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The London Congestion Charging Scheme: A Cost-Benefit Analysis

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Transport for London implemented the London Congestion Charging Scheme in 2003 to reduce congestion and increase the speeds driven by vehicles in the zone. In 2007 TfL completed a cost-benefit analysis showing the schemes benefits to motorists. However, there is much criticism against the analysis and the schemes efficiency.

The following research re-addresses the scheme to provide clarity with a cost-benefit analysis. The analysis considers the life of the scheme from 2003-2008. Also, we find the Net Present Value of the scheme in 2003, and test for sensitivity. Overall, the scheme is too expensive for car drivers.

JEL Classifications: L52, Q58, R41, R48

Key words: London Congestion Charging Scheme, TfL, Cost-Benefit Analysis, Value of Travel Time Savings, Reliability, Safety, Pollution, Net Present Value

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I. History of the London Congestion Charge

In 2003, Transport for London (TfL) implemented a congestion charging scheme charging five pounds to any vehicle driving or parking in a congestion zone. [1] Covering an eight-mile radius, the congestion zone encompasses the boroughs of the City of London, Lambeth, Southwark, Islington and Camden. [2]The scheme operates Mondays – Fridays from 7am- 6pm, on the weekends traveling or parking within the zone is free of charge. TfL provides a wide variety of exemptions and discounts to residents, taxis, ambulance, and blue badge vehicles. In addition, full exemption from the scheme applies to motorcyclists and bicyclists. The revenue collected from the scheme is used purely for road improvements and funding of the London Underground and London Buses. Despite the recent implementation of the congestion charging scheme, the issue of heavy traffic is a continuing problem.

The objective of this research is to identify the costs and benefits associated with the London Congestion Charging Scheme (LCCS) to car drivers, and provide further clarity on previous research. The original impact of the scheme resulted in increased travel speeds within the zone leading to significant time savings benefits. However, traffic speeds have begun to decline moving closer to pre-charging year traffic speeds.[3] We note that although there are less cars on the road, data shows an increase in other types of vehicles specifically motorcycles, buses, and bicycles. In addition, various road works are ongoing in the Greater London area which may also contribute to the slowed traffic speed. Therefore, we set out to determine the costs and benefits of the LCCSe for

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[1] TfL later increased the congestion charge to eight pounds a day in 2007.
[2] TfL later extended the charging zone to include the boroughs of Westminster and Chelsea in 2007.
[3] Traffic speeds are measured in km/hr.

car drivers and to determine if the scheme is beneficial. In addition, we will consider the costs and benefits from the start of the scheme in 2003 until 2008. Previous research has only considered costs for a single year or different periods of the scheme such as considering the five-pound and eight-pound charge.

The following section presents an overview of research literature behind the LCCS. The literature is divided into two distinct categories: literature surrounding urban road pricing and literature specific to the LCCS. The next section explains the methodology behind the research and the data used to calculate the costs and benefits of the scheme. After the methodology and data, we explain the costs associated with the LCCS. The "Cost" section of the analysis discusses the costs associated with the charging scheme to drivers and explains the reasoning behind our calculations. Following the "Cost" section is a description of the benefits of the scheme; this section follows in the same suit as the previous section. Next, we compare the costs and benefits to find an overall cost or benefit of the LCCS for each year. Finally, we consider the net present values of the costs and benefits in the year 2003, and conduct a sensitivity analysis of the discount rate.

II. Literature Review

The basis for research in examining the effects of urban road pricing on consumer behavior concerns both theoretical and empirical studies of congestion schemes. Economic research, which measures how costs of the tax are calculated, as well as estimations of a consumer's behavior is relevant to the study. In particular, the conducted research is working off previous literature to provide clarity on the effects urban road pricing on a consumer- specifically, their chosen mode of transportation and the effects of the charge on their cost of traveling.

A. Urban Road Pricing

R. J. Smeed's inaugural address, "Traffic Studies and Urban Congestion," to the University College London introduces the important reasons for studying traffic (1967, p.34). Through the study of traffic, economists and engineers hope to find measures, which effectively aid in traffic flow and reducing congestion. Smeed's examination of traffic flow, the first in the field, exhibits calculations to justify an optimal number of vehicles on the road that can reach their destination per hour in a town center. After performing the analysis, Smeed concludes that as traffic reaches a maximum any small increase in traffic levels on the road significantly slows travel time. In addition, the choices people make allows traffic to adjust itself to its available capacity. Finally, he suggests that charging people for the congestion they cause is a possible solution to reduce traffic levels.

In agreement with Smeed, May (1992) and Mackie, Jara-Diaz and Fowkes (2001) consider problems associated with road congestion, in particular evaluating value of travel time savings (VOT). May (1992) introduces concerns about the impact that a congestion charging scheme will have on areas in which travelers have a high value of time. Furthermore, she reviews the impact road pricing may have on users switching to alternative methods of transportation seems unclear (1992, p. 325). Mackie et al. (2001) continue with May's conclusions to estimate the necessity of modeling and interpreting a traveler's behavior through VOT. Researchers create utility models to explain the value of time associated with work, which is capable of generating positive utility, leisure, and travel time. Considering the UK approach to calculated travel time benefits, Mackie et al. comments that increased disutility is a result of more crowded conditions. The conclusions drawn from their research is that time is a scarce resource, and the UK practice is to use a single standard value of non-working time per minute for valuing time, disregarding the travel purpose.

In the same year of Mackie et al., Santos and Newbery (2001) look at the SATURN model (Simulation and Assignment of Traffic to Urban Road Networks) that demonstrates where the major sources of congestion derive from. They compute the average charge for eight different towns in the UK, assuming a constant elasticity demand function. From these computations, Santos et al. (2001) were able to derive the average second-best charges through equating the generalized costs of traveling to the value of time, consistent with findings from Mackie et al. (2001), relative to time and distance. Researchers suggest that the average second-best charges are the optimal toll for reducing trips uniformly. In addition, Santos et al. (2001) construct a cost-benefit analysis to assess the benefits from a cordon toll. The results of the analysis show that even the cheapest operating technology produces cases with a benefit-cost ratio only slightly above one (2001, p. 16). Finally, Santos et al. (2001) consider the environmental impact charging schemes have on the environment find modest, but positive impacts.

More recently, Parry et al. (2007) discuss the impact of congestion charging and argue that efficiency from the charges requires a Pigouvian tax. On congestion charges, they consider their feasibility and effectiveness. They argue that it may be infeasible to estimate marginal congestion costs on every single link and intersection in an urban road network (2007, p. 393). Overall, they conclude that electronic road pricing offers the only "hope" of reducing urban gridlock.

B. The London Congestion Charging Scheme

In 2003 after various studies concerning the adoption of road pricing in London, TfL implements the LCCS. Research concerning the LCCS has been associated with positive and negative results. In order to highlight the positive and negative results this section has been divided into two categories and begins with the positive literature.

I. Positive Literature

Nearly forty years after Smeed's original research concerning the City of London Santos and Shaffer (2004) address the effects of the LCCS. They blame levels of traffic above the optimal amount a road network can handle to be a result of drivers using their private vehicle rather than taking public transportation. The analysis performed is a calculation of the elasticity of demand for car trips with respect to general travel costs, using Santos et al. (2001) calculations. They also calculate the marginal cost of congestion inside the London congestion charge zone. The preliminary results reveal that the LCCS has succeeded in reducing congestion and decreased by more than expected, meaning that there may have been an underestimation of elasticities before the scheme's establishment (2004, p. 179).

Leape (2006) praises the success of the scheme. Leape provides information on the impact of the scheme on overall congestion reporting that London experienced a decline in traffic levels between five and fifteen percent. From surveys completed after the implementation of the scheme, it is found that the standard deviation of travel times decreased twenty-seven percent during the morning peak periods and thirty-four percent on the return journey (2006, p. 167). However, due to multiple transport improvements in the year 2003, it is difficult for an analysis to form a direct relationship between the congestion charge and trends in consumer behavior and the economy.

Arguing against criticisms of the scheme, TfL (2007) presents a quantified evaluation of the LCCS taking into account Prud'homme et al. (2005) and Mackie's (2005) research. Using calculation tables provided by the UK Department for Transportation, researchers calculate the efficiency savings of individuals and businesses. With a five-pound charge they find that there is a small monetary loss to road users; with the eight-pound charge the monetary loss increases. TfL admits there are other costs associated with the scheme including the time to register a vehicle and text/ phone charges associated with registration and charge payment. The researchers suggest that amenity impacts are left out of this evaluation and that there may be possible wider impact benefits, including more productive jobs, increased labor force participation and improved competition (2007, p. 220). Overall, TfL concludes the Central London Congestion Charging Scheme continues to be successful.

II. Negative Literature

Although reports commend the LCCS and comment on the increase of the traffic speeds, there are many critics. Since the beginning of the scheme researchers have proven the success of the scheme to be minimal and report the scheme's inefficiency. This section highlights the researchers supporting the inefficiency of the LCCS. Some of the literature rejects congestion charging as the efficient method of reducing high levels of congestion; while other researchers reject London's Congestion Charge.

Similar to Santos et al. (2001) Santos (2004) estimates the potential impacts of charging schemes using the SATURN model. Santos (2004) continues her research through examining the elasticity of demand with respect to generalized cost as calculated with the SATURN model, assuming an elasticity of -.7 maintains consistency with previous research. She finds that as the demand to travel within the zone decreases the cordon toll increases to counteract the decline in demand (2004, p. 356). Finally, Santos (2004) analyzes the distributional to test the impact on consumers. Overall, her results show that cordon tolls can be an effective method to reducing traffic; however, they have a tendency of being regressive thus hurting low-income sectors.

In 2005, despite the applause the LCCS received, Prud'homme and Bocarejo (2005) are the first to reject the scheme. They analyze the LCCS based on estimated demand and cost curves for road usage. They conduct research to test the economic success of the charging scheme. The demand curve represents the demand for road use and the supply curve represents the per-km cost induced by a motorist. The equilibrium point is the point in which the marginal driver's cost is equal to the benefit of using the road; anything beyond this point the driver bears a cost, which is greater than the benefit resulting in not driving. Applying a modified version of the model, Prud'homme et al. find that congestion costs within the congestion zone represent only .03% of the economic output Greater London generates (2005, p. 9). Furthermore, they find that the benefits "net of costs" are negative.

Mackie (2005) discusses the contrasting conclusions drawn by TFL, and Prud'homme et al. (2005). Introducing the components necessary for an accurate cost-benefit analysis he highlights the idea that the LCCS includes an "accelerated depreciation element" (2005, p. 288). Furthermore, the largest difference in the Prud'homme et al. (2005) analysis and TfL's analysis is the value of time savings calculation. Mackie (2005) suggests that TfL presents inflated time savings due to the inclusion of benefits for those traveling outside of the charging zone. In addition, Mackie (2005) suggests that TfL's road pricing scheme requires extremely high resource cost for operation, which consumes roughly two-thirds of the proposed benefits and TfL may be operating a monopoly facility in which they are subjecting Londoners to rent seeking.

Raux (2005) re-examines the findings in Prud'homme et al. (2005). Raux uses the Prud'homme et al. (2005) model and implements equations to test the validity of their findings. He obtains a marginal social cost slightly below that of previous research, but overall the results Raux finds are still consistent with previous research, Prud'homme et al. (2005) and Mackie (2005). The estimated benefits are still less than one third of those estimated by TfL. The researcher considers the measurements to speed; the result is a 35% increase in the estimated congestion benefits. The findings, however, are not sufficient to explain the 1:3 ratio of benefits. Overall, Raux believes the operating cost of the congestion charge does deter from the economic benefits. However, Prud'homme et al. (2005) research is not enough to justify postponing the congestion charge scheme.

A reduction in travel time is a large benefit that congestion charges can provide. Santos and Bhakar (2005) give a more complete assessment of the LCCS's impact on pre-charging motorists and their value of travel time savings. They dismiss the standard approach, as Mackie et al. (2001) presents, to VOT estimations for the LCCS because drivers who value their travel time savings below the five pound charge will always be "losers," as well as those who switch their mode of transportation to buses. Santos et al. (2005) use a basic concept of the generalized cost giving time a monetary cost, consistent with Santos (2004). They assume that only part of the distance traveled is in the congestion zone. In their analysis, relatively few of the losers become winners; however, a significant improvement of benefits is apparent. Finally, Santos et al.(2005) report that if a normal value of travel time savings is assumed the only people who experience a reduction in the generalized cost of travel are those who have an income above £1400 per week, this holds consistent with Santos et al. (2001) and Prud'homme et al. (2005).

Santos and Fraser (2006) consider the impacts of the charge on vehicles. Santos et al. (2006) use a generalized cost elasticity of demand rather than a congestion charge elasticity of demand because the congestion charge left no room to use the standard formula of elasticity, since the charge goes from zero to five. Using reasoning consistent with previous research, they say the congestion charge elasticity will be "roughly equal to the generalized cost elasticity multiplied by the congestion charge share of generalized cost" (2006, p. 275). They find that TfL overcharges cars and undercharges goods vehicles (Lorries, vans etc.); the average charge should be around 4.23 pounds to internalize the negative externality, consistent Santos et al. (2001).

Santos (2008) draws a conclusion consistent with Prud' homme et al. (2005), Mackie (2005), and Raux (2005), and disagrees with TfL (2007). She researches the ratio of costs to benefit ratio and says it has always been around 50%. Although there are benefits of the scheme, there are also dis-benefits such as compliance costs. More importantly, Santos finds that travel time is nearly back to pre-congestion times and now only averages an 8% reduction in congestion. Overall, she concludes that the government is the only agent who ends up better off- drivers end up worse off. Assuming the same methodology used as Santos et al. (2006), the eight pound charge requires a weekly salary of 2,348 pounds or a yearly salary of 122,000 pounds for the commuter to benefit from the congestion scheme Santos (2008, p. 200). After looking at costs, revenues, and benefits she finds that imposing a flat congestion charge, equal for all vehicle types and times of day proves to be an inefficient policy.

Parry (2008) comments on London's scheme, he believes the wide range of charge exemptions weakens the scheme. Finally, in his review he asserts the need for more research on the empirical measurement of efficient tolls for major urban centers on the toll exemption provisions, pricing on other links in the network and toll variation between peak periods. Again, the findings are consistent with previous research, especially Santos (2008).

III. Cost-Benefit Analysis

A. Objective

The objective of the research is to re-examine the costs and benefits to car drivers of the LCCS. The analysis will provide further clarity on previous research. Expanding upon TfL's (2007) analysis we use a discount rate and a dynamic framework to analyze the cost and benefits over time. Additionally, research will look specifically at car drivers and the benefits and costs experienced with the LCCS.[4] It will take into consideration both charge levels as well as the Central Charging Zone (CCZ) and the Western Extension Zone (WEZ).

While data shows that traffic speeds have increased and the amount of cars on the road has decreased because of the LCCS, many question whether drivers are better or worse off under the scheme. Previous research finds the scheme's operating costs too expensive. In 2007, TfL reconsidered the cost-benefit analysis and included a measure of the Value of Travel Time Savings (VTTS).[5] Contrasting to Prud'homme et al. (2005), TfL suggests the benefits are much larger than previously measured. Although TfL (2007) extensively studied the scheme, there is a major shortcoming in their analysis. TfL completes the analysis only for a specific time-period at both a five-pound and eight-pound charge and does not look at the life of the scheme and it's present values.

B. Assumptions

The analysis of this thesis considers the costs and benefits of the LCCS to car drivers. We look only at car drivers in order to compare to previous literature. It is important to consider the social costs and benefits as well as individual costs and benefits of the scheme because the social cost is a representation of the burden placed on the entire economy. Furthermore, the analysis performed, also considers secondary effects of the scheme such as pollution and safety. In addition, the research uses a dynamic framework

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[4] The available data is only limited to car drivers. TfL does not give an estimate on the number of trips other vehicles (e.g. taxis, buses, and coaches) make in a day.

[5] Value of Travel Time Savings (VTTS) is the monetary amount saved during travel. It is representative of both the distance/time spent traveling and the wage of the population under study

rather than static and examines the costs of the congestion charge over the life of the scheme from 2003-2008.

The cost and benefit calculations derive from data provided for car travel during the week and during charging hours. In regards to the distance traveled, it is assumed that the distance remains the same over time at 11.7 kilometers per trip.[6] With a definition of a trip as a round-trip, Santos et al. (2006) assumes cars in London make an average of two trips per day. This results in a total of 23.4 kilometers/day on average for all car drivers.

Additionally, the analysis separates the CCZ costs and benefits from the WEZ costs and benefits. First, we assume the vehicles only enter one of the zones each day to avoid double counting vehicles and the cost of the congestion charge. Second, since the Western Extension Zone only began in 2007 it would have affected the costs and benefits significantly. Calculating the zone separately allows for the avoidance of skewed results. Finally, TfL plans to repeal the Western Extension Zone in January, 2011, furthering our assumptions that the zone would offset the costs and benefits.

C. Data

Data concerning traffic speeds in the congestion zone as well as transportation statistics provide a basis for the analysis. The Department for Transportation (DfT) provides a specific appraisal process necessary for estimating costs of transport schemes throughout the United Kingdom. DfT also gives estimates for Value of Operating Costs (VOC) and Value of Time (VOT). Other data used in the analysis, provided upon request

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[6] TfL in the Impact Monitoring Reports provides the distance of 11.7 kilometers per trip.

from TfL, includes traffic counts into the congestion charging zone (CZZ) and the Western Extension Zone (WEZ), traffic speeds (in km/hr), and purpose of the journey. In addition, Different from the New Earnings Survey data used in previous research, data concerning wages has been collected in the Annual Survey of Hours and Earnings (ASHE). ASHE is more accurate and weighted more appropriately to give a more precise estimation of travel time savings, and values of time.

D. Results

An analysis of the costs and benefits follows the Department for Transportation Appraisal Method. Costs considered in this model are the social costs relating to the schemes operations, and costs to car travelers such as fuel and non-fuel vehicle operating costs and compliance costs. Compliance costs consider the time followers of the scheme take out to pay the congestion charge. The analysis also takes into account benefits of the scheme such as value of travel time savings, reduced pollution, safety savings, and reliability savings. Reliability savings represent the monetary savings of drivers knowing they are able to reach their destination on time.

With respect to the value of time (VOT), the DfT provides base levels for vehicle purpose and type.[7] The value of time for car travelers, including working and non-working times are adjusted for both wage (ASHE) and car occupancy rates provided by TfL. A trip in working time is one in which occurs during the working day, this excludes commuting trips. Non-working time includes trips made outside of the workday including

[7] Value of time (VOT) is the opportunity cost of traveling. It is measured as the pounds per hour a traveler would give up for an extra hour of time.

commuting as well as other forms of trips (i.e. leisure, shopping etc.) These trips do not occur during workday hours for the individual and therefore have lower values of time.

Table 1: Values of Time adjusted for London Wages

£/ hour (2003)	**Average Car (working time)**	**Commuting (non-working time)**	**Other (non-working time)**
2003	43.40	8.95	7.92
2004	43.52	8.92	7.90
2005	41.13	9.06	8.02
2006	45.57	9.30	8.23
2007	45.37	9.20	8.14
2008	44.59	8.95	7.92

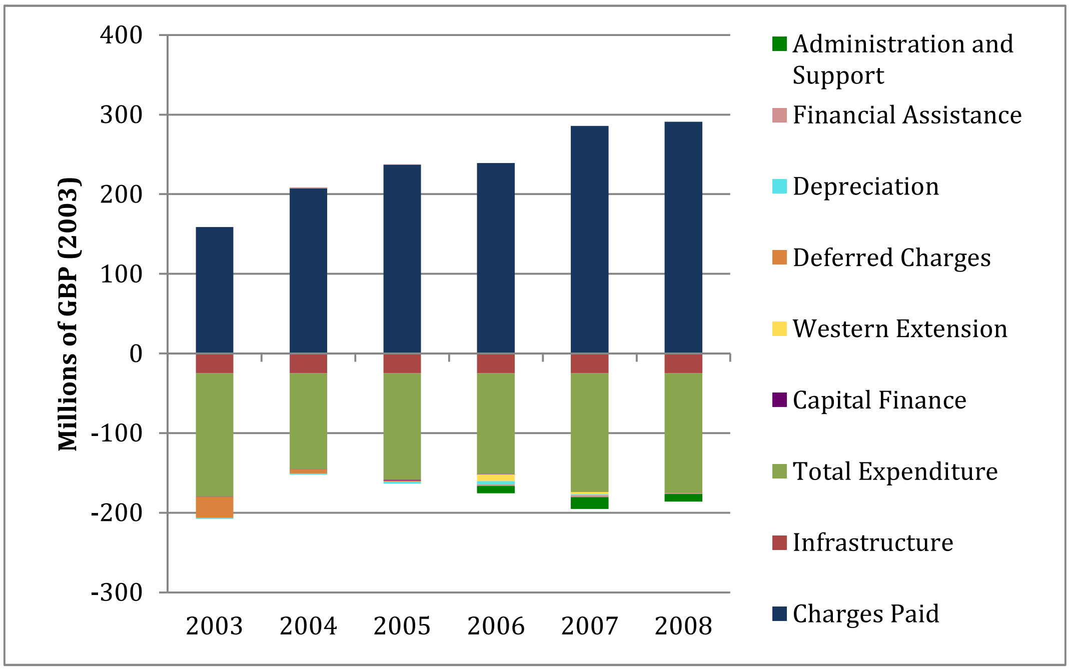
The above table clarifies the differences in the value of times for different types of car drivers/passengers. The average car in working time has the highest opportunity cost for an extra hour of time. It is gathered that time is more valuable to those traveling during working time rather than those who travel during non-working time. Additionally, there are differences in the value of time for those traveling to and from work and those traveling for other purposes such as leisure.

E. Costs

Following the DfT'sTransport Appraisal process, a cost analysis illustrates the costs to business car-travelers and commuting/other car-travelers.

First, it is necessary to consider the operating costs of the LCCS, provided by TfL. Because the costs derive from a financial year running from March to February, it has been assumed that the costs are equal for each of the twelve months. Therefore, the costs were adjusted to represent a calendar year for comparison with traveler costs. The LCCS had a one-time start up costs; however, it was divided among the first ten years of the charge and has been adjusted for depreciation. The cost is the 25 million pounds and resides within the infrastructure costs. Furthermore, it is important to realize that only the first year of the LCCS experienced a cost, all other years have positive values; therefore, the revenues generated from the scheme more than cover the operating costs.

Figure 1: TfL Operating Costs of the LCCS



After computing the operating costs of the scheme, we calculate the costs to the business traveler by car and to the commuting/other traveler by car. Both the fuel costs and vehicle operating costs (VOC) follow the appraisal method. Fuel costs and other non-operating cost calculations derive from distance and speed traveled as well as using parameters outlined by DfT.[8] They are calculated as:

$$L= a+bv+cv^2+dv_3 \quad (1)$$

The analysis assumes that London adequately represents England's populations' preference for vehicle type. To account for the use of both petrol and diesel vehicles the parameters for each type of fuel are used proportionately. Therefore, fuel costs depend on

[8] Where V is speed and a,b,c, and d are parameter values given by DfT; see Appendix1E

fuel type and speed. The other non-fuel costs take into consideration tires, car maintenance and repairs. [9] Again, the calculation takes into account the speed of travel. Non-fuel costs are known as operating costs and are calculated as:

$$C = a + b/v \qquad (2)$$

In addition, the analysis accounts for the time users of the scheme take to pay for the congestion charge; this is known as the compliance cost. The compliance costs represents the monetary value of stopping to pay the congestion charge. Users have the ability to pay online, register cell phones to pay through text messaging, or at a number of machines found throughout a variety of stores in Greater London. For businesses, TfL reports that it costs and additional one pound for each charge; whereas, for commuters/other travelers the cost is only 50p per charge. Finally, the analysis focuses on the congestion charge. To calculate the cost of the congestion charge we assume the cars flowing into the congestion zone are not exempt from the charge or entitled to any discounts. Our reasoning is that residents of the congestion zone are already inside of the zone and therefore not driving through the zone at the same cost as non-residents. The total cost of the congestion charge, then, is multiplied by the inflow of cars into the Central Congestion Zone.

[9] Where V is the speed and a and b are parameter values given by DfT; see Appendix1G

Table 2a: The Costs of the LCCS to Businesses and Commuting/Other Car Travelers using the CZZ

In Millions £(2003)		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Traveler Costs							
Business Traveler							
Vehicle Operating Costs	Fuel Costs	-0.700	-0.650	-0.635	-0.643	-0.657	-0.597
	Non-Fuel Costs	-3.53	-3.24	-3.14	-3.14	-3.60	-3.30
	Compliance Costs	-3.25	-2.97	-2.87	-2.86	-2.87	-2.57
Commuting/ Other Travelers							
Vehicle Operating Costs	Fuel Costs	-6.30	-5.85	-5.72	-5.79	-5.91	-5.37
	Non-Fuel Costs	-11.31	-10.33	-9.97	-9.94	-9.99	-8.94
	Compliance Costs	-14.64	-13.36	-12.90	-12.86	-12.92	-11.57
Business and Commuter/Other	Congestion Charge	-154.16	-151.47	-229.42	-223.48	-219.42	-189.62
Total		**-193.89**	**-187.87**	**-264.66**	**-258.71**	**-255.37**	**-221.97**

Starting in 2007 we are able to apply the same methods to the WEZ and find the costs to both business and commuting/other car travelers. The overall costs in 2007 and 2008 are lower in the WEZ than in the CCZ; however, after only the first year cost to travelers in the WEZ are extremely high.

Table 2b: The Costs of the LCCS to Businesses and Commuting/Other Car Travelers using the WEZ

In Millions £(2003)		**2007**	**2008**
Traveler Costs			
Business Traveler			
Vehicle Operating Costs	Fuel Costs	**-0.52**	**-0.57**
	Non-Fuel Costs	**-2.86**	**-2.70**
	Compliance Costs	**-2.59**	**-2.43**
Commuting/Other Travelers			
Vehicle Operating Costs	Fuel Costs	**-5.33**	**-5.08**
	Non-Fuel Costs	**-9.00**	**-8.46**
	Compliance Costs	**-11.64**	**-10.94**
Business and Commuter/Other	Congestion Charge	**-197.65**	**-179.28**
Total		**-229.590**	**-209.46**

F. Benefits

The benefits of the scheme consider time saved and reliability for business travelers and commuting/other travelers. First, observing the values of travel times savings and reliability our results and calculations are consistent with Santos et al. (2004). Using the value of travel times savings (VTTS) found by Santos et al. (2004) we assume 42.2 pence/km and 4.9 pence/km for business travelers and commuters/other travelers respectively. Weighting the value of travel time savings takes into account that only 10% of car trips are for business purposes while 90% are commuting and other. [10] Therefore, the value of travel time savings respective of the London wage is 8.6 pence/km. Adjusting Santos et al. (2004) estimations of the VTTS for each year according to the wage growth allows us to consider the changes over time. To calculate the total VTTS for the entire year for all car drivers requires the following equation:

$$Yearly\ VTTS = \left(((TS)\left(VTTS_{CT}\frac{p}{m}\right)(CIF_{CT})) * 250 \right) + \left(((TS)\left(VTTS_{BT}\frac{p}{m}\right)(CIF_{BT})) * 250 \right) \quad (3)$$ [11]

Where Time Savings (TS) is calculated as:

$$TS = \left(\left(\frac{60}{S_0}\right)(D) \right) - \left(\left(\frac{60}{S_1}\right)(D) \right) \quad (4)$$ [12]

The only year experiencing a positive benefit for VTTS is the first year. This is a result of slowing traffic speeds and that the schemes largest impact was in its first year.

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[10] TfL reports these figures in the *Impact Monitoring Reports: Sixth Annual Report*.

[11] The variables of the equation are define as follows:

- *(p/m)* : the measurement of pence/minute
- *CIF:* car flow entering a specific zone where commuting/other travelers are defined as *CT* and business travelers are defined as *BT*
- 250 is the total number of chargeable days in a year

[12] *D* is distance- this case using the assumed two trips it is 23.4 km.

After the first year of the scheme, VTTS becomes a negative benefit. Considering the reliability savings, the DfT reports that reliability savings are 30% of the value of travel time savings. Reliability savings represent the increased reliability drivers receive from reaching their destinations on time.[13] As VTTS moves from a positive benefit to a negative benefit, reliability savings move in the same direction.

Table 3a: Benefits of the Scheme to Business and Commuting/Other Car Travelers in the CCZ

In Millions £ (2003)		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Business Travelers							
Value of Travel Time Savings	VTTS	23.48	-3.62	-3.14	-6.17	-8.28	-9.85
	Reliability	7.044	-1.09	-0.94	-1.85	-2.48	-2.95
Commuting/Other Travelers	VTTS	24.53	-3.82	-3.28	-6.45	-8.64	-10.3
Value of Travel Time Savings	Reliability	7.36	-1.15	-0.98	-1.93	-2.59	-3.09
Total		**62.414**	**-9.68**	**-8.34**	**-16.4**	**-21.99**	**-26.19**

Table 3b: Benefits of the Scheme to Business and Commuting/Other Car Travelers in the WEZ

In Millions £ (2003)		**2007**	**2008**
Business Travelers			
Value of Travel Time Savings	VTTS	-7.41	-9.32
	Reliability	-2.22	-2.8
Commuting/Other Travelers	VTTS	-7.74	-9.74
Value of Travel Time Savings	Reliability	-2.32	-2.92
Total		**-19.69**	**-24.78**

The wider economic impacts of the scheme include environmental savings and road safety savings. Environmental savings followed Prud'homme et al. (2005) calculations. These calculations find that for every 1000 vehicle-kilometers driven it costs

13 We use the 30% proportion to remain consistent with previous research. The estimate refers back to the *1995 London Congestion Charging Research Programme* as reported by TfL (2007). The modeling process estimated the reliability of journey time by types of road networks.

29 Euros in vehicle emissions and for carbon dioxide emissions cost 7 Euros.[14] Adjusting the costs using exchange rates and calculating the difference in vehicle-kilometers driven by cars each year we estimate the pollution costs. Similar, to the VTTS, the effect of the scheme on pollution within the charged zone declines. The largest impact appears immediately following the scheme. Because, the change in vehicle-kilometers becomes smaller over time, the savings from lower emission levels decline. Finally, safety accident benefits derive from Impact Monitoring Reports found by TfL. TfL reports that between 2-5% of personal injury accidents reported are a result of the LCCS. Personal Injury accidents include all slight, serious, and fatal accidents reported in the charging zone. Furthermore, TfL reports that a personal injury accident costs £85,000. To calculate the benefit of reduced accidents requires the difference in accidents from year to year.

Table 4a: Wider Impact Benefits of the London Congestion Charging Scheme in CCZ

In Millions £ (2003)		**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Wider Impacts							
Pollution	Transport Emissions	1.304	0.194	0	0.046	0.091	0.308
	CO2 Emissions	0.312	0.047	0	0.011	0.022	0.075
Safety	Accidents (low estimate)	0.2	0.188	0.176	0.262	0.061	0.00635*
	Accidents (high estimate)	0.557	0.523	0.489	0.726	0.169	0.0204*
Total	(low estimate)	**1.816**	**0.429**	**0.176**	**0.319**	**0.174**	**0.38935**
Total	(high estimate)	**2.173**	**0.764**	**0.489**	**0.783**	**0.282**	**0.77235**

*see footnote[15]

[14] See Appendix1G for exchange rates

[15] All 2008 safety estimates are estimates based off facts provided in the *Travel in London Report 2*. It is assumed, since no data is available, that percent changes in the charging hours are proportionate to changes city-wide.

Table 4b: Wider Impact Benefits of the London Congestion Charging Scheme in the WEZ

In Millions £ (2003)		2007	2008
Wider Impacts			
Pollution	Transport Emissions	0.596	0.257
	CO2 Emissions	0.144	0.062
Safety	Accidents (low estimate)	0.0024	0.00283
	Accidents (high estimate)	0.008	0.0091
Total	(low estimate)	**0.7504**	**0.32183**
Total	(high estimate)	**2.173**	**0.3281**

Observing the wider benefits associated with the scheme reveals that the benefits are modest in comparison to the other costs and benefits of the scheme. Furthermore, the modest results are consistent with previous results.

III. Total Costs and Benefits

After calculating all costs and benefits associated with the LCCS we are able to compare the results. We do not compare the operating costs of the scheme to the costs and benefits experienced by car travels in order to avoid double counting the cost of the congestion charge. The congestion charge is considered the revenue for TfL; while it is a cost to car drivers. The high estimate of accident savings is used in order to give the maximum potential of benefits car drivers experienced.

Table 5a: Overall Costs and Benefits in the CCZ

In Millions £ (2003)		2003	2004	2005	2006	2007	2008
Traveler Costs		-193.890	-187.870	-264.66	-258.71	-255.37	-221.97
Traveler Benefits		62.414	-9.68	-8.34	-16.4	-21.99	-26.19
Wide Benefits	(high estimate)	2.173	0.764	0.489	0.783	0.282	0.7724
Total		**-129.30**	**-196.79**	**-272.51**	**-274.33**	**-277.08**	**-247.39**

Table 5b: Overall Costs and Benefits in the WEZ

In Millions £ (2003)		2007	2008
Traveler Costs		-229.590	-209.46
Traveler Benefits		-19.69	-24.78
Wider Benefits	(high estimate)	2.173	0.3281
Total		**-247.107**	**-233.91**

To expand our analysis further, the net present value of the costs, benefits and total are calculated. This enables one to see the net present value of the scheme in 2003. Using the values found in each year we have computed the present value. The Department for Transportation recommends a 3% discount rate for a scheme with a life-time of 35-75 years.

Table 6a: Net Present Value of the Congestion Charging Scheme in the CCZ(3% discount factor)

In Millions £		2003	2004	2005	2006	2007	2008
Present Value Traveler Costs		-193.89	-182.40	-249.46	-236.76	-226.89	-191.47
Present Value Traveler Benefits		62.41	-9.40	-7.86	-15.01	-19.54	-22.59
Present Value Wider Benefits	(high estimate)	2.17	0.74	0.46	0.72	0.25	0.67
Present Value Total		**-129.30**	**-191.05**	**-256.86**	**-251.05**	**-246.18**	**-213.40**
Net Present Value							**-1287.84**

Table 6b: Net Present Value of the Congestion Charging Scheme in the WEZ (3% discount factor)

In Millions £	2007	2008
Present Value Traveler Costs	-203.99	-180.68
Present Value Traveler Benefits	-17.49	-21.38
Present Value Wider Benefits	1.93	0.28
Present Value Total	**-219.55**	**-201.77**
Net Present Value		**-421.32**

Overall, the scheme's cost to drivers greatly outweighs the benefits and is too expensive. The most significant benefits felt by car drivers appeared in the first year; afterwards, benefits gradually decline. In the first year, the average car experienced a cost of £961.05 in the CCZ . However, after the first year, the costs of the scheme increase and by 2008 the average car experienced a cost of £2325.48. In the Western Extension, beginning in 2007, the average car experienced a cost of £ 2253.34 and in 2008 the average cost is £2325.61. This is partially a result of smaller benefits; however, in 2005 TfL implemented a higher £8 charge greatly affecting the cost to car drivers. In addition, the VTTS became a negative benefit, costing drivers rather than providing monetary savings. Finally, the net present value of the scheme at a 3% discount rate is -1287.84 million in the CCZ and -421.32 million, again an extremely high cost to drivers. These results are consistent with previous research including Prud'homme et al. (2005), Mackie (2005) and Raux (2005).

IV. Sensitivity Analysis

DfT recommends a 3% discount rate for long-term projects. However, to test for sensitivity we have tested other discount rates at 2%, 7% and 10% for comparison. The 7% discount rate is chosen because in the United Kingdom's recommended discount rate is much lower than the United States discounting rate. The United States' social discounting rate for long-term projects is 7%; discount rate is a means for comparison of the scheme to U.S. discounting. We have chosen to test the net present value with a 2% discount rate for the purpose of comparing with the low estimate of 3% by DfT.

Table 7a: 2% Discount Rate for Costs and Benefits of the CCZ

In Millions £		2003	2004	2005	2006	2007	2008
Present Value Traveler Costs		-193.89	-184.19	-254.38	-243.79	-235.92	-201.04
Present Value Traveler Benefits		62.41	-9.49	-8.02	-15.45	-20.32	-23.72
Present Value Wider Benefits	(high estimate)	2.17	0.75	0.47	0.74	0.26	0.70
Present Value Total		**-129.30**	**-192.93**	**-261.92**	**-258.51**	**-255.97**	**-224.06**
Net Present Value							**-1322.69**

Table 7b: 2% Discount Rate for Costs and Benefits of the WEZ

In Millions £		2007	2008
Present Value Traveler Costs		-212.11	-189.71
Present Value Traveler Benefits		-18.19	-22.44
Present Value Wider Benefits	(high estimate)	2.01	0.30
Present Value Total		**-228.29**	**-211.86**
Net Present Value			**-440.15**

Again, the net present values of the costs and benefits of the scheme are discounted at 7% to observe the change in the costs and benefits using a United States measure.

Table 8a: 7% Discounting Rate for Costs and Benefits of the CCZ

In Millions £		2003	2004	2005	2006	2007	2008
Present Value Traveler Costs		-193.89	-175.58	-231.16	-211.19	-194.82	-158.26
Present Value Traveler Benefits		62.41	-9.05	-7.28	-13.39	-16.78	-18.67
Present Value Wider Benefits	(high estimate)	2.17	0.71	0.43	0.64	0.22	0.55
Present Value Total		**-129.30**	**-183.91**	**-238.02**	**-223.93**	**-211.38**	**-176.38**
Net Present Value							**-1162.91**

Table 8b: 7% Discount Rate for Costs and Benefits of the WEZ

In Millions £		2007	2008
Present Value Traveler Costs		-175.15	-149.34
Present Value Traveler Benefits		-15.02	-17.67
Present Value Wider Benefits	(high estimate)	1.66	0.23
Present Value Total		**-188.52**	**-166.77**
Net Present Value			**-355.29**

The final discounting rate used in the sensitivity analysis is a 10% discount rate. This rate was chosen in accordance with a higher estimate of the United States social discounting rate for long-term projects.

Table 9a: 10% discounting rate for Costs and Benefits in the CCZ

In Millions £		2003	2004	2005	2006	2007	2008
Present Value Traveler Costs		-193.89	-167.44	-210.23	-183.16	-161.14	-124.83
Present Value Traveler Benefits		62.41	-8.63	-6.62	-11.61	-13.88	-14.73
Present Value Wider Benefits	(high estimate)	**2.17**	0.68	0.39	0.55	0.18	0.48
Present Value Total		**-129.30**	**-175.39**	**-216.47**	**-194.22**	**-174.83**	**-159.75**
Net Present Value							**-1049.96**

Table 9b: 10% Discounting Rate for Costs and Benefits in the WEZ

In Millions £		2007	2008
Present Value Traveler Costs		-156.81	-130.06
Present Value Traveler Benefits		-13.45	-15.39
Present Value Wider Benefits	(high estimate)	1.48	0.20
Present Value Total		**-168.78**	**-145.24**
Net Present Value			**-314.02**

After conducting a sensitivity analysis for the discounting rate used by the DfT, we have been able to compare a variety of other rates. However, the costs of the scheme for car drivers still outweigh the benefits, proving the scheme to be too expensive and inefficient.

IV. Extensions for Future Research

The research looks only at the costs and benefits for 2003-2008. For further expansion on the topic we plan to consider the future values of the scheme over a project lifetime of 31-75 years. Using this form of analysis we can determine if the scheme reaches efficiency in the future. Furthermore, other suggestions for future research include looking at the scheme after the changes take place. In January 2011 TfL plans to repeal the WEZ and increase the charge to ten- pounds. We will be able to further consider the scheme's efficiency after seeing preliminary results of the scheme with a higher charging level as well as the elimination of a zone.

V. Conclusion

Transport for London implemented a congestion-charging scheme in 2003. The main objective of the scheme was to reduce the flow of traffic in the zone and increase traffic speeds. After the first year, the scheme proved to be a success; however, after only the third year traffic speeds began to decline reach pre-charging speeds. The purpose of the research was to reconsider the costs and benefits associated with the London Congestion Charging Scheme. Furthermore, the research expanded on TfL's (2007) Cost-Benefit Analysis to look at the costs and benefits of the scheme over time. We find results consistent to all previous research in opposition to the London Congestion Charging Scheme. The costs associated with the scheme are too high and greatly outweigh the benefits; the first year alone cost each car driving into the congestion zone during charging hours £961.05. To provide a further analysis of the costs and benefits associated with the scheme we also consider the net present value for 2003. With a discount rate of 3% the costs are still high at £1287.84 million in the CCZ and £421.32 million in the WEZ. The scheme's cost for car drivers is too high. Furthermore, as data shows traffic speeds decline to pre-charging levels, cars are now paying for an externality that has not been improved. The results are consistent with previous research rejecting the scheme.

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VII. APPENDIX

Appendix 1A.

The arc elasticity of cars entering the charging zone have been calculated with respect to the congestion charge. The values calculated use a £0-£5 and a £5 - £8 charge for the original zone, a £0- £8 charge for the Western Extension Zone. The values found were .197, .06, and .169 respectively. These arc elasticity values are consistent with previous research, in which the elasticity was found with respect to fuel costs.

Appendix 1B: Traffic Speeds in Central London (km/hr)

2002	14.651
2003	17.71
2004	17.227
2005	16.905
2006	16.422
2007	15.939
2008	15.465

Appendix 1C: DfT base levels for VOT in pounds/hour

Vehicle Occupant	Market Price
Car driver	26.43
Car passenger	18.94
Commuter	5.04
Other	4.46

Appendix 1D: Operating Costs of the London Congestion Charging Scheme[16]

In Millions £		2003	2004	2005	2006	2007	2008
TfL Revenue	Charges Paid	181.64	237.71	271.57	267.56	327.27	333.24
	Infrastructure	-25	-25	-25	-25	-25	-25
	Western Extension				-9.91	-3.23	
	Total Expenditure	-177.11	-137.68	-153.21	-144.89	-170.78	-171.89
	Capital Finance	-0.29	-0.39	-1.02	-0.29		
	Deferred Charges	-30.82	-6.3	-1.61			
	Depreciation	-1.29	-1.67	-2.77	-4.66	-1.27	
	Financial Assistance		1.44	0.47	-2.03	-2.88	-1.4
	Administration and Support				-10.89	-16.8	-0.233
Total		**-52.87**	**68.11**	**88.43**	**69.89**	**107.31**	**134.72**

Appendix 1E: VOC Fuel Parameters (2002 prices in pence/km)

	A	B	C	d
Petrol Car	3.13851511	-0.07309335	0.00084585	-0.00000282
Diesel Car	2.59193679	-0.05248085	0.00052753	-0.00000128

Appendix 1F: Percentage of Petrol vs. Diesel Cars in the United Kingdom

Year	Petrol	Diesel
2002	79	21
2003	78	22
2004	77	23
2005	76	24
2006	75	25
2007	74	26
2008	72	28

[16] Cells which are blank mean that TfL has not reported costs for these years or costs are not applicable. For example, the Western Extension had start up costs in only the years 2006 and 2007.

Appendix 1G: Non- Fuel VOC parameters (2002 prices: pence/km)

Car	a	B
Work	4.069	111.391
Non- Work	3.151	-

Appendix 1H: Yearly Average Exchange Rates (Euro to GBP)

2002	0.62887
2003	0.6924
2004	0.67881
2005	0.68421
2006	0.68205
2007	0.68479
2008	0.79635