Road Pricing: Lessons from London

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1. INTRODUCTION

Traffic congestion arises when the volume of traffic exceeds the free-flow capacity of the link or junction, and in such cases each additional vehicle causes delays to other vehicles and suffers in turn from a slower and thus more costly journey. This negative externality creates a text-book case for a (Pigouvian) corrective tax or charge, and provides the standard argument for road pricing. Models of increasing sophistication, which describe congestion have been developed over the years since the seminal work of Vickrey (1955) and the theoretical case for road pricing is now widely accepted by economists. A charge equal to the marginal congestion cost would make drivers face the true cost of their journey, thus maximising social surplus and internalising the congestion externality.

If the problem is so clear, and the solution so obvious, why has it not been implemented widely in all the towns and cities that suffer from congestion today? There are three broad answers to this question:

(1) Marginal cost pricing in the road sector poses public and political acceptability issues, linked sometimes to concerns about equity.

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(2) Introducing marginal cost pricing in the transport sector does not guarantee an efficient outcome when there are externalities or distortions in other (related) sectors in the economy, which are not priced according to marginal cost.

(3) Marginal cost pricing has proved difficult to implement. Marginal cost pricing would require highly differentiated pricing systems in time and space, which would be expensive to provide and confusing to users (Nash and Sansom, 2001).

Bearing points (1) to (3) in mind, it is clear that first-best pricing is not very relevant from a practical perspective.

A second-best charge can be defined as the optimal charge when the true optimum (the first best) is unavailable due to constraints on policy choice. The Theory of Second Best says that a policy that would be optimal without such constraints may not be second-best optimal if other policies are constrained. Unfortunately, this also poses problems. In order to compute a second-best charge a fair amount of information is still required, including marginal congestion costs and the exact constraints.

The problem of traffic congestion remains and a solution is still required. There is an externality that creates an imperfection in an already imperfect market. A similar problem arises with environmental pollution. Very few, if any at all, real-world charges will come close to the theoretically correct Pigouvian charge. The question is can welfare be increased using a congestion charge that is neither first nor second best?

This paper addresses that question using the London Congestion Charging Scheme and its proposed extension as its test-example. We find that the welfare gains from a congestion charge depend crucially on the location of where the charge applies and charge level and our results are only valid for the set of boundaries that have been proposed by TfL. If the model we use covered a different area, traffic flows and times savings would be different. The political economy of such decisions is not always guided by any efficiency principles, but rather by political forces and lobbies. The final result will be the combination of different pressure and political groups and this may or may not lead to increases in welfare.

In the case of London, we find that the original congestion charging zone and congestion charge yielded gains. We cannot make definite conclusions on the increase of the charge from £5 to £8. We also model and assess the proposed extension and find that the benefit cost ratio would be higher than unity, and therefore the project would be justified on economic grounds. This can be translated to other towns and cities that may be considering the introduction of road pricing, and in general to other sectors of the economy where there are market imperfections. Whilst simple and easy-to-administer solutions may yield important gains in efficiency, they may also yield losses, if they are influenced by political interests, even when they had potential to yield gains had the details of the policy not been so affected by pressure groups. Despite the lobbying and pressure groups that influenced the design of the London Scheme, it has increased welfare. This does not necessarily constitute a general conclusion; the influence of political factors may reduce or eliminate welfare benefits of a project.

2. IMPACTS OF THE LONDON, DURHAM AND SINGAPORE SCHEMES

Road pricing as a demand management tool in city centres has only been implemented in London, Durham and Singapore. The impacts of these schemes are briefly outlined below.

2.1. The Singapore Schemes

The schemes in Singapore have become classic examples of road pricing in the literature. It should be borne in mind however that Singapore is a fairly particular case, as it is an island city-state that measures only 42 km east to west, and 23 km north to south, with a dominating political party (the People's Action Party) that has been in power since 1959. This makes the Singapore road pricing schemes unique cases in unique circumstances.

2.1.1. Area Licensing Scheme – 1975 to 1998

The first road pricing scheme to have ever been implemented anywhere in the world was the Singapore Area Licensing Scheme (ALS) on 2 June 1975. Vehicles were charged on entry (and later exit in the evenings) into the restricted zone (RZ). Vehicles entering the 7 km^2 RZ, which included the central business district, were required to purchase a paper area licence in advance and display it on their windscreen. This was then valid for entry an unlimited number of times whilst valid.

The system was manually enforced by officers standing at the boundaries of the RZ. Violators were fined. Although the vehicles that were exempt varied over the years, by 1989 the only exemptions were granted to public transport buses and emergency vehicles (Willoughby, 2000). There were no discounts for residents, although residents could avoid paying a charge by driving in the zone without crossing the boundary.

ALS increased average speeds from 19 to 36 km per hour (Phang and Toh, 1997, p.99). Traffic volumes during the morning peak hours fell by 45 per cent, and car entries decreased by 70 per cent (Willoughby, 2000, p.10).

2.1.2. Electronic Road Pricing – 1998 till present

Although ALS was successful in drastically reducing traffic volumes and congestion at a minimal operating cost, there were a number of problems with the scheme, such as bunching of traffic just before and after the restricted hours, manual enforcement prone to error, and a general perception that a paper based ALS scheme was becoming out-of-place in a city-state that was becoming high-tech and aspired to be regarded as such (Santos *et al*, 2004). Thus, on September 1, 1998 an Electronic Road Pricing (ERP) scheme replaced the ALS (and also a paper permit system that had been introduced on some expressways outside the city centre). This ERP is as of 2005, still the only one of its kind in the world.

With ERP, there is not one charging area with a defined boundary, but rather, links that are charged. Charging times vary but in general these are from 7:30am to 7pm on very central roads, and from 7:30am to 9:30am on expressways and outer roads.

Vehicles, equipped with In-vehicle Units (IUs), which have a smart card inserted in them, are charged automatically each time they cross a gantry without the need to slow down. If motorists pass through an operational ERP gantry without a properly inserted smart card or with a smart card that has insufficient balance to pay the charge, a valid transaction will not take place. When this happens the enforcement cameras take a digital picture of the rear licence plate and the registered keeper of the vehicle is then fined. The only vehicles exempt are emergency vehicles. ERP rates, published on the Land Transport Authority website, vary with vehicle type, time of day and location of the gantry. In February 2003 a graduated ERP rate was introduced in the first five minutes of the time slot with a higher charge in order to discourage motorists from speeding up or slowing down to avoid higher charges. For example, on some gantries where the charge for passenger cars would be S$1.50 between 8.30 and 9am, and S$0.50 between 9 and 9.30am, it is now S$1 between 8.30 and 8.35am, S$1.50 between 8.35 and 8.55am, and S$1 between 8.55 and 9am, when it changes to S$0.50.

Menon (2000, p.42) reports that although ERP charges were lower than ALS charges, one year after the introduction of ERP, traffic volumes in the RZ had fallen by 15 per cent for the whole day and by 16 per cent during the morning peak, although there had been an increase between 6:30 and 7pm, the last half-hour of ERP operation. At the same time, traffic volumes had increased in the pre-ERP period 7 to 7.30am, mainly as a result of vehicles avoiding the charge. Some months had also seen an increase in traffic in the post-ERP period 7 to 7.30pm. Speeds did not increase, since the idea was not to increase ALS speeds, but rather, to have a fine-tuned system that would charge road users more accurately for actual usage.

2.2. The Durham Scheme

The Durham Scheme is a small and modest example of road pricing. Although it can be seen as the first scheme to have been implemented in England, after the Transport Act 2000[1] was passed, it does not really represent a typical road user charging project, mainly because of its limited scale. Nonetheless, the objective of the charge, which was to reduce traffic demand on a piece of road, was achieved, and therefore the example deserves at least a mention.

On October 1, 2002 Durham County Council implemented a £2 charge for all vehicles using Saddler Street and the Market Place between 10am and 4pm, Monday to Saturday

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[1] The Transport Act 2000 gave local authorities in England and Wales powers to introduce road user charges and/or workplace parking levies to tackle congestion when it appeared it would help achieve the policies in the charging authority's local transport plan.

(Durham County Council, 2003). Saddler Street is a narrow road, and the only public access to the historic city centre, where the Cathedral and the Castle are, as well as some businesses, a school, parts of Durham University and a small number of private houses. This historic city centre is also known as the Peninsula, as it is surrounded by the River Wear.

Since it is a one road toll, the charge is paid on exit from the area on a ticketing machine, that does not give any change, and is monitored by Closed Circuit Television (CCTV). Alternatively, payment is accepted before 6pm at the National Car Parks (NCP) Parking Shop.

A small number of exemptions apply, including emergency vehicles, City Council Liveried vehicles, Public Utility vehicles on emergency duty, Bullion Vehicles, Royal Mail and Recovery Vehicles. The Dean and Chapter of Durham Cathedral, the permanent residents on the Peninsula, and the University are all issued with a limited number of exemption permits, as are the parents of the youngest children at the Chorister School (Durham County Council, 2003). Finally, a small number of transponders are issued for attachment to vehicles with high frequency use. These transponders are attached to the windscreens of vehicles so that the bollard can detect them and lower automatically.

Although drivers who fail to pay the charge are still permitted to use the road, a penalty notice is issued to the vehicle's registered keeper if payment is not made before the end of the working day. The number of violators however is negligible. Vehicles are recorded on the CCTV system and owners traced through the Driver and Vehicle Licensing Agency (DVLA).

The number of vehicles using the road, from the Market Place to the Cathedral, after the scheme was introduced fell by between 50 and 80 per cent, depending on the traffic count used as the base (Durham County Council, 2003, Chart 3). The number of pedestrians increased by 10 per cent on average, from 14,000-14,500 a day to 15,000-16,000 a day (Durham County Council, 2003, Chart 13).

Although the scheme is not technologically advanced, it is a measure that has proved effective for the purpose intended: to reduce traffic on one road in the historic Peninsula.

2.3. The London Scheme

The London Congestion Charging Scheme (LCCS) started on February 17, 2003. The Scheme, implemented and operated by Transport for London (TfL), operates by an area licensing system. All vehicles entering, leaving, driving or parking on a public road inside the zone between 7am and 6:30pm, Monday to Friday, excluding public holidays are charged £8. The charge was originally £5 but was changed to £8 on July 4, 2005.[2]

[2] The analysis in this section is made on the basis of data that was released by TfL before the increase. As of September 15 no data after the increase to £8 has been published. TfL refused to provide us with any data, even if preliminary, despite our requests. The reason they gave us is that they would like to interpret it before it is released in the public domain.

The limit of the charging area is given by the Inner Ring Road, which mainly surrounds Central London. No charge is made for driving on the Inner Ring Road itself.

The charging area is relatively small. It only covers 21 km^2 (8.4 mi^2), representing 1.3 per cent of the total 1,579 km^2 (617 mi^2) of Greater London. There are 174 entry and exit boundary points around the zone. Traffic signs make it clear where exactly the charging zone is.

There are a variety of 90-100 per cent discounts, as well as exemptions. A summary is shown in Table 1.

The charge has to be paid in advance or on the day until 10pm with late payment available between 10pm and midnight but with the charge rising to £10. The charge can be paid daily, weekly, monthly or yearly.

Enforcement is undertaken with video cameras that provide high-quality video signals to Automatic Number Plate Recognition (ANPR) software, which reads and records each number plate with a 90 per cent accuracy rate. At midnight, images of all the vehicles that have been in the congestion charging zone are checked against the vehicle registration numbers of vehicles which have paid their congestion charge for that day. The computer keeps the registration numbers of vehicles that should have paid but have not done so. A manual check of each recorded image is then made and a Penalty Charge Notice is then issued to the registered keeper of the vehicle.

Table 1: Exemptions and discounts

Discount/status	Category
Fully exempt	Motorcycles, mopeds and bicycles Emergency vehicles Public service vehicles with 9 or more seats licensed as buses Vehicles used by disabled persons that are exempt from VED[a] Licensed London taxis and mini-cabs
100% discount with free registration	Certain military vehicles Local government service vehicles (e.g. refuse trucks, street maintenance) Vehicles with 9 or more seats not licensed as buses (e.g. community minibuses)
100% discount with a one-off £10 registration	Vehicles driven for or by individuals or institutions that are Blue Badge holders[b]
100% discount with £10 registration per year	Alternative fuel vehicles – requires emission savings 40% above Euro IV standards Roadside assistance and recovery vehicles (e.g. motoring organisations such as the Automobile Association)
90% discount with £10 registration per year	Vehicles registered to residents of the central zone

Notes:
[a] VED: Vehicle excise duty.
[b] Blue Badges, which existed before the scheme was implemented, are special parking permits issued to disabled people to allow them to park near shops, stations, and other facilities. The badge belongs to the disabled person who qualifies for it (who may or may not be a car driver) and can be used in any vehicle they are travelling in. The discount applies to individual Blue Badge holders anywhere in the EC.
Unemployed 15-25 as a percentage of total unemployed (authors' calculations on OECD data).

Source: www.cclondon.com/exemptions.shtml

2.3.1. Impacts on traffic

According to TfL (2004a, Fig. 3. p.7) the average travel rate in the charging zone during the first year of the scheme was between 3.5 and 3.7 min per km, which is equivalent to an average speed of between 16 and 17 km per hour. This represents an increase of between 14 and 21 per cent with respect to the average speed pre-charging, which was 14 km per hour.

The total number of vehicles with four or more wheels entering the zone during the charging hours was reduced by 18 per cent (TfL, 2005a). Table 2 below presents the key changes in traffic entering and leaving the charging zone.

Table 2: Percentage changes of vehicles entering and leaving the charging zone in 2003 and 2004

	Change inbound 2003 vs 2002	Change outbound 2003 vs 2002	Change inbound 2004 vs 2003	Change outbound 2004 vs 2003
Cars	-33%	-35%	-1%	-2%
Taxis	+17%	+8%	-1%	0%
Buses and coaches	+23%	+21%	+8%	+4%
Vans	-11%	-15%	-1%	-1%
Lorries and other	-11%	-12%	-5%	-5%
Pedal cycles	+19%	+6%	+8%	+8%
Powered two-wheelers	+12%	+5%	-3%	-4%

Source: TfL (2005a, Fig.11, p.25)

As expected, there was a reduction of potentially chargeable vehicles and an increase in exempt vehicles.

Since traffic travelling on the Inner Ring Road does not pay the congestion charge, TfL expected that through traffic, with origin and destination outside the charging zone, would divert and use the Inner Ring Road instead. This indeed happened raising the total veh-km on the Inner Ring Road by 4 per cent when compared with 2002 (TfL, 2004a, 2004b). However, improved traffic management arrangements were put into place on the Inner Ring Road before the Scheme started and this prevented an increase in congestion. For example, between one and two seconds were taken off green light time on radial roads, which were anticipated would have less traffic, and added on to green light time on the Inner Ring Road. That, combined with the end of disruptions linked to road-works in the area during 2002, made a sufficient difference to keep the Ring Road operating satisfactorily with marginally lower levels of congestion during 2003, when compared to pre-charging conditions (TfL, 2004b, p.15). Although during 2004 the Inner Ring Road did not have higher levels of congestion due to re-routing traffic, levels of congestion were comparable to pre-charging conditions (TfL, 2005b, p.13-14).

Traffic outside the Inner Ring Road did not change much. Speed surveys conducted in 2004 show that the main radial routes approaching the zone were only marginally less congested than before the LCCS was introduced (TfL, 2005b, p.18).

2.3.2. Impacts on public transport

Before the Scheme started TfL increased the number of bus places with a combination of more frequent services, new and altered routes, and bigger buses (TfL, 2004a). There was an increase in bus patronage both in 2003 and 2004. Table 3 summarises the main changes.

Table 3: Bus passengers and buses crossing the charging zone boundary

				Charging hours (7am - 6:30pm)					
	AM peak (7-10) Inbound			Inbound			Outbound		
	Passengers	Buses	Passengers	Passengers	Buses	Passengers	Passengers	Buses	Passengers
Autumn 2002	77,000	2,400	32	193,000	8,280	23	163,000	7,800	21
Autumn 2003	106,000	2,950	36	264,000	10,500	25	211,000	9,900	21
Percentage difference	+38%	+23%	+12%	+37%	+27%	+8%	+29%	+26%	+2%

Source: TfL (2005b, Fig. 27, p.45)

The reasons for the increase in bus patronage can be found not just in the LCCS and cars users wanting to avoid the charge by switching mode, but also in the induced demand in response to large-scale London-wide improvements to the bus network (TfL, 2005b, p.45).

Bus reliability in recent years has increased not just as a result of reduced congestion in the charging zone but also as result of increased investment on buses (TfL, 2005b).

Average bus speeds increased by 7 per cent inside the charging zone and by 3 per cent on sections close to the zone and on the Inner Ring Road during the first year of charging (TfL, 2004a). Additional time waited by passengers over and above the route schedule decreased by 24 per cent across Greater London and by 30 per cent in and around the charging zone (TfL, 2005a).

TfL had predicted an increase of 1 per cent in Underground patronage. This did not happen. Underground usage across London and especially in Central London decreased (TfL, 2005b). The reason for this decrease is obviously not related to the congestion charge in any way. If anything the congestion charge might have caused a marginal increase in demand. The reasons for the decrease in passenger levels on the London Underground are probably linked to longer term mode transfer to improved bus services, the slowdown of the economy and the decrease in tourism in London, and the temporary closure of the Central Line in 2003, following a derailment at Chancery Lane station in January (TfL, 2005b). During 2004 Underground patronage recovered returning to 2002 levels (TfL, 2005b).

Although no data has been published for the year 2004, there was no change in rail travel to the charging zone during 2003, after the LCCS was implemented (TfL, 2004b, 2005b).

2.3.3. Impacts on the economy

TfL (2005b) reports that the impact of the Scheme on business performance in the charging zone has been broadly neutral (p.4). They measure business performance in terms of variables such as employment, numbers of businesses, turnover and profitability and find no evidence of any effect from the scheme. They also report that the commercial and residential property markets do not seem to have been affected by the charge either. They also report that an econometric analysis conducted at Imperial College London shows that the congestion charge has had no impact on the central London retail sales (p.5). The trend of the economy in London has been similar to the trend of the economy in the UK, although with more pronounced peaks and troughs.

2.3.4. Generalised cost elasticity of demand

Using the changes in speed and trips registered after the Scheme was implemented, the elasticity of demand for trips with respect to generalised travel costs in London can be estimated. We did this for cars, taxis and Light Good Vehicles (LGVs) both to see what the sensitivity of response was to the charge, and to input the corresponding values in our model of the extension, which we explain below.

The reason for using a generalised cost elasticity of demand rather than a congestion charge elasticity of demand is that the charge increased from zero (before the LCCS was implemented) to £5, leaving no room to use the standard formula $\eta = \Delta Q/\Delta P * P/Q$, where P would have been the congestion charge. This is not a serious problem in transport economics because of two reasons: (a) the congestion charge is just one component of the generalised cost of a trip, which also includes vehicle operating costs and time costs; and (b) the time costs are likely to change once the congestion charge has been introduced.[3]

Given (a), the generalised cost elasticity of demand can be computed. Demand can be measured by vehicle-km or by trips. For our model (explained in Section 3) we needed the elasticity of demand for trips and so that is what we estimated. The generalised cost elasticity of demand for trips gives a measure of the sensitivity of drivers' response when deciding on the number of trips when the generalised cost of those trips changes. Needless to say, since the congestion charge is just one component of the generalised cost, if the congestion charge elasticity of demand could be computed, this would be lower (in absolute value). Dodgson *et al* (2002, p.28) argue that the sensitivity of demand to generalised cost changes will broadly be equal to the fuel price elasticity divided by the fuel share of generalised cost. Using the same reasoning, we could say that the congestion charge elasticity will roughly be equal to the generalised cost elasticity multiplied by the congestion charge share of generalised cost. We return to this point later.

Given (b) it is actually more accurate to estimate the generalised cost elasticity rather than the congestion charge elasticity. With a congestion charge, time costs are likely to be lower, and this needs to be taken into account when assessing the response from drivers to the charge. There will also be an increase in reliability. Dodgson *et al* (2002, p.34) argue that reliability benefits are worth approximately 25 per cent of time benefits and this was the assumption we made for our calculations.

For the time and vehicle operating costs, we followed TAG Unit 3.5.6 of the *Transport Analysis Guidance* (Department for Transport, DfT, 2004a). The speed pre and post charging was assumed to be 14 and 17 km per hour respectively (TfL, 2003, 2004a, b). The number of trips pre and post charging by car, taxi and LGVs were provided by TfL on request. All the tables and details of the elasticity calculations are presented in a Technical Annex published on the Economic Policy website.

The formula used to compute the generalised cost elasticity of demand for trips was

$$\eta = \Delta q/\Delta GC \,.\, GC/q$$

[3] The vehicle operating costs may also change, as fuel consumption for example is higher in conditions of stop and go. However, these changes are likely to be relatively small and for simplification they are ignored in this paper. This is common practice in the road pricing literature.

where q is number of trips by the relevant mode, and GC is Generalised Cost of a trip by the relevant mode (car, taxi or LGV). The values we found are -1.85 for cars, -0.48 for taxis, and -0.75 for LGVs. If we follow the suggestion by Dodgson *et al* (2002, p.28) and multiply these values by the congestion charge share of generalised cost we get rough estimates of the congestion charge elasticities of demand. The congestion charge represents 43 per cent of the GC of a trip by car and 32 per cent of the GC of a trip by LGV, which yields a congestion charge elasticity of -0.80 for cars, and -0.24 for LGVs. This exercise cannot be conducted in the case of taxis, as the congestion charge they pay is zero.

The reason for the very high elasticity in the case of cars can be found in the availability of public transport in London. The relatively low elasticity in the case of LGV is linked to their lack of freedom to work outside normal business hours, which is when the charge applies.

Santos (2004) and Santos and Shaffer (2004) estimate the generalised cost elasticity of demand for trips by car at -1.4 and -1.3 respectively. The difference between their values and ours of -1.85 stems from the fact that they include parking and exclude insurance and depreciation whereas we exclude parking and insurance and include depreciation (although depreciation is included for working cars only). We follow the guidelines published by the DfT (2004a) exactly, and they do not. They use values published in the Automobile Association website, whereas we use the formulae and coefficients from DfT (2004a). Our GC is higher and the estimated elasticity is consequently higher as well.

2.3.5. Marginal congestion cost

If traffic is assumed to be homogenous inside the charging zone, area marginal congestion costs (MCC) can be computed using the following standard equation:

$$MCC = e_{sq} \,.\, b / s(q)$$

where b is value of time in pence per passenger car unit (PCU)[4] per hour, s is speed in km per hour, dependent on traffic volume[5] in the area, q, in PCUs per hour, and e_{sq} is the elasticity of speed with respect to traffic volume.

Santos and Shaffer (2004) and Santos (2004) estimate pre and post-charging MCC at 186.5 pence per PCU-km and 182 pence PCU-km respectively. The area MCC decreased by 2.4 per cent after the implementation of the Scheme. Although detailed speed data on different chargeable vehicles is not available, the MCC in pence per PCU-km can be converted using the relevant PCU ratings. Thus, the pre and post charging MCC for

[4] PCU is a measure of the relative disruption that different vehicle types impose on the network. A car has a PCU rating of 1, a Light Goods Vehicle (LGV) has a PCU rating of 1.5, a Heavy Goods Vehicle (HGV) has a PCU rating of 2.5 or 3, a bus has a PCU rating of 2.5, a motorcycle has a PCU rating of 0.5, and a bicycle has a PCU rating of 0.2. In the US passenger car equivalents (PCE) are used instead. The meaning however is the same.

[5] Since it is an area rather than a link what we are considering we need to talk about traffic volume rather than traffic flow.

LGVs is 280 and 273 pence per LGV.km respectively. Similarly, the pre and post charging MCC for lorries is roughly 466 and 455 pence per HGV.km respectively. The three different chargeable vehicle types (cars, LGVs and HGVs) with different congestive effects pay the same charge, which means that they are not paying for the MCC they produce. If the £5 charge (500 pence) were to reflect the congestion externality of each vehicle type in the charging zone, a car would need to drive on average 2.75 km, a van, 1.83 km, and a lorry, 1.1 km. Using the veh-km from TfL (2005, Table 15, p.29) and the total traffic counts in the congestion zone provided to us by TfL (and available on the Technical Annex published on the Economic Policy website) we can compute the average number of kilometres travelled by the different vehicle types inside the congestion charging zone on a typical weekday. These are 1.98 km for cars, 2.72 km for vans, and 2.51 km for lorries. The conclusion is not only the one expected, but it is also intuitive: cars are overcharged and good vehicles are undercharged. If the charge were to internalise the average MCC of each vehicle type, it would need to be £3.60 for cars, £7.40 for vans, and £11.40 for lorries. Interestingly, if we compute the average of these average MCC internalising charges weighted by the different vehicle types circulating in the congestion zone[6], we get an average congestion charge of £5.15. Put another way, the average charge per vehicle received by TfL is what they would receive if each vehicle type internalised their average MCC and paid a charge accordingly. This is in no way any guarantee of an efficient situation.

2.3.6. Other road transport externalities

Apart from congestion, vehicles impose three other costs on the rest of society: accidents, environmental costs, and road damage (Newbery, 1990). The way in which these externalities can be internalised to achieve an efficient equilibrium depends on the nature of the externality.

Transport accidents for example, impose a range of impacts on people and organisations. DfT (2004b, TAG Unit 3.4.1) describes them as follows:

- medical and healthcare costs[(a)]: in the UK these are borne by the National Health Service, and hence, by tax-payers, or more generally, society;
- lost economic output[(a)]: this is a cost imposed to society;
- pain, grief and suffering[(a)]: this is borne by the individual involved and friends and family;
- material damage[(b)]: this is borne by the insurance companies, and ultimately by the individuals involved;
- police and fire service costs[(b)]: this is borne by society
- insurance administration[(b)]: this is borne by the insurance company and ultimately by the individual;
- legal and court costs[(b)]: this is borne by the individual and by society

[6] The average number of cars in 2003 (post-charging) in the congestion charging zone on a typical weekday was 258,168; the average number of LGVs was 99,405, and the average number of HGVs was 27,878. These values were provided by TfL on request and are published in the Technical Annex on the Economic Policy website.

Those impacts marked [b] are closely related to the number of accidents, while those marked [a] are related to the number of casualties (DfT, 2004b). This is an externality for which there is no efficient level. We cannot say that the efficient level of accidents, or worse yet, of deaths per year is this or that. Human life is invaluable, and even though governments and organisations will need to input some kind of value of life for project appraisal, there is no efficient level of accidents. For the purposes of this paper, it suffices to say, that due to the very specific nature of the accidents externality, and the way in which costs are paid for, it would not make sense to introduce a charge to internalise it. Having said that, there has been some research arguing for the internalisation of accident externalities. Lindberg (2001) for example, develops a theory of accident externality charges and estimates the price-relevant accident cost for Sweden. He even proposes a system to internalise the external cost through an adjustment of the current Swedish insurance system.

Since the main road transport environmental externalities (i.e. global warming and pollution) are related to fuel emissions, which in turn are closely linked to fuel consumption, it seems practical to tax fuel. Fuel duties are a reasonably effective way of dealing with the environmental externality of road transport. In the UK, these are complemented with differentiated vehicle excise duties to reflect the different emissions per unit of fuel consumed by different vehicle types. Thus, diesel vehicles pay a higher vehicle excise duty than petrol vehicles because they are more polluting. Newbery (1998) examines the environmental costs of road transport in the UK and compares them with current levels of transport taxes. He concludes that transport taxes in the UK "appear to more than cover the full social and environmental costs of transport, as well as the cost of providing infrastructure" (p.23).

Finally, road damage costs in Europe are typically borne by the highway authority, who will repair the damage caused by the passage of vehicles (Newbery, 1990). In the UK the highway authority follows a condition-responsive maintenance strategy. Thus, each road is repaired when its condition reaches a pre-determined state. If maintenance is condition-responsive then it is not necessary to charge vehicles for the damage they do to vehicles coming after them, which have to drive on a damaged tarmac, as on average, the condition of the road remains constant (Newbery, 1990). The resources to repair highways in the UK ultimately come from the Treasury, which in turn receives £31.5 billion in fuel duties receipts, Value Added Tax on fuel duties and Vehicle Excise Duties (National Statistics Online, 2004). Heavier vehicles pay a higher Vehicle Excise Duty. For example, as of 2005, a goods vehicle not heavier than 7,500 kg pays an annual Vehicle Excise Duty of £165, whereas a goods vehicle between 27,000 and 44,000 kg pays £650, unless it is 4 or more axled rigid, in which case it pays £1,200 (Driver and Vehicle Licensing Agency, 2005).

Since accidents and road damage can be treated separately, the two candidates for corrective charges are the environmental and congestion externalities. The environmental externality can be easily dealt with by taxing fuel. The congestion externality on the other hand, needs a finer system, which will at least differentiate between peak and off-peak times, and hence, between peak and off-peak traffic conditions. This is what the London congestion charge essentially does. To estimate environmental and accident externalities in London and expect them to be internalised by a congestion charge which was designed to reduce congestion (not accidents or environmental damage) would not be technically correct. Indeed, Malcolm Murray-Clark (Director of Congestion Charging, TfL) explained publicly that reducing environmental externalities was never an objective of the LCCS.[7] The reason why alternative fuel vehicles get a 100 per cent discount (in practice they do not pay the charge) has no emissions reduction purpose, but rather is intended as an added environmental benefit, possible within the structure of the LCCS.

The main objective of the LCCS has always been "to reduce traffic congestion in and around the charging zone" (TfL, 2004b, p.7). It was also expected to contribute to four of the Mayor's ten priorities for transport as set out in his Transport Strategy (GLA, 2001): "to reduce congestion, to make radical improvements in bus services, to improve journey time reliability for car users, and to make the distribution of goods and services more reliable, sustainable and efficient" (TfL, 2004b, p.7). Since the congestion charge was never intended to internalise any externality other than congestion, any assessment of its efficiency should concentrate on the congestion externality.

2.3.7. Increase of the charge from £5 to £8

On July 4, 2005 the congestion charge was increased from £5 to £8. Although as of September 15, TfL has not published any data following the increase, one can expect that the increase in the charge caused further decreases in traffic. The reduction in traffic (vehicles with 4 or more wheels) that was forecast as a result of the variation was between 2 and 6 per cent during charging hours (TfL, 2005c, Annex 5, p.5). We believe the decrease might have been underestimated by TfL but we cannot be definite about it. Assuming the congestion charge elasticities we estimated in Section 2.3.4 (-0.8 for cars and -0.24 for LGVs) the resulting decrease would be 30 per cent in cars, and 10 per cent in LGVs. The problem with this conclusion is twofold. First, the congestion charge elasticity was only inferred from the GC elasticity, not computed directly as this was not possible with a charge varrying from zero to £5. Second, the GC elasticity was computed as an arc elasticity between two observations only. Since we do not know the demand schedule, we cannot be certain about elasticity values on other segments of the curve. Unfortunately we currently have no way of testing our suspicion as no data following the change to £8 will be released by TfL until April 2006.

The week that the charge variation was introduced saw the first of the terrorist incidents in London.[8] It is very probable that this and subsequent incidents had a widespread effect on patronage by all modes, and on travel into central London in general, thus reducing the number of vehicles even further. This also occurred over the summer holiday period, when (in any case) it would have not been possible to make a

[7] Congestion Charging Seminar, organized by the Institution of Highways and Transportation, Imperial College London, 19 March 2003.
[8] Four suicide bombers struck in central London on July 7, 2005, killing 52 people and injuring 700.

definitive assessment of the effect of the charge increase on traffic levels in the charging zone.

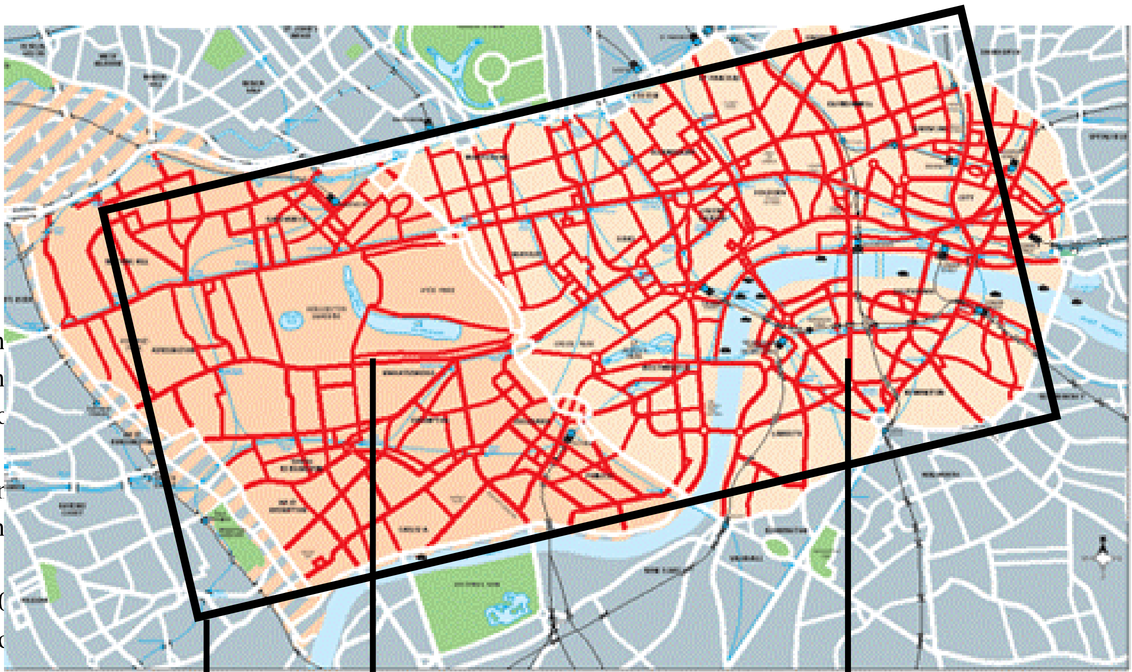
With a GC elasticity above unity it can be expected that when GC increases (due to an increase in the charge that more than compensates any reduction in time costs) revenues will decrease. Despite revenues being lower with an £8 charge, user surplus may go up due to lower travel times for uncharged modes of transport, such as taxis and buses. This may result in an increase in total surplus. No further assessment can be carried out until new travel times and traffic counts are released by TfL.

3. IS THE PROPOSED EXTENSION A GOOD IDEA?

The purpose of this section is to highlight the importance of the location and extension of the charging zone. Indeed the economic benefits of a charging scheme are sensitive to both. As we show here, the extended zone in London for example will increase social surplus. This is interesting not just for London but also for other towns that may be entertaining the idea of road pricing. A larger zone may be worth of consideration, just in case it is found to yield higher benefits.

On August 11, 2004 the Mayor of London published his Transport Strategy Revision (Greater London Authority, GLA, 2004), which allowed for the possibility of a western extension of the Congestion Charging Zone. Consultation on the proposal for a western extension ran between May 9 and July 15, 2005. As of September 15 no final decision has been made on whether the extension will happen.

The proposed area of westward extension covers all of the Royal Borough of Kensington and Chelsea and also areas of the City of Westminster that were not covered by the existing scheme. Figure 1 shows the whole of the area, including the proposed extension.



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existing central London scheme as well as the proposed western extension.

[9] Extending discounts to residents beyond the charging zone is a proposal that came as a result of comments received during the 2004 consultation on the Transport Strategy Revision.

We model[10] the expanded congestion charging area as a rectangular grid, which is a close geometric approximation to the actual shape of the area.

3.1. Surplus impacts

The analysis in this section employs the approach to cost benefit analysis presented in TAG Unit 3.5.3 (DfT, 2004c) by calculating benefits by mode.

The model developed in this paper uses a speed flow curve with linear segments. This translates directly into an Average Social Cost curve with linear segments, shown in Figure 2.[11] When agents decide whether or not to take a trip they consider their marginal private cost (MPC), which in the presence of only congestion externalities is equal to the Average Social Cost (ASC). If the ASC per km of a representative vehicle is c and the total social cost of a flow of q vehicles is $C = cq$, then when an additional vehicle is added to the flow, the total social cost will be increased by

$$MSC = dC/dq = c(q) + q.dc/dq$$

where MSC is marginal social cost. In the literature, the marginal private cost (MPC) is usually set equal to the average social cost (ASC). The reason is that an individual car driver will experience the average social costs, including congestion costs, as his or her marginal private cost (MPC). The MSC is the sum of the MPC and the Marginal Congestion Cost (MCC), or congestion externality, given by $q.dc/dq$. This is the standard model of the economics of congestion for a link. The regulator's problem is to set a corrective charge equal to the MCC, to internalise the congestion externality. For the case of London, a constant £8 area charge is set that does not vary according to which linear segment of the MSC curve is appropriate to the road conditions. However to aid analysis, it shall be assumed that the planner introduces a congestion charge exactly equal to the MCC. This assumption will be later relaxed.

Figure 2 shows the optimal congestion charging policy. As discussed above, the charging authority can achieve the socially optimal level of flow, q*, by imposing a charge equal to MSC(q*) – MPC(q*). This will confront drivers with their Marginal Social Cost of travel as opposed to the Marginal Private Cost, thus eliminating the area of welfare loss ε. Thus the net benefit to society will be equal to area ε, which can be computed by β–α (Newbery, 1990; Rietveld and Verhoef, 1998).

For the purposes of the model, Figure 2 is purely illustrative. Road users are not assumed to be homogenous as is in Figure 2. In reality some groups of users experience an overall fall in cost, by virtue of exemption from the charge or from travel time and vehicle cost savings exceeding the charge. A fall in cost implies an increase in demand for these groups, these groups are said to be 'priced on to the roads'. The computation of the benefit of being priced onto the roads is exactly analogous to the computation of area

[10] The details of the model are presented in a Technical Annex on the Economic Policy webpage.

[11] Except for the congestion externality, all other externalities associated with making a trip are ignored for the time being.

α in the case where users are priced off. The surplus change to users priced on or off the roads is computed by the Rule of a Half (ROH). The ROH is simply the change in total cost divided by 2: $\alpha = ((q^1 - q^*).(C^2 - C^1))/2$. As is made clear by the diagram, the ROH will be exactly equal to the change in surplus when the demand curve is linear. If the demand curve is not in fact linear, then the ROH will just be an approximation.

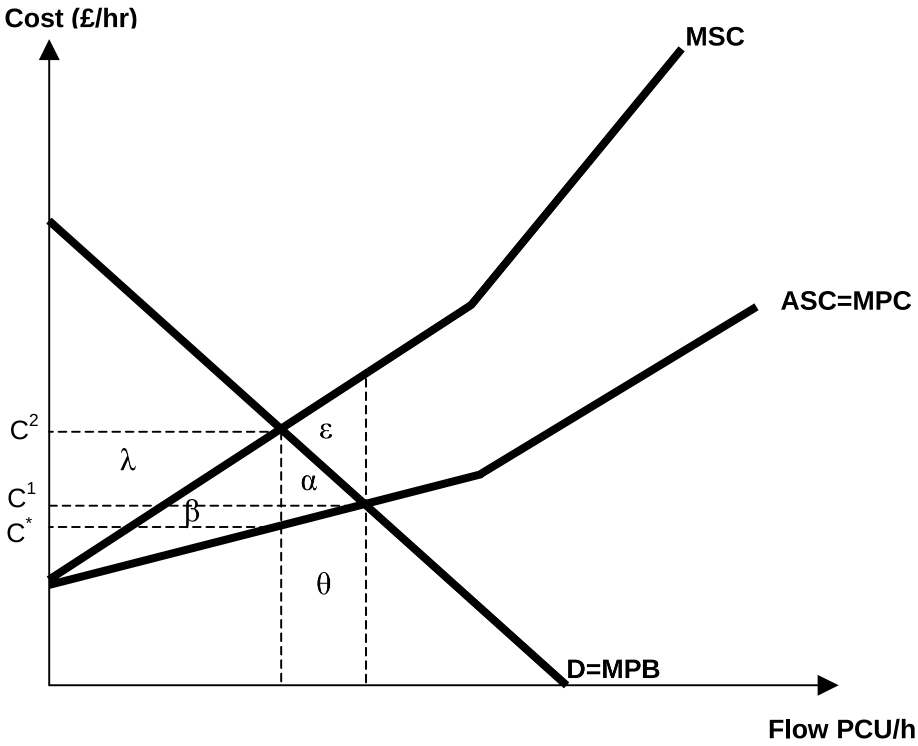

Figure 2. Surplus analysis of road pricing

The area β, which is the fall in costs (excluding the charge) to existing users, is computed in a two step process. First area (β+λ), which is equal to the revenue collected, is computed by multiplying the charge by the quantity of vehicles paying for each group. The area β for each group is obtained by subtracting λ from (β+λ). λ is calculated by multiplying the difference between generalised costs before and after charging by the quantity of vehicles. This is the simplest method of computing β given the outputs of the model. In no way does this process treat revenue as a net benefit. The area λ is simply the transfer that is required to endogenise the marginal external cost of travel and as a result is netted out. Put another way, all of the revenue (β+λ) accrues to the charging authority, here TfL, however part of this revenue is a net benefit in the form of lower real travel costs C*.

Table 4 presents the aggregate changes in user surplus and in total revenue calculated using this methodology.

Table 4: Direct surplus impacts (per year – 2007, 2004 prices)

Change in user surplus (£) (-λ-α)	Change in revenue (£) (λ+β)	Change in total surplus (£) ((β-α) = ε)
36,838,367	49,158,551	85,996,918

Source: Own calculations

The change in revenue predicted by the model is close to the £ 55 million per year given in the Report to the Mayor on the expansion (TfL, 2004c, Table 3, p.12). It should be noted however that the forecast revenues in the Report to the Mayor were computed on the basis of a £5 charge, whereas the ones on Table 4 have been computed on the basis of an £8 charge. For the purposes of comparison, we run the model assuming a £5 charge and found revenues to be £57 million, which is a number even closer to that estimated by TfL (2004c). The change in user surplus however is lower than that estimated in Table 4: £24 million, and the change in total surplus is consequently lower. The reason why revenues are higher with a lower charge is linked to the GC elasticity for cars, which is higher than unity. When the charge increases the GC of a trip increases, and since the elasticity is above unity, the total revenues decrease.

The change in total surplus is higher with an £8 charge because the change in user surplus more than compensates any lost revenues that would have accrued with a £5 charge.

Before moving on to the next section, the incidence of benefits and disbenefits deserves some discussion. If travel is classified as an intermediate good, the Diamond-Mirrlees productive efficiency result applies – the first best level of travel should be pursued regardless of distributional impacts (Diamond and Mirrlees 1971). Certainly freight transport is an intermediate good; passenger transport could be thought of as an intermediate good since it is consumed in the production of work services. If passenger transport is not an intermediate good then it should be taxed like all other consumption goods; to minimise overall tax distortion.[12] Even if the Diamond-Mirrlees result applies it is worthwhile discussing the incidence of benefits of the scheme, although they will not be taken into account in the cost benefit analysis. Table 5 shows a breakdown of the changes in user surplus.

Clearly the biggest losers are those who have a destination or origin in KC and cannot change their route to avoid the charge. The biggest winners are the KC residents who can drive into the central zone at 80 pence per day[13] instead of £8 per day. Further disaggregation of surplus changes would reveal that taxi drivers and passengers benefit most since they are exempt from the charge but still experience the speed benefits. Aside

[12] Newbery (1990) discusses this problem in detail.

[13] They need to pay the congestion charge for five consecutive days in order to qualify for that discount.

from taxi drivers, those with high VOT benefit next most, in particular those driving cars for work purposes. North-South through traffic experiences an increase in total surplus. This is quite surprising given a substantial proportion of traffic is forced to route around the zone, thus facing an increase in cost. The reason for this result is that the extra cost of routing round is small relative to the gain for taxi drivers and passengers who experience the free lunch of higher speeds at no extra cost.

Table 5: Surplus breakdown

Group	Change in user surplus (£ per year)
North-South (inbound/outbound)	-32,895,481
East-West (not from/to CZ)	-23,440,537
East-West (from/to CZ)	51,062,480
Internal	19,193,039
North-South through	11,017,778
East-West through	11,901,088

Source: Own calculations

The main conclusion that can be drawn from this analysis is that different groups will benefit or disbenefit differently. Origin and destination together with the possibility of changing route, the mode of transport used and the purpose of the trip (work or non-work) are all determinants of the impacts of a road pricing scheme on different groups. These determinants will have different effects depending on the exact location of the boundary of the charging zone. The numbers that we computed are of course specific to the Extension as proposed by Transport for London, and the £8 charge. Any city considering the introduction of a road pricing scheme, be it cordon based or an area license like the case of London, or any other type of scheme, will need to estimate the incidence on each group, and even investigate different scheme designs and their impacts, before making a decision. These findings are in line with those from Santos and Rojey (2004), who conclude that the distributional impacts are town and scheme specific. They assess the different impacts on different income groups living in different areas of three English towns (Cambridge, Bedford and Northampton), and find different results in each case. No universal conclusions can be made on the distributional impacts except that these depend on the precise characteristics of the town and scheme in question.

Finally before proceeding on to the analysis of the indirect effects of expanding the charging zone, it is worthwhile testing the sensitivity of the results to the elasticities assumed. Table 6 shows the figures corresponding to elasticities 20 per cent higher and 20 per cent lower than those used.

Table 6: Sensitivity analysis

Elasticity	Ex-post traffic (per hour)			Speed	Surplus analysis
	Into/Out	Internal	Through	km/h	Δ in Total surplus
-20%	23819	9773	3626	24.8	125,562,437
Actual	22672	10139	3687	25.5	122,710,464
+20%	21523	10503	3840	26.0	118,155,427

Note: The GC elasticities computed in Section 2.3.4 (-1.85 for cars, -0.48 for taxis, and -0.75 for LGVs) were increased and decreased by 20 per cent and input into the model.

Source: Own calculations

The figures in Table 6 are a reassurance of the robustness of the model. Speeds and traffic figures move in the expected directions, and the change in total surplus is relatively insensitive to the elasticity employed. The result that may seem surprising is that the change in total surplus falls with elasticity. Although this may seem counterintuitive at first sight, it should be borne in mind that the increase in total surplus increases with the elasticity only when the toll is also allowed to decrease and there is no switching effect. In this model, the toll is fixed at £8 and drivers have the option of switching route. There are two possible explanations for the final gain decreasing with elasticity. Firstly, the toll may be above the optimal level, so that too many vehicles are being priced off the roads[14]. Secondly, there may be too much switching. Switching effects are costly and these costs may offset part of the gain of the initial traffic reduction (with its consequent increase in speed and lower travel time costs).

3.2. Other impacts

3.2.1. Environmental externalities

The details of calculations of emissions are given in the Technical Annex. In brief, parameters from the *Design Manual for Roads and Bridges* (Highways Agency *et al*, 2003) [15] were used to compute emissions of carbon dioxide, particulate matter, nitrogen oxides and carbon monoxide per km before and after the implementation of charging. This emission value was then multiplied by the total kilometres travelled inside the zone. The increased emissions from drivers switching to go around the zone was then added to this figure.

The monetisation of the reduced emissions intrinsically carries some degree of uncertainty. Clarkson and Deyes (2002) review the literature and conclude that £70/tC at 2000 values and prices is the value that enjoys the greatest support in the literature. This

[14] Santos *et al* (2001) find that the change in total surplus may be negative if the charge is too high.
[15] Volume 11, Section 3, Part I, Annex 2.

is also the value suggested by DfT (2004e). Clarkson and Deyes (2002) also suggest increasing it by £1/tC per year in real terms, which yields £77/tC in 2007 values and 2000 prices. The high and low estimate values of the health costs of carbon monoxide, nitrogen oxides and particulate matter were taken directly from McCubbin and Delucchi (1999). All values were converted to pounds and inflated to 2004 prices using HM Treasury's GDP Deflator Series. Estimates for the values of nitrogen oxides and particulate matter from DfT (2004e) were also used.

Table 7 provides a summary of the social costs of the different pollutants and Table 8 gives the environmental results we found. The range of values reflects the considerable uncertainty attached to them.

Table 7: Social cost of the different pollutants (£ per tonne, 2007 values and 2004 prices)

	(a)	(b)	
		Low estimate	High estimate
Carbon	86	-	-
Particulate matter	429,566	8,013	75,736
Nitrogen oxides	1,187	1,325	19,433
Carbon monoxide	-	11	84

Note: Carbon dioxide tonnes have been converted to tonnes of carbon.

Source: (a): DfT (2004e), (b): McCubbin and Delucchi (1999)

Table 8: Welfare benefits of the reduction in emissions

Pollutant	Change in yearly emissions (tonnes)	Change in yearly emissions (%)	Discounted welfare effect (£ for 10 year period) Low estimate	Discounted welfare effect (£ for 10 year period) High estimate
Carbon dioxide	4,137.5	25	3,059,747	3,059,747
Particulate matter	0.6	14	41,364	2,217,380
Nitrogen oxides	4.2	7	43,242	707,861
Carbon monoxide	59.4	33	5,373	42,987
Total			**3,149,726**	**6,027,976**

Note: All monetary values are in 2007 values and 2004 prices. Carbon dioxide tonnes have been converted to tonnes of carbon. Only one central estimate was used for carbon emissions.

Source: Own calculations

The 25 per cent fall in carbon dioxide emissions shown in Table 8 is not out of line with the reported 19 per cent fall in carbon dioxide emissions experienced after implementation of the initial charging scheme in the CZ (TfL, 2004b, p.94, Beevers and Carslaw, 2005).

Although there has been no attempt to quantify the changes in carbon monoxide emissions, TfL (2004b, p.93, 2005b, p.101) gives a preliminary percentage change of 12 per cent in nitrogen oxides and particulate matter emissions in the CZ. These values again, are not too different from the ones presented in Table 8.

It should be noted however that TfL (2005b) states that “it is not possible to detect changes in measured air quality that could be associated with the introduction of congestion charging” (p.101). This means that computing environmental changes as part of the benefits of the extension might constitute an overestimate of the positive changes that the scheme could deliver. Notwithstanding that, we produce estimates of benefits excluding and including the environmental impacts in the cost benefit analysis of Section 3.3. In any case, Table 8 shows that, even when using the highest estimates for environmental costs, the increase in benefit caused by the reduction in emissions is small, relative to the change in total surplus presented in Table 4. We return to this point in Section 3.3.3.

3.2.2. Accidents

The *Third Annual Report* claims that “traffic changes brought about by the scheme have been responsible for between 40 and 70 additional accidents saved per year in comparison with the background trend” (TfL, 2005b, p.5). From traffic accidents involving personal injury in London, about 87 per cent are slight, 13 per cent are serious, and 1 per cent are fatal (TfL, 2005b, Figure 78, p.106; (TfL, 2001, Table 16, p.28; TfL, 2004e, Table 6.1.1, p.50).[16] Applying these shares to the upper and lower bounds of TfL, the increase in social surplus due to accidents savings could be anywhere between £2.1 and £3.7 million per year, at 2007 values and 2004 prices.[17]

Using data from the *Transport Statistics for London 2001* (TfL, 2001, Table 16, p.28) and from the London Travel Report (TfL, 2004e, Table 6.1.1, p.50) we conducted our independent calculations.

Table 9 shows the number of casualties in London for the period 2000-2003, the cost per casualty and the total cost of casualties per year.

[16] Figure 78 (TfL, 2004b) corresponds to traffic accidents on the Inner Ring Road and within the charging zone only, but the shares are the same as those derived from Table 16 in TfL (2001) and Table 6.1.1 in TfL (2004e), which cover the whole of Greater London.

[17] These numbers were computed following the DfT (2004b) guidelines. A fatal accident has a cost of £10,488, a serious accident has a cost of £4,742 and a slight accident has a cost of £2,763 at 2004 prices. These values include insurance administration, damage to property and police costs. A fatal casualty has a cost of £1.7 million, a serious casualty has a cost of £192,044 and a slight casualty has a cost of £14,808, also at 2004 prices.

Table 9: Cost of road traffic casualties in London

	Severity		
	Fatal casualties	Serious casualties	Slight casualties
2001	299	5,769	38,483
2002	282	5,320	36,127
2003	272	4,872	33,378
Cost per casualty	£1,709,031	£192,044	£14,808
	Cost fatal casualties £ million	Cost serious casualties £ million	Cost slight casualties £ million
2001	511	1,108	570
2002	481	1,022	535
2003	464	936	494

Source: TfL (2001, Table 16, p.28) and TfL (2004e, Table 6.1.1, p.50)

The point we are trying to make here is that the reduction in casualty costs may not be related to the LCCS. This reduction was £151 million between 2001 and 2002, when there was no congestion charging, and £144 million between 2002 and 2003. The statistics suggest that there is a long-term downward trend in both the number of accidents and casualties that is not in anyway related to the LCCS but rather to accident reduction measures.

Nonetheless, and as we do not have enough data to make a definitive assessment, we shall include the high and low estimates of accident savings of £3.7 and £2.1 million per year at the time of considering potential additional benefits of the extension of the zone.

3.2.3. Public transport effects

The impact of the expansion of the congestion charging zone on Public Transport is quite complicated, since revenues from the scheme are required by law to be reinvested in public transport, and the exact allocation of revenue between modes and across areas is yet to be decided.[18]

A realistic model of bus transport is necessarily complicated.[19] This paper infers a bus time saving from published data on the impact on bus speeds of the initial scheme in the CZ. To make the inference the following assumptions are made: (1) The ratio of bus speed to car speed that held in the CZ before charging was introduced holds ex-ante in KC. (2) The ratio of the change in bus speed to the change in car speed experienced in the CZ applies in KC.

Given these two assumptions and values from TfL publications, the initial bus speed in KC is inferred to be 10.8km/h and the increase in bus speed as a result of charging is inferred to be 3.7km/h.

[18] Greater London Authority Act 1999.

[19] Small (2004) models the CZ charging impacts of road pricing on costs and service quality of public transport buses, and the second-round effects of these changes on the behaviour of public transport operators and potential users.

With this estimated average speed increase in place, the total surplus impact of reduced journey times for bus users was calculated in three steps. First total bus passengers were obtained from screen-line survey data provided by TfL. It was assumed that the number of passengers per bus stays constant throughout the entire duration of the bus journey through KC. Second the average distance travelled by buses in KC was computed by looking at a basket of routes available on the TfL website and computing distances using internet journey planning software. Finally the time savings per passenger were computed using the speeds and distances already calculated and the VOT given in the appendix. The time saving per passenger was multiplied by the total bus passengers to obtain an estimate of the change in total surplus. This change in total surplus and other key bus passenger details are given in Table 10.

Table 10: Surplus benefits to bus passengers

Passengers per hour	Drivers per hour	Change in total surplus (£/year)
9669	446	36,713,546

Source: Own calculations

There is no published literature on the benefits to bus passengers of the western expansion of congestion charging. However the orders of magnitude can at least be compared to the estimated benefits from the original scheme in the CZ. In the *Six Months On* report TfL estimated time savings to bus passengers to be £20 million at 2003 prices. Prud'homme and Bocarejo (2004) estimated the effect to be a benefit of €31million (approximately £21.3 million) at 2004 prices. These figures, computed for a £5 charge in the CZ, updated to 2007 prices, are £22 and £23.5 million respectively. If we compute the benefits to bus passengers using our model calibrated to a £5 charge, rather than a £8 charge, the benefits we get are £24.3 million, at 2007 prices. This is very close to the numbers reported in TfL (2003) and Prud'homme and Bocarejo (2004), which gives us some confidence that the number presented in Table 10 is probably a good estimate.

It is important, however, to point out that the estimate given above does not take into account any benefits from falls in waiting time. This omission is realistic given the assumptions of the traffic model. It is assumed that there is no variation in speeds throughout the charging day, and bus frequencies are essentially a policy variable, so the model predicts no change in waiting time. In reality due to non-constant speeds, and also due to the hypothecation of revenues resulting in extra buses, excess waiting times are expected to fall by a large amount. TfL cite a reduction of 24 per cent in excess waiting time for the first year of charging in the CZ (TfL, 2005a). In addition the figure above assumes a static number of bus passengers. In reality some of those priced off the roads will switch to bus transport.

For the two reasons discussed above, the figure of £36.7 million is probably an underestimate of the benefits to bus passengers.

3.2.4. Business impacts

On the whole the business impacts of the CZ scheme were quite minor. Initial studies by TfL (2003) and Bell *et al* (2004) documented large negative impacts. However initial falls in retail activity have since been reversed and it is likely that most of the negative effects attributed to the scheme were due to other factors such as the Iraq war or the closure of the central line.

These results from the CZ cannot be regarded as transferable to KC. The workplace population of the western extension zone is only 1/6 of that in the CZ (TfL, 2004c). Hence one would expect a higher proportion of leisure or shopping trips by car compared to the CZ. Moreover KC has a higher proportion of retail stores, which are the group most likely to be negatively impacted by congestion charging. Based on these two facts, one might expect the business impacts of introducing charging in KC to be more adverse than for the CZ.

3.2.5. Traffic effects on the Central Zone

For the purpose of the cost benefit analysis, allowance must be made for the expected negative feedback of the expansion on traffic speeds in the CZ. TfL assumes an annual disbenefit of £10 million per year to account for the negative impact of residents of KC travelling into the CZ at much lower cost (TfL, 2004c). The same value of £10 million is assumed in this paper.

3.2.6. Shoe leather costs

The Western Extension could impose potentially large compliance costs on charge payers. The time cost of paying the charge will vary depending on the means used to pay, for instance users can currently pay on the internet, by phone, by SMS, or at retailers. In the 2004 Report to the Mayor (TfL, 2004c) compliance costs are given as £8 million per year. In private correspondence with TfL, estimated compliance costs were said to lie in the range £5 million to £10 million, and were described as a "notional allowance for time and effort in complying with the charge". Due to lack of an alternative estimate, the £8 million value is employed.

3.3. Cost Benefit Analysis

The objective of this section is to mimic the cost benefit analysis conducted by TfL, thus providing an independent check of their figures. Second round transport effects, such as those from investment of the scheme, are omitted; the analysis concentrates on the direct and indirect impacts discussed above.

3.3.1. Costs of the scheme

The level of costs assumed and their profile over time is critical to the outcome of the cost benefit analysis. The only published predictions of costs for the Western Extension are given in the Report to the Mayor (TfL 2004c). A summary of the cost information provided in this report is presented in Table 11. The figures have been adjusted since TfL assume the scheme starts 6 months earlier than is assumed in this study.

Table 11: TfL's predicted costs (2004 prices)

	2004	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16
TfL design and management	2.25	3	2.75	1	1	1	1	1	1	1	1	1	1
Scheme procurement and implementation (low)	20.25	46.5	25.25	0	0	0	0	0	0	0	0	0	0
Scheme procurement and implementation (high)	24.75	54.7	32.5	0	0	0	0	0	0	0	0	0	0
Scheme operation (low)	0	0	0	50	50	50	50	50	50	50	50	50	50
Scheme operation (high)	0	0	0	60	60	60	60	60	60	60	60	60	60

Source: TfL (2004c)

3.3.2. Discount rate and changes over time

The model only applies to the year 2007, since it employs a 2007 VOT. However to facilitate a cost benefit analysis it is assumed that the benefits for subsequent years are equal to those in 2007. The TfL report on the extension also assumes a flat profile of benefits. It is difficult to predict accurately how benefits will change over time. The Le Chatelier-Samuelson principle predicts that the long run elasticity of travel demand with respect to travel costs will be greater than the short run elasticity. This combined with increasing VOT, suggests a rising benefits profile. On the other hand one might expect traffic to increase over time since travel is a normal good. Since the balance of these effects is not obvious, benefits are assumed constant over time.

Two further assumptions are necessary: a 3.5 per cent discount rate and a scheme length of ten years. The 3.5 per cent discount rate is that recommended by the Treasury

Green Book (HM Treasury, 2003). A scheme length of ten years is chosen for consistency with TfL, who choose this time period because it is the legislated period of hypothecation.

3.3.3. Cost Benefit Table

Traditionally schemes are evaluated using a benefit-cost ratio (BCR). The *Transport Analysis Guidance* (DfT, 2004d, TAG Unit 3.5.4) defines the BCR as follows:

$$\text{BCR} = \frac{\text{Net Present Value (NPV)} + \text{Present Value Cost to Public Accounts (PVC)}}{\text{Present Value Cost to Public Accounts (PVC)}}$$

$$\Rightarrow \text{BCR} = \frac{\text{Present Value of Benefits (PVB)}}{\text{Present Value Cost to Public Accounts (PVC)}} \quad \text{(since NPV = PVB – PVC)}$$

The Net Present Value of a scheme is the discounted stream of benefits accruing to road users (PVB) less the discounted stream of costs borne by the relevant public body (PVC). Thus the BCR seeks to provide a measure of the benefit per unit of cost incurred.

For the Western Extension, the revenue of the scheme exceeds the cost, and hence the PVC will be negative. Moreover since most of the benefits of the scheme accrue to TfL, in the form of the area β in Figure 2, the PVB to road users will be negative. Although calculating the BCR above would yield a positive number, it would essentially be meaningless. This is a problem the DfT recognise: "the BCR is of limited value where projects (road user charging, for example) result in significant revenues accruing to public accounts" (DfT, 2004d, TAG Unit 3.5.4). To retain the interpretation of the measure of benefit per unit of cost, we use the adjusted BCR defined below (ABCR).

$$\text{ABCR} = \frac{\text{Present Value of Total Surplus Gain}}{\text{Present Value Costs Excluding Revenue}}$$

The Present Value of Total Surplus Gain is sum of the social gain (β-α), the benefits to bus users, the benefits from the reduction in emissions and accidents, the disbenefits of higher traffic in the CZ, and the disbenefits of compliance costs. The Present Value Costs Excluding Revenue is simply the costs of implementing and running the scheme.

Therefore the ABCR gives an indication of the benefits per unit of cost. Table 12 gives the cost benefit analysis for the first year of operation.

Table 12: Costs and Benefits for one year (2007)

Costs (£ mill 2004 prices)		**Benefits (£ mill 2004 prices)**	
Scheme operation	50 (low) 60 (high)	Change in total surplus excluding times savings to bus users, environmental and accident benefits	86.0
Design and management	1	Time savings to bus users	36.7
		Feedback effects on CZ	-10
		Charge payer compliance costs	-8
Total costs		Total benefits	122.7
Low estimate	51		
High estimate	61	Environmental and accident benefits	
		Low estimate	2.5
		High estimate	4.1
		Total benefits including environmental and accident benefits	
		Low estimate	125.2
		High estimate	126.9

Source: Own calculations

Table 13 shows the discounted costs and benefits of the expansion.

Table 13: Costs Benefit Analysis of the Expansion (2004 prices, 2007 base year, 10 year horizon)

Statistic	**£ mill, discounted**
PVB exc. env. and acc.	901.3
PVB inc. env and acc. (low)	922.5
PVB inc. env and acc. (high)	938.8
PVC (low)	546.0
PVC (high)	653.4
BCR exc. env and acc (low cost)	1.65
BCR exc. env and acc (high cost)	1.38
BCR (low cost and low env. and acc.)	1.69
BCR (low cost and high env. and acc.)	1.72

BCR (high cost and low env. and acc.)	1.41
BCR (high cost and high env. and acc.)	1.44

Source: Own calculations

Even if we assume high costs and exclude environmental and accident benefits, the ABCR is 1.38. This allows us to answer the question this section proposed – "Is the proposed extension a good idea?" – the answer is a tentative yes. Following the guidelines presented in DfT (2004e), this scheme would be classified as 'low' value for money if high costs are assumed, and 'medium' value for money if low costs are assumed. It is important to analyse how these ABCRs compare with other published estimates. TfL's preliminary report on the extension cites four ABCRs; a high and low sensitivity for each cost bound. Using the mean of the low and high sensitivity figures, the ABCRs are 0.90 and 0.75, which are substantially lower than those estimated here. The first and most obvious reason is that TfL's estimates are based on a £5 charge and ours are based on an £8 charge. For comparison purposes we computed the ABCRs assuming a £5 charge in our model. Although they are lower than the ones reported in Table 13, they are still higher than those reported by TfL. Our lowest ABCR estimate with a £5 charge is 1.16. This excludes environmental and accident effects as TfL does.

Our ABCRs get even higher if we allow for a higher VOT. We conducted a VOT sensitivity analysis to see how the ABCR varies when the VOT are scaled up and down. If we scale up the value of time by 34 per cent to reflect the difference between average London incomes and national incomes, reported in the New Earnings Survey (Office for National Statistics, 2003), the model predicts an ABCR of between 1.78 and 2.13, always excluding environmental and accident benefits. Also, as expected, increasing the value of time has diminishing marginal effect. This occurs because as the values of time increase, fewer agents are priced off the roads, speeds decrease, and less of the deadweight loss of congestion is eliminated. In addition, decreasing speeds imply fewer benefits to bus users.

4. THE POLITICS OF CONGESTION CHARGING

The LCCS charge does not constitute a first-best charge, or a second-best charge either. It does not vary with vehicle type or time of the day. Yet, it is an example of how a crude dirty solution can increase welfare.

There were three decisions that TfL had to make when designing the Scheme: (a) the level of the charge, and whether it was going to differ by vehicle type or time of the day; (b) the times when the Scheme was going to operate; and (c) the exact limits of the CZ. All three decisions could have been based on economic principles. However, they were based on political considerations, and the results of an extensive consultation process in which TfL engaged before the Mayor confirmed the final Scheme Order.

The level of the charge was not chosen on the basis of a calculation of the MCC. The selection of the appropriate charge is crucial to correctly internalise the congestion externality. However, due to the rather crude nature of an area licensing scheme, precise calculations are impossible as the system lacks the ability to adequately charge differentiated prices both temporally and spatially. Ultimately, the Mayor settled upon the £5 charge, deciding that it provided adequate incentive to achieve significant congestion reduction, but with less public backlash likely to be associated with a £10 charge, which had been under consideration. Also, the proposed heavy goods vehicle (HGV) charge of £15 (3 times the car charge) was reduced to be the same as that for cars, mainly as a result of the responses of the commercial vehicles sector to the public consultations.

On July 4, 2005 the charge was increased from £5 to £8. This was done despite the opposition of those who bothered to respond to the public consultation on the potential increase (and a few other changes) held between December 7, 2004 and February 28, 2005. Presumably respondents were more likely to be people or organisations who strongly opposed the increase, and non-respondents were probably people and organisations that either were indifferent or did not support the increase enough to make their voice heard. From those responding there was substantial opposition. The new charge is £8 for all vehicle types. Given that the disruption produced by a HGV is higher than that produced by a car, to charge both the same cannot be justified on any economic grounds.

This is an example of how politics can influence the level of the charge, which from an economic point of view should be equal to the MCC of each vehicle type. On the one hand, the pressure from the haulage industry ensured a uniform charge. On the other hand, despite the opposition that came through in the consultation, the charge was increased by 60 per cent. There is a possibility that if the charge had been higher for HGVs in the first place, no increase would have taken place.

The ROCOL (2000) recommendation on charging times was 7:00am to 7:00pm, Monday to Friday, excluding public holidays. However, the LCCS hours of operation are 7:00 to 6:30pm. At a conference in London in March 2003, Malcolm Murray-Clark (Director of Congestion Charging, TfL) explained that the decision to change the evening end-time was primarily a result of lobbying by the entertainment community. It was argued that having the charge apply until 7pm would discourage theatre-goers from entering the CZ.[20]

The exact limits of the CZ were also slightly changed a few times before the final Scheme Order was confirmed. This was again, based on pressure groups wanting to qualify for the 90 per cent discount, and from businesses wanting to be excluded from the CZ in the fear they would suffer losses.

All three major decisions were based on political considerations, rather than on economic efficiency. Yet, the LCCS is a success: congestion has decreased, travel times

[20] Congestion Charging Seminar, organised by the Institution of Highways and Transportation, Imperial College London, 19 March 2003.

have decreased, and average speed has increased. This indeed shows that much can be achieved with an unsophisticated and easy to implement policy.

The technology used in the LCCS is also very simple. The method was chosen due to its relative ease of implementation as compared to full-scale electronic road pricing. ANPR technology was selected as a feasible intermediate between an inexpensive but inefficient paper-based system and a sophisticated yet complex and expensive electronic road pricing system (ROCOL, 2000).

The three decisions on charge level, times of operation, and limits of the area are not trivial. Indeed it has been shown that making mistakes on any of these can cause losses. Santos *et al* (2001) for example, simulate cordon tolls in eight English towns and find that if the toll is set at a level too different from the optimal one, it can cause loss of welfare, rather than any gain. May *et al* (2002), Verhoef (2002), and Mun *et al* (2003) arrive to similar conclusions and endeavour to find methods for identifying optimal toll locations and levels. Their models are theoretical and cannot be applied to real world situations. In any case, there is both theoretical and empirical evidence that shows that charge level (which in turn is linked to charging times) and location are of fundamental importance for the success of a scheme.

With these matters being so important, it is surprising that planners will base their decisions on political judgement. May *et al* (2004) report that officials in charge of designing cordons in England[21] will typically base their decision on judgement of how to avoid adverse impacts, gain public acceptance, and be practical. Approaches they cite include focusing on the city centre, together with any major traffic generators on its fringes, placing the cordon within the city centre ring road if one existed, using a simple charge structure with uniform charges for all crossing points, and keeping the charge at a level sufficiently low to be acceptable, amongst others.

On the other hand, it may be argued that a large policy decision such as the congestion charge should be influenced by political factors, namely the views of Londoners. The LCCS has so far succeeded to the point that Londoners re-elected the Mayor in 2003. They are unhappy with having to pay the charge, but happy with the benefits from the charge.

The change from £5 to £8 might yield similar results. It is too early and there is no data to make an assessment but further reductions in traffic, albeit the disbenefit suffered by those changing route, travel time, or travel mode, may produce further increases in social surplus.

Finally, a cost benefit analysis of the proposed expansion reveals that the benefit cost ratio would be higher than unity. The proposed variation has already been affected by political lobbying, as during 2004, there was a public consultation on the Draft Transport Strategy Revision, which included a proposal to extend the charging zone. For example, residents entitled to a 90 per cent discount include not only all the residents living within the extended and the original charging zone boundary, but also residents that live beyond

[21] Their paper summarises the results of in-depth interviews with practitioners in six UK local authorities who at the time were considering the implementation of congestion charging.

the original and extended zone boundary. On the other hand, businesses are not keen on ending up inside the extension, as they fear their businesses will slow down.

The results on the consultation on the extension show strong opposition. Again, like in the case of the consultation on the increase, the respondents were probably people and organisations that opposed, and wanted to prevent, the variation from being confirmed.

Figure 3 shows the representations to the proposed extension as reported in TfL (2004d).

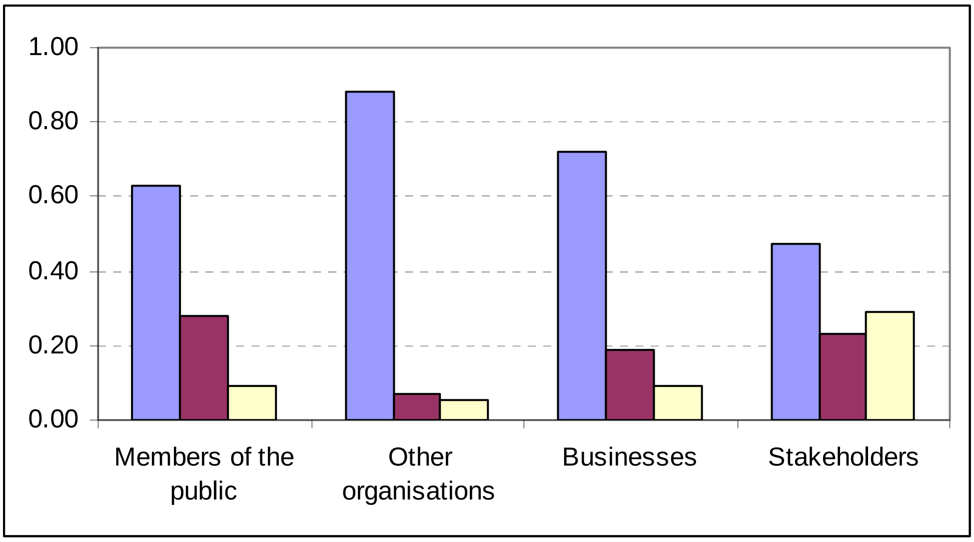

Figure 3. Representations to the proposed extension

Key oppose support neutral
Source: TfL (2005d, Table 6, p.31)

As expected, those who lived or had businesses in the original congestion charging zone were far more likely to support the proposed extension than those from anywhere else; after all, they are already paying for the charge and they will only benefit from less congestion in a wider area. Of residents in the original congestion charging zone 56 per cent supported the proposal, whereas only 23 per cent of residents in the ‘buffer’ zone, defined as broadly one km around the original congestion charging zone and the proposed extension, 28 per cent of residents in the proposed extension, and 27 per cent of residents in the rest of London supported it (TfL, 2004d, Table 10, p.34). Similarly, only 10 per cent of businesses in the area of the proposed extension, 12 per cent in the ‘buffer’ zone and 18 per cent in the rest of London supported the proposal, in contrast with 32 per cent of businesses located within the original congestion charging zone, who supported it (TfL, 2004d, Table 14, p.36).

Londoners recognise that congestion was and is still a problem, and that something should be done about it, even if that means introducing or extending a congestion charging scheme, as long as they themselves are exempt. Thus, 66 per cent of residents in KC oppose the extension. If, however, the extension goes ahead, they want to qualify for a discount. This extends to residents near the original congestion charging zone and proposed extension areas combined, who are just outside the boundary for discounts, and have successfully lobbied to be included.

According to TfL (2004c), the reduction in traffic in the proposed extension of the charging zone is very likely to be lower than the one experienced in the original congestion charging zone, in the order of 5 to 10 per cent only. Some of the reasons to expect a lower decrease in traffic and increase in speed are: (a) around 30 per cent of the potentially chargeable vehicles entering the area of the extension are already paying the charge because they use the original congestion charging zone (TfL, 2004c, p.3); (b) the extension is 1.4 times more densely populated than the original congestion charging zone (TfL, 2004c, p.2-3), (c) the extension has a greater proportion of car travel by residents and as result a higher proportion of households would be able to take advantage of a residents' discount (TfL, 2004c, p.3). Some residents that currently do not drive during charging hours may be attracted to the roads making use of their discount, with which they will be able to drive in the original congestion charging zone.

In our simulations we find a decrease in the number of trips of 16 per cent and also get a larger speed increase that the one observed in the CZ. It should be borne in mind however, that we assume an £8 charge, whereas TfL (2004c) assumes a £5 charge. The comparisons to the impacts experienced in the CZ are also on the basis of a £5 charge.

The charge level and the limits of the charging area, together with the make-up of residents and exemptions and discounts, determine the percentage reduction in traffic and the gains to be grasped. Despite these decisions being taken on the basis of political rather than economic considerations, the original charging zone increased social surplus, and the extension is likely to do the same.

4.1. General lessons

The LCCS is an economic and political success. The lessons that can be drawn from the experience and that we suggest should be taken into account by other towns and cities considering the idea of road pricing are as follows:

a) Inform the public and listen to the public

Before it was implemented the proposal on the congestion charging scheme in London was sent out for public consultation twice. The idea was to inform the public and listen to what they had to say. On both occasions, 6,000 notices were placed 250 metres apart on streets in and around the London Inner Ring Road. Consultation meetings were also held with key stakeholders. 66,000 public information leaflets on the proposed scheme were distributed to all the 33 London boroughs and advertisements giving details of the scheme and how to participate in the consultation exercise were published in 11 London newspapers and broadcast on 11 London radio stations. As explained above, the level of the charge, the charging times, and the charging zone limits, were all influenced by the results of the consultation. After the Mayor confirmed the Scheme, but before it started three million leaflets were delivered to every household in London twice. The leaflets contained information on where the charging area was, who would be affected and what those affected would need to do. Information on the scheme was broadcasted on all main radio stations and TV channels, and published in most newspapers. A website with information and the possibility of making inquiries was also opened in July 2002.

b) Do not make the final decision subject to a referendum

The Mayor of London was determined to introduce congestion charging and even made it a central part of his manifesto for election in May 2000. He was happy to conduct public consultations but he never made the final decision subject to the result of any referendum. The city of Edinburgh in Scotland, on the other hand, which had been contemplating the possibility of introducing road pricing since 2001, when the Transport (Scotland) Act 2001 (Acts of the Scottish Parliament, 2001) was passed, made the decision subsequent to an affirmative referendum in Edinburgh. About 74% of Edinburgh residents who participated in the referendum voted 'no' and the plans were abandoned as a result.[22] Although the Mayor in London was elected with a manifesto that contained a proposal on congestion charging, and re-elected three years later, it is not clear that a referendum would have supported the LCCS. Congestion charging is just one of the many policies proposed and implemented by the Mayor.

c) **Make a careful cost benefit analysis**

In London several alternatives were evaluated, each one accompanied by a cost benefit analysis. Do also a sensitivity analysis of the results to the elasticities assumed. Before a scheme is implemented there is no data on how drivers will respond to the charge, and errors in the elasticities assumed will have costs. The cost of these errors should not turn a viable scheme into a non-viable one.

d) **Make a careful assessment of the distributional effects**

This assessment should concentrate on who will gain from the scheme and who will lose. This will depend on the scheme design and on the characteristics of the town in question such as where people live and what mode of transport they use. It will also depend on the availability of no-chargeable modes and facilities such as public transport and dedicated cycle lanes.

[22] Over 60% of eligible voters participated in the postal referendum held from 7 to 21 February 2005, making it a success in terms of turnout.

e) Consider the geographical characteristics of the town or city in question

Although a licensing scheme like the London one may work in towns and cities that have a dense and congested network in the city centre, it may not work in places that have other types of congestion. Towns that do not have dense road networks may only suffer congestion on the main avenues or motorways. In those cases, it might prove more effective to introduce tolls on just those roads.

f) Do not base the charge level on MCC calculations

Using a first best policy when there are imperfections in other related markets will not yield an efficient outcome. Furthermore, a second best policy, will also be typically very difficult to design, let alone implement. Instead, be practical and make the scheme clear and easy to understand.

In a theoretical world we would like to internalise externalities perfectly. In reality, political factors influence most economic policies. This problem is not in any way restricted to the transport sector. Other sectors that may suffer from similar constraints in economic policy include for example network utilities and polluting industries.

The LCCS constitutes a market solution, even though it is not a perfect internalisation of the marginal congestion cost. It is rather a rule of thumb solution that shows that it is possible to internalise at least part of the congestion externality by mimicking the market, even when there is not enough information to introduce a first-best or second-best charge. Other towns may find the experience of London useful and even transferable. An unsophisticated and easy to administer policy can go a long way in increasing welfare as long as the political economy influencing its design has a neutral or positive effect.

5. BRIEF ACCOUNT OF OTHER CITIES

With the success of the LCCS in reducing traffic levels and increasing speeds it is worth asking whether the experience is transferable to other cities. The answer to that is may be. A ‘may-be’ rather than a ‘yes’ stems from the fact that different cities have different road layouts and different transport systems, not to mention different socio-economic and geographic characteristics.

Gerondeau (1998), for example, emphasises the fact that major urban centres are heterogeneous. He points out that traffic conditions tend to be better in areas that have dense networks of motorways or that are served by wide roads and avenues, against those where there are no such roads. On the other hand, the Los Angeles-Long Beach-Santa Ana region in the US, with the entirety of its motorway network, is the American urban area with the highest congestion levels. The annual number of hours of delay per traveller is 93, computed as the 'extra time spent traveling due to congestion' (Schrank and Lomax, 2005)[23].

Apart from any difference between city centres in this respect, in the case of London there was a clear political commitment from the Mayor. Political will may even be the main reason for the achievements of the LCCS. This is not the case in Paris, for example, where the Mayor, PS Bertrand Delanoë, has no intention whatsoever of introducing road pricing (Les Dosiers du Net, 2003). There is no legislation that would allow him to do so and he does not seem to be interested in having that legislation passed either.

Paris is the hub of France's motorway network and is, like many English towns including London, surrounded by an outer ring road, the Peripherique. This orbital motorway is 35 km long and has between three and four traffic lanes, depending on the segment. It carries one million vehicles daily and is subject to much congestion (Wikipedia, 2004).

Although relatively expensive for the taxpayer, public transport in Paris is excellent. The Paris Metro system consists of 16 lines, with over 200 km (120 mi) of track, over 300 stations, and an average distance between stations of approximately 300 metres. On top of that there is a second network of regional express lines, the RER (Réseau Express Régional). It consists of five lines and interconnects with the Paris Metro (Wikipedia, 2004).

The urban area of Paris is 2,723 km^2 (1,051 mi^2) and is very densely populated in comparison with other Western cities, including London. At the 1999 French census the population density in the city of Paris was 20,164 inh. per km^2 (52,225 inh. per mi^2), or 24,448 inh. per km^2 (63,321 inh. per mi^2) if the parks of *Bois de Boulogne* and *Bois de Vincennes* are excluded (Wikipedia, 2004). With such dense population an exemption to residents would probably be needed to gain public acceptability for a road charging scheme. This would in turn jeopardise the gains in efficiency that could be derived from road pricing.

However, the most important factor is that there is a lack of political will. The position of the Parisian government is that road pricing constitutes 'a negative measure to solve traffic problems, which generates perverse effects of social segregation' (Le Monde, 2003). Their policy concentrates on improving public transport in order to encourage drivers to leave the car at home. They look at the LCCS 'with interest' but 'for the moment, such a system does not appear to be a measure that could be applied in Paris' (Les Dosiers du Net, 2003).[24]

[23] The steps followed for this calculation are described on pages 4 to 7 in Schrank and Lomax (2005). The annual delay per traveller is the extra travel time for an area divided by an estimate of the number of people travelling by a motorised mode during the peak periods (6 to 9am and 4 to 7pm). The extra travel time is computed in comparison to some standard. The standard values used in Schrank and Lomax (2005) are 60 miles per hour on the freeways and 35 miles per hour on the streets.

[24] There is an additional comment in Les Dosiers du Net article on the visit of Ken Livingstone to Paris in November 2001. Apparently he took the Parisian underground together with the transport minister for Paris and made a remark on the lines of 'having seen more trains in ten minutes in Paris than in an hour in London'.

With such a good public transport network and without the political will of the Mayor to introduce congestion charging or even the legislation that would be needed, a system in Paris like the LCCS does not seem to be an option in the near future.

Rome, on the other hand, already has a system in place, which has some similarities with the LCCS. Rome is an ancient town with narrow roads that were not originally designed for cars. Only about 40 per cent of trips are made by public transport, while the remaining 60 per cent are made by private transport (PRoGR€SS, 2004). The share of public transport in the total number of trips made by motor-vehicles fell from 56 per cent in 1964 to 34 per cent in 2004. In order to reverse this trend, the municipality produced a number of urban, transport and traffic plans with aims that include land use planning and traffic demand management (PRoGR€SS, 2004).

The first restrictions to the entry of vehicles to the historical centre in Rome were introduced in 1989 (PRoGR€SS, 2004). These restrictions were not enforced systematically until 1994, when police started to block the entrances into the Limited Traffic Zone (LTZ). Residents, together with certain groups of workers in the area were exempt and could get virtually free permits to enter. In 1998 non-residents working inside the zone were required to pay to obtain an annual permit for entry into the zone. A number of parking restrictions according to the category of permits were also implemented.

As of 2005 the system is a combination of different permit types that allow different movements. There are seven sectors, A, B, C, D, E, F and G, inside the LTZ (STA, 2005). Different types of permits allow circulation with and without parking in different sectors at different times. For example, residents of sectors A to F, can hold permits for circulating and parking in those sectors, but not in sector G. Residents of sector G can hold permits for circulating and parking in sector G but not in any of the other sectors. Although most permits are valid during all the hours during which the scheme operates, goods vehicles have additional restrictions regarding times.

The crucial difference between the LCCS and the scheme in Rome is that in London, all those willing to pay the charge in order to use the charging zone can do so, whereas in Rome the city centre is closed in the first instance, and those wishing to drive in it need to get a permit. Not everyone can qualify for a permit, which means that drivers willing to pay may not be allowed into the LTZ.

Table 14 summarises the vehicles that qualify for permits and the costs of those permits.

All permits are valid for a year, except for the first two permits that a resident gets, which have no expiration date. Residents and registered disabled also get In-Vehicle Units for free. This technology has some similarities with the one used in Singapore, and uses an In-Vehicle Unit with a smart card, given to them for free. When a vehicle equipped with an In-Vehicle Unit that has a valid smart card inserted in it crosses one of the 23 automatic entries, the smart card communicates with the road-side sensor using radio-frequency and the vehicle is not fined. In all other cases, the photograph taken whenever the vehicle crosses an entry is checked against the list of authorised number plates. A fine is issued if the licence plate is found not have a permit (STA, 2005).

About 70,000 trips per day are made through, into or out of the area (PRoGR€SS, 2004). The scheme operates in the historic centre only, which has an area of 4.6 km^2 (1.8 mi^2), representing only 0.36 per cent of the area of Rome, which is 1,290km^2 (500 mi^2). The area is considerably smaller than the London CZ, which, as pointed out in Section 2, represents 1.3 per cent of the total area of Greater London.

The hours of operation of the LTZ are Monday to Friday from 6.30am to 6pm, except public holidays, and on Saturdays from 2pm to 6pm (STA, 2005). Two wheelers do not need permits. A night scheme will be introduced in Summer 2005. This will be from June 17th until August 10th, and from August 20th to September 17th. No vehicles will be allowed to circulate from 11pm to 3am on Fridays and Saturdays, unless they hold a permit. The area will be a reduced version of the LTZ.

Table 14: Permit types and their costs

Permit Type	Stamp	Permit
Residents	€ 14.62	€ 16.16 for each one of the first two, € 320.87 **plus** € 16.16 for each additional one
Residents outside the LTZ that have an address inside[a]	€ 14.62	€ 320.87 **plus** € 114.29
Artisans and craftsmen who work inside the LTZ and who can demonstrate that they need to carry their materials in a vehicle	€ 14.62	€ 29.08
Automobile mechanics	€ 14.62	€ 29.08 for a permit for his car and the cars that he may be repairing in his garage
Officials and employees of associations, professional offices and businesses inside the LTZ that have parking spaces in their premises	€ 14.62	€ 114.29
Technological services	€ 14.62	€ 29.08
Goods services[b]	€ 14.62	€ 29.08
Commercial representatives[c]	€ 14.62	€ 320.87
Night workers	€ 14.62	€ 93.63
Doctors that work for the Italian National Health Service and have their clinics inside the LTZ	€ 14.62	€ 29.08
Press, radio and TV workers	€ 14.62	€ 320.87
Free lance, international and news bureaus Journalists	€ 14.62	€ 320.87
Compulsory school		
Family car carrying children	€ 14.62	€ 93.63
School bus	€ 14.62	€ 29.08
Temporary permits[d]	€ 14.62	€ 5.16
Disabled	Free	Free

Notes:
[a]The residence is the place where the individual lives permanently, where he pays taxes, is registered for voting and with a doctor, etc. However, an individual may have to live somewhere else temporarily, for example, for work reasons. In that case the individual would reside outside the LTZ but would have an address inside.
[b]Additional restrictions apply for lorries heavier than 3,500 kg, which can only enter the LTZ between 8pm and 7am.
[c]Permit is valid only from 9am to 6pm
[d]Permit is valid for a maximum of 3 months. These include people who are disabled temporarily, or have to do medical or veterinary visits, marriages, and funerals, amongst others.

Source: www.sta.roma.it/.

In the US the problem of congestion is so serious that commuters there rank traffic among the top three regional policy problems together with the economy, education and/or crime (Kockelman and Kalmanje, 2005).

The U.S. House of Representatives passed the Transportation Equity Act: A Legacy For Users (TEA-LU) (H.R.3) on March 10, 2005. The section on motor vehicle congestion relief of the Act states that 'Each State that has an urbanized area with an urbanized area population of over 200,000 individuals shall obligate in each of fiscal years 2005 through 2009 a portion of the State's apportionments… for congestion relief activities in such urbanized areas…' (Section 1201, Title 1, Subtitle B). Further down it states that 25 per cent of that sum 'shall be obligated at the discretion of the State department of transportation' for a number of congestion relief measures including 'demand relief projects and activities that shift demand to non-peak hours or to other modes of transportation or that reduce the overall level of demand for roads through such means as telecommuting, ridesharing, alternative work hour programs, and value pricing'.

The city that has the worst congestion in the whole of the United States is Los Angeles. The *2005 Urban Mobility Report (*Schrank and Lomax, 2005) considers the whole urban area of Los Angeles, Long Beach and Santa Ana together, and reports a travel time index. This is computed as the ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds, of 1.75, which indicates that a trip made during peak times takes 75 per cent longer than a trip made in free-flow conditions. For example, a 40 minute trip in free-flow conditions takes 70 minutes during the peak period.

The Department of Transportation in California is aware of the problem and some congestion pricing projects have been implemented since the year 1995. However, it should be borne in mind that, if there are two opposites, this is London and Los Angeles. The projects are therefore very different.

Los Angeles is the centre of the huge Southern California freeway system, with wide motorways that have several lanes and carry millions of commuters daily. There are four major toll highways in this area. These are the State Route 73 (San Joaquin Hills Transportation Corridor), the State Route 133 (Eastern Transportation Corridor), the CA-241 (Foothill/Eastern Transportation Corridors), and the CA-261 (Eastern Transportation Corridor) .

Drivers who use any of these four toll facilities have the option of paying their tolls in cash of via the Electronic Toll Collection (ETC) system, called FasTrak. Although these toll facilities do not offer High Occupancy Vehicle (HOV, carpool) discounts, FasTrak users automatically receive a discount at the mainline toll plazas.

Finally, there is also the State Route 91 (SR 91) express lanes in Orange County, California. These opened in December 1995 as a four-lane toll facility (DeCorla-Souza, 2004). Tolls vary with direction, day of the week and time of the day to reflect the level of congestion delay in the adjacent free lanes that can be avoided by using the toll lane, and to maintain free-flowing traffic conditions on the toll lanes. There are message signs before entering the SR 91 Express Lanes showing the current toll schedule, which is subject to change without notice in order to optimise traffic flows (Orange County Transportation Authority, 2003). Vehicles with three or more occupants are not charged except when travelling eastbound from 4pm to 6pm on weekdays, the peak period in the heavy traffic direction. During that time they receive a 50 per cent discount (DeCorla-Souza, 2004).

New York, another city famous for its high congestion levels, is a different matter. It is the city with the highest population in the US, with 8 million people in 800 km^2 (309 mi^2). When the whole of the New York Metropolitan Area is taken into account, NewYork-Newark (state of NewYork-New Jersey-Connecticut has a population of over 17 million in an area of 7,964 km^2 (4,075 mi^2) and a travel time index of 1.39 (Schrank and Lomax, 2005).

60 per cent of residents, including many middle class professionals, use public transport to commute (Wikipedia, 2004). This pattern is strongest in Manhattan, where the underground service (the New York Subway) is more frequent and reliable and traffic congestion is worse than in the outer boroughs. The New York Subway is the largest in the world, with 1,093 km (656 miles) of track. The underground system serves all boroughs with the exception of Staten Island, which is served by the Staten Island Railway via the free Staten Island Ferry, which connects to various underground lines (Wikipedia, 2004).

New York City is also served by the Port Authority of New York and New Jersey's PATH subway system, which connects the borough of Manhattan to New Jersey. In addition to these there is an extensive bus network, which is both publicly and privately operated (Wikipedia, 2004).

The Manhattan area could perhaps be compared to central London, and a system like the LCCS would perhaps have a chance of working. There are some charges in place already, although these are very different from the LCCS.

The Port Authority of New York and New Jersey adopted a variable toll strategy for users of the electronic toll collection system (E-ZPass) in March 2001 (DeCorla-Souza, 2004). There is a 20 per cent discount from normal tolls for off-peak use of its bridges and tunnels crossing the Hudson River between New York and New Jersey.

The New Jersey Turnpike Authority also operates a 238 km (148 mile) facility with 28 interchanges, where a variable pricing program was implemented in the Autumn of 2000. Charges are around 12 per cent higher during peak traffic hours than during off-peak hours for users of the ETC system.

There are also proposals to place tolls on 12 city-owned bridges over the East and Harlem Rivers, which connect Manhattan with the Burroughs of Queens, Brooklyn, and the Bronx (DeCorla-Souza, 2004).

Zupan and Perrotta (2003) explore the idea of congestion pricing in New York in the light of the LCCS. They conclude that the equivalent charging area would be Manhattan's Central Business District (CBD). This area is very similar to the London CZ: each weekday, over 800,000 motor-vehicles enter the Manhattan CBD, which is just under 21 km^2 (8.4 mi^2). Only 22 per cent of the traffic pay to enter at the two tunnels under the Hudson River operated by the Port Authority of New York and New Jersey and the two tunnels under the East River operated by the Metropolitan Transportation Authority (Zupan and Perrotta, 2003).

Zupan and Perrotta (2003) model four different charging schemes showing a range of options for pricing some or all of the 19 entry points to Manhattan's CBD. These are:

(a) Flat charges on the East River Bridges of the same level as the Metropolitan Transportation Authority (MTA) currently charges on the two parallel MTA tunnels;

(b) Charges that vary with time of day on East River bridges with MTA charges modified to match them;

(c) A system similar to the LCCS charging at 60^{th} Street, which is the boundary of Manhattan CBD, for 13 daytime hours on weekdays combined with flat charges on the East River during the same time period;

(d) A full variable pricing system with variable charges at all entries, including the East River bridges, MTA crossings and at 60^{th} Street.

They conclude that all four systems would generate substantial revenues. These would be US$700 million, US$740 million, US$760 million, and US$1.7 billion for the four schemes respectively (Zupan and Perrotta, 2003).

Schemes (a) and (b) would reduce daily entries by about 5 per cent, or over 40,000 vehicles (Zupan and Perrotta, 2003). Schemes (c) and (d) would reduce daily entries by 9 per cent and 13 per cent respectively, or over 73,000 and 105,000 vehicles. The result of this would be an increase in average speed and a reduction in travel time. Zupan and Perrotta (2003) do not provide estimates of these.

6. CONCLUSIONS

This paper assessed the original London Congestion Charging Scheme and its impacts, and it simulated and analysed the proposed extension to include most of Kensington and Chelsea. It also touched upon the political economy of the congestion charge and the increase of the charge from £5 to £8 per day. The possibility of transferring the experience to Los Angeles, New York, Rome and Paris was also discussed.

The LCCS has had positive impacts. This was despite the charge level and location having been influenced by pressure groups. It is difficult to assess the impacts of the increase of the charge from £5 to £8, which took place on July 4, 2005, because no data has been released by TfL. The week the charge was changed there were terrorist attacks in central London. This coupled with the fact that it was done during the school holidays, means that it might take some time before any conclusions on the effects of the increase can be drawn.

The proposed extension of the charging zone seems to be an efficient change on economic grounds, at least for the specific boundaries, method of charging and level of charging that is currently planned. Our benefit cost ratios computed under different assumptions of costs and benefits are all above unity. Our model however is limited and our results should not be taken as definitive. Firstly, the model used is a partial equilibrium analysis. Mode switching was not modelled explicitly and the substitution effects of taxing people to drive in to KC were omitted. Despite this, most of the predictions of the model accord well with the outcomes of charging in the CZ, although the predicted speed increase is too high. Secondly, the ABCR is sensitive to both the costs and the values of time. This paper has provided no independent corroboration of the costs published by TfL. If these costs are an underestimate, then the scheme may be less viable. The values of time assumed here on the other hand are unlikely to have been overestimated. If anything, the value of time could be higher and the ABCR could increase even more.

Other towns and cities may find the experience of London useful and even contemplate the possibility of introducing a similar scheme. A crude and easy to enforce policy can indeed increase welfare as long as the political economy influencing its design does not jeopardise its intended effect.

The CBD in Manhattan may be the most similar area to the original CZ, and may thus be a place where a similar scheme could be implemented. Los Angeles on the other hand, is very different in nature, and would need another type of pricing. It already has a system of tolls in place on some motorways that have been operating successfully since 1995. Rome already has a permit system for entry into the historic centre. The main difference between the Rome scheme and the LCCS is that in London anyone willing to pay the charge to drive inside the CZ can do so, whereas in Rome, a permit is needed first. Not everybody qualifies for such a permit, which means that traffic is regulated with a quantity (command-and-control type) policy, rather than a market mechanism. Finally, Paris does not even have the necessary legislation in place. There is no political interest in the introduction of any measure that would charge road users. The Mayor of Paris prefers to concentrate on the carrot only, rather on both the carrot and the stick. Public transport investment has priority in Paris, and no proposals on road pricing have ever been considered.

The original LCCS has demonstrated the merits of an area licence to internalise at least part of the congestion externality. The use of imperfect instruments to deal with market failures is not new in the design of real-world economic policies. It is however the first piece of evidence in the Western world of a pricing scheme to manage traffic demand. It works but attention is drawn to the potential inefficiency of the politics involved in the specification of such measures.

The main lesson from the original and planned congestion charging system in London is that a simple imperfect instrument may internalise part of the externality and yield gains, even when it is influenced by political factors.

Appendix

Table A2: Generalised Cost Calculations

Component		Car W	Car NW	LGV W	LGV NW	TAXI W	TAXI NW
VOT (2004 prices 2007 base) per per hour		£36.02	£8.25	£14.59	£7.80	£65.00	£36.52
Fuel operating costs	***a***	0.136	0.136	0.185	0.185	0.136	0.136
$L = a + bv + cv^2$	***b***	-0.0024	-0.0024	-0.0033	-0.0033	-0.0024	-0.0024
(L = fuel per km, V = speed)	***c***	0.000016666	0.00001666	0.00002529	0.00002529	0.000016666	0.000016666
Non-fuel operating (Perceived)	$\boldsymbol{a_1}$	4.28	4.01	6.21	7.51	4.28	4.01
$C = a_1 + b_1/V$ (C: cost per km)	$\boldsymbol{b_1}$	117.14	-	40.59	-	117.14	-

Source: DfT (2004e), TAG Unit 3.5.6

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