Automated Congestion Charge Payment Scheme Using Smartnav Intelligent Satellite Navigation System

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Synopsis:

This paper will cover the use of Smartnav off-board satellite navigation (Sat-Nav) system to provide automated payment of the London Congestion Charging Zone (CCZ) authorised via the driver at point of entry to the congestion zone. The Smartnav Sat-Nav system utilises GSM communications to provide route download from the Smartnav control centre and payment authorisation from the driver. Alternatively the system is able to warn drivers of entry to the congestion zone, even when not using the routing service, and route around the zone when requesting a route with congestion zone-avoidance set.

The system utilises off-board navigation and can be over-air (and over-internet) configured and new charging zones and toll-road systems can be easily implemented at the route server end without the need to change the in-vehicle hardware. The credit card details of the system owner (not always the driver, e.g. fleet or company vehicles) are maintained at the control centre and on entering a congestion or toll zone the driver is requested to authorise payment by pressing the in-vehicle Smartnav button (switch). The authorisation is communicated over-air to the control centre and payment to the zone controlling authority transferred.

The on-board system is also configurable to maintain route tracking automatically for fleet tracking (e.g. Fleetstar) and stolen vehicle location tracking (e.g. RAC Trackstar) applications, hence for future road tolling or zone charging based on either frequency of use or distance travelled, the system is capable of calculating cost both on and off board and again making authorised automated payments at point of use or summarised usage reports for annual or monthly usage payments by other means.

London Congestion Charging

Figure 1: Congestion Charging Zone, coming to a town near you?

Love or hate it, there can be no doubt that it has had the desired effect and reduced traffic congestion in central London. There must equally be no doubt it has also made a significant contribution to the wealth of the city, even if not at the expected levels (estimated at £80 million for 2004), and has recouped much of its initial £200 million investment cost. The potential for rollout in other UK metropolitan areas can only be a question of when and not if similar schemes will be implemented.

One of the initial teething problems with the London scheme was the payment method; manual methods and keyed entries to the payment system were fraught with "user" errors and many people who had legitimately paid received threatening letters of prosecution due to systematic errors. Most of these manual errors are now resolved and there are several payment methods that allow automated payment schemes through mobile telephony; dial-in payment and short message service (SMS r.e. text message), automated transfers by credit and debit card and other such schemes.

These automated schemes still rely on the vehicle driver taking an action on their return from their vehicle or once they arrive at their destination, within or through the congestion zone. This may seem like a minor inconvenience to many motorists, but it can be problematic to a busy individual or to someone who travels infrequently through the zone itself, but often nearby. A simplified method can be achieved by use of a GPS based Sat-Nav system with off-board (off-vehicle) communications capability that can both prompt for and perform the necessary payment option at point of entry to the zone.

This is the focus of this paper and the application of such a system to wider zone charging and road tolling schemes is also considered.

Smartnav System

The Smartnav system was developed by Trafficmaster with an off-board routing engine to allow the system to have a low cost in-vehicle unit (IVU) platform, with the majority of the cost associated with classic navigation systems (mapping and routing engines) taken off-board for speed of routing and overlay of additional traffic information.

The off-board nature also means the driver never has to update their in-vehicle system, the mapping is updated quarterly at the route server and the inclusion of GSM communications means that any IVU firmware updates can be done remotely over-air. Similarly the system can be easily enhanced for road closures, additional zones or zone changes and road-tolling systems without the need for a change in the IVU. All updates and changes are performed at the route server, the driver need never worry about updates. For Trafficmaster this has allowed the system to incorporate live traffic congestion information from the UK's motorway and major trunk road network, producing a system that produces traffic impacted routing, congestion avoidance and live traffic information updates while on-route (having an off-board stored route allows the system to determine if new congestion events will impact your journey). Having a strategic alliance with the RAC and other agencies has also permitted Trafficmaster to incorporate daily road closures, accident reports and congestion information from roads not covered by the Trafficmaster network into the routing engine.

In-Vehicle Unit (IVU)

The IVU contains all the in-vehicle electronics, including the GPS receiver and a dual-band GSM/GPRS modem. The device is a slim unit that can be covertly installed and offers both direct speaker driven vocalised information or can be interfaced with one of Trafficmasters' in-vehicle display units to provide visual information (turn icons, estimated time of arrival information, accident camera alerts etc). The device is fully automotive rated (electrically and mechanically) for both 12V and 24V supplied vehicles.

Off-Board Routing

The principle of off-board routing is that the route is calculated by a host computer off-board (off-vehicle) and then downloaded to the IVU. The route is downloaded over a GSM link to the Smartnav IVU and comprises of junction information and directions to be spoken by the IVU (speech is permanently located in the IVU and not downloaded). Consequently the route download is compact and requires only a short duration link from the server to the IVU.

Figure 2: Smartnav, one-button Satellite Navigation

Figure 3: Trafficmasters' congestion sensor network covers 8500 miles of the UK road network.

Figure 4: Smartnav In-Vehicle Unit (IVU)

The concierge nature of the system also allows a great deal of flexibility, not only can a driver request, while in motion, an address, they can ask for relatively obscure location sensitive service such as “The nearest petrol station.”, “The closest ABC Bank cash-point.” Also the address information may be provided in an incomplete format, such as “Technocentre Coventry.”, or “RIN, London.” The off-board server not only contains all UK addresses and postcodes, it also includes all UK businesses and service providers, all UK toll roads and charging zones (congestion or otherwise).

Congestion Zone Mapping

The CCZ overlay will be performed both off-board in the routing engine and on-board in the IVU, hence the system will be both a passive and active zone alarm system[1]. Consequently the Smartnav user will be warned of congestion zones while both on-route and while driving un-routed.

The system for implementing congestion zone warning both off-board and on-board could potentially use different methods, and several were considered before determining the most appropriate solution for this application.

Figure 5: The London Congestion Charging Zone (map courtesy of the BBC)

Corridor Method

There are a limited number of approach roads into the London congestion charging zone, these could be set-up in a mapping tool as corridor entries into the zone and used as warning indicators for zone entry. A similar system is in use by Trafficmaster for accident blackspot alerts[1].

In the case of a zone the size of the London scheme the method starts to become unwieldy and is difficult to update easily for changes in zone layout. Additionally the zone warnings would have to be provided on all entry points to the CCZ, making the in-vehicle side much more complex and driving around the perimeter road at different times could impact message generation as corridors are passed and GPS shifts generate false positions. The corridor technique would also produce a relatively large data set requirement for the London CCZ and using the method for additional CCZs as these come on-line could start to produce memory limitations for such complex geographic regions.

The corridor method is much better suited to single or limited point of entry schemes such as the Durham CCZ or road, tunnel and bridge tolling schemes.

Polygonal Zoning

The CCZ can be produced as a series of geographic positions on the congestion zone perimeter road. This creates a polygon overlay on the route server map, and in the IVU. The advantage of using a polygon is that it can capture any minor roads or pathways that might otherwise have been missed by a corridor technique. It is also slightly easier to compensate for urban canyoning problems by allowing the warning messages to be inset by the typical canyon shift from the perimeter road (this also eliminates problems of GPS positional shift perpendicular to the polygon). By calculating the vehicle distance and direction from the perimeter road creates a simple polygon zoning scheme with programmable hysteresis for both alarming (“You are approaching a CCZ.”) and CCZ entry warnings (“You are entering a CCZ.”).

The real benefit of the polygonal zoning technique comes when the zone changes (e.g. expands or contracts) as the polygon shape can be relatively easily modified with marginal increase in the data

[1] Trafficmaster have a system for accident blackspot location (speed camera) warnings on Smartnav that is a passive function (i.e. does not rely on being on a supplied route). This feature is an additional service option for Smartnav users.

set size. Similarly new CCZs are relatively easy to cope with as replicated functional polygons in different geographic positions (both on and off-board).

Congestion Zone Avoidance or Payment?

Active Auto-Avoid Navigation

The user can select on their Smartnav webpage whether to avoid the London CCZ or not. If selecting to disable CCZ warnings then it is assumed either the driver or vehicle has a CCZ pass or will arrange their payments accordingly and the IVU will not produce warnings or avoid the CCZ while routing. As this is done at the server end this will be a feature until the driver enables CCZ warnings on their webpage or may be done via the Smartnav Personal Assistant (PAs) during a voice call to set-up a route.

If enabling warnings the server will choose to produce a route avoiding the London CCZ (unless the destination or start point is within the CCZ). It will also provide warnings while on a route if this takes the driver close to the London CCZ so that the driver is aware that a wrong turn could be expensive!

Passive Warnings

As the CCZ overlay is available to the IVU when not using Smartnav for routing, warnings of approach to a CCZ will still be provided (e.g. “Congestion zone ahead, turn left at next junction to avoid.”). This is classed as a passive warning system as there has been no downloaded route, hence the Smartnav system is not being used, just the IVU. This is similar to the accident black spot warnings, but will be available at no cost to Smartnav users.

Vehicles fitted with the Smartnav optional display screen can make the necessary CCZ warning option changes themselves in-vehicle via displays’ menu system (not available on current display models). This is particularly useful for those users who drive near the London CCZ regularly and do not want repeated warnings vocalised, but may wish to know of other CCZs when travelling elsewhere and can adjust their IVU response options on-the-fly.

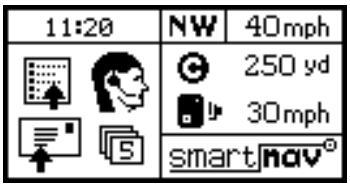

Figure 6: Small Display Option Screen showing CCZ Warning.

Automated Payment

Potentially the Smartnav system has 2 methods of providing payment to Transport for London (TfL) for the congestion zone, however, these are only possibilities and the commercial reality of implementing this is not yet fully evaluated. It is included here for completeness, but at the present time is not intended to be a feature of the system.

Transport for London has established a relatively simple short message service (SMS) payment scheme using the vehicle registration and a registered credit card. This would need the last 4 digits of the credit card entering into the IVU and could be done either via the Smartnav user webpage or the in-vehicle display where available. The IVU could then prompt a driver to authorise payment by pressing the in-vehicle Smartnav button on entry to the CCZ and the IVU would then transmit the code to TfL (81099). As the IVU could flag this payment in its non-volatile memory (if authorised) the warnings could be defeated for the rest of the days travel in and out of the CCZ.

Another alternative is to use the Internet and the customers’ credit card details, if held by Trafficmaster, to enable payment. Again the IVU would request user authorisation for Trafficmaster to make the payment and this would be relayed to the Smartnav control centre and an automated payment via the Internet could be made. Yet again the IVU could record this payment and disable further warnings until resetting the CCZ payment flag at midnight.

Either of these automated payment schemes requires the user to register their credit card details and may prove more difficult than they initially look. Also there is limited flexibility in using the method for

late payments, but then the driver can still use their handset or own Internet access for these additional features.

Other Applications of Sat-Nav in Road User Charging

Durham Congestion Charging Zone

Although this paper is primarily about the London CCZ, it is easy to forget that the Durham CCZ preceded Londons' by almost 4 months (Durham going live on 1st October 2002 and London on 17th February 2003). The Durham scheme is, however, significantly simpler in concept and involves only a single road; Saddler Street (this becomes the North and South Bailey as it progresses over the Cathedral/Castle peninsula). All other entry roads to Saddler Street are already pedestrianised or inaccessible to vehicles.

The operation of the scheme is also payment on-entry via an automated toll barrier, hence more similar to a toll road than the traditional concept of a CCZ. There is also no automated payment scheme via SMS or TCP/IP at the moment, hence the only feature a Sat-Nav system like Smartnav can offer is a vocalised warning that the user will enter a CCZ en-route (the destination or start point would have to be within the Durham CCZ).

As an effective method of reducing congestion the Durham CCZ is an example to all, having reduced traffic by 90% in the CCZ and had a much higher level of support than the London scheme. However due to it's simplicity there is little that a Sat-Nav scheme can offer as a driver benefit other than its' verbal warning about the Durham CCZs' presence on the route.

Figure 7: The Durham CCZ is more similar to a toll road in concept and operation (map courtesy of Durham County Council).

Toll Roads, Bridges and Tunnels

As with the Durham CCZ, the main problem with the majority of UK toll roads, bridges and tunnels are that they are a pay-per-use systems that have relatively unsophisticated enforcement schemes (barrier at entry/exit points). There are some RFID automated payment schemes, but these are specific to each road/bridge/tunnel, hence are not integrated. The casual motorist will not have too much of a problem with these systems but they must be a particular frustration for long-distance haulage contractors who use many of these toll infrastructures but not sufficiently to equip all their vehicles with the multiple RFID tags that would be required to ensure national coverage.

A sophisticated duplex communication capable IVU, such as Smartnav, would be a possible solution to multiple charging schemes, given sufficient will by the operators to provide a simple over-air payment and recognition capability, or via pay-per-use scheme based on haulage fleet reporting systems. Unfortunately these integrated systems require a degree of co-operation, trust and dialogue between operators of the toll infrastructure and the haulage contractors that does not appear to be occurring. It is possible that a governmental scheme of the type introduced this year in Germany is the only possible solution for a truly integrated tolling system for the UK.

New Zones

The addition of new zones to the mapping overlay is relatively simple with a polygonal zoning scheme, the new polygons are added to the routing map with the same status of function as the London CCZ. The on-board IVU zone can then be extracted from the routing engine zone and downloaded to an IVU on its' next route request, regardless of the impact of the route on the new

CCZ. Once downloaded the new CCZ becomes a passive warning when off-route and an active warning on route request via any CCZs.

London Congestion Charging Zone Western Zone Expansion

The Mayor of Londons' Office published a revision to the Transport Strategy on 11 August 2004. The revision allows for a western extension of the central London congestion-charging zone, extending to Notting Hill and Bayswater at the northern extreme and to West Brompton and Chelsea in the south (all north of the river Thames).

Expanding the polygon for London CCZ to accommodate this is relatively simple and highlights one of the major benefits of off-board routing; simplicity of updates. As with the new zones discussed above, the IVU polygon will be extracted from the routing engine overlay and downloaded to each IVU on the users next route request.

Figure 8: London Congestion Charging Zone and Proposed Western Extension (map courtesy of TfL).

Conclusion

The polygonal zoning method has many benefits for use in congestion charging zone overlay for satellite navigation systems, not least the flexibility of future updates as zones are added or expanded (or contracted) as their use and application is modified by local authorities. Having off-board routing and over-air upgradeable IVU's has also proved to be a valuable tool for future proofing and both active and passive zone warnings, providing additional use from a Sat-Nav system, other than just routing.

In the future the system may be capable of automated payment and exemption notifications, but the suitability of the positioning system (GPS), and possibility of positioning errors in the urban environment of London in particular, suggest that a manual authorisation scheme will always be essential to avoid errors in charging drivers using the perimeter road.

Caveat

This paper is purely a discussion paper and does not imply that Trafficmaster will implement any of the above schemes or methods. There may be commercial reasons or alternatives not considered here that impact the above discussion points. There is no commitment from Trafficmaster to implement any congestion zone schemes at this time.

Acknowledgements

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References

Congestion Charging: Six Months On, Report, Transport for London, October 2003.

Congestion Charging, Update on Scheme Impacts and Operations, Transport for London, February 2004.

Draft Transport Strategy Revision: Central London Congestion Charging, Report to the Mayor Following Consultation with Stakeholders, Businesses, Other Organisations and the Public, July 2004.

London Safety Camera Partnership (www.lscp.org.uk)

Spotlight on Durham's charge, Bill Wilson, BBC News Online, 11 February 2003 (http://news.bbc.co.uk/1/hi/england/2721545.stm).