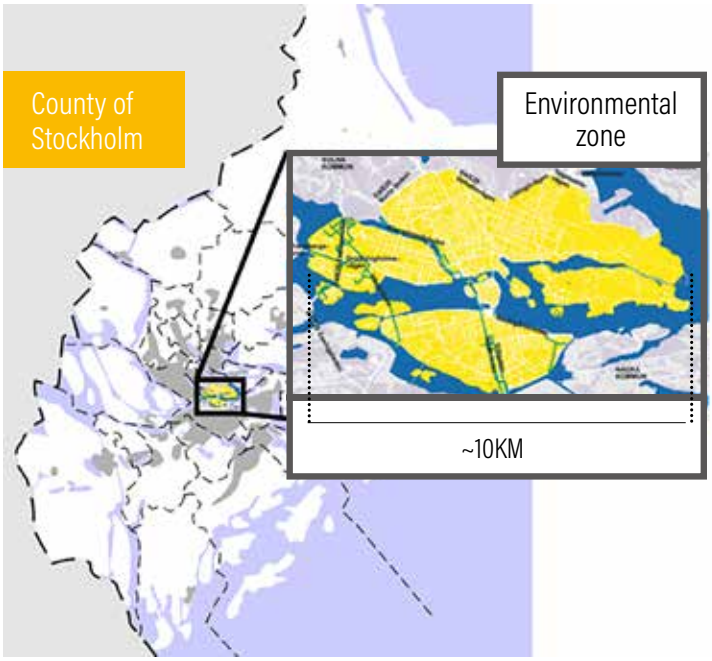
- Vehicles of Euro II standard or lower can no longer enter LEZ
- Vehicles of Euro III standard can enter LEZ till the end of 2015
- Vehicles of Euro IV standard can enter LEZ till the end of 2016
- Vehicles of Euro V standard and Enhanced Environmentally Friendly Vehicles (EEFVs) can enter LEZ till the end of 2020.

Enforcement within LEZ is carried out by random inspection by traffic police. Vehicles that fall short of required standards are subject to a fine of SEK 1,000 (about USD 111.8). Enforcement of the law is very strict. For example, if a bus with passengers on board is found not to be in compliance with the standard, the bus will be banned from the zone. All the passengers are required to leave the bus and walk if they wish to enter LEZ.

Implementation Effect of the Low Emission Zone

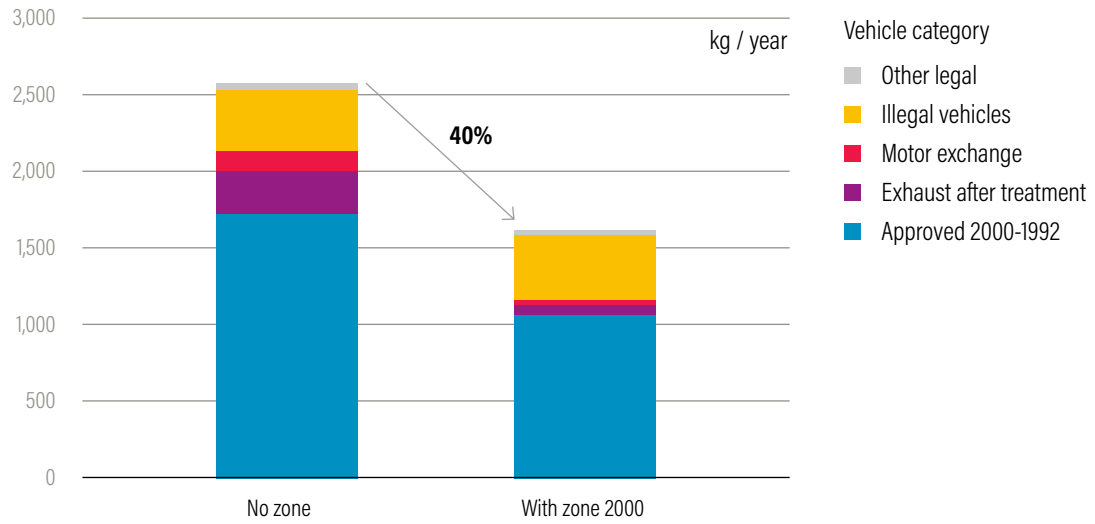
After implementation of LEZ, concentrations of both NO_2 and PM within the area dropped substantially. In addition, noise in the LEZ has been reduced because EEFVs now represent a larger share of vehicles within the zone. According to Johansson and Burman (2001), emissions of PM from heavy-duty vehicles in the zone decreased about 40 percent by 2000, after four years of LEZ enforcement, as shown in Figure 5-8.

Figure 5-7 | **Stockholm's Low Emission Zone**



Source: Johansson, 2014

Figure 5-8 | **Emission of PM with and without LEZ from heavy-duty vehicles in Stockholm 2000**



Source: Johansson and Burman, 2001

Continuous monitoring of the PM from exhaust emissions within and outside the LEZ from 1996 to 2001 showed that the actual reductions occurring outside the zone after the LEZ policy was implemented in 1996 were greater than inside the zone (Johansson 2014).

Stockholm Best Practices Summary

Both the CC and LEZ polices have contributed to reduced traffic congestion and improved air quality in Stockholm. In general, the success of Stockholm's congestion alleviation and emissions reduction policies can be attributed to the following factors:

Establishment of a national-level tax law legally safeguards the implementation of the policy

The Swedish Constitution specifies that infrastructure in Stockholm cannot be subjected to a local charge, and that residents outside Stockholm shall not pay tax to Stockholm authorities. Therefore, CC in Stockholm had to be approved and managed by the Swedish national government through voting by the parliament (the Riksdag). Stockholm's congestion tax is in nature a national-level tax, and the setting-up procedure and revenue management are the responsibility of the central government. The fact that CC in Stockholm is part of the national taxation system plays a key role in assuring its successful implementation:

- Mandatory. Formulating CC as a tax enhances the legitimacy of the policy, and makes it compulsory for citizens. Violations will be treated as breaking the law.
- Empowering. Stockholm is able to include vehicles from other regions in the charging scheme, enhancing its coverage and its authority.
- Credible. Revenues and revenue allocation from the congestion tax are transparent to the public, which improves acceptability, and facilitates communication between the government, citizens, and political parties.

The Municipal Council of Stockholm invested heavily in building communication channels with the public. At the height of the publicity campaigns for the policy, the Mayor of Stockholm attended radio and TV interviews twice a day and held press conferences to disclose the latest updates, thereby effectively avoiding the spread of rumors and unverified reports. In addition, the Swedish Transport Agency stressed the importance of simplifying the messages to minimize public confusion.

Public inquiry is required for all policy-making in Sweden. The government first solicits the opinions of communities and social groups before developing a proposal. The proposal can be released to the public only after it has been approved and voted through by the Riksdag. The public inquiry into the congestion tax lasted two years, allowing sufficient time for the government to collect feedback and analyze public demands and concerns. The congestion

policy was then developed on the basis of analyzing this information. The public inquiry phase can also serve as the means to balance different stakeholder interests.

The public in Sweden is generally more concerned with environmental issues and related health risks than with traffic congestion. Accordingly, the government emphasized the beneficial air quality impacts of the CC policy, which helped to win support from citizens.

Seven-month system trial helps gain public support

Many cities that are considering congestion alleviation and emissions reduction policies often conduct evaluations of CC outcomes based on theory and model calculations, rather than on the basis of actual operating conditions. Stockholm carried out a trial of the CC system before the referendum, which could help the public see benefits from the scheme, including reduced congestion and better air quality. After the trial was completed, the government promptly released an assessment report that showed positive outcomes to the public, which reinforced support. This tactical approach contributed to the 51.3 percent favorable vote in the referendum.

Reliable technologies provide safeguards for operation and management of the system

Before establishing the CC system, Stockholm compared features of three technology options, namely the London model, GPS based positioning system, and a gantry-based monitoring system. DSRC and ANPR were selected in the end, on the basis of overall considerations for manpower, funds, implementation, enforcement, and technical maturity. Stockholm combined the two types of monitoring technology, and set up monitoring equipment over bridges that provide natural access points to the inner city, ensuring a charging system that features drive-through processing, and multi-lane and free-flow driving. Later, with improved recognition capacity, Stockholm upgraded the charging system to use ANPR as the key vehicle identification and inspection technology.

Finances are transparent to maintain long-term public trust in the policy

Public confidence in the CC policy depends largely on whether charging revenues are managed in a transparent and just manner. Because the CC is a national-level tax policy, the revenues are part of the national budget, are managed by the Riksdag, and are allocated mainly to infrastructure projects for Stockholm and affiliated counties. All revenue allocations are clearly stated on the tax bill for the public to see, ensuring transparent fund collection and redistribution, and a high level of public confidence.

CONCLUSIONS

The geographic conditions, political situations, and transportation systems are different in London, Singapore, and Stockholm. However, CC polices have been successfully implemented in all three cities. The LEZs established in London and Stockholm have received positive results as well. Table 6-1 compares practices in the three cities, including challenges, stakeholder concerns, complementary measures, public communication strategies, technology selection procedures, and policy outcomes.

Based on the experiences of these three cities, we conclude that the key factors in successful implementation of congestion and emissions control policies include: some form of legal safeguard from national government; strong policy objectives on the part of local government; a comprehensive feasibility study; equity and transparency during policy implementation; reliable technologies; effective public communication; and sound complementary measurements.

In China, city authorities are the decision-makers regarding LEZ/CC policies, while national government plays an important role in policy promotion. Based on the combined experiences of London, Singapore, and Stockholm, and features that are unique to China, we propose the following recommendations for decision-makers:

National Government

- *Legal Safeguard:* the national government should combine the objectives of local LEZ/CC schemes with national transportation strategies in a clear and consistent manner. National government should also support the implementation of local congestion alleviation and emissions reduction policies through favorable legislation, regulation, and policies.

Table 6-1 | **Comparison of the LEZ/CC Schemes in London, Singapore, and Stockholm (I)**

Features	London	Singapore	Stockholm
Policy	LEZ and CC	CC	LEZ and CC
Summary	Legal safeguard from national government, and political commitment from local government Clear policy objectives, and thorough consideration of details Comprehensive public consultation, with open and transparent public communication Well-designed complementary measurements for transport sector Effective management and continuous improvement	Thorough consideration of policy results, while balancing theory and public acceptance Highly controlled technology development and management Emphasis on social equity and not-for-profit Focus on public communication and public participation	National law on taxation Effective communication between government and citizens Successful system trial Strong technology support Transparent revenue allocation
Timeline	CC in 2003 (less than 3 years' preparation) LEZ in 2008	ALS in 1975 and ERP in 1998 (with 13 years of preparation) GPS-based ERP (stage II) in 2017	LEZ in 1996 CC in 2007 (4 years' preparation)
Prerequisites	Initiated by national government and mayor	Initiated by government	Trial Referendum
Exemptions	Multiple exemptions, including ultra-low emission discount	No exemptions, except for emergency vehicles such as police cars, fire trucks, and ambulances	Multiple exemptions
Charging Hours	7:00 am–6:00 pm, Monday to Friday	7:30 am–8:00 pm, Monday to Friday 12:30 pm–8:00 pm on Saturdays 7:30 am–1:00 pm on public holidays (differs on some road sections)	6:00 am–6:30 pm, Monday to Friday
Rate	Daily flat rate of £11.50 (about USD 14.2)	Charge triggered by passing gantries. Rates vary from 0 to SGD 12 (about USD 8.4), depending on vehicle type, time, and location	SEK 35 (about USD 3.8) charge incurred when passing gantries during rush hours Daily maximum of SEK 105 (about USD 11.3)
Revenue Allocation	Dedicated to improving transport system of London during the first 10 years of implementation	Revenue to national government, no dedicated usage	Dedicated to infrastructure development in Stockholm Details of revenue allocation shown on tax bill

Table 6-1 | **Comparison of the LEZ/CC Schemes in London, Singapore, and Stockholm (II)**

Features	London	Singapore	Stockholm
Challenges	Impacts on low-income groups, and overall economy Issues of traffic diverging and compulsory enforcement Technical feasibility	Privacy of vehicle owners Safety of cash card Charging of non-local vehicles System reliability	Theft of vehicle license plates Public boycott Blocking or changing of vehicle plates to escape charging Charging system malfunction Privacy of vehicle owners
Concerns from Stakeholders	Decreased business activities in zone Increased cost of transportation to logistics suppliers Dividing charges between taxi drivers and passengers	Over-charging of taxis with multiple entries to charging zone Indirect negative influence on business activities in the zone Financial pressure on low-income groups	Negative influences on retailers within charging zone Business relocation from downtown area, causing recession within the zone Large number of complaints from public
Complementary Measures	Improved public transportation service Alternative detour plan Optimized traffic signal timing Exclusive parking zone for residents around charging boundaries	Reduced vehicle registration fees Introduction of carbon emissions-based vehicle scheme Revised certificate of entitlement for vehicles "Free Pre-Peak Travel" on MRT	Extension of public transport services Improved bicycle lanes and sidewalks
Public Communication Strategies	National government released *Road Charging Options for London* Promotion of CC policy during election campaign Professional surveys of public and key stakeholders Open access details of the policies in newspaper, radio, television, and other media Road shows and community meetings to communicate with residents	Land Transport Authority Gallery, and reader-friendly brochures Open-to-all traffic information Community partner teams to manage traffic within communities, and to promote policies Social work Alerts on charging rate adjustments Use of CC rather than road tolls to put emphasis on congestion alleviation	Public inquiry to collect feedback and understand public expectations Emphasis on environment during promotion Pioneer of CC trial project Frequent and accurate disclosure on policy implementation Easy-to-understand communication materials
Selection of Enforcement Strategies	ANPR • Verified technology • Quick to set up (completion within mayor's term) • Influences on cityscape	DSRC • Stable • Intelligent • Environmentally friendly • Flexible • Easy to use • Affordable	Early stages: ANPR+DSRC Now: ANPR • Labor and construction cost • Recognition rate • Installation of cameras for policy enforcement as required by law

Table 6-1 | **Comparison of the LEZ/CC Schemes in London, Singapore, and Stockholm (III)**

Features	London	Singapore	Stockholm
Policy Results	CC policy (within one year of policy becoming effective): • Number of private vehicles entering charging zone dropped by 30% during charging hours, with level of congestion dropping by 30% • Number of buses and coaches entering the central area increased by 20%, • Number of bus passengers entering charging zone during morning rush hours increased from 77,000 to 106,000 LEZ policy (by June 2013): • Over 95% of vehicles entering zone have met specified emissions requirements • Concentration of PM dropped by ~2.46–3.07% within the zone, and by 1% outside the zone	• The number of vehicles in Singapore has continuously increased, but traffic volume in the restricted zone remains unchanged • Ideal speed has been reached in restricted road sections • Temporal-spatial redistribution of traffic flow achieved during rush hours • Share of public transport increased to 66% during rush hours	Trial implementation of CC policy: • ~10%–15% reduction in vehicle emissions in inner city • ~10%–14% reduction in air pollutant concentrations • 21% reduction in traffic volumes LEZ policy: • PM emissions from heavy-duty vehicles across the city decreased by 40% 4 years after introduction of LEZ

Municipal Government

- *Strong Policy Objectives:* the municipal government should set clear and strong objectives before implementing any LEZ/CC scheme. Strong objectives are the starting point for developing an effective plan, and can help to ensure consistency throughout policy preparation, implementation, operation, management, and monitoring. Consensus on objectives and the implementation process should be reached early on because multiple local government agencies will be involved during policy development and enforcement.
- *Comprehensive Feasibility Study:* local government should conduct comprehensive studies focusing on implementation details, such as charging fees and targets. Modeling and scientific analyses are important to evaluate different scenarios and provide support to decision-making.
- *Equity and Transparency in Policy Implementation:* the allocation of revenues from congestion charging is critical to policy implementation outcomes. It is recommended that revenues be dedicated to transportation system improvement, and that the process is transparent to the public. This is helpful in raising policy acceptability among the public.
- *Reliable Technologies:* adopting innovative and advanced technologies should not be the main focus of technology selection. Field-proven technologies that are well suited to the local context offer the greatest chance of successful implementation.
- *Effective Public Communication:* Public communication is one of the key elements in ensuring policy acceptability. Communication strategies should be effective, and updated to take account of public feedback. This enables public communication to serve its purpose of improving policy acceptability.

- *Sound Complementary Measurements:* the LEZ/CC scheme should be considered as an effort to improving transportation and environmental quality. A complete set of complementary measures that offer viable alternative travel options and mitigate potentially unwelcome impacts of the scheme should be developed before implementation.

Every city will have its own methods for achieving the successful implementation of CC and LEZ policies. Strong political will is a prerequisite. The development of a supportive political framework and appropriate technical approaches are equally important. The implementation of LEZ/CC policies has significant impacts on the lives of city residents, which necessitate close attention and involvement on the part of government agencies. Government departments and agencies, especially transportation and environment agencies, will not be able to work in isolation. They have to coordinate and work together, and communicate extensively with different stakeholders.

The implementation of LEZ/CC in Chinese cities will encounter many challenges and barriers similar to those experienced by London, Singapore, and Stockholm. However, it is to be hoped that the government's and the public's resolution to combat traffic congestion and reduce air pollution will clear all obstacles on the way to success.

ENDNOTE

1. We use the term "safeguard" to mean some form of national legal status for CC/LEZ policies that protects and ensures their robustness and continuity over time.

2. Other cities have seen positive results from implementing the CC policy, such as Milan (Italy), Gothenburg (Sweden), Oslo, Trondheim, and Bergen (Norway).

3. The former Department for Transport.

4. On the other hand, statistics show that the volume of traffic in the original zone was still approximately 30 percent lower than during the pre-CC period, and has remained so till the present day.

5. The dramatic drops in week 1 and week 52 are due to Christmas and New Year Holiday.

6. Vehicles eligible for ALS exemptions at the beginning include: buses, taxies, motorcycles, commercial transportation vehicles, police vehicles, military vehicles, ambulances, fire trucks, and cars with more than four seats.

7. The five special holidays include New Year's eve, Lunar New Year, Hari Raya Aidilfitri, Deepavali, and Christmas.

8. LTA considered reducing the charge for carpool vehicles (over four persons); however, considering the fairness principle, it dropped the idea.

9. In addition, school break will also be considered for rate calculation.

10. For example, the previous price transition was SGD 2 (about USD 1.4) from 8:00 am to 8:30 am, and SGD 3 (about USD 2.1) from 8:30 am to 9:00 am. After adjustment, the price transitioned from SGD 2 (about USD 1.4) from 8:05 am to 8:30 am, SGD 2.5 (about USD 1.7) from 8:30 am to 8:35 am, then SGD 3 after 8:35 am (about USD 2.1).

11. For more information on Traffic Smart, see https://www.onemotoring.com.sg/content/onemotoring/en/imap.html?param=redirect

12. This violation is relatively common near the charging gate adjacent to Buddhist Temple in Sima Road, for example.

13. A facility commonly seen on the street that is used to pay various bills and government charges.

14. An online shopping website popular in Singapore.

15. Depending on its width, the cost of a single charging gate is about SGD 1 million to 3 million.

16. The Central Computer System runs 24 hours/day, to ensure that all ERP charging gantries can operate normally. The center also monitors operation of all systems, and is responsible for enforcement monitoring and charging transaction treatment. The system is watched over by three shifts of personnel in 24 hours, six persons per shift.

17. According to interviews with LTA, the annual operating and maintenance cost of one charging gate is about SGD 300,000. The figure of 13% is calculated based on interviews with the project team; according to Luo (2009), the operating cost at that time accounted for 20 percent of total income.

18. The lowering of ARF is partly due to the introduction of the certificate of entitlement (COE) in 1990.

19. The function is similar to that of the public transport card in China, which can be used not only for traveling, but also for shopping in convenience stores.

20. The temperature limit is set considering the circumstance when a vehicle is parked in the open during summer. The IU and cash card must be functional under these conditions.

21. The IU is upgraded to duo-model, i.e., it accepts both in-contact and non-contact IC card (Mitsubishi Heavy Industries 2015b).

22. The specific test procedure is complicated, and not described in detail here. For more detailed information, see: https://www.mhi.co.jp/technology/review/pdf/e504/e504015.pdf

23. VQS COE is paid for as a one-time purchase by the driver when buying a car; it is a "sunk cost" for the buyer, and creates little public discontent after the car is purchased. But ERP is a variable and continuing cost, which is paid in accordance with road-use conditions. The cancellation or loosening of COE, compensated by an increase in ERP may lead to long-term public discontent. An added risk is that, if the VQS quota is increased and compensated by a high ERP price, more cars will be purchased and more discontent may be caused. Based on this, Singapore government has not altered VQS policy.

24. The initial time and charge rate as broadcast were adjusted before implementation.

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