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Jörg Bellmann /Andreas Eichinger/
Alexander Eisenkopf/Andreas Knorr

Urban Congestion Charging with an Environmental Component –

The Central London Congestion Charge

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Discussion Papers

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Jörg Bellmann, Dipl.-Pol., Mag.rer.publ.

Forschungsreferent im Projekt „Möglichkeiten und Grenzen des Road Pricing" am Deutschen Forschungsinstitut für öffentliche Verwaltung Speyer

Andreas Eichinger, Dipl.-Ökonom

Economist und Projektleiter am European Center for Aviation Development – ECAD GmbH, Darmstadt

Universitätsprofessor Dr. rer.pol. Alexander Eisenkopf

Inhaber des Lehrstuhls für Allgemeine Betriebswirtschaftslehre & Mobility Management an der Zeppelin University Friedrichshafen

Universitätsprofessor Dr. rer.pol. Andreas Knorr

Ordentliches Mitglied des
Deutschen Forschungsinstituts für öffentliche Verwaltung Speyer

Inhaber des Lehrstuhls für Volkswirtschaftslehre, insbesondere nationale und internationale Wirtschaftspolitik an der Deutschen Hochschule für Verwaltungswissenschaften Speyer

Contents

Abstract

Congestion charging or more general road pricing describes the levying of fees for the use of certain road sections. One of the world's largest and most sophisticated congestion charging schemes has been introduced in Central London on 17 February 2003. Its primary objective is to sustainably relieve regularly congested Central London roads of individual transport. It had been intended to alter the scheme in order to tackle traffic related emissions and to confront climate change. However, the so-called Emissions Related Congestion Charge scheduled for introduction on 27 October 2008 has finally been scrapped. The aim of the following treatise is threefold. Firstly, it introduces to the general economic principles of road pricing in order to internalize external costs. Secondly, on the one hand it provides an overview of important aspects of London's charging scheme and on the other hand presents impacts of the congestion charge so far. Finally, this treatise discusses the forecasted impacts of the proposed emissions related variations to the existing charging scheme.

1. Introduction

Congestion as well as accidents, environmental and noise pollution are all inevitable and negative concomitants of transport. Traditional approaches in order to overcome or at least mitigate these problems were on the one hand the continuous extension and upgrading of infrastructure and on the other hand the extensive promotion of public transport. In essence, both strategies did not lead to the desired results, irrespective of the difficult further extension of infrastructure due to the political resistance of citizens and local authorities directly concerned. What is more, the alternative public transport is characterised by a stagnating or even declining modal split while the number of passengers transported increases in absolute terms.

A basic economic principle states that every user of a resource should bear the full costs incurred by using that specific resource in order to warrant an efficient resource allocation. In case the pricing mechanism is not applied for the rationing of infrastructure access or not similarly applied for all modes of transport, the resulting inefficiencies and misallocation – including intermodal distortions in allocation – will inevitably lead to significant economical costs and, therefore, welfare losses. These losses can be ostensively illustrated by the example of road traffic congestion and road transport related environmental pollution.

Meanwhile, technological change enabled the imposition of genuine use-related access charges – apart from the relatively primitive, incomplete as well as inaccurate toll and vignette systems. However, public acceptance of such systems is still regularly low whenever the introduction of a real congestion charging systems is politically discussed. Nevertheless, more and more cities all over the world successfully introduce road pricing systems – the Asiatic city state Singapore being the forerunner. In 1975, initially a vignette-based systems has been introduced in Singapore, however this system has been replaced by a more sophisticated electronic charging system in 1998. Further, but technically less complex, substantially smaller and pursuing diverging aims, congestion charging systems are operated in several Norwegian cities, in Sweden (Stockholm), in Australia (Melbourne) and Canada (Toronto).

2. Objectives of Road Pricing

Road pricing describes the levying of fees for the use of certain road sections. Firstly, road charges may be used to generate revenues in order to finance road infrastructure. Secondly, they may serve as a means to reduce transport-related negative external effects as congestion (congestion charging) or environmental damages (environmental pricing). In this term, road pricing serves as a means to assign the full costs incurred by users when using a specific resource, in our case road infrastructure or the environment, in order to minimise the welfare alleviating misallocation of resources. Ultimately, politicians decide about the level of cost allocation – costs can in principle be fully or partially assigned to respective users.

2.1 Financing of Infrastructure

The generation of revenues for financing road infrastructure can be one purpose of road pricing. Normally, expenditures on roads are provided by public budget. But public budgets often underlie fiscal constraints. Furthermore, according to the basic economic principle, that every user of a resource should bear the full costs incurred by using that specific resource, costs of road infrastructure use should be passed on to the road users. For these reasons, road tolls seem to be an effective means for financing infrastructure. Firstly, infrastructure supply – both new construction and improvement – with financial requirements independent of road use can be financed by tolls. Secondly, road tolls can be earmarked for structural maintenance. These maintenance costs result either from the use of road infrastructure or are uncoupled of traffic. Finally, routine and winter maintenance costs, which quite naturally arise due to road use, can be directly borne by road users.[1]

Toll financing has been successfully implemented in Norway as a supplement to government funding. Until now, seven Norwegian cities, including Oslo, Bergen and Trondheim, have implemented urban toll rings. Furthermore, several inter urban projects are financed through road tolls. In Norway, toll revenues are supposed to cover investment costs but not operation and maintenance of the road or pub-

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1 See *Teubel* (2001), pp. 47-51; *Stützer* (2007), pp. 30-40.

lic transport network. Furthermore, toll income can be transferred to public transport investment programmes only to a certain extent. But it is prohibited to use the charging schemes for traffic management purposes. Therefore, the effects on traffic volumes and congestion have been negligible, less than a five percent decrease. Today, road tolls contribute about 35 percent to the total annual state road construction budget.[2]

2.2 Reducing Congestion

Charges aiming at regulating and/or rationing infrastructure and at assigning the actual cost of congestion to respective road users are commonly known as congestion pricing. Thus, congestion pricing essentially represents a special kind of road pricing. The London Congestion Charge dealt with in this treatise is such a charge as the politicians responsible for its introduction essentially wished a sustainable increase of the average travelling speed and a reduction of congestion within Central London. Besides London, politicians in Singapore[3] and Stockholm[4] seek to reduce traffic volumes and congestion via road tolls.

Economically, the phenomenon of congestion occurs if demand for road space exceeds supply. Charges might be levied in order to regulate or ration road use, e.g., in cases where infrastructural resources are scarce. Up to the point of maximum capacity of a road or a road network, vehicles enter a specific part of the road or road network without causing negative effects. Both, traffic flow measured in the number of vehicles passing a certain point at a certain time and traffic speed, are not negatively influenced by additional vehicles on the road/road network. All vehicles move with high speeds and hence travel times are minimized. When the road or road network reaches its maximum capacity, traffic flow reaches its maximum and any additional vehicle entering the specific road/road network impedes the vehicles already moving. This obstruction turns out in a slowdown in travel speed and an increase of travel time. If vehicles keep on enter-

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2 For an overview of the Norwegian experiences see *Ramjerdi* (2004) and *Wærsted* (2005).

3 See e.g. *Chin* (2005) and *Menon* (2006).

4 See e.g. *Puls* (2008), pp. 63-74.

ing this specific road/road network, both traffic flow and traffic speeds finally decrease steeply. As speed reaches zero, travel time tends to infinity. Consequently, congestion is the difference between the times needed for a certain mileage, e.g., a kilometre, during uncongested and congested times. This means, congestion can be described as travel time delays, which moving vehicles impose on each other.[5]

The continuous demand for road space can be explained by the gap between the total costs, which incur due to the use of a road, and the costs each vehicle driver is personally faced with. In deciding whether and when to travel users regularly account for their own private costs, i.e., merely their own necessary time expenditure, fuel costs, parking levies etc. For example, as traffic moves with high speed time required for travelling a particular distance is minimized. Thus, time costs and fuel costs are low. As aforementioned, as more and more vehicles enter a certain road or road network, average traffic speed drops and travel time and, hence, time and fuel costs increase. Nevertheless these external costs, which each single driver imposes on other road users or even the whole society, are ignored by him or her.

The determination of road charges follows marginal cost considerations as these reflect additional costs, which incur as a result of the additional use of the existing infrastructure by a further vehicle. Figure 1 below illustrates this basic principle.

The ordinate resembles the costs of infrastructure use while the abscissa shows the number of vehicles using the infrastructure. D represents a typical falling demand curve; consequently, the use of the infrastructure in question decreases with increasing costs of use. In case the number of vehicles simultaneously using the respective infrastructure at a certain point of time exceeds the optimal amount f^K reciprocate obstructions, congestion and traffic jams, are the consequence. In such a case private and social costs of an additional journey diverge; thus, social marginal costs (SMC) exceed private marginal costs (PMC). The difference between private marginal costs and social marginal costs reflects marginal congestion costs.

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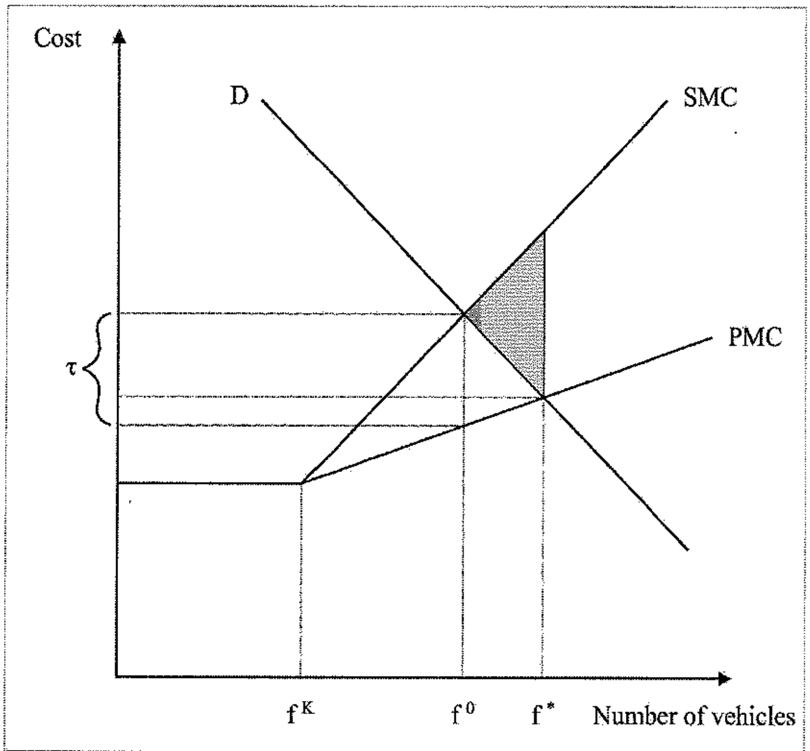
5 See *Teubel* (2001), pp. 77-83; Transport for London (2003b), pp. 45-48; *Button* (2004): pp. 4-5; OECD/ ECMT (2007), pp. 28-30 and pp. 48-49.

Figure 1 The economically optimal road charge



Source: Teubel, U. (2001), p. 38.

As described above, if no road pricing scheme exists users will purely incorporate their own private marginal costs, particularly their own time (including congestion) and vehicle operating costs, when making a decision about a journey; thus, excessive use of infrastructure may occur very often during certain peak times (f*). Economically, too many journeys are undertaken; consequently, social welfare losses occur (the grey triangle illustrates these welfare losses). However, these welfare losses may be avoided if all external costs – in this case all congestion costs incurred – are fully internalized. The optimal congestion charge is therefore identical with the marginal congestion cost, i.e., the monetarized additional travel time which the road users impede on each other. According to the theoretical ideal case demand will then decrease to the economically optimal level (f^0). Consequently, the average travelling speed will increase. If the existence of an elastic demand curve is assumed, the introduction of a road use charge amounting to τ would be an adequate solution to the problem.

Such a charge equals the additional external congestion costs incurred by an additional vehicle using the respective infrastructure.[6]

However, the identification of an optimal charge for parts of or a whole inner-city road network is in practice surely more complicated than suggested by this simple and static model. The standard congestion model is based on the assumption of identical road users, which do not differ in the type of cars they use or in their value of time. Obviously, travel time is a key cost component but the values of travel time and travel time savings differ between road users according to trip purpose, income, age and gender. Hence, road pricing schemes should in principal be reviewed on an individual basis. Furthermore, it is assumed that congestion is solely caused by excess demand. Interruptions of the traffic caused by crossroads, traffic lights, traffic incidents such as crashes or broken-down vehicles, road works or bottlenecks, e.g., tunnels or bridges, are not taken into account. However, such congestion causes play an important role with regard to urban congestion.[7]

2.3 Improving Environment

Road pricing in order to improve the quality of the environment follows the same mechanisms as congestion charging. Road users ought to be faced with the total cost they cause by their use of road infrastructure. This means that road users should be made aware of the (marginal) social costs of road transport. As in case of congestion charging, vehicle drivers make their decision to start a trip solely upon (marginal) private costs. The costs of environmental damages caused by road traffic are not relevant for individual decision-making. A charge should be set at the level of the (marginal) environmental costs to internalize these negative external effects. A charging scheme implemented in order to reduce congestion will, as a side effect, reduce road traffic related emissions because reduced traffic and congestion level and higher speed entail fewer emissions. Ergo, most charges can

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6 See *Teubel* (2001), pp. 83-86; *Blow/Leicester/Smith* (2003), pp. 2-3; *Button* (2004): pp. 5-8; *Rouwendal/Verhoef* (2006), pp. 107-108.

7 For a detailed critique see *Teubel* (2001), pp. 90-92; *Puls* (2008), pp. 31-34.

be set to pursue both reducing congestion and restraining environmental damages.[8]

Environmental costs can be split into costs due to air pollutants, greenhouse gases and traffic noise. The most common air pollutants are oxides of nitrogen (NO_x), e.g., nitrogen monoxide (NO) and nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO) and particle material (PM). They are all directly or indirectly resulting from engine combustion processes. Ozone for instance is a secondary pollutant formed by the reaction of NO_x and other compounds with sunlight. Particle materials can be sub-divided into fine particles, i.e., particles less than 2.5 μm ($PM_{2.5}$), and coarse particle, which have a size of less than 10 μm (PM_{10}). Besides fuel combustion, they stem from brakes and tyres abrasion. All air pollutants harm human health. They aggravate respiratory, reduce lung functions and cause respiratory diseases. Furthermore, inhaled CO reduces the ability of blood to carry oxygen and accelerates the greenhouse effect.[9]

Greenhouse gases, the best known is without any doubt carbon dioxide (CO_2), do not damage human health directly but cause the so-called greenhouse effect. Usually a natural balance between energy coming into the Earth's atmosphere from the sun and the energy being released from the Earth back into space exists. Much of the high-energy radiant energy from the sun is absorbed in the Earth's upper atmosphere; however, some of the ultraviolet radiant energy passes through. This ultraviolet radiant energy reaches the Earth's surface and warms it. As the Earth cools down again, it releases energy as infrared radiation. Greenhouse gases absorb some of the energy released as infrared radiation as the Earth cools down, re-emit it and then some of the energy is sent back towards the Earth rather than into space. The average temperature of the Earth results out of this warming and cooling process. Without this effect, the Earth's surface temperature would be approximately 30°C lower. Since pre-industrial times human activities are changing the composition of the atmosphere. Concentrations have steadily risen from 280 parts per million

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8 See *Hartwig* (2001), p. 172; *Teubel* (2001), p. 41-43; *Beevers/Carslaw* (2005a), pp. 6881-6883. *Santos/Rojey/Newberry* (2000) estimate road transport related emissions of eight pollutants, among others NO_x, PM and CO_2, for eight towns in the UK. They conclude that any congestion charging scheme will bring along environmental benefits.

9 See *Holmén/Niemeier* (2003), pp. 61-64.

(ppm) in 1750 to 380 ppm in 1998. The main reasons for this increase are the burning of fossil fuels and deforestation. Hence, anthropologic greenhouse gases accelerate the natural greenhouse effect and enforce the global warming. Predicted consequences of global warming include meltdown of ice sheets, sea-ice and land glaciers, a raise of sea levels, changing rainfall patterns and the increased occurrence of droughts and floods.[10]

One main character by which vehicle pollutants can be categorised is their impact range. Air pollutants as carbon monoxide (CO) and fine particles ($PM_{2.5}$ and PM_{10}) but also oxides of nitrogen (NO_x) have local impacts, i.e., the places of emission and caused damage are congruent. In particular, urban areas suffer from local air pollution. In contrast, greenhouse gases as carbon dioxide (CO_2) have a global scale. "Climate change is an externality that is global in both its causes and consequences. The incremental impact of a tonne of greenhouse gas on climate change is independent of where in the world it is emitted (unlike other negative impacts such as air pollution and its cost to public health), because greenhouse gases diffuse in the atmosphere and because local climatic changes depend on the global climate system".[11]

Present figures of air pollutants and greenhouse gases emissions for Germany indicate that fossil energy use is the main source of emissions (NO_x 87.1 percent, PM_{10} 43.4 percent, CO 85.4 percent, CO_2 94.7 percent). The road transport fraction of total national emissions is 36.6 percent (NO_x), 19.9 percent (PM_{10}, including abrasion from roads, tire and brakes), 34.6 percent (CO) and finally 17.7 percent in regard to CO_2.[12]

10 See *Lenzen/Dey/Hamilton* (2003), pp. 38-42 and more detailed Stern Review (2006), pp. 2-22.

11 Stern Review (2006), p. 25; see *Quinet* (2003), pp. 365-369.

12 See Umweltbundesamt (2008).

3. The Central London Congestion Charging Scheme

3.1 Background to the Congestion Charge

An Ipsos Mori opinion poll carried out in summer 1999 found that for one third of the Londoners traffic congestion was an important problem that required the attention of the Mayor. 19 percent even stated that traffic congestion was the most important problem. By way of comparison, just about one fifth regarded crime or law and order as an urgent problem.[13]

In the early days of the new millennium, London was home of approximately 7.3 million residents and offered about 4 million jobs. Most people lived in Inner London (2.7 million) and Outer London (4.5 million). Only 160,000 people lived in Central London. In contrast, 1.3 million jobs existed in Central London while about 1.2 million and 1.7 million jobs existed in Inner and Outer London respectively. The considerable disparity of residents and jobs in Central London explains why approximately 1.1 million people commuted to Central London every morning. More than three quarters of these commuters used public transport; 41 percent commuted by National Rail, about one third travelled by London Underground and seven percent entered Central London by bus. Only 16 percent opted for individual transport. Car users accounted for a share of 12 percent while four percent travelled by taxis, motorcycles or pedal cycles.[14]

Furthermore, 378,000 vehicles entered the Central London Congestion Charging Zone and travelled 1.64 million vehicle-kilometres between 7:00 and 18:30 (with a peak in the morning hours) on an average weekday in 2002. They reached an average network speed of 14.2 km/h. In 1986, the average network speed was still 17.2 km/h. During uncongested times the travel rate (as the inverse of speed) stabilized at a level of 1.9 min/km between the mid-1980s and 2002 while additional travel time rose from 1.6 min/km in 1986 to 2.3 min/km in 2002. Consequently, network travel rates increased from 3.5 min/km in 1986 to 4.2 min/km in 2002. In other words, vehicle users suffered from excess travel time of 2.3 min/km. Traffic patterns

13 See ROCOL (2000), p. 5.

14 See Transport for London (2003), p. 16; Greater London Authority (2001), pp. 47-55; *Butcher/Young* (2008), pp. 3-7.

in all other parts of London were less severe and remained unchanged over the time. At the end of the 1980s, traffic in Outer London moved with an average speed of 32.9 km/h and average speed remained unchanged during the 1990s. The night-time uncongested network speed even amounted to 50 km/h (or a travel rate of 1.2 min/km) in 2001; this is much the same as the value measured 10 years before. The 'all day' travel rate of 1.8 min/km did not change between 1989 and 2000. The average congestion level was therefore 0.6 min/km.[15]

Traffic congestion has been on the political agenda for quite a long time. In the early 1960s, the UK Ministry of Transport published reports such as the Buchanan report (1963) and the Smeed Report (1964). Both reports argued that drivers should pay for the travel time delays they impose on one another. If they were charged, some of the driver would quit travelling or would travel at a different time or by a different mode which would lead to less traffic and congestion. Despite the economical attractiveness, all proposals were refused because of technical problems, fears of welfare losses and lacks of political support. The first step to overcome the political unwillingness was The Greater London Authority Act (GLAA) which passed Parliament in 1999. This act sets up an authority for Greater London (Greater London Authority, GLA), which consists of a directly elected Mayor and a directly elected London Assembly. The GLAA instructs the Mayor to prepare a Mayor's Transport Strategy, which should outline the Mayor's transport policies, and enables the Mayor to implement a road user charging scheme and/or workplace parking levies. The GLAA earmarked net revenues for traffic improvement projects for the first ten years of operation.

In order to forecast the impacts of different congestion charging schemes in London two main studies were carried out. First, the Government Office for London set up the London Congestion Research Programme in 1991 which published its final report in 1995. This study discussed a wide range of technical options, charging zones and times and their impacts on congestion and welfare. Second, the Government Officer for London established an independent working group of transport professionals called the Review of Charging Option for London (ROCOL) Working Group in 1998. This working group should investigate how a road user charge and a workplace parking levy could be introduced in Central London and which impacts on traffic

15 See Transport for London (2003), pp. 51-63.

levels, speeds and revenues these measures would have. The next milestone on the implementation path was the Mayoral Election in May 2000. Candidate Ken Livingstone made the introduction of a congestion charge to one of the main themes of his election campaign. After being elected, the new Mayor of London, Ken Livingstone, stated in his Mayor's Transport Strategy his aim to cut weekday traffic levels by 15 percent. The plan for the implementation of congestion charging as a part of the Mayor's Transport Strategy underwent a public consultation process which started mid 2000. During this process several modifications were made and the Mayor of London finally adopted the scheme in February 2002.[16]

3.2 Working of the Congestion Charge

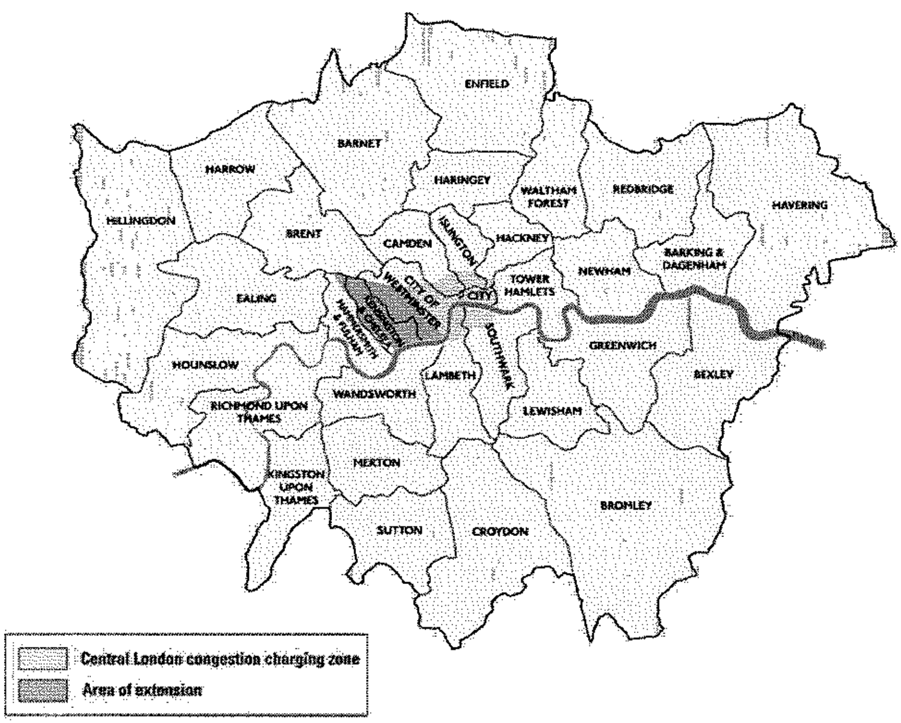
The Central London Congestion Charging Scheme was introduced on 17 February 2003. The £5 daily charge was being levied between 7.00 and 18.30 on weekdays for driving and/or parking a car within the 22 km^2 Charging Zone, which is limited by the so-called Inner Ring Road linking Marylebone Road, Euston Road, Pentonville Road, Tower Bridge, Elephant & Castle, Vauxhall Bridge, Victoria Hyde Park Corner and Marble Arch and it thus covers the government and business district as well as the financial centre and places of public entertainment. The Inner Ring Road itself does not belong to the Charging Zone. In principle, London's charge thus represents some kind of area licence as the purchaser gains the right to enter and leave the Charging Zone as often as he or she desires within a certain time period.

Since the implementation of the charge three main changes have been made to the charging scheme. The charge was raised to £8 in July 2005 and an enlargement of the Charging Zone, the so-called Western Extension, which doubled its size, followed in February 2007. There is still no charge for using the boundary roads around the extended zone. In addition, the A40 Westway running from east to west and the part of the Inner Ring Road that runs between the original Charging Zone and the Western Extension Zone from north to south are still exempted from the charge. The Western Extension was accompanied by a shortening of the charging period. Since its imple-

16 For the history of the congestion charge see *Dix* (2002) and *Peirson /Vickerman* (2008), pp. 79-81.

mentation, charging hours have been 7.00 to 18.00 on a working day.[17] On 27 November 2008, the Mayor of London, Boris Johnson, announced the abandonment of the Western Extension of the Congestion Charging Zone. A public consultation held in September/October 2008 found that over two thirds of London's population as well as businesses responding to the consultation supported its removal. It should be noted that the earliest point in time that the Western Extension could be removed is 2010.[18]

Figure 2 Location of the London Congestion Charging Zone



Source: TfL 2006b, p. 194.

The daily charge is basically payable on the day of travel. Besides the regular daily tariff weekly, monthly or yearly licences (being valid for 5, 20 or 252 consecutive charging days) may be purchased at a reduced price. Despite the periodical payment types roughly half of the road users prefer the standard daily payment. Some vehicle classes are automatically exempted from the congestion charge, e.g., two

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17 For a detailed map of the central London charging zone see http://www.tfl.gov.uk/tfl/roadusers/congestioncharge/whereandwhen/assets/DetailMapECCZ.pdf.

18 See Greater London Authority (2008).

wheeled vehicles (motorcycles, mopeds and bicycles), buses and coaches (featuring more than nine seats), taxis (if registered in London), operational vehicles of the fire brigades, NHS (National Health Service), other emergency services, police and local authorities as well as vehicles driven by disabled persons who are exempt from Vehicle Excise Duty (VED). Furthermore, disabled persons holding a so-called Blue Badge, drivers of vehicles propelled by alternative fuels (gas and electric motors or fuel cells) as well as breakdown and recovery services can register for a 100 percent discount. Residents living within the Charging Zone can apply for a 90 percent discount. All users eligible for one of the aforementioned discounts are required to annually register with Transport for London (TfL), which is responsible for levying of the congestion charge, for a registration charge of £10; otherwise these users would forfeit their privileges.

The congestion charge may be paid in various ways – most rarely used is postal payment where users have to fill in a form, entering the charge due, and then send the form accompanied by a cheque, their credit or debit card details to Transport for London. Approximately one percent of all users use postal payments, which are therefore negligible and are further made up almost entirely of payments by residents when registering for the discount. More popular are payments by credit or debit card via mobile text message or call centre. In order to use the mobile phone text service a registration is required and this payment method can only be used to pay the charge on the day of travel. Furthermore, the charge may be paid in cash, by cheque and by credit or debit card at numerous retail outlets, petrol stations or self-service machines. Most regularly used is online payment by credit or debit card by using a dedicated website.[19]

The charging scheme is enforced by a network of cameras installed at the borders and within the Charging Zone in order to photograph number plates of vehicles entering or moving within the Charging Zone. Parked vehicles are checked by foot patrols. The collected data is matched with data stored in a database. If a driver has already paid the charge or is exempted from payment the image is immediately deleted. At midnight, all remaining captured number plates are checked against the database. If the £8 charge is paid the photo is wiped out of the database. Otherwise the image is saved. In case of payment arrives by midnight on the day following the day of travel £10 has to

19 See Transport for London (2008a), pp. 208-210.

be paid. Otherwise the registered keeper of the vehicle will receive a Penalty Charge Notice (PCN) of £120 which will be reduced to £60 in case it is settled within two weeks. If the fine will not be paid after 28 days it automatically increases to £180. Transport for London may even seize or decommission vehicles in case of repeated contempt.[20]

3.3 Effects and Assessment

The final Road Charging Options for London (ROCOL) report discussed several road user charging options, which differed regarding to geographical areas and used technologies. In case of an area licensing scheme covering Central London and using Automatic Number Plate Recognition (ANPR) with a £5 daily charge the report suggested a reduction of traffic volume in Central London by 12 percent measured in driven vehicle kilometres. According to the report traffic speeds in Central London could increase from 16 km/h to 18 km/h between 6.00 and 22.00. Thus, travel times would be shorter and more reliable. The expected implementation costs of the scheme were forecasted at £30 million to £50 million and the annual operation costs were likewise estimated at £30 million to £50 million. The charging scheme could collect total annual revenues at £260 million to £320 million. The annual net revenues were projected at £230 million to £270 million.[21]

3.3.1 Impacts on Traffic

According to Transport for London about 50,000 vehicles less entered the Charging Zone one year after its introduction on a charging day during charging hours – a reduction of 14 percent. The number of chargeable vehicles entering the Charging Zone plummeted by 27 percent or about 60,000 vehicles. In detail, 33 percent less cars and minicabs entered the Charging Zone per day during charging hours. The number of both vans and lorries declined by 11 percent. In contrast, the number of exempted vehicles climbed by 18 percent

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20 For basic information about the Central London Congestion Charging see Transport for London (2007a).

21 See ROCOL (2000), pp. 69-88.

(19,000 vehicles). The number of London licensed taxis entering the Charging Zone increased by 17 percent and 23 percent more buses and coaches crossed the Inner Ring Road. The share of chargeable vehicles entering the Charging Zone fell from 70 percent in 2002 to 59 percent in 2003. On the opposite, the share of exempted vehicles of the total number of vehicles increased from 30 percent to 41 percent. These figures did not significantly change until 2007. It is noteworthy that the increased charge of £8 introduced in July 2005 had only minor effects on traffic patterns. When comparing data of autumn 2005 with data of spring 2005 a slight reduction of traffic entering the Charging Zone (two percent) can be observed.[22]

Table 1 Traffic entering the Central London Charging Zone during charging hours, 07:00-18:00 and 07:00-18:30 respectively

	2002		2003			2006			2007
	Vehicles	Percentage share	Vehicles	Percentage share	2003 vs. 2002	Vehicles	Percentage share	2006 vs. 2002	2007 vs. 2002
All vehicles	378,000	100%	324,000	100%	-14%	316,000	100%	-16%	-16%
Potentially chargeable	266,000	70%	193,000	59%	-27%	186,000	59%	-30%	-29%
Cars and minicabs	195,000	52%	130,000	40%	-33%	125,000	39%	-36%	-36%
Vans	55,000	15%	49,000	15%	-11%	48,000	15%	-13%	-13%
Lorries and others	15,000	4%	13,000	4%	-11%	13,000	4%	-13%	-5%
Not chargeable	112,000	30%	131,000	41%	18%	130,000	41%	16%	15%
Licensed taxi	56,000	15%	66,000	20%	17%	63,000	20%	13%	7%
Buses and coaches	13,000	4%	16,000	5%	23%	16,000	5%	25%	31%
Powered two-wheelers	28,000	7%	31,000	10%	12%	28,000	9%	0%	-3%
Pedal cycles	16,000	4%	18,000	6%	19%	24,000	7%	9%	66%

Source: TfL (2007b), pp. 21-22; TfL (2008a), p. 41.

During the first year of operation the overall amount of daily driven vehicle-kilometres within the Central London Congestion Charging Zone during charging hours dropped from 1.64 million vehicle-km to 1.45 million vehicle-km (or 12 percent). The shortened operating hours lead to further traffic reduction. Potentially chargeable vehicles have seen the greatest decline. Within the Central London Congestion Charging Zone, the total number of driven vehicles-km of chargeable vehicles decreased by 28 percent from 2002 to 2006, while kilometres driven by non-chargeable vehicles increased by 16 percent in the same period. In particular, the use of bicycles substantially increased

22 See Transport for London (2006b), p. 22.

by 43 percent. The distance travelled by licensed taxis and buses/coaches increased by 12 percent and 25 percent respectively. Despite the overall increase of pedal cycle kilometres cyclists account for a mere seven percent of all vehicle-km. About 20 percent of the traffic circulating within the original Central London Charging Zone is generated by taxis. In total, non-chargeable vehicle contribute two fifths to the total amount of traffic circulating within the original Charging Zone. Table 2 provides detailed figures.

Before the inauguration of the Western Extension of the Central London Congestion Charging Zone, about 250,000 vehicles entered the area of the Western Extension Zone on an average charging day during charging hours. Roughly three quarters of these vehicles would be subjected to the charge. Transport for London studies noted that due to the introduction of the charge 13 percent to 17 percent fewer vehicles would enter the Western Extension Zone. The number of potentially chargeable vehicles, which would avoid travelling into or through the Western Extension Zone, would drop by 39 percent to 51 percent. Meanwhile, 10 percent to 12 percent more taxis and busses were projected to travel into the Charging Zone.[23] Table 3 compares the traffic volume and percentage vehicle shares entering the Western Extension Zone before and after charging. After the introduction of the congestion charge to the Western Extension Zone forecasts of Transport for London were nearly matched in that way that 12 percent less vehicles entered the Western Extension Zone. In addition, the number of potentially chargeable vehicles dropped by 18 percent while the number of exempted vehicles rose by three percent. However, it has to be pointed out that the increase of non-chargeable vehicles was primarily boosted by the growing number of incoming powered two-wheelers and pedal bicycles. The number of taxis and busses entering the zone did not change at all. The reduced number of vehicles that are subject to the congestion charge resulted in a slight decrease of their share in total vehicles to 67 percent; thus, the share of exempted vehicles is 33 percent.[24]

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23 See Transport for London (2007b), p. 152.

24 See Transport for London (2008a), p. 20.

Table 2 Vehicle-kilometres (vkm) in million within the Central London Congestion Charging Zone and share of total traffic during charging hours, annualised weekdays

	2002		2003			2006			2006		2007		
	pre-charging		charging hours 7:00-18:30						charging hours 7:00-18:00				
	Vehicles	Percentage share	Vehicles	Percentage share	2003 vs. 2002	Vehicles	Percentage share	2006 vs. 2002	Vehicles	Percentage share	Vehicles	Percentage share	2007 vs. 2006
All vehicles	1.64	100%	1.45	100%	-12%	1.41	100%	-14%	1.34	100%	1.34	100%	0%
Potentially chargeable	1.13	69%	0.85	58%	-25%	0.82	58%	-28%	0.78	58%	0.77	58%	-1%
Cars and minicabs	0.77	47%	0.51	35%	-34%	0.49	35%	-37%	0.46	34%	0.44	33%	-4%
Vans	0.29	18%	0.27	19%	-5%	0.26	19%	-9%	0.25	19%	0.25	19%	0%
Lorries and others	0.07	4%	0.07	5%	-7%	0.07	5%	-7%	0.07	5%	0.07	5%	9%
Not chargeable	0.51	31%	0.6	42%	18%	0.59	42%	16%	0.56	42%	0.57	42%	2%
Licensed taxi	0.26	16%	0.31	21%	22%	0.29	20%	12%	0.27	20%	0.27	20%	-1%
Buses and coaches	0.05	3%	0.07	5%	21%	0.07	5%	25%	0.07	5%	0.06	4%	-11%
Powered two-wheelers	0.13	8%	0.14	9%	7%	0.13	9%	0%	0.12	9%	0.12	9%	2%
Pedal cycles	0.07	4%	0.09	6%	29%	0.1	7%	43%	0.09	7%	0.11	8%	17%

Source: TfL (2007b), p. 26; TfL (2008a) p. 46.

Table 3 Traffic entering the Western Extension Charging Zone during charging hours, 07:00-18:00

	2006		2007		
	Vehicles	Percentage share	Vehicles	Percentage share	2007 vs. 2006
All vehicles	253,000	100%	221,000	100%	-12%
Potentially chargeable	182,000	72%	149,000	67%	-18%
Cars and minicabs	138,000	55%	107,000	48%	-23%
Vans	36,000	14%	33,000	15%	-8%
Lorries and others	9,000	3%	9,000	4%	0%
Not chargeable	70,000	28%	72,000	33%	3%
Licensed taxi	35,000	14%	35,000	16%	0%
Buses and coaches	10,000	4%	10,000	5%	0%
Powered two-wheelers	13,000	5%	14,000	6%	8%
Pedal cycles	12,000	5%	13,000	6%	8%

Source: TfL (2008a), p. 20.

The traffic volume measured in driven vehicle-kilometres within the Western Extension decreased from 1.12 vehicle-km to 1.02 vehicle-km between 2006 and 2007, which translates to a reduction of 10 percent. Therefore, the actual reduction in driven vehicle-kilometres is at the lower end of Transport for London's forecasts of between 10 and 14 percent. The number of potentially chargeable vehicles has dropped by 14 percent and now accounts for 72 percent of the traffic within the Western Extension Zone. Meanwhile, the distance travelled by discounted or exempted vehicles, including pedal cycles, has increased by six percent to a share of 28 percent. See Table 4 for detailed information.

Table 4 Vehicle-kilometres in million within the Western Extension Congestion Charging Zone and share of total traffic during charging hours, annualised week-days

	2006		2007		
	Vehicles	Percentage share	Vehicles	Percentage share	2007 vs. 2006
All vehicles	1.12	100%	1.02	100%	-10%
Potentially chargeable	0.85	76%	0.73	72%	-14%
Cars and minicabs	0.67	60%	0.55	54%	-18%
Vans	0.15	13%	0.15	15%	-2%
Lorries and others	0.04	3%	0.04	4%	1%
Not chargeable	0.27	24%	0.29	28%	6%
Licensed taxi	0.12	11%	0.13	13%	4%
Buses and coaches	0.03	3%	0.04	4%	13%
Powered two-wheelers	0.06	5%	0.06	6%	9%
Pedal cycles	0.06	5%	0.06	6%	4%

Source: TfL (2008a), p. 25.

3.3.2 Impacts on Congestion

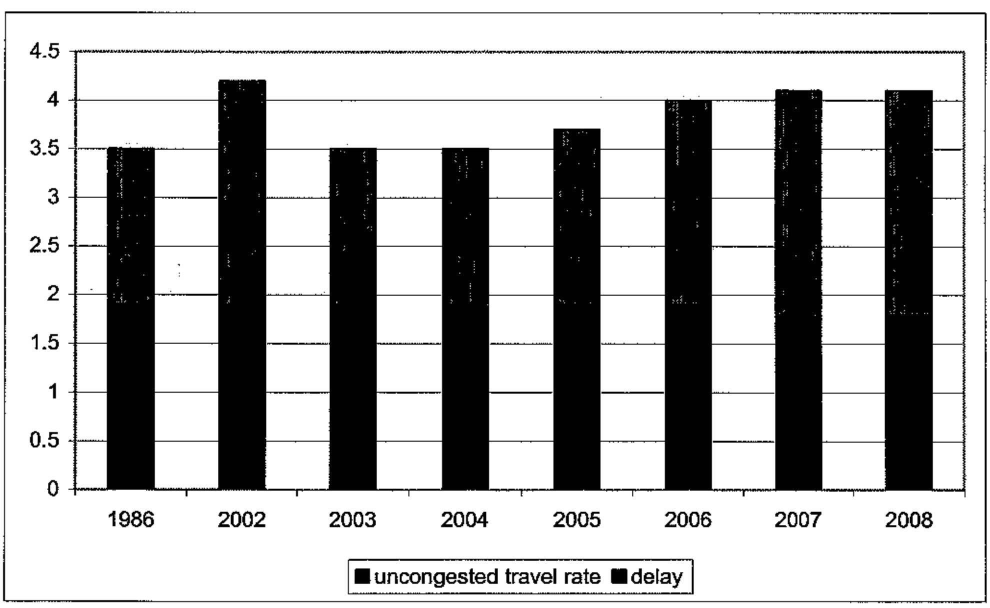
Central London faced one of the most severe traffic congestion levels in the UK in the past. Following the implementation of the Central London Congestion Charge, Transport for London expected a 20 percent to 30 percent reduction in congestion within the Charging Zone during charging hours.[25]

Following ever increasing average excess travel as well as average travel rates during the 1980s and 1990s, both fell by 30 percent between 2002 and 2003 and then stabilized at the level of the mid-1980s. The average travel rate within the Charging Zone dropped from 4.2 min/km in 2002 to 3.5 min/km in 2003 and the average excess travel rate decreased from 2.3 min/km to 1.6 min/km. Subsequently, the average network speed within the zone increased from 14 km/h to 17 km/h. Beevers/Carslaw (2005a) state that this increase in average speed within the Charging Zone is not part of a general trend in entire London. Instead, they concluded that the acceleration of traf-

25 Transport for London (2003), p. 51.

fic is directly linked to the introduction of the charge.[26] However, an increase of congestion can be observed in Central London since 2005. In 2008, vehicle users were suffering from delays at the level of pre-charging times (2.3 min/km) and pre-charging travel rates (4.1 min/km). However, these increases cannot be traced back to a growing number of vehicles entering the Charging Zone or increased vehicle kilometres driven within the Charging Zone. Both remained unchanged. Transport for London explained the increase in congestion by changes to effective network capacity allocation and stated that the increase of congestion in the Charging Zone positively correlated with road work activities due to the necessary renewal of sub-surface infrastructure, general maintenance and improvement works and long-term infrastructure measures such as the building of bus lanes. Furthermore, changes to the traffic light system had negative impacts on average traffic speeds.[27]

Figure 3 Average travel rates, uncongested travel rates and travel time delays in the Central London Congestion Charging Zone during charging hours



Source: TfL (2003b), pp. 51-55; TfL (2007b), p. 183; TfL (2008a), pp. 56-58.

26 See Beevers/Carslaw (2005a), pp. 6879-6881.

27 See Transport for London (2007b), pp. 37-40 and 48-52; Transport for London (2008a), pp. 56-58.

The fear that due to the introduction of the congestion charge an increase in traffic and congestion might more regularly occur on the Inner Ring Road, which limits the original Charging Zone but is exempted from the charge did not materialize. Congestion decreased on the Inner Ring Road up to 20 percent – from 1.9 min/km in 2002 to 1.6 min/km in 2003. Since its all time low level in 2003, congestion is currently increasing due to ongoing street and road works but users of the Inner Ring Road still benefit from modest congestion reductions.[28]

The average travel rate under uncongested conditions in the Western Extension Zone, which accounts for 1.8 min/km, does not differ from the average travel rate in the original Charging Zone. Vehicles in both areas move with an average speed of 33 km/h. Before the introduction of the charge travel time delays were about 1.75 min/km. Adding uncongested travel rates of 1.8 min/km, the charging hour travel rate was 3.55 min/km. Hence, the traffic moved with an average travel speed of just 17 km/h. After the introduction of the congestion charge to the Western Extension Zone, excess travel times during charging hours declined to 1.7 min/km. Although the Western Extension obviously reduced traffic entering the Western Extension Charging Zone by 12 percent, the expected congestion benefits of 17 to 24 percent did not materialize so far. As seen within the original Charging Zone, increased road works and changes in traffic light timings had a negative impact on travel time.[29]

Prior to the Western Extension of the Congestion Charging Zone, Transport for London expected no overall changes to traffic on the free passage route running between the original zone and the Western Extension Zone but forecasted a minor increase to traffic on western boundary roads. Transport for London's expectations were actually met. The slight increase of vehicles using the free passage route and in driven vehicle-kilometres must be seen against the background of a sharp decline of vehicles and vehicle-kilometres between 2005 and 2006. In 2007, both figures stabilized at the level of 2005, i.e., the

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28 See Transport for London (2004), pp. 14-15; Transport for London (2007b), pp. 40-41; Transport for London (2008a), pp. 58-59.

29 See Transport for London (2007b), pp. 183-185; Transport for London (2008a), pp. 61-62 and 76-84.

number of vehicles running on the boundary road as well as driven vehicle-kilometres show a minor decrease of two percent.[30]

3.3.3 Impacts on road safety and air quality

More important, the frequency of reported accidents with personal injuries has also been decreasing within the original and extended Charging Zone. However, this development approximately corresponds to the long lasting trend; thus, the influence of congestion charging cannot be exactly quantified.[31]

Primarily, the Central London Congestion Charging Scheme has been implemented in order to reduce traffic congestion in Central London and to generate revenues for transport improvements. But traffic-related emissions have also been decreasing. The Central London Congestion Charge led to a reduction in the volume of circulating traffic, which allowed the remaining traffic to move more efficiently at a higher speed. Hence, congestion has diminished and traffic speed has increased inversely. Beevers/Carslaw (2005a) for example noted that an increase in speed might bring along a decrease in emissions. In their analyses for three different vehicle types Beevers/Carslaw (2005a) found that vehicle speed has a significant effect on emissions of NO_x and CO_2 in Central London. However, their results for PM_{10} are somewhat different. The influence of average vehicle speed on emissions of PM_{10} is less distinct. Such emissions are more dependent on drive cycle dynamics, i.e., the variation in average speed or acceleration and deceleration, than on average traffic speeds.[32]

Table 5 summarizes the annual emission changes for the Central London Charging Zone and the Inner Ring Road. Within the Charging Zone, total road transport related reductions amounted to 13.4 percent for NO_x, 15.5 percent for PM_{10} and 16.4 percent for CO_2 between 2002 and 2003. Reductions associated with traffic volume/speed changes amounted to 7.9 percent in emissions of nitrogen oxide (NO_x), 6.3 percent in particle material (PM_{10}) and 15.7 percent in carbon dioxide (CO_2). Referred to NO_x and PM_{10} most of these re-

30 See Transport for London (2008a), pp. 28-33.

31 See Transport for London (2008a), pp. 98-104.

32 See *Beevers/Carslaw* (2005a), pp. 6881-6883.

ductions were associated with higher traffic speeds or less congestion respectively. The reduction of CO_2 was evenly distributed to traffic speed and traffic volume changes. It must be stressed that traffic volume changes caused an increase of emissions on the Inner Ring Road while higher speeds influenced vehicles emissions positively. A "greener" vehicle stock based on vehicle technology changes resulted in further emission reductions of NO_x of about 5.5 percent and of PM_{10} of 9.2 percent both within the Charging Zone and on the Inner Ring Road. The carbon dioxide emission reductions associated with advanced vehicle technology accounted for slightly less than one percent in both areas. Ongoing vehicle technology improvements resulted in additional reductions of emissions between 2003 and 2006, which led to additional emission reductions of NO_x, PM_{10} and CO_2 of 17.3 percent, 23.8 percent and 3.4 percent respectively. However, these effects are obviously no effect of the congestion charging scheme.

Table 5 Changes to emissions of NO_x, PM_{10} and CO_2 (in percent) in the Central London Congestion Charging Zone

	Inside charging zone			Inner Ring Road		
Change	NO_x	PM_{10}	CO_2	NO_x	PM_{10}	CO_2
Flow change - car	-4.5	-4.6	-11.2	-1.6	-1.8	-3.9
Flow change - light goods	-0.1	-0.1	-0.1	1.7	3.2	2.3
Flow change - rigid goods	-1.6	-1.0	-0.7	1.6	1.0	0.7
Flow change - articulated heavy goods	-0.4	-0.2	-0.2	0.4	0.2	0.2
chargeable vehicles	-6.6	-5.9	-12.2	2.1	2.6	-0.7
Flow change - taxis	2.3	3.8	2.4	2.0	3.6	2.1
Flow change - bus and coach	2.9	1.0	1.2	3.2	1.1	1.4
Flow change - motorcycles	-	0.4	0.2	0.2	2.4	1.0
exempted or discounted vehicles	5.2	5.2	3.8	5.4	7.1	4.5
Traffic volume change	-1.4	-0.8	-8.4	7.4	9.7	3.8
Speed change	-6.5	-5.5	-7.3	-7.7	-6.9	-8.5
Traffic volume and speed change	-7.9	-6.3	-15.7	-0.2	2.8	-4.7
Vehicle stock change	-5.5	-9.2	-0.7	-6.7	-9.6	-0.7
Traffic volume and speed change + vehicle stock 2003 versus 2002	-13.4	-15.5	-16.4	-6.9	-6.8	-5.4
Additional 'background' change from technology improvement (fleet turnover) 2003-2006	-17.3	-23.8	-3.4	-17.5	-20.9	-2.4

Source: TfL (2007b), p. 66.

The figures of Transport for London almost correspond with the results of Beever/Carslaw (2005b) who analyzed the impacts of the congestion charge on traffic speed, traffic volume and emissions of NO_x, PM_{10} and CO_2 inside the Charging Zone and on the Inner Ring Road between 2002 and 2003/2004. Within the Charging Zone, total NO_x, PM_{10} and CO_2 emissions declined by 12.0 percent, 11.9 percent and 19.5 percent respectively due to changes in travel speed and vehicle-kilometres. Vehicle technology improvements contributed further NO_x, PM_{10} and CO_2 emission reductions of 3.9 percent, 4.0 percent and 0.4 percent respectively. Thus, overall NO_x and PM_{10} emissions declined by 15.9 percent and total CO_2 emissions dropped by 19.9 percent within the Charging Zone. In contrast to the findings of Transport for London, Beever/Carslaw (2005b) suggest that traffic volume changes measured in vehicle-kilometres on the Inner Ring Road did not lead to increasing emissions of PM_{10} but instead reduced them by 3.4 percent. Further, traffic volume and speed changes had no impact on CO_2 emissions on the Inner Ring Road and additional benefits due to greener vehicle technology were negligible. Beevers/Carslaw (2005b) come to the conclusion that higher travel speed and the lower congestion level as well as less traffic volume, which resulted from the Central London Congestion Charging Scheme, have a significant positive effect on vehicle emissions. Regarding to CO_2 emissions, a congestion charging scheme as implemented in London will contribute to governmental climate change reduction plans more effectively than new vehicle technology.[33] However, in a further study Beevers/Carslaw (2005a) found that not in all cases fewer emissions result from higher speeds. For some vehicle types emissions of NO_x, and PM_{10} have actually risen between pre-charging times and post-charging times.[34]

As table 6 shows, the impact of the Western Extension on vehicles emissions were less significant. Transport for London stressed that changes in estimation methodology and the less intense change of traffic volume and less intense acceleration of traffic could be blamed for the marginal reduction of traffic emissions. Changes in traffic volume and composition as well as in speed reduced the emissions of NO_x, PM_{10} and CO_2 by 5.2 percent, 5.7 percent and 9.2 percent respectively. Long term changes in vehicle stock by purchasing more environmentally friendly vehicles and the removal of older ones

33 See *Beevers/Carslaw* (2005b), p. 3.

34 See *Beevers/Carslaw* (2005a), p. 6883.

brought additional reductions of about seven percent for NO_x, 6.5 percent for PM_{10} and roughly three percent for CO_2.[35]

Table 6 Changes to emissions of NO_x, PM_{10} and CO_2 (in percent) in the Western Extension Zone

Change	Inside western extension			Western extension boundary		
	NO_x	PM_{10}	CO_2	NO_x	PM_{10}	CO_2
Flow change - car	-10.6	-10.6	-10.9	-1.4	-1.4	-1.4
Flow change - light goods	-4.1	-3.3	-4.4	1.5	1.1	1.7
Flow change - rigid goods	0.0	0.0	0.0	4.2	4.2	4.2
Flow change - articulated heavy goods	0.0	0.0	0.0	4.0	4.0	4.0
chargeable vehicles	-14.7	-13.9	-15.3	8.3	7.9	8.5
Flow change - taxis	0.0	0.0	0.0	-7.9	-7.6	-7.7
Flow change - bus and coach	1.5	1.4	1.4	-1.4	-1.4	-1.4
Flow change - motorcycles	1.9	2.0	2.0	-5.0	-5.0	-5.2
exempted or discounted vehicles	3.4	3.4	3.4	-14.3	-14.0	-14.3
Traffic volume and composition change	-2.5	-4.2	-6.5	0.9	-0.3	-0.5
Speed change	-2.7	-1.4	-2.8	-0.9	-0.6	-1.1
Traffic volume/ composition and speed change	-5.2	-5.7	-9.2	-0.1	-0.9	-1.6
Vehicle stock change	-6.8	-6.5	-1.8	-7.3	-5.4	-1.6
Traffic volume/ composition and speed change + vehicle stock 2007 versus 2006	-12.0	-12.2	-11.0	-7.3	-6.3	-3.2

Source: TfL (2008a), p. 106.

However, it should be noted that the emissions of NO_x, PM_{10} and CO_2 caused by exempted or discounted vehicles have risen in the original Charging Zone as well as in the Western Extension Zone.

3.3.4 Financial impacts

Before the introduction of the scheme, Transport for London calculated the number of vehicles subject to the congestion charge to on average 150,000 daily. However, in the first two years of operation the number of valid charges on each charging day amounted to about 110,000 and dropped due to the higher charge of £8 introduced in 2005 to roughly 100,000 daily payments. Since the addition of the

35 See Transport for London (2007b), pp. 65-72; Transport for London (2008a), pp. 104-111.

Western Extension, the number of valid daily charges has been increasing to 150,000. In essence, the success of the congestion charge in reducing traffic implied a revenue shortfall. Furthermore, more vehicle owners applied for an exemption or discount than previously expected. Besides the lower number of chargeable vehicles entering the Charging Zone the operation costs were higher than anticipated.[36] The ROCOL report concluded that the total annual revenues from the charge and the penalty payments would be £260 million to £320 million. The annual operating costs were expected to be £30 million to £50 million. Thus, the net annual revenues were estimated at £230 million to £270 million. Consequently, the expectations of the ROCOL working group and even the analysis of Transport for London, which predicted annual net-revenues in the range of £130 million to £150 million (excluding revenues from penalty charges), turned out to be unreachable.[37] In the first year of operation the scheme generated net-revenues of £68 million while operating costs amounted to £97 million. After the introduction of the higher £8 charge in July 2005 net-revenues increased from £97 million in the financial year 2004/2005 to £122 million in 2005/2006. However, the Western Extension in February 2007 had only marginal implications for net revenues because both revenues and operating costs increased relatively inline. The enlarged Central London Charging Scheme raised net revenues of £268 million in the financial year 2007/2008. The operating costs amounted to £131 million. Subsequently, the charging scheme generated net-revenues of £137 million in 2007/2008.

Table 7 Scheme revenues and costs

	Forecast ROCOL (£5)	**2003/ 2004**	**2004/ 2005**	**2005/ 2006**	**2006/ 2007**	**2007/ 2008**
Total revenues	260-320	165	190	210	213	268
Total costs	30-50	97	92	88	90	131
Net-revenues	230-270	68	97	122	123	137

Sources: TfL, several annual reports.

36 See *Leape* (2006), pp. 169-170.

37 See ROCOL (2000), p. 77; Transport for London (2002), p. 149.

4. Emissions Related Congestion Charging in Central London

4.1 Background to the Emissions Related Congestion Charge

The following section provides an overview of the key air pollutants in London. The data is taken from the London Atmospheric Emissions Inventory (LAEI) 2003 Report, which mainly focussed on emissions and air pollution of road transport in the area of Greater London.[38]

In 2003, total NO_X emissions of all emission sources amounted to 4,063 tonnes in Central London and 67,041 tonnes in Greater London. In both areas road transport contributed about 40 percent to the total NO_X emissions. About 192 tonnes and 3,076 tonnes of PM_{10} had been blown out in Central London and in Greater London respectively. In Central London as well as Greater London about two thirds of the total PM_{10} emissions were caused by road transport. The overall emissions of CO_2 were 32,833,731 tonnes in Greater London and 1,505,340 tonnes CO_2 in Central London. Roughly one quarter of the overall emissions of CO_2 in Central London (370,971 tonnes) as well as in Greater London (7,515,108 tonnes) could be attributed to road traffic.[39]

As in case of the Central London Congestion Charge, the political framework for London's Emissions Related Congestion charge was set by the Greater London Authority Act (GLAA) 1999. This act requires the Mayor to draw up strategies for transport and air quality. The Mayor's Transport Strategy (2001) states the aim of the Mayor to tackle congestion, improve air quality and reduce greenhouse gas emissions of road transport.[40] Furthermore, the Mayor's Air Quality

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38 The LAEI 2003 Report separates London into several sub-areas. Central (Greater) London corresponds to the Central London Congestion Charging Zone (without the Western Extension Zone). The area of Greater London includes all 32 London boroughs and the City of London.

39 Based on the London Energy and CO_2 Emissions Inventory, the Mayor's Climate Change Action Plan estimates the total amount of London's carbon dioxide emissions (excluding aviation) at 44.3 million tonnes in 2006. Ground based transport contributed 9.6 million tonnes or 22 percent. Private cars and motorcycles accounted for roughly half of ground based transport related emissions and one quarter can be traced back to road freight. In total, taxis and busses contributed nine percent.

40 See Greater London Authority (2001), pp. 1-12.

Strategy, published in 2002, focussed on tackling emissions of NO_x and PM_{10} of road traffic by reducing traffic and emissions of individual vehicles.[41] The plan of cutting road traffic related CO_2 was substantiated by The Mayor's Energy Strategy (2004), which aimed at reducing CO_2 emissions of road transport by 20 percent (compared to 1990 levels) by the year 2010, and by 60 percent (compared to 2000 levels) by 2050.[42] Further interim targets were set by the Mayor's draft Further Alterations to the London Plan (2006) which aimed at decreasing CO_2 emissions by 30 percent compared to 1990 levels by 2025. Finally, the Mayor's Climate Change Action Plan, published in 2007, marks the latest political attempt concerning the reduction of London's greenhouse gas emissions. According to this plan, London's emissions of CO_2 shall be lowered to a level at 60 percent below 1990 levels by 2025. The ground based transport sector is to contribute savings of seven tonnes CO_2 per year.[43]

Between August and October 2007, the Emissions Related Congestion Charging Proposals underwent a public and stakeholder consultation. The CO_2 discount should have been introduced in February 2008, while the higher charge should have been implemented in October 2008. An attitudinal survey among Londoners undertaken by Ipsos MORI on behalf of Transport for London between September and October 2007 found that most of the people living in London were concerned about climate change. However, after receiving information about the proposals, including the charging levels and the types of vehicles affected, 66 percent of the Londoners were in favour the proposals, while 21 percent opposed it. Even the majority of those who use their cars within the original Charging Zone and the Western Extension Zone supported the proposals. Furthermore, about 70 percent of Londoners agreed that cars that emit more CO_2 should pay a higher charge. It is noteworthy, that a majority of Londoners believed the proposals would not personally affect them or only to a limited extent (83 percent).[44] However, following the consultations, Transport for London decided to postpone the introduction of the higher charge for polluting vehicles and the CO_2 discount to 27 October 2008.

41 See Greater London Authority (2002), pp. 85-155.

42 See Greater London Authority (2004), p. 55.

43 See Greater London Authority (2007), pp. 15-30 and pp. 131-159.

44 See Ipsos MORI (2007).

Hence, the proposed Emissions Related Congestion Charge became subject to the Mayoral elections held on 1 May 2008. While the emissions charge has been a key element of the election campaign of the Mayor of London Ken Livingstone (Labour), his opponents Boris Johnson (Conservative) and Brian Paddick (Liberal Democrats) rejected the plans. Only Sian Berry (Greens) supported the emissions charge.[45] A new Ipsos MORI survey undertaken in March 2008, again on behalf of Transport for London, confirmed the findings of the preceding survey, even though the amount of Londoners in favour of a higher charge for polluting vehicles declined to 58 percent. But once again, 82 percent of the questioned Londoners stated that the new CO_2 related charge would not personally affect them or only to a limited extent.[46] It should be noted that a London-wide poll undertaken by ICM Research for Porsche Cars Great Britain in January 2008 undermined the position of the emission charge supporters. According to this poll, three quarters of Londoners said the £25 charge for VED Band G vehicles is unfair and the Mayor seeks to raise extra revenues in the first place.[47] However, on 7 July 2008 the new elected Mayor Boris Johnson has announced to scrap the proposals of his predecessor Ken Livingstone. He stated that the emissions charge would have made congestion worse by allowing thousands of low emitting cars to enter the Charging Zone for free.[48]

4.2 Working of the Emissions Related Congestion Charge

Emissions Related Congestion Charging was supposed to start on 27 October 2008. Cutting congestion was still set to be the primary objective of the congestion charge. Furthermore, an emissions related

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45 For an overview of the transport policies of candidates for London Mayor Elections see Butcher/Young 2008, pp. 59-69.

46 See Ipsos MORI (2008).

47 See ICM Research (2008). Porsche Cars GB started a campaign against the introduction of a £25 charge on larger vehicles in February 2008. It included a judicial review issuing the case to the High Court of Justice. According to Porsche, the increase of the congestion charge from £8 a day, or £0.80 for residents, to £25 is both unfair and disproportionate and even TfL forecasts that the charge will increase congestion and is unsuitable for cutting CO_2 emissions.

48 See *Kirkup* (2008).

component should have been added to the existing congestion charging scheme. The new Central London Congestion Charging Scheme has been considered as a means to promote individual behavioural change, to increase people's awareness of the impacts of their transportation choice and, thus, to tackle climate change. In the short run, drivers should have been encouraged to use public transport more frequently. Over time, the purchase of cars, which emit less carbon dioxide, should have been made more attractive. In order to reach these aims Transport for London intended to change the level of the congestion charge according to the vehicle's CO_2 emissions level. The foreseen alterations would have included three CO_2 emissions levels, which should have been based on Vehicle Excise Duty bands. In the UK, all owners of new cars have been paying their Vehicle Excise Duty according to their CO_2 levels since March 2001. The Vehicle Excise Duty scheme consists of seven bands, band A to G, where band A represents the lowest CO_2 level. Band G covers cars emitting the highest level. Cars with CO_2 emission of less than 120 g/km CO_2, which is equivalent to bands A and B, and which furthermore meet Euro 4 emission standards, would have been eligible for a 100 percent discount. Simultaneously, the current alternative fuel discount would have been phased out until January 2010. Potentially chargeable vehicles with emissions of more than 226 g/km CO_2 – band G cars - should have paid a higher charge of £25. Potentially chargeable vehicles with an engine size of more than 3001 cc and manufactured before 2001 would have been subject to the higher charge, too. Even residents owning a band G or equivalent car would have been subject to the higher charge. For all other potentially chargeable vehicles no changes would have been arising. Thus, cars emitting between 121 g/km and 225 g/km CO_2 still would have been subject to the £8 standard charge. Cars emitting 120 g/km or less, which do not meet Euro 4 standard, would have also been subject to the £8 standard charge. Finally, no changes would have been arising for older cars powered by an engine up to 3000 cc and registered before 2001.

4.3 Impacts of the Emissions Related Congestion Charge

Transport for London developed models to predict the impacts on traffic congestion and the environment of the Proposed Emissions Related Congestion Charge. These models are based on data collected by Transport for London's automatic number plate recognition system, car market studies and behavioural surveys exploiting the individual travel and vehicle purchase behaviour. The models are based on the assumption that car drivers within the Charging Zone could respond to the Emissions Related Congestion Charge in several ways. They could, e.g., simply continue to drive and pay the higher charge, drive less frequently, travel by another mode of transport, drive elsewhere or at different times, purchase a less emitting car in order to replace the more polluting one or, if the driver is already in possession of a discounted car, use the car inside the Charging Zone at all.

Transport for London figured out that the proposed Emissions Related Congestion Charge would only have minor impacts on the vehicle fleet composition, on traffic, congestion and, finally, vehicle emissions. Behavioural studies and research into car market trends indicate a small net reduction of cars entering the Charging Zone of 1,000 per day in 2009 and 2,000 per day in 2010. The number of band G cars entering the Charging Zone would slightly decrease while the daily number of bands A and B cars entering the zone would increase. This relatively insignificant impact in the short term can be explained by the limited number of low emitting cars available on the car market and the relatively modest change in the charge from £8 to £0 making the purchase of such a car more interesting compared to the financial change that high emitting cars are faced with (£8 to £25). In the long run, due to the potential encouragement of bands A and B cars Transport for London studies assume a growing effect on traffic and congestion. Drivers of low emitting cars, who did not travel within the Charging Zone so far, could be encouraged to do so and in doing so the decline due to the less travelled kilometres of band G cars could be offset. Depending on the relative responses of low and high CO_2 emitting car drivers, car traffic would slightly decrease or even increase. Hence, congestion is also either to increase or decrease, which would probably lead to further emissions of CO_2. According to the proposal's findings, up to 5,000 tonnes CO_2 could be saved in 2009 and up to 7,500 tonnes CO_2 in 2010. Emissions of NO_x and PM_{10} are forecasted to decrease or increase slightly in 2009 (+50 tonnes to -40 tonnes of NO_x, +5 tonnes to –5 tonnes of PM_{10}) and in 2010 (+90 tonnes to +30 tonnes of NO_x, +10 tonnes to +5 tonnes of PM_{10}).[49]

49 See Transport for London (2008b), pp. 48-51.

Table 8 Traffic and congestion: projected impacts within the Charging Zone

		2007	2009	2010
Cars entering the extended zone per charging day	Band G	33,000	25,000-30,000	18,000-27,000
	Bands A and B	3,000	9,000-12,000	25,000-28,000
Vehicle kilo-metres			-0.6%-0.2%	-0.7%-0.3%
Congestion			-1.2%-0.3%	-1.5%-0.5%

Source: TfL (2008b), p. 49.

According to Transport for London the set-up and publicity costs were estimated at £13.5 million in 2008. The planned changes should have added £1.5 million to £2.5 million to the current operating and monitoring costs of £131 million. In addition, the changes to the charging scheme should have generated £29 million to £49 million in additional revenue in 2009 and £18 million to £61 million in 2010 respectively.[50]

4.4 Critical Assessment of the Emissions Related Congestion Charge

In the preceding section we have presented the impacts of the planned emissions charge on traffic, congestion and air quality. Apparently, if the emissions charge had been implemented, it would have had a limited impact on air quality. As described, even studies conducted for Transport for London concluded that the charge would have only slightly decreased traffic, congestion and emissions of the greenhouse gas CO_2 as well as air pollutants NO_x and PM_{10}. The positive traffic and congestion effects due to the constrained use of high polluting band G cars would have been offset by the extended use of bands A and B cars. Hence, the relatively minor reduction of emissions, which would have resulted from less band G cars, would have been offset by the extended use of bands A and B cars.

50 See Transport for London (2008b), pp. 58-59.

In 2003, roughly half of the total traffic emissions of NO_x and PM_{10} in Central London were emitted by vehicles, which were not eligible to the charge. Taxis emitted even more NO_x and PM_{10} than all private cars together. In Greater London, only 18 percent of total traffic NO_x emissions and 16 percent of total traffic PM_{10} emissions could be attributed to non-chargeable vehicles. Taxi emissions of NO_x and PM_{10} amounted to three percent and six percent respectively. Cars on the contrary contributed 34 percent respectively 41 percent to the total NO_x and PM_{10} emissions of road traffic in Greater London. In terms of CO_2 emissions, one third of the total traffic related emissions in Central London were exhausted by vehicles, which are exempted from the charge. In detail, taxis and busses were accountable for 19 percent respectively 12 percent. In the Greater London area, the share of CO_2 emissions of all non-paying vehicles together did not exceed nine percent. Taxis and busses emitted three percent respectively five percent. Table 9 provides detailed data on emissions and information about the location taken from the London Atmospheric Emissions Inventory 2003.[51]

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51 See Greater London Authority (2006), pp. 67 and 75.

Table 9 Relative contribution by vehicle type to total emissions of various pollutants of road traffic in Central London and Greater London in 2003

	Central London						Greater London					
	NO_x		PM_{10}		CO_2		NO_x		PM_{10}		CO_2	
	tonnes/year	%	tonnes/year	%	tonnes/year	%	tonnes/year	%	tonnes/year	%	tonnes/year	%
Potentially chargeable												
Cars	234.7	14.9	23.1	17.8	143,383.5	38.7	9,056.5	33.6	804.8	40.9	4,711,754.5	62.7
Vans	159.8	10.1	24.6	18.9	53,217.4	14.3	2,929.3	10.9	444.4	22.6	912,094.1	12.1
Lorries and others	460.8	29.2	20.5	15.8	49,953.1	13.5	10,211.4	37.9	410.7	20.9	1,193,646.4	15.9
Total	855.3	54.2	68.2	52.5	246,554.0	66.5	22,197.2	82.5	1,659.9	84.4	6,817,495.0	90.7
Not chargeable												
Licensed taxi	285.7	18.1	38.0	29.3	70,104.6	18.9	892.2	3.3	125.1	6.4	226,895.2	3.0
Buses and coaches	425.5	27.0	14.1	10.9	43,065.5	11.6	3,740.1	13.9	107.2	5.5	395,888.8	5.3
Powered two-wheelers	10.5	0.7	9.6	7.4	11,246.7	3.0	88.9	0.3	73.8	3.8	74,829.3	1.0
Total	721.7	45.8	61.7	47.5	124,416.8	33.5	4,721.2	17.5	306.1	15.6	697,613.3	9.3
All vehicles	1,577.0	100.0	129.9	100.0	370,970.8	100.0	26,918.4	100.0	1,966.0	100.0	7,515,108.3	100.0

Source: GLA (2006), pp. 67 and 75 and own calculations.

The importance of non-chargeable vehicles as a significant pollutant source becomes more obvious when comparing the spatial allocation of the emissions of different vehicle types in London. In 2003, about 30 percent of the NO_x, PM_{10} and CO_2 emissions of taxis in the entire area of Greater London were exhausted in Central London. Motorcycles and busses emitted between 10 and 15 percent of their total air pollutant and greenhouse gas emissions in Central London. However, cars, vans and lorries circulating within Central London contributed only three percent, six percent and five percent respectively to overall CO_2 emissions of the particular vehicle type in Greater London. Conversely, more than 95 percent of the emissions of cars, vans and lorries occurred outside Central London while Taxis taken together emitted only about 70 percent of their overall CO_2 emissions in Inner London and Outer London.[52]

Moreover, because of their pronounced design standards, London taxis have a larger size and weight and, hence, most taxis feature high emission levels (see Table 10). Even Transport for London itself states that "given their prevalence in Central London, they are a significant source of road transport CO_2 emissions".[53] For that reason, stricter taxi emissions standards have been implemented. By July 2008 all taxis will have to meet Euro 3 standard for NO_x and PM_{10} otherwise taxi drivers will lose their taxi licence.

Table 10 Emissions per passenger kilometre of different modes of transport in London

Source	NO_X	PM_{10}	CO_2
Cars	0.49	0.02	133
Buses and Coaches	0.22	0.06	71
Taxis	1.26	0.28	501

Source: GLA (2001), p. 37.

As mentioned above, the impacts of CO_2 on climate change are not coupled to the actual location of its output. Instead, greenhouse gases diffuse into the atmosphere so that the total amount of emissions is relevant for their impact on the global and, therefore, also on the local

52 See ibid.

53 Transport for London (2007c), p. 26.

climate system. Thus, a proper means for tackling greenhouse gases should effectively reduce the total amount of emissions. Besides the fact that the proposed emissions charge would not have cut the level of CO_2 emissions effectively, the relatively marginal contribution of Central London's emissions to the CO_2 emissions in entire London should be taken into account. Road Transport emitted about 371,000 tonnes CO_2 in Central London in 2003. Chargeable vehicles emitted 247,000 tons. In the same year, road transport produced about 7.5 million tonnes CO_2 in Greater London. The total emissions of all sources in Greater London were 33.8 million tonnes CO_2. In other words, road transport contributed one quarter of the CO_2 emissions of all sources in Greater London. Road transport in Central London accounted for roughly five percent of all traffic related CO_2 emissions and merely contributed 1.1 percent to the total carbon dioxide emissions of all sources in entire London. Thus, even if the emission charge had been implemented and would have effectively cut CO_2 emissions, it would not have had a substantial impact on London's CO_2 footprint.

Transport for London has already stated in its First Annual Report published in 2003 that due to the change of traffic volumes and patterns congestion charging is actually reducing road vehicle emissions. However, Transport for London expected that despite the remarkable impacts on traffic volumes and congestion the changes in primarily local pollutants directly from the scheme would be comparatively small because congestion has to be seen as only one of many emission factors in London. Air quality is also dependent on the pollution of other sources, the weather and on-going technological vehicle improvements. Furthermore, congestion charging in London mainly affects cars, which are not the vehicles with the highest emission levels per (passenger) vehicle-kilometre. Finally, because of chemical reactions, dispersion and mixing in the atmosphere, changes in emissions from traffic do not induce equivalent alterations in local concentrations of air pollution.[54]

5. Conclusion and Agenda for Future Research

The case of London demonstrates that road pricing appears to be an appropriate measure for dealing with congestion reduction and inter-

54 See Transport for London (2003), p. 202.

nalization of negative external effects caused by congestion. After the first year of operation, the congestion level had already fallen significantly but has been steadily increasing since then. In 2008, congestion reached its pre-charging level. However, this increase cannot be considered to be a sign of failure of the congestion charge. In reality, the increase has correlated positively with less effective network capacity allocation. This is also the reason why congestion did not decline within the Western Extension Zone while traffic has been decreasing.

In succession to the implementation of congestion charge in Central London as well as its Western Extension emissions of NO_x and PM_{10} have decreased significantly. But it has to be considered that technology improvements have comparable or even wider impacts on vehicles' emissions than speed changes and/or traffic volume changes. In contrast, ongoing vehicle technology improvements have not been affecting CO_2 emission so far. Beneficial impacts on emissions of CO_2 can be attributed to traffic volume and speed changes. However, further research is needed in order to investigate the impacts of the rising congestion level on traffic emissions.

The preceding chapters have demonstrated that the proposed changes to the charging scheme would not have been effective in tackling emissions of CO_2. Even studies conducted by Transport for London concluded that the reductions of CO_2, which would have been arisen by the constrained use of high polluting cars, would have been offset by extended use of low emitting cars. Furthermore, the emissions charge would not have been covering vehicle types significantly polluting such as taxis, buses and motorcycles, which are all exempted from the charge. These vehicle types contribute much to the traffic inside the original zone as well as the Western Extension. Hence, fuel taxes seem to be more effective in internalizing external effects caused by traffic related greenhouse gases. However, regarding local air pollutants road pricing schemes might be a more suitable approach.[55] Finally, CO_2 emissions reductions have to be assessed against the background of overall emissions output in the entire area of London. Traffic inside the Charging Zone contributes only 1.1 percent to the overall emissions of all sources emitted in London.

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55 See *Bickel/Friedrich* (1995), p. 121; *Puls* (2008), p. 75; *Rich/Nielsen* (2008), p. 269.

A broad agenda for future research with respect to the wider effects of road pricing exists. First, the effects on vehicle emissions have been largely ignored so far. Second, despite, or even because of, relatively few practical examples of charging schemes it would be worthwhile to intensely study political, psychological and other success criteria for the introduction of a road pricing schemes. Finally, despite the fact that the proposed Emissions Related Congestion Charging Scheme would not have cut emissions significantly, it was part of Livingstone's election campaign. One may suppose that the decision to introduce an emission charge was on the one hand taken for fiscal reasons. On the other hand, Ken Livingstone expected to receive a political reward by setting an environmental issue on the political agenda. Evidently, he was beaten by his political rival Boris Johnson who has announced to scrap the Emissions Related Congestion Charge.

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