

## **Demand Elasticities for Car Trips to Central London as revealed by the Central London Congestion Charge**

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### **1 Introduction**

- 1.1 In February 2003 London's central area congestion charge was introduced at the rate of £5 per day. There was a substantial reduction in the volume of traffic entering, leaving and circulating within the charged area – the Central Charging Zone. In July 2005 the central area charge was increased to £8 and in February 2007 the £8 charge was also applied to the Western Extension Zone, accompanied by a reduction in the charging hours, from 0700 – 1830 hours to 0700 – 1800 hours.
- 1.2 This Report supplements Transport for London's Sixth Annual Monitoring Report by describing analysis undertaken to investigate the elasticity of trips by cars (including minicabs or private hire vehicles) to the central London charging zone in response to the charge. The elasticity estimates derived are intended to assist the understanding of the effects of congestion charging in central London.
- 1.3 It does not examine the use of cars that are no longer used for trips to the charging zone. Nor does it distinguish the effects at a disaggregate level or consider the contribution of new trips by car or minicab that may be made into the zone as a result of the charge making journey times shorter.
- 1.4 It has to be borne in mind that the estimates obtained here are derived from road users travelling to central London – a rather special group with various characteristics and with transport options that may not apply to road users in other locations.
- 1.5 This Report is structured as follows:
  - Section 2 presents the elasticity estimates calculated from the changes in demand and travel costs for car trips to the charging zone following the introduction of the congestion charge.
  - Section 3 presents elasticity values for car travel more generally from other sources such as WebTAG and the wider literature and compares the particular trip-based elasticity values derived here with those from other sources.
  - The conclusions drawn from this work are summarised in Section 4.
  - Appendix A summarises the main changes in road traffic levels; Appendix B the main changes in trip costs following the introduction of the charge; and Appendix C the principal inputs to the elasticity calculations.

## 2 Elasticity estimates

### Elasticity measure

2.1 All elasticities measure the percentage change in one variable in response to a change in another variable, in this case the change in demand for car trips in response to a change in the cost of car trips. The elasticity values calculated in this note are arc elasticities. The *arc elasticity* measure calculates the percentage changes in demand and cost as an average of the before and after values. It uses the midpoint formula.

2.2 As an example, if

|       |   |                   |     |
|-------|---|-------------------|-----|
| $C_1$ | = | original cost =   | 100 |
| $C_2$ | = | final cost =      | 120 |
| $D_1$ | = | original demand = | 100 |
| $D_2$ | = | final demand =    | 90  |

The *arc elasticity* calculation is  $[(D_2 - D_1)/(0.5*(D_1 + D_2))] / [(C_2 - C_1)/(0.5*(C_1 + C_2))]$   
 $= (-10/95)/(20/110) = -10.5/18.2 = -0.58$

2.3 The average fall in demand across the part of the demand curve between 100 and 90 is slightly more than 10% and the average increase in cost across the cost curve between 100 and 120 is slightly less than 20%. The resulting arc elasticity value of -0.58 is higher than the point elasticity value from the same data, measured as the percentage changes from the original costs and demand, so giving here an elasticity of -0.50 from a 10% change in demand and a 20% charge in cost.

2.4 If we had been dealing with cost reductions and increased demand the arc elasticity value would have been lower than the point elasticity value.

2.5 As we are dealing here with non-marginal changes in cost and demand, the focus is on arc elasticities rather than point elasticities.

### Demand responses

2.6 The elasticity values quoted here are based on the change in car and minicab trips into charging areas within charging hours, taken from TfL's annual reports monitoring the impacts of the congestion charge, and on the changes in the money costs of trips as a result of the charge. They thus incorporate a wide range of responses among a wide range of trip types and the responses are measured as changes in trips rather than the more normal change in vehicle kilometres. These issues are explored in the following paragraphs.

2.7 **Which responses?** Trip responses to a charge levied in a particular area during particular hours will be varied: a trip may not be made at all; it may be made by a different mode; it may avoid the charged area by driving around it or by changing destination; it may be made at different times to avoid charging hours.

2.8 In this analysis, described in Appendix A, we start with the overall reduction in trips entering the charging zone during charging hours and deduct from this estimates of the numbers of trips which divert around the charging zone or travel outside charging hours in order to avoid charges. Thus the main elasticities quoted here are effectively the measures of other responses to charges – changing mode, changing destination or changing trip frequency – by trips to/from or through the charging zone. These elasticities are more comparable to the literature values which typically describe responses to changes in fuel costs.

- 2.9 Of the overall reduction in car trips entering the charging zone during charging hours, it is estimated from Behavioural Surveys that in the original central charging zone (CCZ) around 30% are diverting around the charging zone or travelling during non-charging hours (from Table 5.1 of the *Second Annual Impacts Monitoring Report*, April 2004), whereas in the western extension zone (WEZ) this proportion is around 20% (from *Understanding Driver Responses: Behavioural Survey Post-Introduction of WEZ*, MVA, April 2008).
- 2.10 **By which car trips?** Charges affect categories of car and minicab trips differently. Licensed minicabs are exempt from charges, as are some vehicles used by the emergency services and the disabled. Alternative fuel vehicles and vehicles used by blue badge holders get a 100% discount, while residents of the charged areas get a discount of up to 90%. Other cars have to pay the full charge (now £8 per day) or the registered fleet vehicle charge (now £7 per day). The main calculation is of the demand elasticity among those eligible for the charge.
- 2.11 In some places, however, the elasticities across all car and minicab trips, whether or not they are eligible for the charge, are given. In Appendix A, analysis of anonymised camera data indicates that in the CCZ around half of cars pay the full charge or the fleet charge, some 30-40% are exempt or receive 100% discounts and around 10% receive residents' discounts. In the WEZ, around 40% pay the full or fleet charge, around 40% are exempt or receive 100% discount and around 20% of trips receive residents' discounts.
- 2.12 **Change in trips or vehicle kilometres?** The change in demand is measured as the change in the number of trips into the charged area during charging hours rather than the more normal demand response of the change in the number of vehicle kilometres. So the change in demand takes no account of changes in car trips or kilometres travelled within the charged area. The change in the number of vehicle kilometres would encompass the reduction in the number of trips made as well as trips being shortened in length. Here we are measuring the change in the number of trips into the charged area, which includes trips no longer made by car and trips which have been shortened in order to avoid the charged area. We are not measuring the change in vehicle kilometres travelled while inside the charging zone.
- 2.13 It is not possible to determine how closely our demand response of the number of trips made into the charged area matches the more normal demand response of the change in the number of vehicle kilometres, but the two measures may not be too different, since they both include trips no longer made by car and trips which are shorter in length.
- 2.14 Measures of the overall reduction in car trips during charging hours in response to charges in the CCZ and WEZ are given in Table 2.1 below. There is a larger reduction in all car and minicab trips in the CCZ (36% as opposed to 23%). There is still a larger reduction in chargeable trips in the CCZ than in the WEZ (53% as opposed to 43%), even though a larger proportion of trips in the WEZ than the CCZ are made by residents and regarded as non-chargeable.
- 2.15 If we confine the change to chargeable trips which change mode, destination or frequency, the reductions are 37% in the CCZ and 34% in the WEZ.

**Table 2.1: Net Car Trip Response to £8 Charges**

| Car Trips  | CCZ  | WEZ  |
|--|------|------|
| All car and minicab trips  | -36% | -23% |
| All car and minicab trips which change mode, destination or frequency        | -25% | -18% |
| Chargeable car and minicab trips   | -53% | -43% |
| Chargeable car and minicab trips which change mode, destination or frequency | -37% | -34% |

Cost change

- 2.14 The changes in the money cost of trips (fuel cost and congestion charge) brought about by the charge – for vehicles liable to the charge – are described in Appendix B and shown in Table 2.2 below for a 'typical' driver making 2.5 trips per day each on average 17 kilometres long.

**Table 2.2: Changes in Money Costs of Charged Trips**

| <b>Congestion charge</b> | <b>CCZ</b> | <b>WEZ</b> |
|--------------------------|------------|------------|
| £0 to £5                 | +119%      | n/a        |
| £0 to £8                 | +191%      | +191%      |
| £5 to £8                 | +33%       | n/a        |

Elasticity estimates

2.15 The resulting central elasticity estimates, based on these trip lengths and frequencies, as well as for variants around these central estimates are shown in Table 2.3 on a following page. The principal inputs to the estimates are set out in Appendix C. The variants are in:

- the assumptions of the number of trips and the length of trips made per day by car users entering the charging zone,
- in the CCZ where parking charges can be high, to a measure of travel cost which includes parking charges as well as fuel costs and charge payments,
- an alternative valuation of the congestion charge as a 'penalty charge' of £5 for having to pay for something which was previously free at the point of use and 0.5 times the actual charge. This values the £5 charge at £7.50 and the £8 charge at £9, and has been derived within TfL as a means of fitting a constant elasticity curve to the charge levels of £5 and £8, and
- estimates have also been made of the elasticity with respect to the change in generalised cost, in which the value of travel time, at a London non-business value of car time of £10.8 per hour, is added to fuel costs and charge payments. At this value of time and at travel speeds in London, the value of the time spent per trip is over 5 times the value of the money (fuel) cost per trip.

2.16 The main findings are:

- The central elasticity estimates, of the change in mode, destination and trip frequency among chargeable car trips in response to the change in money costs (fuel cost and the charge) are: -0.47 in the CCZ and -0.42 in the WEZ.
- Variations in assumptions about the numbers and lengths of trips made by cars into the charged areas give elasticity ranges of -0.40 to -0.51 for the CCZ and -0.36 to -0.46 for the WEZ
- In the CCZ the elasticity in response to the introduction of the £5 charge, at -0.55, was much higher than that of -0.16 in response to the increase in the charge from £5 to £8.
- In the CCZ, if parking charges are included in the money costs of both the without and with-congestion charge cases, the elasticity with respect to the £8 congestion charge increases to -0.72.
- If the congestion charge were valued not at its money cost but at a formula of £5 plus half of the actual money cost (so the £5 charge would be valued at £7.50 per day and the £8 charge at £9 per day), the elasticity of demand with respect to £5 and £8 charges would be almost constant, at -0.44.
- In the CCZ, if values of time are included along with fuel costs and charge costs in a measure of generalised costs, the elasticity with respect to generalised costs is in excess of -2.0.
- Elasticities measured across all car and minicab trips, including those not eligible for the charge, are smaller. The central estimates are -0.29 in the CCZ and -0.20 in the WEZ.

Table 2.3 Elasticity results - based on changes in mode, destination and trip frequency

| Area | Elasticity wrt to  |         |                  | Assumptions       |   |  | Elasticity                           |                                      |                                      | Elasticity               |                          |                          |
|------|--------------------|---------|------------------|-------------------|---|--|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------|--------------------------|--------------------------|
|      | money cost<br>fuel | parking | gen cost<br>time | trip length<br>km | trips per<br>day                                | other  | chargeable car trips only<br>£0 - £5 | chargeable car trips only<br>£5 - £8 | chargeable car trips only<br>£0 - £8 | all car trips<br>£0 - £5 | all car trips<br>£5 - £8 | all car trips<br>£0 - £8 |
| CCZ  | ✓                  |         |                  | 17                | 2.5   |  | -0.55                                | -0.16                                | -0.47                                | -0.35                    | -0.09                    | -0.29                    |
|      | ✓                  |         |                  | 17                | 2   |  | -0.48                                | -0.15                                | -0.42                                | -0.30                    | -0.09                    | -0.26                    |
|      | ✓                  |         |                  | 20                | 2.5   |  | -0.61                                | -0.18                                | -0.51                                | -0.39                    | -0.10                    | -0.32                    |
|      | ✓                  |         |                  | 15                | 2.5   |  | -0.51                                | -0.16                                | -0.44                                | -0.32                    | -0.09                    | -0.28                    |
|      | ✓                  |         |                  | 20                | 2   |  | -0.53                                | -0.16                                | -0.45                                | -0.33                    | -0.09                    | -0.28                    |
|      | ✓                  |         |                  | 15                | 2   |  | -0.45                                | -0.15                                | -0.40                                | -0.29                    | -0.08                    | -0.25                    |
|      | ✓                  | ✓       |                  | 17                | 2.5   | parking charges averaged across all car trips                | -0.89                                | -0.25                                | -0.72                                | -0.57                    | -0.14                    | -0.45                    |
|      | ✓                  |         |                  | 17                | 2.5   | charge cost = £5 plus 0.5*actual charge                      | -0.43                                | -0.39                                | -0.44                                | -0.28                    | -0.22                    | -0.28                    |
|      | ✓                  | ✓       |                  | 17                | 2.5   | charge cost = £5 plus 0.5*actual charge plus parking charges | -0.68                                | -0.56                                | -0.67                                | -0.43                    | -0.32                    | -0.42                    |
|      |                    | ✓       | 17               | 2.5               | non-business car value of time = £10.8 per hour | -3.18  | -0.54                                | -2.12                                | -2.02                                | -0.31                    | -1.34                    |                          |
| WEZ  | ✓                  |         |                  | 17                | 2.5   |  |                                      |                                      | -0.42                                |                          | -0.20                    |                          |
|      | ✓                  |         |                  | 17                | 2   |  |                                      |                                      | -0.38                                |                          | -0.18                    |                          |
|      | ✓                  |         |                  | 20                | 2.5   |  |                                      |                                      | -0.46                                |                          | -0.22                    |                          |
|      | ✓                  |         |                  | 15                | 2.5   |  |                                      |                                      | -0.40                                |                          | -0.19                    |                          |
|      | ✓                  |         |                  | 20                | 2   |  |                                      |                                      | -0.41                                |                          | -0.20                    |                          |
|      | ✓                  |         |                  | 15                | 2   |  |                                      |                                      | -0.36                                |                          | -0.17                    |                          |
|      | ✓                  |         |                  | 17                | 2.5   | charge cost = £5 plus 0.5*actual charge                      |                                      |                                      | -0.40                                |                          | -0.19                    |                          |
|      | ✓                  |         | ✓                | 17                | 2.5   | non-business car value of time = £10.8 per hour              |                                      |                                      | -1.92                                |                          | -0.93                    |                          |

### 3 Elasticity values from other sources

3.1 There is a long history of the analysis of travel demand elasticities: the response of different travel demands – eg, car kilometres, public transport trip kilometres, car ownership – to changes in travel costs – either ‘own mode’ or ‘competing mode’ costs. Many of the existing values have been based on analysis of the responses to past changes in fuel prices, and are often expressed as the change in demand in response to a 10% change in fuel costs.

3.2 This section summarises the information currently available from the DfT on elasticities, from the National Traffic Model and WebTAG guidance and the transport literature generally.

#### DfT Sources

3.3 The Department for Transport’s *National Transport Model (NTM) – Working Paper 3* provides information on the elasticities assumed for the model’s base calibration and those revealed by the use of the model in forecasting mode. The calibration process aimed to reproduce an elasticity of car traffic with respect to fuel cost of -0.3 in the 1998 calibration year.

3.4 When the model is used in forecasting for 2010 lower elasticity values are revealed. The reduction is said to be attributable to a number of factors including: the fall in the price of fuel combined with improved engine efficiencies; changes in car ownership and employment patterns; changes in public transport fares and rail overcrowding levels. In the logit model, elasticities are higher when competition between modes is at its strongest, so the model elasticities change as costs change or the mix of traveller types varies over time.

**Table 3.1: National Transport Model Elasticities of car traffic with respect to Fuel Costs**

|                                | First round own price elasticity | Own price elasticity after 6 iterations |
|--------------------------------|----------------------------------|---|
| Low travel demand assumptions  | -0.24                            | -0.22                                   |
| High travel demand assumptions | -0.19                            | -0.17                                   |

3.5 The high travel demand assumptions incorporate higher GDP forecasts and values of time, so fuel costs become a lower proportion of total costs and there is a smaller traffic response to a percentage change in fuel costs.

3.6 WebTAG Unit 3.11.1 *Model Structures and Traveller Responses for Public Transport Schemes* gives expected trip kilometre elasticities in response to changes in fuel costs. They are given as benchmarks against which the implied elasticities produced by validated models can be checked. Values are given as fairly large ranges from Low to High and values are expected to increase over time, as the range of available responses increases. The central values are just over -0.1 in the short term rising to -0.3 in the longer term.

**Table 3.2: WebTAG Elasticities of Car Kilometres with respect to Fuel Costs**

|                    | High  | Central | Low   |
|--------------------|-------|---------|-------|
| 1 year             | -0.28 | -0.125  | -0.07 |
| 5 years            | -0.32 | -0.2    | -0.13 |
| 10 years or longer | -0.48 | -0.3    | -0.19 |

## Literature Reviews

3.7 There have been major recent reviews of elasticity values in the literature, including two independent reviews commissioned by the Department for Transport. They include:

- Graham and Glaister: *Road Traffic Demand Elasticity Estimates: A Review*. Transport Reviews, 2004
- Goodwin, Dargay and Hanly: *Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review*. Transport Reviews, 2004
- Toner and Mackie: *Elasticities for Road User Charging schemes: Principles, Application and Evidence*, Version 1.0b, 7.10.2005

3.8 These reviews all reach the same general conclusions summarised in the Table below.

**Table 3.3: Summary of Elasticity Values from the Literature**

|                           | Short Run<br>- soon after price change |                                   | Long Run<br>- within 3 to 5 years    |                                   |
|---------------------------|--|-----------------------------------|--------------------------------------|-----------------------------------|
|                           | Car trips with respect to fuel price   | Car km with respect to fuel price | Car trips with respect to fuel price | Car km with respect to fuel price |
| Graham and Glaister       | -0.16                                  | -0.16                             | -0.19                                | -0.26                             |
| Goodwin, Dargay and Hanly | -0.1                                   |                                   | -0.3                                 |                                   |
| Toner and Mackie          |  |                                   |                                      |                                   |
| - Fowkes et al 1991       | -0.1                                   |                                   | -0.3                                 |                                   |
| - Goodwin 1992            | -0.15                                  |                                   | -0.3 to -0.5                         |                                   |

3.9 Most of these sources express the elasticity values as those appropriate to a 10% change in fuel prices. The elasticities are expressed in relation to a change in money costs. There is generally no indication whether they were calculated as point elasticities or arc elasticities, but in the context of a 10% change in fuel costs this may not matter too much. The short run is generally taken to be soon after the price change, when change of mode would be the principal response: the long run is generally taken to be some 3 to 5 years following the price change when changes in destination, trip frequency and even locational decisions may add to the response.

3.10 Toner and Mackie make the points that:

- Demand can be measured in trips (lower response) or vehicle km (higher response, as people take shorter trips), and
- Particularly in the longer term, elasticities with respect to fuel price change can be suppressed as people switch to lower fuel consumption vehicles or driving behaviour.

3.11 They quote the following car own-price elasticities from Fowkes et al (1991)

- Change in fuel consumption with respect to change in fuel price is in the range -0.2 to -0.7, depending on the time horizon. This may in part be attributable to drivers switching to more fuel-efficient cars
- The change in traffic levels with respect to change in fuel price is less, in the range -0.1 to -0.3

3.12 They also quote the following values from Goodwin et al (2004)

- A real sustained fuel price rise of 10% will lead to the volume of traffic falling by 1% (short term: 1 year) and 3% (long term: 5 years). This is consistent with the findings from Fowkes et al (1991): ie, traffic elasticities with respect to fuel prices of -0.1 in the short term and -0.3 in the longer term
- The volume of fuel consumed will fall by 2.5% in the first year and 6% in the longer run, again broadly consistent with Fowkes et al (1991).

3.13 And from Graham and Glaister (2002)

- Short term elasticities of fuel with respect to price are in the region of -0.3: long term elasticities are between -0.6 and -0.8
- Short term elasticity of traffic with respect to fuel price is around -0.15 (short term) and -0.3 (long term)

3.14 Todd Litman's 2007 paper *Transportation Elasticities: How Prices and Other Factors Affect Travel Behaviour*, April 2007 quotes elasticity values from many past sources but pays particular attention to Goodwin, Dargay and Hanly, 2004, quoting mean vehicle kilometre elasticities of -0.1 in the short term and -0.3 in the longer term. He draws attention to the dynamic nature of the response to higher charges, again quoting Goodwin, Dargay and Hanly – if the real price of fuel increases by 10% and stays at that level, traffic volume falls by about 1% within a year and by about 3% in about 5 years or so. Fuel consumption would fall by about twice as much as vehicle kilometres, with increased efficiency of fuel use contributing to reduced fuel consumption.



## 4 Conclusions

- 4.1 The literature leads us to expect a short-term elasticity of road traffic, measured as total car trips or car kilometres, with respect to the money costs of fuel consumption of -0.10 to -0.15, increasing to around -0.30 in the longer term, around 5 years.
- 4.2 These values were typically derived from relatively small increases in fuel costs. They are often expressed as the reduction in traffic attributable to a 10% increase in fuel costs.
- 4.3 The demand responses to congestion charges measured here are effectively short-term elasticities of selected car trips, measured from travel demand changes soon after charges were introduced.
- 4.4 The demand elasticities in response to the congestion charge have been considerably higher than the values in response to fuel costs in the literature. Central estimates among potentially chargeable cars making movements which terminate in or travel through charging areas are -0.47 in the CCZ and -0.42 in the WEZ. These elasticities refer to changes in travel mode, destination and trip frequency for a specific selection of trips. They do not include re-routing or changing the time of travel to avoid charges. Moreover, some cars may be used by other household members for other trips.
- 4.5 In addition to these points, there are several reasons why elasticities should be higher than the expected values in the literature:
- The charge represents a much larger change in cost than a 10% increase in fuel cost. In the CCZ, at 2.5 trips per day each of 17 kilometres, a £5 charge is equivalent to an increase of 119% in fuel costs and an £8 charge to an increase of 191%. The congestion charge is a change of a much larger order than a 10% change in fuel costs and a 1% change in demand.
  - The congestion charge was well advertised prior to its introduction, giving people time to assess whether and how to avoid it, whereas past increases in fuel prices tended to be generated by unexpected crises.
  - The congestion charge was introduced as a long-lasting or permanent change, whereas past increases in fuel costs might have been seen as more temporary.
  - There is a more obvious connection between the congestion charge and specific trips (that enter the charging area) than between fuel cost increases and specific trips. A fuel cost increase would apply to all car trips – it might seem inescapable - and there might be substantial elapsed time between buying the fuel and making a trip that uses that fuel.
  - The elasticity measures used may be different. In this analysis we have used arc elasticities. Values in the literature may well have been based on smaller cost changes and been calculated as point elasticities, which would be smaller.
- 4.6 On the other hand, many of the car trips to central London benefit from employer assistance, either because they are trips made for employers' business purposes or because employers subsidise their employees' motoring costs, including parking costs and the costs of congestion charge payments. This employer assistance should act to reduce the demand response and therefore the elasticity values.
- 4.7 The elasticity with respect to the £5 charge in the CCZ was higher at -0.55 than the elasticity with respect to the £8 charge, at -0.47. The lower demand elasticity in response to the change from £5 to £8, at -0.16, suggests that those more sensitive to price have largely been deterred by the initial £5 charge and that the remaining car users are less sensitive to additional charges.
- 4.8 While the demand response to the change in charge from £5 to £8 was generally perceived to be small, the resulting elasticity of -0.16 is much more in line with the typical elasticity identified in the literature.

- 4.9 Elasticities are slightly different in the CCZ and WEZ, at -0.47 and -0.42. The higher elasticities in the CCZ probably reflect the better alternatives available, particularly the better public transport alternative.
- 4.10 Variations in assumptions give variations in elasticities around these central estimates. In the CCZ, elasticities with respect to money costs vary between -0.40 and -0.51 with different assumptions, though they increase to more than -0.72 if parking charges are also added in to money costs. In the WEZ they vary between -0.36 and -0.46.
- 4.11 Elasticities with regard to generalised cost in the CCZ are around 4.5 times higher than the elasticity with regard to money cost, reflecting the relative values of time and money costs.
- 4.12 In the CCZ around half of post-charging car trips pay either nothing or the heavily discounted residents' charge: in the WEZ this proportion may be higher, around 60%, with a higher proportion of around 20% paying the residents' charge, compared with around 10% in the CCZ.
- 4.13 The WEZ results are a better guide than the CCZ results to what might happen if charging were applied elsewhere in London. Central London is unique in terms of its very high share of total trips being made by public transport and its place at the focus of network rail and underground networks. An important consideration in relation to charging in other parts of London will be the treatment of residents. Will large residents' discounts persist and over what area will they apply? If these elasticity values were to be used in revenue calculations as well as in travel demand estimation, any loss of revenues from trips diverting around charged areas or avoiding charging hours would also need to be allowed for.

#### Short and long-run elasticities

- 4.14 The literature generally finds that long-run elasticities (around five years) are around three times greater than short-run elasticities. When the elasticities are of changes in vehicle kilometres in response to increases in fuel prices, the higher longer-run elasticities will reflect a combination of:
- Changes in home or work locations, locations for other activities or in the number of trips made, which will generally act to reduce vehicle kilometres and hence increase the value of the elasticity,
  - Offset by changes to more fuel efficient vehicles or driving styles which will generally act to allow vehicle kilometres to be maintained, so reducing the elasticity value.
- The first set of changes tends to predominate, causing elasticity values to be higher in the longer term.
- 4.15 In measuring the elasticity of car trips with respect to the congestion charge, the first of these sets of changes, in locations and trip numbers, or even the time of trips, might be expected to be repeated, causing elasticity values to rise through time. The second set of changes, allowing the higher costs to be avoided at least in part, are less likely to be found. Perhaps the nearest equivalent would be combining a number of trip activities into one day for which the congestion charge is paid, thereby allowing previous trip activities to be maintained and getting better value for money from the charge payments.
- 4.16 This reasoning would cause us to expect that the elasticity with respect to charges might increase through time.
- 4.17 There are other offsetting arguments though:
- The short-run changes have been large, which may indicate less scope for further increases in the scale of change.
  - A relatively high proportion of continuing car trips can be expected to be less sensitive to congestion charges, either because they are exempt or enjoy a 100% discount, or because they are employer's business, in-work trips, which are often the least responsive to money

costs.

- The congestion charge and its relatively high level were advertised well in advance, giving trip makers more opportunity to plan changes to their behaviour than would normally be available in response to an unexpected fuel price increase.
- The introduction of the congestion charge was accompanied by an initiative to improve public transport services, particularly bus speeds and frequencies, which may not be repeatable and which may have acted to increase the short-run elasticity.

4.18 On balance, therefore, we might expect any increase through time in the elasticity with respect to charges to be small. It should also be affected by any other change over time in car and public transport generalised costs, particularly their relative costs.

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## Appendix A

### Demand Response to Charges

- A.1 A congestion charge of £5 per day in the Central Charging Zone (CCZ) was introduced in February 2003. In July 2005 the charge was increased to £8 per day. In February 2007, the charging area was extended to include the Western Extension Zone (WEZ) and the charging hours were reduced from 0700 – 1830 hours to 0700 – 1800 hours.
- A.2 The effects of the charge on traffic levels have been reported in a series of Impacts monitoring Annual Reports published by TfL. The Fifth Annual Report was published in July 2007.

#### Central Charging Zone

- A.3 Aggregate-level changes in traffic levels in the CCZ are reported in the Annual Reports. The Fifth Annual Report provides the data shown in Table A.1. This shows changes in vehicle numbers entering the CCZ during charging hours as follows:
- Among all four or more wheeled vehicles there was an 18% reduction in 2003 and a further 3% reduction in 2005, attributed to the change in charge from £5 to £8;
  - Among cars and minicabs, there was a 33% reduction in 2003 and a further 3% reduction in 2005, giving a 36% reduction in 2006 over 2002;
  - There were reductions in the numbers of both vans and HGVs of 11% in 2003 and 13% by 2006;
  - There were increases in the numbers of uncharged vehicles. Licensed taxi movements increased by 17% in 2003 but fell subsequently so that by 2006 they were 13% higher than in 2002, and bus/coach movements were 23% higher in 2003 and 25% higher by 2006.

**Table A.1: Year-on-year changes in traffic entering the central London charging zone during charging hours**

| Vehicle type           | 2003 vs 2002 | 2005 vs 2004 | 2006 vs 2002 |
|------------------------|--------------|--------------|--------------|
| All vehicles           | -14%         | -2%          | -16%         |
| Four or more wheels    | -18%         | -3%          | -21%         |
| Potentially chargeable | -27%         | -3%          | -30%         |
| - cars and minicabs    | -33%         | -3%          | -36%         |
| - vans                 | -11%         | -3%          | -13%         |
| - lorries and other    | -11%         | -4%          | -13%         |
| Non-chargeable         | +18%         | -4%          | +16%         |
| - licensed taxis       | +17%         | 0%           | +13%         |
| - buses and coaches    | +23%         | -4%          | +25%         |
| - powered two-wheelers | +12%         | -9%          | 0%           |
| - pedal cycles         | +19%         | +7%          | +49%         |

- A.4 TfL's Second Annual Monitoring Report gives an estimated breakdown of the reduction in car driver movements into the charging zone, summarised in Table A.2 below. This suggests that around 70% of the total reduction is accounted for by conventional responses to travel cost increases – transfer to another mode, to other destinations or reducing trip frequency – with the other 30% being responses which are more specific to the congestion charge – diverting around the charged area or making the trip outside charging hours.

**Table A.2: Estimated reduction in car driver movements coming into the charging zone**

| Movement change   | Trips per charging day | % of total change |
|---|------------------------|-------------------|
| Transfer to public transport                                | 35,000 to 40,000       | Around 70%        |
| Transfer to other modes – walk, cycle, taxi, car share, etc | 5,000 to 10,000        |                   |
| Travel to other destinations, reduce frequency              | Under 5,000            |                   |
| Through trips diverting around charged area                 | 15,000 to 20,000       |                   |
| Travel outside charging hours                               | Under 5,000            |                   |
| Total reduction in car trips into charged area              | 65,000 to 70,000       |                   |

A.5 The report *Follow-up Survey of Respondents to the 2002 Behavioural Responses Survey*, MVA, May 2004, presents the findings of surveys which compared people's actual and anticipated behavioural responses to the central area congestion charge. Actual responses are based on a survey of 274 drivers who had driven into the charging area during charging hours and been interviewed in 2002 before charging was introduced, and would decide for themselves whether they would continue to drive and pay the charge or do something different. The unexpanded results from these 274 respondents, who for some or all journeys would not pay the charge and continue to drive, are summarised in Table A.3 below. Respondents were asked to consider journeys like those they were making when originally interviewed in 2002.

**Table A.3: CCZ Behavioural Survey Responses**

| Respondents  | Trip type                            | Change mode, change destination, change frequency | Divert around charged area or travel outside charging hours |
|--|--------------------------------------|---|---|
| All respondents  | All similar journeys                 | 60%   | 40%   |
| All respondents  | Most recent similar journey          | 54%   | 46%   |
| Car drivers – excluding CCZ residents and taxi/minicab drivers | All similar trips terminating in CCZ | 62%   | 38%   |
| Car drivers – excluding CCZ residents and taxi/minicab drivers | All similar trips through CCZ        | 54%   | 46%   |
| Car drivers – excluding CCZ residents and taxi/minicab drivers | Most recent trip terminating in CCZ  | 71%   | 29%   |
| Car drivers – excluding CCZ residents and taxi/minicab drivers | Most recent trip through CCZ         | 39%   | 61%   |

#### Western Extension Zone

- A.6 For the Western Extension the Fifth Annual Monitoring Report gives information on flow changes for around the first 3-4 months following introduction of the charge. Automatic traffic count data, gathered on the principal roads into the WEZ area, indicates that traffic flows are of the order of 10%-15% below what might have been expected.
- A.7 Anonymised camera data for the periods immediately before and after the introduction of charging in the WEZ area suggests that traffic entering and leaving the WEZ area during charging hours fell by 17% with the introduction of charging.

- A.8 The camera data for the short time period around the introduction of WEZ charging indicates that movements by vehicle type into and out of the WEZ area during charging hours changed as follows:
- 'Car and minicab' movements fell by 23%,
  - Van movements fell by 12%,
  - HGV movements fell by 7%,
  - Taxi movements fell by 4%, and
  - Bus and coach movements fell by 5%.
- A.9 These data indicate that traffic reductions following the WEZ £8 charge were lower than those following the CCZ £8 charge, with WEZ car and minicab trips, for example, falling by 23% whereas CCZ car and minicab trips fell by 36%, with the higher proportion of cars being eligible for the residents' discount contributing to this (see Tables A.5 and A.6).
- A.10 Table A.4 summarises survey information on behavioural responses following the introduction of WEZ charging, from *Understanding Driver Responses: Behavioural Survey Post-Introduction of WEZ*, MVA, April 2008.. Sample sizes are small: 84 non-residents and 93 residents who took their own decisions about whether to continue driving and pay the charge. The proportion of responses diverting around the charged area or travelling outside charging hours, at around 20%, is smaller than these proportions in the central area.

**Table A.4: WEZ Behavioural Survey Responses**

| Respondents   | Change mode, destination, or frequency | Divert around charged area or travel outside charging hours |
|---------------|--|---|
| Non-residents | 83%                                    | 17%   |
| Residents     | 79%                                    | 21%   |

#### Disaggregated Travel Changes

- A.11 The reduction in the number of trips has been greatest among car and minicab trips where the reduction has been of the order of three times greater than the reduction in van or HGV trips.
- A.12 Among non-charged vehicles, there has generally been an increase in trip making: taxi movements into the CCZ increased by 13% between 2002 and 2006, though they may have fallen slightly from their high level immediately following the introduction of charges in 2003, and taxi trips into and out of the WEZ area fell in the period immediately after the introduction of WEZ charging.

#### Disaggregation by chargeable and non-chargeable vehicles - CCZ

- A.13 The large negative response to charges among car and minicab trips has happened despite minicabs being exempt from charges. Different analyses based on congestion charging camera data to identify the disaggregation of car trips by charge-paying category are summarised in Tables A.5 and A.6. Not all vehicles are recognised by the camera data and TfL's vehicle database: the dataset AD-0913-Unique VRMs Captures 1.xls identifies 23% of cars over the six months from August 2007 to January 2008 as 'Contravention Candidates'.
- A.14 Of the identified vehicles, the different categorizations of cars in the CCZ are summarised in Table A.5 and of cars in the WEZ in Table A.6.

**Table A.5: CCZ car trips by payment category**

| Source  | Full charge | Fleet | Residents discount | Selected partner | 100% discount | Evader |
|---|-------------|-------|--------------------|------------------|---------------|--------|
| LTS Calibration of CCS Response Jan 2007 data | 41%         | 5%    | 12%                | N/I              | 39%           | 3%     |
| Halcrow analysis: Feb – Mar 2007 data         | 53%         | 4%    | 9%                 | 1%               | 30%           | 2%     |

**Table A.6: WEZ and CCZ car trips by payment category**

| Source                                | Full charge | Fleet | Residents discount | Selected partner | 100% discount | Evader |
|---------------------------------------|-------------|-------|--------------------|------------------|---------------|--------|
| Halcrow analysis: Feb – Mar 2007 data | 37%         | 4%    | 20%                | 1%               | 37%           | 1%     |

- A.14 In addition to the uncertainty caused by the cameras' inability to recognise vehicles referred to in para A.12, there are other sources of uncertainty attached to this data:
- Converting anonymised camera identifications into trips – the above estimates all appear to be a categorization of trips rather than camera observations;
  - Identifying how many trips are made by residents – the normal practice is to assume that trips made by cars whose registered owner's address is in the charging zone are eligible for a resident's discount;
  - The data analysed by Halcrow relates to cars photographed entering the charging zone in the morning peak period only (0700 – 1000 hours), whereas the LTS Calibration of CCS Response data relates to cars entering and leaving the CCZ during charging hours; and
  - It is possible that car types are classified differently in different analyses. The Halcrow analysis, for example, includes in the 100% discount category: 100% discount cars plus Blue Badge holders plus Exempt cars plus Public Carriage Office cars.
- A.15 The principal conclusions drawn from this data for the CCZ are:
- Around half of cars pay the full charge or the fleet charge;
  - Some 30 – 40% of car trips fall into exempt or 100% discount categories, while around 10% enjoy residents' discounts.
- A.16 In the WEZ, the residents' proportion is higher, at around 20% as opposed to around 10% in the CCZ, the 100% discount/exempt category accounts for around 40% and the full charge or fleet charge is paid by around 40% of car trips.

#### Demand Reduction in the CCZ

- A.17 Table A.7 below sets out the principal changes in different types of car trips. In the CCZ area, allowing for all demand responses, there has been a 36% reduction in car and minicab movements, so the remaining movements are 64% of the pre-charging movements, with around half of these (32% of pre-charging movements) paying a high charge. If, for the moment, the assumption is made that all of the trip reduction will have come from vehicles eligible for high charges, the reduction among such vehicles will have been 53%, 36% out of 68% (the 36% reduction plus the remaining 32%).
- A.18 If demand responses are divided into the two categories of trips which are no longer made by car (they change modes, destinations or frequency) and those which continue to be made by car but do not enter the charging area during charging hours (they divert around it or travel at uncharged times of the day), then the demand reduction is 37% with 16% diverting around the charged area or travelling at uncharged times of the day.

Demand Reduction in the WEZ

- A.19 In the WEZ, there has been a 23% reduction in car and minicab trips, so the remaining movements are 77% of the pre-charging movements, with full charge-payers being around 40% of these, or 31% (40% of 77%) of the pre-charging car trips. Again on the assumption that all of the trip reduction will have come from vehicles eligible for high charges, the reduction among such vehicles will have been 43%, 23% out of 54% (the 23% reduction plus the remaining 31%). If, as survey data suggests, 80% of these trips have transferred to other modes, changed their destination or changed frequency, then this reduction accounts for 34% of chargeable car trips, with 9% of car trips diverting around the charged area or travelling in uncharged hours..
- A.20 These calculations are summarised in Table A.7. The overall reduction in chargeable car trips in response to an £8 daily charge was 53% in the CCZ and 43% in the WEZ. The loss of trips to other modes, destinations or trip frequency was 37% in the CCZ and 34% in the WEZ.

**Table A.7: Reduction in chargeable car trips in CCZ and WEZ**

|   |                 | <b>CCZ</b> | <b>WEZ</b> |
|---|-----------------|------------|------------|
| % reduction in car and minicab trips - all responses              | A               | 36%        | 23%        |
| Post-charging car trips as % of pre-charging trips,               | $B = 1 - A$     | 64%        | 77%        |
| % lost to other modes, destinations or frequency                  | C               | 25%        | 18%        |
| % diverting around charged area or avoiding charging hours        | D               | 11%        | 5%         |
| Post-charging chargeable car trips as % of all pre-charging trips | E               | 32%        | 31%        |
| Chargeable car trips lost to all responses.                       | $F = A/(A+E)$   | 53%        | 43%        |
| Chargeable car trips lost to other modes, destinations, frequency | $G = C/(C+D+E)$ | 37%        | 34%        |

Disaggregation by purpose

- A.21 Roadside surveys undertaken within and near the Western Extension Zone (WEZ) before and after charging was introduced there in February 2007, reported in *WEZ Roadside Interviews*, November 2007 provide some information on journey purposes before and after the introduction of charging. There was not much change. The post-charging car trips in total were 88% of the pre-charging total. Trips to/from work and employers' business trips together accounted for 68% of trips in both surveys and there were only small changes in the percentages accounted for by other trip purposes.



## Appendix B

### Changes in trip costs

- B.1 Relevant trip costs fall into two categories: money costs and the other, non-money components of generalised costs. Money costs include fuel costs, charge costs and, possibly, parking costs. Not all car trips incur a parking charge and many of the elasticity values in the literature are elasticities with respect to fuel costs only. The principal non-money cost is that of the travel time incurred in making the trip. There may be an additional cost attached to the unreliability of that travel time.

#### Money costs – Fuel costs

- B.2 The fuel cost per car kilometre has been estimated from DfT's standard speed dependent fuel consumption formula given in WebTAG 3.5.6, the price of fuel and speeds.
- B.3 Fuel consumption, per average car, in litres per kilometre, is given by WebTAG 3.5.6 as:

$$L = a + b.v + c.v^2 + d.v^3$$

where L = consumption, expressed in litres per kilometre

v = average speed in kilometres per hour

a, b, c and d are parameters defined for each vehicle category.

For an average car they are:

$$a = 0.17813952$$

$$b = -0.00405874$$

$$c = 0.00004606$$

$$d = -0.0000001481$$

Litres per kilometre for the average car therefore fall from 0.142 at 10 km/h to 0.114 at 20 km/h

- B.4 WebTAG 3.5.6 gives an average fuel cost in 2005 (in 2002 prices) for an average car of 79.1p per litre, consisting of resource cost of 24.1 pence per litre, fuel duty of 43.2 pence per litre and VAT of 11.8 pence per litre, calculated as 17.5% of the resource cost and fuel duty. In 2005 prices, given the intervening change in the all items RPI from 176.2 to 192.0, the price of a litre of fuel for an average car is 86.2p.
- B.5 Average speeds in different parts of London are taken from TfL's Congestion Charging Monitoring Reports and from observed/modelled speeds. Prior to charging being introduced, the average travel rate (in minutes per kilometre) in the charged area was 4.2, or 14.3 kilometres per hour. In 2005, the average travel rate was 3.7 minutes per kilometre, or 16.2 kilometres per hour.
- B.6 Modelled speeds for the charged area show speeds increasing from 14.1 km/h pre-charging to 16.4 km/h with a £5 charge and 16.9 km/h with an £8 charge and in Inner London increasing from 21.9 km/h pre-charging to 22.4 km/h with a £5 charge and 22.5 km/h with an £8 charge.

#### Trip Lengths

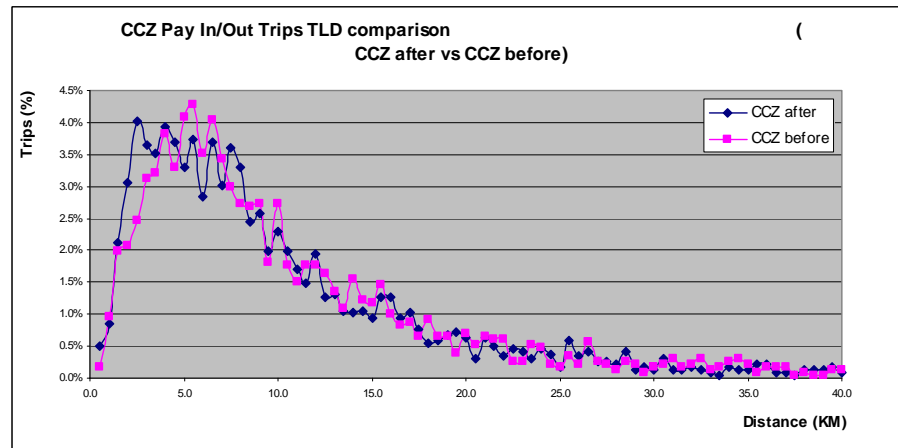
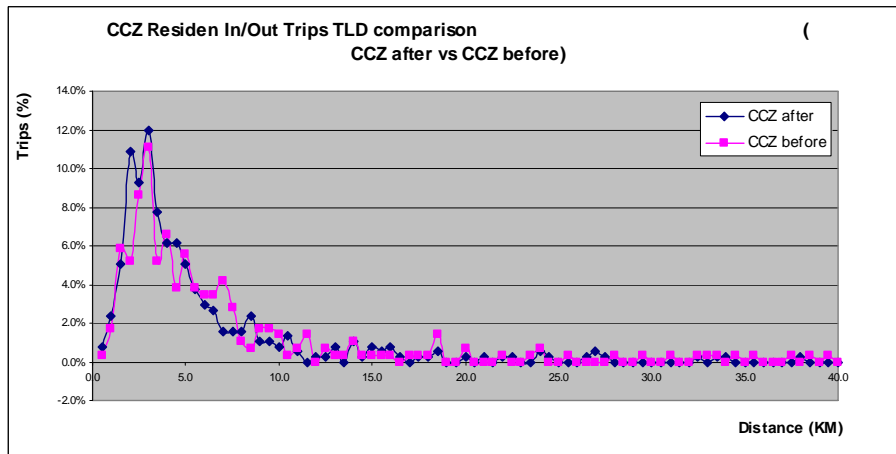
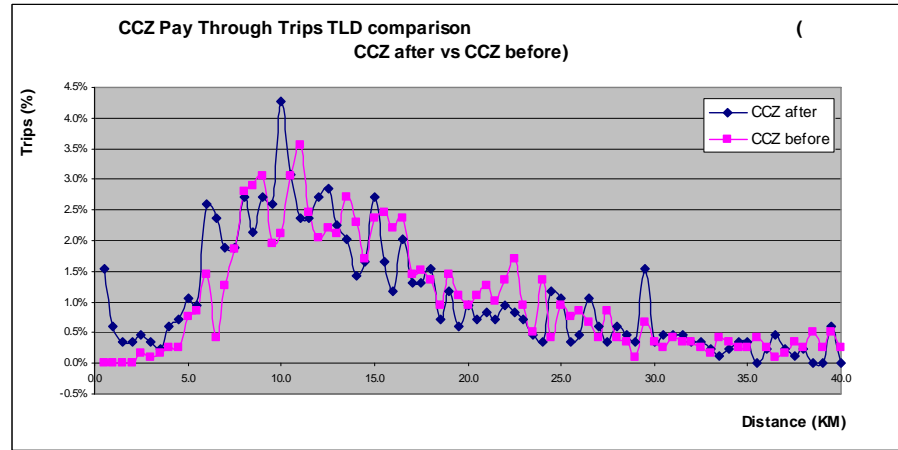
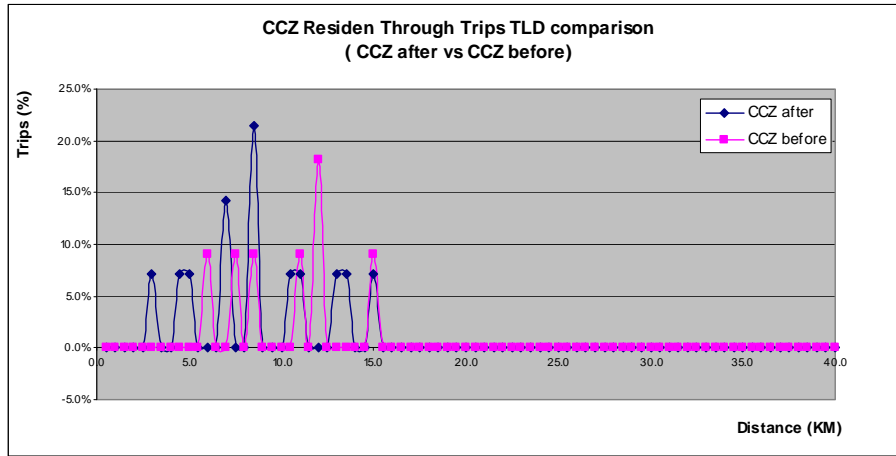
- B.7 The fuel costs of a typical car trip will depend principally on the trip length and driving conditions and speeds.
- B.8 The 2006/07 survey *Congestion Charging – Central London and Western Extension Area Behavioural Surveys* undertaken for TfL by Halcrow, RAND Europe and Accent gives travel time information for the respondents' first trips into the charging zone on the survey day. Among 621 respondents, making trips for a mix of purposes, the average trip time was around 70 minutes with peaks in the travel time distribution around 30 to 45 minutes, 60 to 90 minutes and over 120 minutes. If those making trips of over 120 minutes are excluded as likely to be infrequent, unrepresentative trips, the average trip time becomes 57 minutes. Given the traffic speeds in Central, Inner and Outer London around the time of the surveys, a 70 minute journey time implied an 'average' trip distance of around 30 kilometres, which seems very long.

- B.9 Previous modelling had suggested that the removal of 1 vehicle kilometre in the charged area was associated with the removal of 2.14 kilometres in the Inner area and 1.25 kilometres in the Outer area before any allowance was made for induced trips, ie, around 4.4 km were removed for every car kilometre removed from the central charging zone. These calculations were repeated assuming a typical car trip of 4 kilometres in the charged area, 8.56 kilometres in the Inner area and 5.0 kilometres in the Outer area, or just over 17 kilometres in total. But this is a very uncertain figure that is reviewed below.
- B.10 In this work we have attempted to obtain better estimates of trip lengths to, from and through the charging zones from surveys and models.

#### Trip Lengths from Roadside Interview Surveys

- B.11 For the central charging zone (CCZ) we have analysed data from roadside interview surveys conducted on the Thames bridges in the zone, conducted in 2001 as part of the LATS Roadside Interview Survey (to give a pre-charging picture) and similar surveys conducted in 2007 (which are taken as representing a post-charging picture). The crow-fly distances measured for different types of trip in the two surveys are presented in Figure B.1 and summarised in Table B.1.
- B.12 Trip lengths measured from Roadside Interview data might be expected to be above average since longer distance trips will have a higher probability than shorter distance trips of being intercepted at an interview site. This will be less true in the case of a complete screenline or cordon, when every trip crossing the cordon should have an equal probability of interception. In the case of an incomplete screenline or cordon, the important factor is likely to be which roads are surveyed, since main roads are more likely to accommodate longer distance trips and minor, local roads shorter distance trips.
- B.13 In this case there is a reasonably complete screenline so the surveyed trip lengths may not overstate true trip lengths by very much, though since there is necessarily a river crossing involved, shorter distance trips within the charging zone are likely to be under-represented. The surveyed trips will also include through trips as well as trips to, from and within the charging zone.
- B.14 Across all trips there is a reduction in trip lengths following charging. Analysis of Roadside Interview Survey data collected on Thames bridges in the CCZ in Table B.1 indicates that before charging 18% of surveyed trips in total were over 30 kilometres long, compared with only 13% following charging. Within any trip category, though, the changes were not so large. In the largest trip category – trips to/from the charged area by non-residents - 13% of trips before charging and 12% following charging were more than 30 kilometres long. The bigger impact on the change in overall trip lengths is the change in the numbers of trips in different categories. In particular, there is an increase in the number of trips by residents to/from the charging zone, which have the shortest average trip length, and a reduction in the number of through trips by non-residents, which have a high average trip length.
- B.15 The four diagrams on the following page show the trip length distributions before and after charging of four categories of trips: trips to or from the CCZ and through the CCZ made by residents and those eligible for the charge. Residents' trips are shorter than trips made by those eligible for the charge. The modal trip length of trips to/from the charging zone by residents is around 3 kilometres, for example, while that for those eligible for the charge is around 6 kilometres.

**Figure B.1: Trip length distributions of CCZ residents' and charge-paying trips before and after charging**



**Table B.1: Trip Length distributions from Roadside Interviews on Thames Bridges in CCZ**

| Surveyed Trips    | Pre-charging  |         |           |         |       | Post-charging |         |           |         |       |
|-------------------|---------------|---------|-----------|---------|-------|---------------|---------|-----------|---------|-------|
|                   | Through trips |         | To/from   |         | Total | Through trips |         | To/from   |         | Total |
|                   | Residents     | Non-res | Residents | Non-res |       | Residents     | Non-res | Residents | Non-res |       |
| Trip length (Km)  |               |         |           |         |       |               |         |           |         |       |
| % of trips        |               |         |           |         |       |               |         |           |         |       |
| 0 – 5             | 0             | 20      | 156       | 573     | 749   | 3             | 53      | 246       | 676     | 978   |
| 5 – 10            | 3             | 220     | 70        | 703     | 996   | 5             | 204     | 73        | 696     | 978   |
| 10 – 15           | 4             | 289     | 16        | 337     | 646   | 5             | 198     | 20        | 325     | 548   |
| 15 – 20           | 0             | 186     | 11        | 186     | 383   | 0             | 105     | 11        | 199     | 315   |
| 20 – 25           | 0             | 125     | 4         | 99      | 228   | 0             | 66      | 6         | 94      | 166   |
| 25 – 30           | 0             | 64      | 3         | 57      | 124   | 0             | 52      | 4         | 69      | 125   |
| 30 – 35           | 0             | 36      | 5         | 53      | 94    | 0             | 29      | 3         | 33      | 65    |
| 35- 40            | 0             | 36      | 4         | 25      | 65    | 0             | 16      | 1         | 30      | 47    |
| 40 – 45           | 0             | 26      | 1         | 39      | 66    | 0             | 9       | 1         | 38      | 48    |
| 45 – 50           | 0             | 24      | 4         | 30      | 58    | 0             | 14      | 1         | 27      | 42    |
| > 50              | 3             | 152     | 15        | 169     | 339   | 1             | 99      | 10        | 174     | 284   |
| <b>Total</b>      | 11            | 1178    | 289       | 2271    | 3749  | 14            | 845     | 376       | 2361    | 3596  |
| <b>% of trips</b> |               |         |           |         |       |               |         |           |         |       |
| 0 – 5             | 0             | 2       | 54        | 25      | 20    | 21            | 6       | 65        | 29      | 27    |
| 5 – 10            | 27            | 19      | 24        | 31      | 27    | 36            | 24      | 19        | 29      | 27    |
| 10 – 15           | 36            | 25      | 6         | 15      | 17    | 36            | 23      | 5         | 14      | 15    |
| 15 – 20           | 0             | 16      | 4         | 8       | 10    | 0             | 12      | 3         | 8       | 9     |
| 20 – 25           | 0             | 11      | 1         | 4       | 6     | 0             | 8       | 2         | 4       | 5     |
| 25 – 30           | 0             | 5       | 1         | 3       | 3     | 0             | 6       | 1         | 3       | 3     |
| 30 – 35           | 0             | 3       | 2         | 2       | 3     | 0             | 3       | 1         | 1       | 2     |
| 35- 40            | 0             | 3       | 1         | 1       | 2     | 0             | 2       | 0         | 1       | 1     |
| 40 – 45           | 9             | 2       | 0         | 2       | 2     | 0             | 1       | 0         | 2       | 1     |
| 45 – 50           | 0             | 2       | 1         | 1       | 2     | 0             | 2       | 0         | 1       | 1     |
| > 50              | 27            | 13      | 5         | 7       | 9     | 7             | 12      | 3         | 7       | 8     |
| <b>Total</b>      | 100           | 100     | 100       | 100     | 100   | 100           | 100     | 100       | 100     | 100   |

B.16 The surveyed average trip lengths are summarised in Table B.2. The average trip length before charging is 17.4 km, reducing to 15.5 km after charging, largely because of the changes in the numbers of trips in the different trip categories.

**Table B.2: Average crow-fly distances of car trips surveyed on the Thames bridges in the CCZ, kilometres**

|               | Before charging |         |       | After charging |         |       |
|---------------|-----------------|---------|-------|----------------|---------|-------|
|               | Through         | To/from | Total | Through        | To/from | Total |
| Residents     | 30.0            | 10.5    |       | 12.0           | 7.3     |       |
| Non-residents | 23.6            | 15.0    |       | 21.2           | 14.8    |       |
| Total         |                 |         | 17.4  |                |         | 15.5  |

B.17 Buchanan's *CLoCCS 2007 surveys: Report of roadside interviews* reports on roadside surveys conducted between 0700 and 1900 hours at six sites on the western boundary of the Central Charging Zone in autumn 2006 and autumn 2007, spanning the introduction of WEZ charging in February 2007. The six sites were on relatively minor roads:

- George Street
- Seymour Street
- Mount Street
- Constitution Hill
- Buckingham Gate
- Rochester Row

Oxford Street, Piccadilly and Victoria Street were not surveyed.

B.18 Table 6.4 of the report gives grouped crow-fly distances between stated origins and destinations via the survey site. The distance groupings are <2 km, 2 to 5 km, 5 to 10 km, 10 to 20 km, 20+ km. Assuming average distances of 1.5 km for the shortest band, 25 km for the longest band and mid-point distances for the other bands, average trip (crow-fly) distances are 9.8 km in 2006 and 10.7 km in 2007.

B.19 As these surveys were not conducted on the major roads they probably under-report average trip lengths to the CCZ.

Trip Lengths in the LTS Model

B.20 LTS model car trip matrices, by purpose, at three charge levels - £0, £5 and £8 – have been analysed to establish the patterns of car trips into the charged areas and associated average trip lengths. Trip patterns and trip lengths for trips to, from or within the Central Charging Zone for the three LTS modelled time periods of am peak, inter peak and pm peak, which will extend beyond charging hours, are summarised at CIOX level in Table B.3.

B.21 The LTS model runs from which this data have been drawn are:

- LTS 5406cc0                      £0
- LTS 5406cc5                      £5
- LTS 5406ref3                      £8
- LTS 5406wz8                      £8 extended to WEZ area

**Table B.3: Trips and Trip Lengths To/From/Within Charging Zone in LTS Model, thousands of trips and trip kilometres**

| Trips per day, '000             | £0   | £5   | £8   | £8 extended to WEZ area |
|---------------------------------|------|------|------|-------------------------|
| Intra Charging Zone             | 53   | 51   | 50   | 131                     |
| Inner London – CZ               | 68   | 60   | 57   | 71                      |
| Outer London – CZ               | 30   | 26   | 25   | 41                      |
| External – CZ                   | 12   | 10   | 10   | 13                      |
| CZ – Inner London               | 63   | 57   | 54   | 68                      |
| CZ – Outer London               | 26   | 24   | 22   | 39                      |
| CZ – External                   | 9    | 7    | 7    | 11                      |
| Total                           | 261  | 234  | 224  | 373                     |
| <b>Average trip lengths, km</b> |      |      |      |                         |
| To Charging Zone                | 16.2 | 16.6 | 16.9 | 16.9                    |
| From Charging Zone              | 15.7 | 15.4 | 15.4 | 15.8                    |
| Within Charging Zone            | 1.9  | 1.8  | 1.9  | 2.5                     |
| To, from, within Charging Zone  | 13.1 | 13.0 | 13.0 | 13.1                    |

- B.22 The changes in trips between these matrices are derived by applying YAL/NAL factors. These have the effect of making some changes in the average lengths of trips in some CIOX categories, but when these are combined with the changes in the numbers of trips in different categories, average trip lengths of all trips to, from and within the charged areas are broadly unchanged at 13 kilometres. These are car trips to/from/within the charging areas: they exclude trips through these areas. The charging area in the right hand column adds WEZ to CCZ which changes the numbers of trips accessing the charged area, but has no real impact on average trip lengths.
- B.23 Average trip lengths are around 13 kilometres when intra-charging zone trips are included. For trips to or from the charging zone – trips, excluding through trips, which would cross the charging zone boundary – the average trip length is around 16 kilometres.

#### Trip Lengths from Camera Data

- B.24 The estimation of trip lengths from anonymised camera data is an imprecise process dependent on assumptions which are necessarily inaccurate. They are calculated as crow-fly distances between two points. The origin point is assumed to be the centre of the relatively large areas, covered by two-digit postcodes, in which it is assumed that the registered car owner lives. The destination is assumed to be the centre of whichever charging zone the dataset applies to.
- B.25 The resulting estimates are 'lumpy'. The table below from the CCZ dataset indicates that trip lengths were either 1, 2, 6, 7, 8, 9, 16, 18 or 20 kilometres long, or longer

**Table B4: Trip Lengths Estimated from Camera Data**

| Distance km | Trip type     |        |       |                   |          |                  |
|-------------|---------------|--------|-------|-------------------|----------|------------------|
|             | 100% discount | Evader | Fleet | Full charge payer | Resident | Selected partner |
| 0           |               |        |       |                   |          |                  |
| 1           | 289           | 12     | 47    | 347               | 530      | 0                |
| 2           | 442           | 16     | 75    | 792               | 640      | 10               |
| 3           | 0             | 0      | 0     | 0                 | 0        | 0                |
| 4           | 0             | 0      | 0     | 0                 | 0        | 0                |
| 5           | 0             | 0      | 0     | 0                 | 0        | 0                |
| 6           | 2,533         | 114    | 258   | 3,508             | 4,894    | 2                |
| 7           | 3,240         | 219    | 506   | 6,073             | 5,060    | 434              |
| 8           | 8,765         | 335    | 282   | 7,852             | 1,710    | 50               |
| 9           | 6,276         | 214    | 120   | 6,104             | 204      | 12               |
| 10          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 11          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 12          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 13          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 14          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 15          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 16          | 564           | 21     | 33    | 526               | 6        | 0                |
| 17          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 18          | 1,855         | 78     | 130   | 2,184             | 8        | 36               |
| 19          | 0             | 0      | 0     | 0                 | 0        | 0                |
| 20          | 466           | 23     | 61    | 649               | 4        | 6                |

B.26 The average car trip lengths in each dataset – CCZ and WEZ - calculated on this basis, and including trips of up to 150 kilometres in length, are around 17-18 kilometres for cars recorded in both charging zones and 19 kilometres for cars recorded in the CCZ only.

B.27 There are variations by car types. Residents' car trips average only 6 – 8 kilometres: fleet and selected partner car trips on average are considerably longer, at 30 kilometres plus, but these may be the categories of car trips where the assumption that the trip starts at the registered owner's address is least appropriate.

B.28 For full charge payers, average car trip lengths vary between around 22 and 25 kilometres.

Parking charges

B.29 The study *Monitoring Congestion Charging: Changes in Parking Usage and Revenues*, July 2004 undertaken by Arup for the Association of London Government in 2004 identified that the number of paid parking acts in the charged area had fallen broadly in line with the reduction in the number of car trips into the charged area. On-street parking acts in the charged area fell by 28% between 2002 and 2003 while off-street parking acts in the Corporation of London area fell by 30%.

B.30 That study also pointed to increased parking charges in some boroughs between 2002 and 2003 as the congestion charge came in. Table B.5 below shows that hourly charges were raised in LB Lambeth and in the City of London, while the cost of a resident's permit generally increased but was reduced for residents of those parts of LB Lambeth inside the charging zone.

**Table B.5: Parking Charges in Central London Boroughs**

| Borough               | Cost of parking (per hour) |               | Cost of residents' permits |      |
|-----------------------|----------------------------|---------------|----------------------------|------|
|                       | 2002                       | 2003          | 2002                       | 2003 |
| City of Westminster   | £1.50 - £4.00              | £1.50 - £4.00 | £90                        | £100 |
| Corporation of London | £3.00                      | £4.00         | £150                       | £220 |
| LB Camden             | NS                         | NS            | £86                        | £90  |
| LB Lambeth            | £1.50 - £2.00              | £3.00 - £4.00 | £60                        | £50  |
| LB Southwark          | £1.20                      | £1.20         | £76                        | £76  |
| LB Tower Hamlets      | NS                         | NS            | NS                         | £55  |

Source: *Monitoring Congestion Charging: Changes in Parking Usage and Revenues, July 2004*

- B.31 The *Update of London Parking Supply Study* July 2005 undertaken by MVA for TfL says that the average cost of 2 hours of parking in a public off-street car park in Central London was £2.57 per hour, up from £2.40 per hour in the 1999/2000 survey. In Central London, the average charges for parking stays of different durations in public off-street car parks, which are normally charged for, are as shown in Table B.6.

**Table B.6: Parking Charges at Central London Public Off-Street Car Parks**

| Duration, hours | £      |
|-----------------|--------|
| 2 hours         | £5.14  |
| 4 hours         | £9.48  |
| 9 hours         | £17.64 |
| 12 hours        | £20.16 |

Source: *Update of London Parking Supply Study, July 2005*

- B.32 This survey also gives useful data on the estimated number of car parking spaces in different categories by borough. The estimates for the central London parts of relevant boroughs are given in Table B.7. The main car park categories are:
- POS public – public off-street car parks open to the public and usually charged,
  - PNR – private non-residential car parks, privately owned and normally provided free of charge to, say, employees but customers may be charged,
  - OSN – on-street controlled parking, which mainly comprises parking at meters or Pay-and-Display bays, and parking in residential bays.
- B.33 Among the off-street spaces, the public spaces and the PNR other spaces (around 60% in total) may be charged for while the PNR employee spaces are likely to be provided free of charge.

**Table B.7: Estimated Numbers of Parking Spaces in Central London Boroughs**

| Borough       | POS public | PNR employee | PNR other | OSN yellow lines | OSN red lines |
|---------------|------------|--------------|-----------|------------------|---------------|
| Westminster   | 8,500      | 6,200        | 1,400     | 10,100           | 200           |
| City          | 4,200      | 3,200        | 200       | 3,600            | 100           |
| Camden        | 2,700      | 1,900        | 1,000     | 4,300            | 100           |
| Lambeth       | 900        | 1,300        | 700       | 2,900            | 0             |
| Southwark     | 1,600      | 2,000        | 1,000     | 4,300            | 100           |
| Tower Hamlets | 900        | 600          | 700       | 1,400            | 0             |
| Islington     | 1,100      | 1,400        | 700       | 2,900            | 0             |
| Total         | 19,900     | 16,600       | 5,700     | 29,500           | 500           |

Source: *Update of London Parking Supply Study, July 2005*



B.34 In the SPAM2 Strategic Policy Analysis Model, the assumed Central London car parking charges for trips of typical 3-hour weekday parking durations are set out in Table B.8.

**Table B.8: Typical Parking Costs in SPAM2 model**

|               | PNR    | Off-street paid | On-street paid |
|---------------|--------|-----------------|----------------|
| Commuting     | £11.63 | £12.57          | £8.31          |
| Non-commuting | £12.16 | £12.16          | £11.19         |

Source: SPAM Model – Car Parking Input Parameters

B.35 The 2006/07 survey *Congestion Charging – Central London and Western Extension Area Behavioural Surveys* identified that of its sample of those making trips by car into the central charging zone in 2006/07, 48% of respondents paid to park and on average they paid £11.80 per day. These estimates are broadly compatible with the surveyed information on the numbers of parking spaces of different types and with other estimates of typical parking costs. We therefore propose to take these assumptions into our analysis:

- the parking charge per day is £11.80,
- 48% of those who drive into the charged area pay to park,
- which gives an 'average parking charge' of £5.67 for all cars coming into the charged area.

B.36 Table B.5 indicates that some parking charges increased at the time the congestion charge was introduced, so the £5.67 post-charging average parking charge is assumed to be around 10% less (at £5.10) pre-charging.

#### Congestion charge

B.37 The daily charge for driving in the charged area was originally £5 and from July 2005 has been £8. The main analysis has taken these actual money costs and divided them by the typical number of trips made by a car in a (charging) day in the charging zone to get an estimated congestion charge per trip.

B.38 An alternative approach has drawn on analysis using the LTS model to 'fit' a constant elasticity curve to charge levels of £0 and £8,. This has developed an 'effective charge' of the congestion charge roughly equal to:

$$\text{Effective charge} = £5 \text{ plus } 0.5 * \text{actual charge}$$

The £5 charge may represent a perceived 'penalty charge' for having to pay for something that previously had been free at the point of use. So, in this case the £5 charge has an effective charge of £7.50 and the £8 charge has an effective charge of £9.

#### Trips per day

B.39 The daily congestion charge needs to be divided by the number of trips made per day to bring the congestion charge and other trip costs to a common basis. Camera data provide the best source of the number of trips made by a vehicle in a day, but even here assumptions have to be made in interpreting the camera data which inevitably will introduce statistical error into the estimate.

B.40 Two datasets – cars recorded entering the CCZ in the am peak and entering the WEZ in the am peak – were supplied. The WEZ and CCZ datasets were analysed separately.

B.41 In the WEZ dataset, for all trips recorded in WEZ but not CCZ, no values were recorded for numbers of entries or numbers of exits, so this data was not analysed. In other parts of the datasets, for cars recorded in the CCZ or both the CCZ and WEZ, if there were no values for numbers of entries or exits it was assumed that one entry or exit had been made.

B.42 To convert numbers of entries and exits into trips, residents and non-residents of the charged areas were treated differently.

B.43 For those in either dataset recorded in both charging areas, the assumption was:

- For residents of either charging area, the total of entries and exits was divided by two. ie, a trip would involve an exit from the home charging zone and an entry into the other charging zone.
- For non-residents of either charging zone, the total of entries and exits was divided by three. ie, a trip would consist of an entry into the first charging zone, an exit from that zone and an entry into the second charging zone.
- For those in the CCZ dataset recorded in the CCZ only, each entry or exit was regarded as a trip. For a resident, the trip would be an exit from the charging zone: for a non-resident the trip would be an entry into the charging zone.

B.44 These assumptions may be the best that could be made, but they do not apply to:

- Through trips. A through trip by a non-resident recorded in both charging zones might have two entries and two exits, while a trip by a resident through his home charging zone and the other charging zone might have two exits and one entry
- Trips made internally within either charging zone.

B.45 The average numbers of trips per car per day, for different categories of car, are shown in Table B.9. Across all car types the average number of trips is estimated at 2.7 or 2.8 per day. Variations in trip rates are estimated for different car types. Residents and exempt or 100% discount cars, which include licensed minicabs, are estimated to make more trips; full charge payers, who might be expected to be most sensitive to the congestion charge, make relatively few trips, estimated at 2.0 per day in WEZ and 2.5 in the CCZ.

**Table B.9: Estimated trips per day by types of cars**

| Car type             | WEZ dataset | CCZ dataset |
|----------------------|-------------|-------------|
| Exempt/100% discount | 3.2         | 3.2         |
| Evader               | 2.1         | 2.6         |
| Fleet charge payer   | 2.3         | 2.9         |
| Full charge payer    | 2.0         | 2.5         |
| Resident             | 3.4         | 3.0         |
| Selected partner     | 2.4         | 3.2         |
| <b>Average</b>       | <b>2.7</b>  | <b>2.8</b>  |

## Appendix C

### Inputs to the elasticity calculations

C.1 The elasticity values presented in Table 2.3 of this note are all arc elasticities calculated using the formula:

$$\frac{[(D_2 - D_1)/(0.5*(D_1 + D_2))]}{[(C_2 - C_1)/(0.5*(C_1 + C_2))]}$$

where C<sub>1</sub> = original cost  
 C<sub>2</sub> = final cost  
 D<sub>1</sub> = original demand  
 D<sub>2</sub> = final demand

C.2 The basis of the calculations is the change in the numbers of trips and in the cost per trip resulting from the introduction of the congestion charge. The cost per trip always includes fuel costs and can include parking charges and the value of time, as well as the congestion charge. The basis of the cost estimates is set out below.

C.3 The changes in demand, in the numbers of trips, are the changes in mode, destination or frequency of car and minicab trips as set out in rows 2 and 4 of Table 2.1.

#### Fuel costs

C.4 Fuel costs per trip are calculated from a number of factors:

- A standard trip length of 17 km, with variations around this,
- The standard DfT/WebTAG speed-dependent fuel consumption formula,
- Traffic speeds in Central and Inner London, pre- and post-charging as follows, based on TfL's observed and modelled speeds.
- A 2005 fuel cost of 86.2 pence per litre.

C.5 Traffic speeds, in kilometres per hour, are:

|                    | £0   | £5   | £8   |
|--------------------|------|------|------|
| Central London     | 14.1 | 16.4 | 16.9 |
| Inner/Outer London | 21.9 | 22.4 | 22.5 |

C.6 The resulting fuel costs for a typical 17 kilometre trip are £1.66 with no charge and £1.62 with an £8 charge

#### Congestion charge costs

C.7 In most cases the congestion charge per trip has been calculated simply by dividing the charge by the number of trips estimated to be paid by charge-payers, around 2.5 per day, so with an £8 charge this would equal £3.20 per trip.

C.8 In the normal case, therefore, of 2.5 trips of 17 kilometres each being made, the additional cost per trip that the charge adds to fuel costs is an increase of 191% with an £8 charge and 119% with a £5 charge.

C.9 An alternative approach has attempted to represent the congestion charge in a way that smoothes out the demand response to £5 and £8 charges. Modelling undertaken within TfL determined that a charge of (£5 plus 0.5\*actual charge) had this effect. Thus the £5 charge is represented as £7.50 and the £8 charge as £9. This representation could be described as a perceived penalty charge of £5 for having to pay for road use which had previously been free at the point of use, and a valuation of the actual charge at a reduced rate.

### Parking charges

- C.10 Data from different sources identified the typical central area parking charge per day of £11.80, post-charging, with 48% of those who drive into the charged area paying to park, which gives an average parking charge of £5.67 among all car drivers driving into the charged area. Divided by 2.5 trips, this gives an average parking charge per trip of £2.27.
- C.11 Elasticities incorporating parking charges have only been calculated for the central area, where there was better information, and not for the Western Extension zone.
- C.12 Averaging parking charges among those who do and do not pay them is not entirely satisfactory. For those who do not pay them, the elasticities which omit parking charges are probably reasonable estimates. For those who do pay to park, the averaged parking charge is too low, but we do not know the different demand responses among those who do and do not pay to park.

### Values of time

- C.13 In the calculation of elasticities with regard to generalised costs, a non-business value of time of £10.80 per hour, which adds a London weighting to the standard DfT WebTAG value of time, has been used, on the basis that non-business trips are more likely to have been deterred by the congestion charge than business trips.
- C.14 The typical 17 kilometre trip takes almost an hour which, at the speeds prevailing with an £8 charge, had a time value of £8.64. The ratio of the time cost to the fuel cost per trip is therefore £8.64:£1.62 or 5.3:1. This is high by historical standards, when a ratio of around 3:1 was more common. In recent years, however, the real costs of car use have fallen while values of time have increased in real terms, and the values used here have been further inflated by applying a London weighting.

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