CONGESTION CHARGING TECHNOLOGY TRIALS IN LONDON

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1. BACKGROUND

The Central London Congestion Charging scheme was introduced on 17 February 2003 in an area of 22 square kilometres in the heart of London. (See Figure 1 below). The objectives of the scheme were to reduce the amount of traffic in Central London by 10-15%, thereby decreasing the levels of congestion and providing consequent benefits for bus operation, a safer and more pleasant experience for pedestrians and cyclists and a generally enhanced urban environment.

Early results showed that the targets in terms of traffic reduction were surpassed with the volume of traffic in the Congestion Charging area currently some 21% less than pre-charging days. (The number of cars has actually reduced by 32%; increases in the numbers of buses, taxis and powered two wheelers produce the net reduction of 21%).

Transport for London (TfL) is now reviewing the lessons learnt from the introduction of the scheme and investigating means to develop the scheme in the future. A number of issues are driving this review, foremost among these are the desire to reduce operating costs, the need to make the scheme as user friendly and equitable as possible whilst retaining a good level of user comprehension and acceptance among the general public.
1.1 Why is TfL Carrying Out Technology Trials?

The camera enforcement technology currently being used by Congestion Charging is supported by Automatic Number Plate Recognition (ANPR). This form of technology was not the most advanced when it was chosen for utilisation for the Central London scheme. It was, however, a form of technology that had been proven to be efficient and, crucially, one which could be successfully deployed within the very tight implementation timescale that the Mayor of London had stipulated. A typical boundary point is shown in Figure 2 below with the enforcement camera in the background.

Camera / ANPR technology currently uses fibre optic cable to convey information from roadside cameras to a hub site, where information is processed. There is a finite geographical limit over which this technology can be practically utilised. Although the Camera / ANPR technology to be used in the western extension to the zone, due to be introduced in February 2007, will be upgraded to allow roadside image processing, the extended zone probably represents the geographical extent to which the current technology can be efficiently utilised.

The remit of the technology trials encompasses the goal of making the Congestion Charging scheme more user friendly from an operational perspective in addition to seeking to refine the enforcement and possible future payment / billing technology. Among the facilities which TfL is
investigating is the possibility of automatic pre-payment and post-payment. This is not currently possible, as drivers paying the Congestion Charge in advance must nominate the day which they intend to travel into the zone. There is no facility to pre-pay for a certain number of days or deposit a certain level of credit into a pre-paid account for example, which can then be used as and when the individual decides. Research carried out by TfL indicates that such a feature would be welcomed by motorists, by introducing a degree of flexibility that would aid the travelling public and, at the same time, help to reduce the scheme’s operating costs. There are a number of other areas which TfL is also looking at to improve the operation of the scheme.

The current Central London Congestion Charging scheme charge is £8 per day, having risen from £5 in July 2005. But the charge does not differentiate between single entries and multiple entries / exits to or from the zone. The £8 charge applies equally to a vehicle making a journey which involves one or more crossings of the zone boundary or a journey wholly within the zone.

No account is taken of factors such as the direction of travel, the time of day, the level of congestion over the traversed road etc. TfL’s engagement with stakeholders has identified instances such as vehicles paying the £8 charge when they are making single journeys in the contra-peak flow direction.

There is currently also no distinction drawn between emission levels of different vehicles for charging purposes – a situation which the Mayor of London has shown particular interest in addressing. Refined technology could provide more flexibility for policy options such as these.

Similarly no account is taken of the distance a vehicle travels in the zone – or beyond. As we know, the Department for Transport is looking at the possibilities of road user charging which would account for factors such as distance, time of day, etc. It is likely that distance based charging in London could probably only be addressed within the parameters of developing a wider sub-regional, regional or national scheme.

TfL also has a remit to reduce operating costs of the Congestion Charging scheme. The current camera based enforcement regime tends to require a relatively high human intervention rate which increases the level of operating costs. The increase in the charge to £8 has resulted in a reduction in the proportion of operating costs against the revenue accrued. The new technologies being trialled by TfL could result in a further reduction of operating costs.

2. STAGE 1 TRIALS

Stage 1 trials, initiated some three years ago and completed in 2004, examined a variety of technologies from the perspective of providing proof of concept rather than detailed assessment of their viability. Stage 1 trials were specifically orientated towards identifying those technologies that could be investigated further.
Stated objectives of the Stage 1 trials were to:

- examine how technology could support the existing Central London Congestion Charging scheme and proposed Western Extension by lowering costs, improving accuracy and making it more user friendly.
- examine how new technology could support more advanced congestion charging schemes, which might in future replace or supplement the existing approach.

2.1 New Camera / ANPR Operation

The current camera / ANPR technology involves relaying images from roadside cameras to a hubsite by means of fibre optic cables. The processing of the images then takes place within the hubsite. The trials examined the feasibility of replacing the current analogue cameras with digital ones and undertaking the image processing in the roadside cabinet adjacent to the enforcement camera. Once processed, the data would then be relayed by means of a broadband Digital Subscriber Line to the hubsite. The replacement of analogue cameras by digital ones should have benefits in terms of enhanced image quality and there will be considerable cost savings associated with transferring data by broadband rather than by fibre optic. There will also be substantial savings in the amount of hubsite equipment that needs to be employed.

When the western extension of the zone is introduced in 2007, this refined version of Camera / ANPR technology will be used.

2.2 Satellite Navigation Technology – Global Positioning Satellites (GPS)

Vehicles are fitted with an On Board Unit (OBU), which communicates with GPS satellites, which identify the location of the vehicle. As the present Congestion Charging scheme in London is based on vehicles crossing a designated boundary, the precise identification of the location of a vehicle in relation to the boundary is a critical feature of any technology to be used in the future if the Congestion Charging scheme develops in a manner, which continues to place reliance on a boundary to determine eligibility for charging.

If a vehicle is marginally inside the charging zone, it will obviously be eligible to receive a valid charge, whereas if it is marginally outside the zone, it should not be charged. For this reason it is necessary for a GPS system to identify a vehicle precisely – within 1 metre – if this technology is to be employed effectively for enforcement and payment purposes. Such precise identification has not yet proved possible in all areas of Central London. The accuracy of the GPS solutions trialled was such that, on average, a buffer zone of 60
metres around the boundary of the Central London Congestion charging zone would be required to 99% confident that a position reported as being within the zone actually was so. Around some parts of the boundary this increases to 250 metres or more.

OBUs need to be permanently installed with access to a power supply in a vehicle. The units should ideally be part of the vehicle build and retrofitting of units is likely to be problematic. This element of the operation associated with satellite based charging is likely to mean that widespread utilisation of such technology for road pricing purposes is some years in the future.

The scale and density of tall buildings and the configuration of relatively narrow streets, particularly in the City of London, have prevented the level of precision location of vehicles, which would be necessary to utilise this form of technology in the medium term future with respect to the Central London Congestion Charging scheme. TfL does, however, recognise the future potential of GPS and is continuing to trial an enhancement of GPS (described in Stage 2 below).

2.3 Digital Mobile Phone Technologies

Mobile telephone technology is based on a network of cells which form the framework for communication. Generally the denser the urban area, the smaller the cell sizes are. In London the cell sizes were not refined enough to facilitate identification of vehicles to the degree of precision that we were seeking. Even in Central London the cell sizes in certain areas were too great to produce precise vehicle location needed to make mobile technology the basis of an enforcement / payment technology in the medium term future.

Using the location based services of GSM mobile phone technology to establish the position of a vehicle gave results with an average error, as quoted by the operators of 800 metres and as observed during the trials of 2,400 metres.

The key opportunity of GSM identified during the Stage 1 trials was to utilise micro- or pico- cell GSM. This would allow cell sizes of 25 metres to be used, potentially covering one junction or charging point. The consequent application of mobile phone technology in potential value added services was explored in Stage 2 of the trials.

2.4 Dedicated Short Range Communication (DSRC) – Tag (Transponder) & Beacon

DSRC involves communication between roadside beacons and transponders placed in vehicle windscreens. Technology can be either microwave or infrared based. Initial findings produced, when DSRC was originally trialled during Stage 1 at two locations in Inner London produced encouraging results and it was decided to undertake further trials (described in Stage 2 below).
Roadside DSRC beacons mounted at a height of 6 metres can achieve a vehicle transponder detection rate over a 2-lane (8 metre wide) highway in excess of 99%.

In order to meet current evidential requirements and to cater for those drivers whose vehicles are not fitted with transponders, a camera and ANPR system will be required to operate in conjunction with any future DSRC system.

A DSRC solution could be applied as an overlay to the existing 203 camera sites serving the existing Central London Congestion Charging zone.

3. STAGE 2 TRIALS

Key objectives of the Stage 2 trials were:

- move from proof of concept to a proof of technical feasibility for selected technologies
- investigate technologies not examined in Stage 1
- address issues raised in Stage 1
- increase awareness of the development of relevant technologies

Following the successful initial DSRC trials, it was decided to extend the scope of the trials and to introduce a mini-zone trial area. The scope of the Stage 2 trials also includes further refined testing of certain features of GPS and mobile phone technology.

3.1 Mini-Zone Trial Area

The trial area is located immediately to the south of the River Thames between Southwark Bridge and Tower Bridge. (It is shown in Figure 3 below) It is a relatively small area (0.97 square kilometres) with 18 boundary locations, which represent a good variety of road types to be found within an inner city environment – carriageway widths that range from less than 4 metres to more than 12 metres, including one-way streets, locations where the carriageway is formally marked as one lane in each direction, others where there are two lanes in each direction, others where there is one lane in one direction and two lanes in the opposite direction. There are also examples of locations where traffic islands have been used to segregate traffic lanes and others where nearside bus lanes are also present. Each of these carriageway configurations offers a different challenge to be addressed by the forms of technology being trialled.
The trial area was chosen after consultation with the Mayor of London, who directed that a mini-zone trial area should be located in Central London and should lie wholly within the existing Central London Congestion Charging zone. The precise location of the zone was chosen following discussions with local borough councils. (For planning and highway related purposes London is divided into 33 local councils). An area was chosen where the local borough council, Southwark, was sympathetic to the concept of Congestion Charging. Representatives of TfL attended a number of public meetings to inform major stakeholders such as community and neighbourhood groups about the trials and to seek residents’ views and input.

The major aspect of public interest relating to the trials focused on the installation of roadside equipment in connection with DSRC element of the trial.
TfL is aware of other cities in the world that have been utilising DSRC roadside equipment such as Singapore and Stockholm and the DIRECTS trials in Leeds. In all these cases the roadside infrastructure has consisted of gantries spanning the width of the road. There was an appreciation at the early stages of the trials that any form of technology which TfL wished to develop would have to incorporate roadside infrastructure that was as sympathetic to the urban environment as possible. For this reason it was
decided at an early stage of the trials that gantries that spanned the width of
the carriageways would not be acceptable in London.

Figure 6 : DSRC Roadside Infrastructure from Stockholm superimposed
on a London street

This decision has meant that suppliers of DSRC roadside infrastructure have
been faced with a particularly challenging requirement in that they have been
requested to refine their equipment in a manner and a speed which no other
client city or state in the world has demanded.

Figure 6 above represents a photomontage of the Stockholm DSRC
equipment superimposed on a street within the London mini-zone area, which
would not be considered environmentally acceptable within a London setting.

3.2 Volunteer Programme

Another challenge relating to Stage 2 of the trials was the recruitment of a
sufficiently large number of vehicles needed to ensure that the trial was as
statistically valid as possible.

As TfL lets the contracts for bus services throughout London, one obvious
source of volunteer recruitment was the buses that pass through the mini-
zone trial area. Each of these buses has been fitted with a DSRC transponder
in their windscreens.
The fleet operated by Southwark Council such as street cleaning, refuse and housing maintenance vehicles are also taking part in the trials. Other participants in the trial include Guy’s Hospital, a major Accident & Emergency hospital, which has allowed TfL to fit transponders to vehicles serving the hospital including emergency ambulances. Certain private companies, including taxi firms, whose vehicle fleets regularly operate with the mini-zone area are also taking part. The trial vehicles are supplemented by 12 of TfL’s own vehicles bringing the total number of participating vehicles to 530.

The drivers of each of the vehicles outlined above, with the exception of TfL’s own vehicles, do not need to modify their travel behaviour in any way. They carry out their normal activities, driving their usual routes with DSRC capture rate being gauged and corroborated by supporting camera and ANPR systems.

TfL has striven to create an environment in which the all drivers taking part in the trial feel a degree of ownership of the trials by producing a regular newsletter which keeps them informed of the trial’s progress.

### 3.3 Refined Satellite Navigation Trials

Although the satellite coverage of London currently is not comprehensive, TfL has been working with the European Space Agency (ESA) to gain access to computer software that will simulate the anticipated satellite coverage in London in future years. Usage of this software is also aiding TfL in drawing conclusions about the consequent accuracy of vehicle location that can be expected in the future. The European Union is scheduled to launch its GALILEO constellation of satellites over the next decade. In total this constellation should amount to 27 satellites and once in position these should allow significantly greater precision coverage of London. The trials with the simulation software, Polaris, have produced encouraging results with many more areas of London having visibility of four satellites at any one time – four being the minimum number of visible satellites necessary to achieve a precision fix of a vehicle.

Figure 7 below indicates the number of satellites that are currently visible from streets in the City of London and Figure 8 represents the same area with enhanced visibility created by Polaris.
Figure 7: Current Satellite coverage of streets in City of London

Figure 8: Satellite Coverage of streets in City of London with Polaris software

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One integral test of a satellite based system for road charging which TfL undertook was to give each of the roads within the mini-zone trial area an arbitrary high, medium or low classification based on traffic flows and assign notional differential charging tariffs to each road classification. Groups of volunteer drivers would then follow different routes within the mini-zone and their route records would be subsequently be matched with billing performance for accuracy. TfL examined the system performance of 14 vendors, whose results ranged from a figure of 0.5% variance from the true billing figure to 150% variance.

One element of this aspect of the trials was the need for TfL to undertake a considerable amount of groundtruthing. Available commercial base maps, even Ordnance Survey, do not provide sufficiently accurate detail of the road configuration necessary to support a satellite based road charging enforcement and payment system. TfL carried out much detailed groundtruthing in order to identify precisely features such as centre of roads, location of carriageway lanes, one-way streets etc. This information was then used to provide an accurate template for the refined satellite navigation trials.

3.4 Digital Mobile Phone Technologies

Although not currently sufficiently mature at this stage for deployment as a core technology for an urban road charging scheme, TfL believes that mobile telephone technology does offer scope for some important value added services, which form the basis of the Stage 2 trials relating to wireless communication.

The Value Added Services focus on communication with the vehicle driver to relay information which TfL believes could be useful. Such examples tested to date include notification of entry into the zone; account balance and account top-up facilities; Paypoint locations; traffic alerts; local news and community events.

The information can be passed to the drivers by means of a number of different innovative technologies;

i) Speech using interactive voice and text to voice transmission
ii) SMS texting
iii) Multi-media message – maps with Congestion Charging information relayed directly to mobile phones.
Voice interaction allows the driver of a vehicle to interact with an incoming message without having to physically hold the phone within the car. An example of its application is that it allows a driver the facility to place credit on a Congestion Charging account simply by making a verbal response to a given cue contained within the incoming message.

One issue which TfL is currently examining is the identification of a mobile phone in relation to an expected vehicle. By means of bluetooth technology messages would only be sent to a specific mobile phone once it was established that the phone is turned on and actually located in the expected vehicle.

3.5 Dedicated Short Range Communication (DSRC)

The Stage 2 trials were designed to examine how well this technology would perform in an area rather than a small number of individual locations. The mini-zone area in Southwark, described above, forms the location for these trials.

The mini-zone area consists of 20 locations with DSRC related roadside infrastructure, 18 of which form boundary points for entry to the zone or exit from it. For the purposes of the trial, TfL has designated these locations as Urban Charge Points (UCPs).
Whilst the majority of vehicles participating in the trial simply carry out their normal business without any modification to their travel behaviour, TfL’s own 12 vehicles have allocated specific routes to follow each day. These routes have been chosen to incorporate vehicle manoeuvres that are particular to an urban traffic environment, such as U-turns; tailgating close behind another vehicle; overtaking at a UCP so the vehicle presents itself on a section of the carriageway where the DSRC equipment would not logically be expecting it; passing a UCP on an inside traffic lane whilst a tall vehicle (often a double-decker bus) is driving on an outside traffic lane thereby creating a potential case of obscuration.

TfL is continuing to refine the roadside infrastructure associated with urban DSRC operation and the length of the horizontal outrigger is dependent on the carriageway width. Figure 10 below shows an example of a short outrigger attached to a vertical column giving DSRC coverage of a 4-metre wide street.

Figure 10: DSRC Infrastructure, Copperfield Street

Figure 11 below shows DSRC infrastructure giving coverage across a 10-metre wide street in the mini-zone area.
Results have been particularly encouraging with the main supplier's DSRC equipment capturing 99.95% of all vehicle passages past the UCPs. There has been a high rate of ‘readability’ between the different suppliers’ equipment with transponders from the two participating suppliers being read with a high degree of accuracy by the other’s roadside infrastructure.

TfL has also carried out a refinement of the DSRC trial through spatial matching whereby the front of the vehicle through the DSRC read is matched with the rear registration plate captured by the accompanying camera / ANPR system. This process is especially beneficial where there are restricted lengths of carriageway. Spatial matching results are running in excess of 99% accuracy.

4. CONCLUSIONS

TfL believes that there is considerable scope in developing the various forms of technology that we have been examining during the trials. A further stage of the trials is currently being initiated, which will focus on customer usability and interoperability with charging systems in other areas.

One particular area which has been highlighted by the technology trials is that of streetscape integration and the necessity of ensuring that roadside infrastructure associated with future forms of enforcement and payment technologies are as visually unobtrusive and as sympathetic to the urban environment as possible. It could well be that in developing Congestion
Charging in London the aesthetic challenge will be as great as the technological challenge.

In the medium to longer term, there could be potential to introduce a distance based charging system in an urban environment which uses satellite technology. Mobile telephone technology could also offer a wide range of possibilities to provide additional supporting services to the driver.

In the shorter term the favoured form of technology, to which the Congestion Charging scheme in London is likely to migrate, will be DSRC. We believe that the trials have been successful in identifying DSRC as a viable form of technology for urban road pricing in the short term future.