DARTFORD TRAFFIC MANAGEMENT CELL – USING TRAFFIC SIGNALS TO MANAGE THE NORTHBOUND A282 FLOWS THROUGH THE DARTFORD TUNNELS

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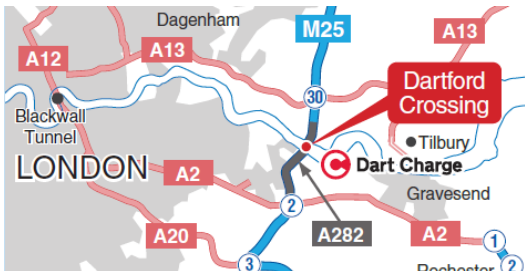
1. Introduction

1.1. The M25 London Orbital crosses the Thames on the east side of London at the Dartford Crossing (Figure 1). The Queen Elizabeth Bridge carries southbound traffic over the Thames with two dual lane tunnels for northbound flow. Technically the crossing is it is the A282 not the M25 but is generally is perceived as the M25.

FIGURE 1: LOCATION PLAN



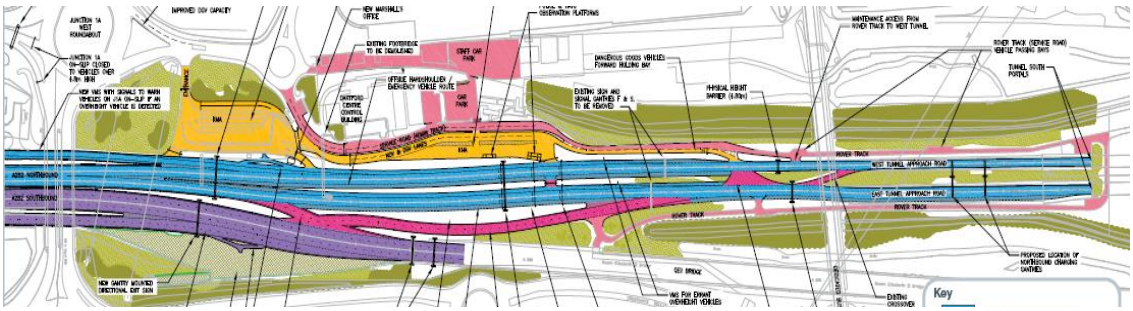
1.2. Because of the level of traffic congestion at the Dartford Crossing, the Dartford Free Flow Charging (DFFC) scheme, now known as Dart Charge, has been implemented. Road layout changes allowing free-flowing traffic and the use of charging technology now allows motorists to remotely pay to use the crossing without having to stop at booths. Payment can be made through a variety of methods including telephone, text message, online and at retail outlets. The primary means of compliance is enforceable signing on the approach to J1a, advising drivers of dangers goods and over sized vehicles to either divert off at J1a, declare themselves to the Kent Marshalling Area or align themselves to the correct lanes (in the case of height).

1.3. The northbound charging booths provided a secondary traffic management function in controlling traffic entering the two northbound tunnels (known as the west and east tunnels). These tunnels impose a number of physical and safety constraints :

a) The substandard headroom in the west tunnel;
b) Restrictions on the passage of vehicles carrying dangerous goods in both tunnels and abnormal loads;
c) Restrictions on vehicles that are too high, wide or long through both tunnels; and
d) The need to avoid queuing traffic in the tunnels.

1.4. To mange northbound traffic flow (typically 85,000 vehicles per day) now that the plaza booths have been removed a traffic safety system known as the Traffic Management Cell (TMC) with traffic signals and traffic barriers and advance detection has been introduced from June 2015. Figure 2 shows an overview of the TMC.

FIGURE 2: OVERVIEW OF THE TMC



1.5. The TMC is controlled by the TMC Control System (TMCCS) that provides a strategic operational control facility for the operational staff that manage the crossing 24 hours per day. The TMCCS also interfaces to other systems including existing tunnel systems (SCADA), CCTV infrastructure and SERCC Godstone for fallback control, control of signs (AMIs, EMS and MS4Rs) and MIDAS. It will also be used in collaboration with DVSA when a vehicle triggers their ANPR/WIMS site.

1.6. This paper briefly explains the key aspects of the operation of the TMC from a traffic control perspective which is a small but crucial element of the overall scheme that will be fully reported elsewhere.

FIGURE 3: THE TMC (AUGUST 2015)

2. Operational Requirements

2.1. The specific objectives of the TMC are shown in Table 1. The TMC provides support for the operators undertaking the routine operation of northbound traffic, particularly:

a) Stopping traffic to allow convoys (Dangerous Goods or Abnormal Loads) to enter either or both tunnels;
b) Extracting non-compliant vehicles that have not followed advanced enforceable signing;
c) Metering traffic through the tunnels to avoid stationary/queuing traffic; and
d) Closing one or both tunnels in the event of an operational problem or emergency.

2.2. The major operational processes involving the TMC are described below. As operational experience using the TMC increases operating procedures are being refined and the TMC enhanced and modified to support this.

2.3. Barriers are used to support traffic signal operation during nudging, extraction and tunnel closures. More information about barriers is given below.

TABLE 1: OBJECTIVES OF THE TMC	
Objective	**Comment**
1. Detect over-sized vehicles (height, width, length), bring traffic to a halt and support the extraction of the non-compliant vehicle	Over height vehicles could damage the tunnels but over length and over width vehicles are a potential risk to other vehicles
2. Discriminating between over height vehicles that too high for the west tunnel but low enough for the east tunnel or too high for either tunnel	Typically something in the order of twelve over height vehicles per day are detected and extracted.
3. Bring traffic to a halt and support the extraction of unauthorised dangerous goods vehicles	Determined by orange plate detection
4. Bring traffic to a halt in order to release a vehicle or convoy into either tunnel	Typically petrol tankers with approximately 1000 tankers on a week day using the tunnel
5. Bring traffic to a halt and support the closure of either or both tunnels	Closures can be for emergencies or routine planned maintenance etc
6. Meter traffic into either or both tunnels.	To prevent queuing in the tunnels

2.4. A PA system allows recorded messages to be played to selected lanes or allow operators to issue instructions to drivers to support operation. MS4R variable message signs controlled by the TMCCS provide additional information to drivers.

Abnormal Loads and Convoys

2.5. Abnormal loads and convoys of dangerous goods vehicles (typically petrol tankers) are held in forward holding bays then when northbound traffic is stopped are allowed to enter and pass through the tunnels with an operator escort if required. Typically convoys use the west tunnel so only northbound traffic in Lanes 1 and 2 has to be stopped but occasionally the east tunnel is used which requires all four northbound lanes to be stopped.

2.6. When operators initiate the convoy injection process the TMCCS shuts down the northbound flow in Lanes 1 and 2 and then supports the operators through the process to bring out the convoy and reinstate the northbound traffic flow.

Nudging

2.7. When non compliant vehicles (dangerous goods vehicles or over sized vehicles) are detected the TMCCS automatically closes the relevant lane pair after a short delay designed to stop the non compliant vehicle just before the Zone B stoplines (this delay is based on the average vehicle speed and if the road surface is wet or dry). Operators can abort automatic shutdown if appropriate, or if necessary initiate it.

2.8. Once the non compliant vehicle is stopped any vehicles between it and the stopline are nudged forward and allowed to proceed to the tunnel until the non compliant vehicle is at the Zone B stopline. The aim of nudging is to control single vehicles.

2.9. When operators select the nudge facility on the TMCCS an automated process commences involving raising barriers, turning the signals to green for a short period, reverting to traffic red and then lowering the barriers.

2.10. To reduce tailgating the use of shorter starting and leaving ambers is being trialled. The use of variable amber timings is discussed further below.

Extraction

2.11. Once the non compliant vehicle is at the Zone B stopline it is taken into area between the Zone B and C stoplines known as the 'Cell' ready to be extracted to the left and away from the tunnels. Operators can then initiate the extraction and the TMCCS raise barriers that normally prevent the left turn manoeuvres and other barriers to prevent the vehicle from going forward into the tunnel are lowered (Figure 3).

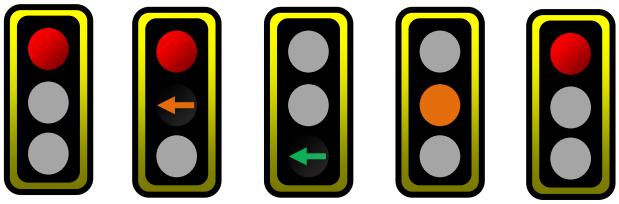
2.12. Once all barriers are in the correct positions the vehicle extraction process commences:

- The Zone C barrier is raised ;
- Left turn starting amber arrow (as shown in Figure 4);
- Left turn green arrow
- Leaving amber;
- Red; and
- The barrier is lowered after a short delay.

FIGURE 3: EXTRACTING A VEHICLE

2.13. Figure 4 shows the traffic signal sequence used during extraction. Amber and green arrows support 'full' signal displays in normal operation and left turn arrows during extraction, see below. These 'Active' aspects are installed in Zone B as well as Zone C so that in the event of the failure of the Zone C controller the Zone B controller can support extraction.

FIGURE 4: SIGNAL SEQUENCE DURING EXTRACTION



2.14. If the non compliant vehicle is in Lanes 1 or 2, which is normally the case, Lanes 3 and 4 can continue to operate but if the non compliant vehicle is in Lane 3 or 4 all traffic northbound traffic flow has to be stopped to extract the vehicle.

Metering

2.15. Metering traffic through the tunnels is used to limit flow to prevent queuing in the tunnel. The signals cycle from green to red at a cycle time the operators can adjust to achieve the required level of metering.

3. Wroughton Test Facility

3.1. Due to the complex operational nature of the system and the need to end to end the system in a realistic environment with vehicles a test facility was setup at the Science Museum facility at Wroughton Airfield near Swindon.

3.2. Both factory and site acceptance testing was undertaken at Wroughton as well as extensive operational testing to develop the initial baseline system configuration, signal head alignment and operator training.

FIGURE 5: WROUGHTON TEST FACILITY

3.3. The site was constructed longitudinally to scale including approach length sufficient to permit HGVs to accelerate to design speeds as well as;

a) TMCCS;
b) Communications;
c) Gantries with detection (see Figure 5);
d) Signal Controllers;
e) Signal heads; and
f) Barriers.

3.4. It was not however possible to construct the site to full width including emergency access ways due to the width of the runway.

4. Key Features of the TMC

4.1. This section describes some of the key features of the TMC.

Layout

4.2. Figures 2 and 3 show the TMC and this section describes some of the key features. As can be seen from these figures the TMC comprise:

a) Four lanes of traffic managed in two pairs of two lanes; and
b) Dual stoplines for each lane approximately 30m apart.

4.3. The approach to the first stoplines is known as Zone A, The first stopline is Zone B, the second stopline Zone C and the area after Zone C is Zone D. The area between the Zone B and C stoplines is known as the 'Cell'.

4.4. Zone B has dual height signal heads and additional gantry mounted signal heads. And is used to bring free flowing traffic to a stop and for nudging, extraction and metering. Traffic signals at Zone C are used to support nudging and extraction of non-compliant vehicles.

Controllers

4.5. Zone B is managed by one controller and Zone C by a separate controller so that operation can be maintained if one controller fails.

4.6. A third traffic signal controller is used at the forward holding bay where dangerous goods vehicles are held until they are escorted through the tunnels. An SIS disconnection device is installed at this location due to the lack of protection to poles (and the nature of vehicles queued at this location).

4.7. All controllers are linked and a 'heartbeat' is used between all controllers to verify when a given controller fails and allow the system to failsafe.

4.8. Controllers are LV, this was dictated due to the red light enforcement requirements at Zone B and the subsequent desire to minimise spares holding and reduce complexity.

4.9. The controller has options for start-up depending on inputs present from the TMCCS or whether the controller is in manual, including, starting up to:
a) Lamps off;
b) Red; or
c) Full Green.

Method of Control

4.10. The TMC remains on green for northbound traffic unless there is a reason to stop traffic:
a) Stopping traffic flow to allow convoys to enter either or both tunnels;
b) Extracting non-compliant vehicles;
c) Metering traffic through the tunnels; and
d) Closing one or both tunnels in the event of an operational problem or emergency.

4.11. In the event of failure of the TMCCS operators can manually control the TMCCS or control fall back to SERCC (Godstone).

4.12. The TMCCS/signal controller interface is a UTC interface but the TMCCS to roadside communications is via PLCs (Programmable Logic Controllers).

Barriers

4.13. Two types of barriers are used:
a) Short high speed barriers used in association with traffic signals; and
b) Longer slower speed barriers to prevent unauthorised manoeuvres.

4.14. The short high speed barriers are used in association with traffic signals in Zone B and C during nudging and extraction and also at the convoy entry traffic signals. If the tunnel is closed for a longer period long barriers at Zone B are lowered to reinforce the closure.

4.15. Long barriers, which are much lower speed, are used to control other manoeuvres, e.g. to prevent moves between Lanes 1 and 2 / Lanes 3 and 4 or to prevent non compliant vehicles going ahead into the tunnels during extraction.

4.16. Loops beneath barriers ensure that the barrier cannot be closed when a vehicle is under the barrier with ultrasonic detectors on the short barriers and infrared beams on the long providing additional clearance detection.

4.17. Barriers are controlled by the TMCCS.

'Active' Aspects

4.18. To support nudging and extraction active aspects support the use of:
a) A full amber or arrow for starting ambers; and
b) A full green or green arrow for extraction.

4.19. Active aspects are provided by LED arrays with only a subset of the array illuminated when the arrow is required.

4.20. It is generally considered that the active aspects work well. Appropriate authorisation was obtained from the DfT before use.

Variable Amber Timings

4.21. The TMC traffic signal controllers support the use of ramp metering timing ranges that allow starting and leaving ambers to be varied between 1 and 5 seconds. The intention is to trial reduced amber timings during nudging and extraction to improve the control of traffic. Appropriate approvals are being obtained for this as described below.

Other Facilities

4.22. Other facilities at the TMC include:
a) Red light camera enforcement is provided at the Zone B stoplines;
b) Average speed enforcement for 50mph is provided on the approaches to and through the tunnels;

4.23. There is full CCTV monitoring of the TMC with recording facilities to support prosecution.

4.24. An XML publisher is being provided to support exchange of data using UTMC data objects (Incident object).

Interlocking

4.25. The TMCCS utilises interlocking to ensure that safety is maintained, e.g. barriers associated with traffic signals in Zone B and C cannot be lowered until the associated traffic signals are at red, convoys cannot be brought out until signals at Zone B and Care at red etc.

4.26. As part of the ongoing refinement interlocking will be reviewed and refined to optimise performance, for example would it be sufficient for the traffic signal at the convoy entry to be going to red before the Zone B and C signals can start to reopen because of the physical separation of the signals. Maintaining safety will of course be the critical factor.

Authorisation and Approval

4.27. The general approach has been to maximise use of approved equipment and processes based on good practice. The primary technology differences of the TMC from prevailing traffic signals technology are as follows and their use is covered by an application for authorisation made to the Department for Transport (DfT Case 4270):
a) The use of barriers on the public highway;
b) The use of non-standard signal sequences, both at start up and in some modes of operation;
c) The use of metering timings and metering backing boards in a non-'ramp' environment; and
d) The role of an operator in delivering a safe and efficient system.

4.28. Traffic signals are designed to manage conflicts but the TMC has been deemed by the DfT not meet this requirement so has been implemented as a ramp metering installation. Traffic signal controllers are approved to TR2500 but modified to provide ramp metering timing ranges as defined in MCH1965D (Ramp Metering System Requirements Specification). Approval is by trial assessment as defined in TRG0600 (but this process will cease to exist when the TSRGD:2015 comes into force).

5. Detection

5.1. Detection of over height, over width and over length vehicles as well as dangerous goods vehicles is undertaken on the A282 and Junction 1A approaches to the TMC and at the TMC. All detection technology is being reviewed and refined in light of operational feedback/need.

Over Height/width/Length Vehicles

5.2. Dual technology over height detection is used to detect over height detection:
a) Detector broken beam solution using Coeval equipment; and
b) A scanning solution using SICK detectors.

5.3. SICK scanning detectors are currently used to detect over length and over width vehicles however an alternate detection technology is being explored for over width detection.

Dangerous Goods Vehicles

5.4. There is a well established process for vehicles carrying dangerous material and drivers should report to a marshalling area and self declare then they will be allowed back into the general traffic flow or included in escorted convoys (Figure 6).

FIGURE 6: HIGH PROPORTION OF GOODS VEHICLES

5.5. An SSL designed solution has been implemented to detect orange plates on the approaches to the TMC and when applicable initiate an extraction.

6. Organisational Context

6.1. Connect Plus (the Employer) working on behalf of Highways England (Employer's Lender) via the M25 DBFO (COFA – Call Off Framework Agreement) has overall responsibility as the DBFO Company and has subcontracted to Connect Plus Services (CPS) all of its obligations in respect of Dartford Crossing operations. CPS has supervised the works and continues to operate the resulting arrangements. As a separate contract, Sanef now collect the crossing charge on behalf of Highways England.

6.2. Atkins acted as design consultant to CPS and provided the reference design and specification and support through the implementation process and initial operation.

6.3. A technical assurance team comprising DTBTech (Dan Blackburn), Ian Routledge Consultancy (Ian and Peter Routledge) and PTC (Mark Pleydell) provided technical assurance to Highways England and CPS through the reference design development, implementation and initial operation.

6.4. The contract was a design build contract with Balfour Beatty as the Contractor with SSL providing technical design and support. System / equipment suppliers are as follows:

a) Barriers supplied by Automatic Systems;
b) TMCCS supplied by SSL;
c) Traffic signal controllers and infrastructure supplied by MOTUS; and
d) Traffic signal heads including intelligent amber/green arrows by Aldridge.