CLIENT PROJECT REPORT CPR2000

Use of MS4 Variable Signs and Signals to Display Signs for Advance Warning of Road Works
Final Report - December 2014

P A Morgan, B Lawton and C Wallbank (née Reeves)
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Executive summary

Introduction

The Traffic Signs Manual Chapter 8 Part 1: Design (2009) gives guidance for relaxation scheme road works which involve the temporary closure of one or more lanes on the carriageway. Advance warning signs are placed in the approach and lane change zones of road works, in order to inform road users that there are road works ahead, and also which of the lanes remain open to traffic and which will be closed to traffic. Supplementary guidance to Chapter 8 provides a number of alternative Temporary Traffic Management (TTM) techniques which use a reduced number of advance warning signs provided on A-frames at ground level.

Advance warning signs are typically placed on the verge (nearside) 1 mile, 800m, 600m, 400m and 200m in advance of the first cone of the entry taper of the lane closure. For single offside or nearside lane closures on dual carriageway roads where the national speed limit applies, advance warning signs can alternatively be placed both on the verge and on the central reserve (offside) 1 mile, 800m and 400m in advance of the first cone.

These TTM techniques for relaxation scheme road works still require road workers to set out these advance warning signs, an activity which exposes them to high risk. Therefore further alternative measures for providing advance warning signs in order to inform road users that there are road works ahead – including which of the lanes remain open to traffic and which will be closed to traffic – are being developed.

Consequently, a programme of work was initiated to investigate the feasibility of using electronic Variable Signs and Signals (VSS), which are installed across the network and currently used to manage incidents and events, in place of conventional signs on A-frames at ground level to display lane closure information. This research project has specifically sought to evaluate the use of MS4 Variable Message Signs (VMS).

The specific outcomes that the Agency was seeking from this task were:

- **Outcome 1**: Evidence of whether lane closure information displayed on MS4 VMS for advance warning of road works on relaxation scheme works are as effective as (or better than) existing methods (i.e. Chapter 8 and IAN 150/14 Revision 2 TTM) in terms of driver behaviour;

- **Outcome 2**: Evaluation of the risk benefits to road workers associated with the elimination of the placement, maintenance and removal of temporary advance signing.

- **Outcome 3**: An understanding of likely implications for – and impacts on – the Traffic Officer Service (TOS), which is responsible for the management of VSS, if road works were to be routinely signed using MS4s.

As well as fulfilling the specific objectives described above, additional tasks were carried out as part of this project, such as a review of literature exploring the effect of different signing on driver behaviour on the approach to road works.
Methodology

The assessment of the effectiveness of MS4s as the sole means of signing works was achieved primarily by analysing traffic behaviour during a series of lane closures signed using the existing method (control) in use at the time of the trial and comparing this against driver behaviour during a series of lane closures signed using MS4 VMS (experimental).

The sampling design created for the trial was based around experience gained from previous signing trials and involved the proposed collection of 15 nights of data for single lane nearside (lane 1) closures and 15 nights of data for single lane offside (lane 3) closures for both control and experimental conditions. A balanced design was proposed to ensure that variations in traffic flow, composition and driver behaviour throughout the week were controlled as far as possible.

Covert video recording, using camera systems provided by TRL (the UK’s Transport Research Laboratory), allowed the measurement of traffic flows and the effect of signing the works using MS4s on driver lane choice and behaviour.

The Measurement of Injury Risk (MIRi) Index applies to the deployment and retrieval of TTM for relaxation closures, considering the risk to road workers only.

The MIRi tool quantifies risk using three factors:

- Likelihood of collision
- Duration of exposure
- Severity of injury in such collisions

The scores generated by the tool provide an indication of the relative risk to road workers when installing and removing TTM using various techniques including those already in widespread use by the Traffic Management (TM) industry.

Using the tool quantifies the risk to road workers associated with installing and removing TTM only and does not take into account differences to the risk associated with working within a closure.

The omission of conventional signs on A-frames at ground level in advance of the road works was examined using the principles of the MIRi Index. In terms of the risk to road workers, this replicates the scenario in which suitable advance signing for drivers is provided by VSS instead.

The likely implications for – and the impacts on – the TOS which is responsible for the management of VSS were considered in terms of both the availability of the technology infrastructure and staffing resources through an analysis of data and feedback from East Regional Control Centre (ERCC) staff.

Conclusions

The on-road trial was successful in demonstrating that the use of MS4 VMS to display the advance warning of lanes open and lanes closed for road works are at least as effective as IAN 150/14 Revision 2 and Chapter 8 TTM. In this respect the on-road trial provided confidence that Outcome 1 was achieved.
For nearside (lane 1) closures, the results showed that the pattern of vehicles changing lanes between the 800m to 400m distances did not differ between the experimental and control groups, and that the pattern of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign did not differ between the experimental and control groups.

For offside (lane 3) closures, the results showed that the pattern of vehicles changing lanes between the 800m to 400m distances did not differ between the experimental and control groups. The pattern of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign differed in the middle lane, which was not safety-critical.

The MIRi Index estimates that the risk to road workers when installing and removing TTM using only MS4s to provide advance warning signing is 18% lower for nearside closures than when using Off Side Signs Removal, and 30% lower for offside closures than when using Sign Simplification. It is safer still relative to the risk to road workers when installing and removing a full Chapter 8 relaxation layout.

The risk reduction in the case of MS4s arises from the reduction in total time it takes to install/remove the closure and the elimination of carriageway crossings to install the advance warning signs. Outcome 2 was therefore successfully demonstrated.

With regard to Outcome 3, the on-road trial provided an understanding of the likely impact upon the TOS and the dependency this technique will have on MS4 VMS availability.

The greatest impact upon the TOS is related to the level of resource that was required for this trial to constantly monitor the accuracy of the electronic setting displayed on the MS4s. Availability of fully functional MS4s (i.e. ones not exhibiting faults) was relatively low, with 29% of the required MS4s – and subsequently 66% of planned trials – being affected by a fault on one or more of the MS4s. The trial did not observe any occurrence where the availability of the MS4s was affected due to normal operations i.e. by an unplanned incident.

**Recommendations**

The reliability of the MS4s is currently likely to be insufficient for them to be used as the sole method for signing relaxation works, irrespective of whether this approach is comparable to using ground level signing in terms of road user behaviour.

Assuming these technological issues can be resolved, other changes to the current way of working would also be required to ensure that MS4s can be used to provide drivers with suitable advanced warning of road works. For example, the Agency would require a system which is intelligent enough and flexible enough to allow simultaneous signalling of incidents and road works. A dedicated system alarm for any VSS in use as the sole method for signing road works would also be beneficial.

Other approaches that would represent a more significant shift from the current approach to managing VSS could mitigate the risk associated with this approach. For example:

- Management of VSS used to sign road works from a centralised unit, so that all Regional Control Centre (RCC) operators are able to operate all VSS across the network. This would make it more likely that an RCC operator would be available to deal with a VSS failure immediately that this is alerted.
• Providing on-road staff with alerts directly when the VSS relevant to their works fails. This would remove the risk of a delay in an RCC operator informing on-road staff of the failure.

• Providing TM staff with the ability to control the relevant VSS in full, whether temporarily or otherwise. This would ensure that TM staff fully own the risk to on-road staff that would be associated with VSS failure. This could include testing of the relevant VSS in advance. This approach would require appropriate protocols for control of the VSS to be handed over temporarily from National Traffic Information Centre (NTIC) and the RCC to TM staff, so that they do not unwittingly overwrite the VSS. Although this approach is not dissimilar to the current situation, TM staff would be less likely to be aware of what is occurring on adjacent sections of the network, so this might introduce the risk that an incident close to the works is not signed.
1 Introduction

This report forms the final deliverable for Task 098 (4/45/12), Use of MS4 Variable Signs and Signals to Display Signs for Advance Warning of Road Works.

1.1 Background

The Traffic Signs Manual (TSM) Chapter 8 Part 1: Design (Department for Transport, 2009) gives guidance for relaxation scheme road works which involve the temporary closure of one or more lanes on the carriageway. Advance warning signs are placed in the approach and lane change zones of road works, in order to inform road users that there are road works ahead, and also which of the lanes remain open to traffic and which will be closed to traffic.

On dual carriageway roads to which the national speed limit applies, TSM Chapter 8 Part 1: Design indicates, in Plan DZB6, that advance warning signs should be placed on the verge (nearside) and on the central reserve (offside) in the approach and lane change zones ahead of road works for both nearside and offside lane closures. These should be located 1 mile (Diagram 7001/7001.1) in advance of – and 800m, 600m, 400m and 200m (Diagram 7202/7208) in advance of – the first cone of the entry taper of the lane closure, as illustrated in Figure 1.1 for a single offside lane closure.

Supplementary guidance to Chapter 8, in the form of Interim Advice Note 150/14 Revision 2 (Highways Agency, 2014), provides a number of alternative Temporary Traffic Management (TTM) techniques which use a reduced number of advance warning signs provided on A-frames at ground level.

Advance warning signs are typically placed on the verge (nearside) 1 mile, 800m, 600m, 400m and 200m in advance of the first cone of the entry taper of the lane closure. For single offside or nearside lane closures on dual carriageway roads where the national speed limit applies, advance warning signs can alternatively be placed both on the verge and on the central reserve (offside) 1 mile, 800m and 400m in advance of the first cone. Both layouts are illustrated in Figure 2.1 and are considered operationally valid alternatives to the layout shown in Figure 1.1 (Highways Agency, 2014).

These TTM techniques for relaxation scheme road works still require road workers to set out these advance warning signs, an activity which exposes road workers to high risk.

Figure 1.1: Example Chapter 8 signing layout for an offside (lane 3) closure
Therefore further alternative measures for providing advance warning signs in order to inform road users that there are works ahead – including which of the lanes remain open to traffic and which will be closed to traffic – are being developed.

Consequently, a programme of work (known as the 1C Road Worker Safety Programme) was initiated to investigate the feasibility of using electronic Variable Signs and Signals (VSS), which are installed across the network and currently used to manage incidents and events, in place of conventional signs on A-frames at ground level to display lane closure information. This research project (known as 1C3) has specifically sought to evaluate the use of MS4 Variable Message Signs (VMS). Utilising the MS4s in place of signs provided on A-frames at ground level has the potential to reduce road worker exposure to risk.

Current TSM Chapter 8 guidance states that gantry signals (and, by implication, MS4s) may be used to support temporary signs (Paragraph D6.13.5) but cannot be used in place of temporary signs. This approach therefore represents a shift away from the guidance given in Chapter 8 both in terms of conventional signing and the use of VSS.

1.2 Task objectives

The overall task objective was to evaluate, via a series of on-road trials and desktop studies the use of MS4 VMS to display the advance warning of lane closures for relaxed scheme works.

The specific outcomes that the Agency was seeking from this task were:

- **Outcome 1**: Evidence of whether lane closure information displayed on MS4 VMS for advance warning of road works on relaxation scheme works are as effective as (or better than) existing methods (i.e. Chapter 8 and IAN 150/14 Revision 2 TTM) in terms of driver behaviour;

- **Outcome 2**: Evaluation of the risk benefits to road workers associated with the elimination of the placement, maintenance and removal of temporary advance signing.

- **Outcome 3**: An understanding of likely implications for – and impacts on – the Traffic Officer Service (TOS), which is responsible for the management of VSS, if road works were to be routinely signed using MS4s.

As well as fulfilling the specific objectives described above, additional tasks were carried out as part of this project, such as a review of literature exploring the effect of different signing on driver behaviour on the approach to road works. This literature review is contained in Appendix A and Appendix B.

1.3 Structure of this report

Within this report:

- Section 2 sets out the signing layouts used for the control trials (conventional signs on A-frames at ground level only) and experimental trials (MS4s only).

- Section 3 presents the methodology used for managing the on-road trials, including details of:
the measures taken to ensure the safety of the trials,
- the resourcing and responsibilities of those involved in the trials,
- the selection of trial locations,
- the different phases of the experimental trials, and
- the approach adopted to capture data.

- Section 4 details the results of the trials in terms of the data collected and the statistical analysis undertaken. This addresses **Outcome 1**.

- Section 5 evaluates the risk benefits to road workers associated with the elimination of the placement, maintenance and removal of temporary advance signing as a result of the use of MS4s to sign road works. This addresses **Outcome 2**.

- Section 6 investigates the potential impacts on operational requirements were MS4s to be routinely used to sign road works, including the availability of technology infrastructure and staff resources. This addresses **Outcome 3**.

- Section 7 presents the conclusions and recommendations based upon the findings of all of the elements of the project.
2  Signing of on-road trials: ground level signs and MS4s

This section outlines the signing layouts which were used in order to achieve the objectives and outcomes of this task, as stated in Section 1.2. Trials of using MS4s to sign relaxation scheme lane closures were investigated for both nearside (lane 1) and offside (lane 3) closures.

2.1  Control trials layout

Ground level signs to Diagrams 7001, 7001.1, 7202 and 7208 in the Traffic Signs Regulations and General Directions 2002 (TSRGD; Great Britain, 2002) were placed in the approach and lane change zones of the road works, in order to inform road users of the road works ahead and to indicate which lanes were open to traffic, and which were closed.

The Off Side Signs Removal layout (OSSR), detailed in IAN 150/14 Revision 2 and illustrated in Figure 2.1(a), was used consistently across all nearside (lane 1) closure control trials. Similarly, the Sign Simplification layout, detailed in IAN 150/14 Revision 2 and illustrated in Figure 2.1(b), was used consistently across all offside (lane 3) closure control trials. (At the time of control data collection, IAN150/12 (Highways Agency, 2012) was the extant version of IAN150 and did not permit the use of OSSR for offside lane closures.)

Figure 2.1: Control layouts for nearside (lane 1) and offside (lane 3) single lane closures
2.2 Experimental trials layout

For the experimental trials, all the advance warning signs at ground level were replaced by displays on the first three MS4s upstream of the first cone of the taper, as shown in Figure 2.2 and Figure 2.3.

Figure 2.2 shows the MS4 layouts used for nearside (lane 1) closures during the experiment, and Figure 2.3 shows the corresponding MS4 layouts for offside (lane 3) closures during the experiment.

![Diagram showing MS4 layouts for single nearside (lane 1) closure]
Figure 2.3: Experimental layout for a single offside (lane 3) closure

The location of the first cone of the taper was fixed so that it was 400m downstream of the last MS4 before the works. The position of the other two MS4s used was allowed to vary within the ranges displayed because the MS4s on this section are not sited at fixed intervals.
3 Trials methodology

The trials were carried out on the M4 in Area 3 of the Highways Agency’s strategic road network by the following parties:

- **TRL**, who were responsible for coordinating, monitoring, analysing and reporting the trials.
- **EM Highways**, the Asset Support Contractor (ASC) for Area 3, who were responsible for traffic management and related activity (e.g. maintenance).
- The Traffic Officer Service’s (TOS) **East Regional Control Centre (ERCC)** who were responsible for the operation and management of the MS4s used in the trials.

3.1 Ensuring the safety of the on-road experimental trials

The safety of both on-road staff and road users is fundamental to any on-road trial, and the nature of these on-road trials required a detailed understanding and management of the likely risks. A number of safety measures were therefore put in place to ensure the risks were reduced so that they were As Low As Reasonably Practicable (ALARP):

- The **1C Governance Board** was used to manage the policy, procedural and operational requirements of the on-road trials associated with the 1C Road Worker Safety Programme.
- A **Trials Delivery Team** was established to oversee the 1C3 task specifically, to identify and review the risks associated with the trials, and to design appropriate mitigations to manage the risks ALARP. This team consisted of key individuals from TRL, EM Highways and the Agency (both the Network Delivery and Development directorate and the Traffic Officer Service based at the East RCC).
- A **Safety Report** (TRL, 2014) was produced by the Trials Delivery Team to document how the on-road trials would be undertaken, and to provide evidence that all risks during the experiment were managed ALARP. The production of this ensured that:
  - all foreseeable ‘undesirable events’ and hazards were identified and considered,
  - practicable control measures were implemented:
    - to minimise the likelihood of undesirable events/hazards occurring, and
    - to minimise their impact should they still occur.

The hazards and mitigations were documented in a hazard log contained within the Safety Report. This hazard log is presented in Appendix C. This was reviewed and signed off by the 1C Governance Board prior to the commencement of the experimental trials.

The Safety Report also identified the specific actions associated with the planning, management and operation of the trials, and assigned roles and responsibilities for these actions to specific individuals within the Trials Delivery Team.
The Safety Report was a 'live' document which was regularly reviewed and updated over the course of the trials to ensure that it remained applicable and fit for purpose. Where necessary, protocols and practices were updated and/or added to ensure that the trials could be undertaken safely.

3.2 Provision of resources

Ensuring that the on-road trials were undertaken safely required that TRL, EM Highways and the ERCC provided equipment, expertise, facilities and staff to support the trials. These resources were as follows:

3.2.1 TRL monitoring resource

During the project, TRL coordinated the trials and acted as the independent monitoring body; as such, TRL provided:

- The experimental design.
- Support to the approvals process required to enable the trial to commence.
- Suitable camera equipment to record driver behaviour.
- Support to operational trials including coordination of the Trials Delivery Team.
- Analysis of video footage to obtain traffic counts (including HGVs) for both control and experimental conditions.
- Data handling, management and storage for the duration of the trial.
- Data analysis, interpretation and reporting of the results of the project.

3.2.2 EM Highways resource

During the project, EM Highways carried out the trials and, as such, provided:

- The identification of safe taper locations for deployment of the control and experimental layouts, based on proposals from TRL in accordance with the site selection criteria in Section 3.3.
- A generic risk assessment, followed by site-specific risk assessments and method statement preparation associated with on-road implementation of the experimental condition.
- Dedicated resources, in accordance with the trial protocols set out in the Safety Report:
  - On-road: A dedicated TTM Leader, responsible for the deployment of monitoring equipment in accordance with the risk assessment/method statement for this activity.
  - In the Regional Control Centre (RCC): An EM Highways Staff Member to support operational risk controls and provide an insight to the RCC Dedicated Operator (see Section 3.2.3) of on-road working practices during the trials.
- The deployment and retrieval of camera equipment (see Section 3.5).
• Appropriate data from each site/layout, with particular attention given to ensuring memory cards from camera systems were returned with accurate identifying information (sign distance, time and date).

• Observations of traffic behaviour as required.

• Supporting data regarding weather, visibility, topography, etc.

• The deployment and retrieval of all associated TM equipment.

3.2.3 East Regional Control Centre resource

During the project, the ERCC operated and managed the MS4s used in the trials and, as such, provided:

• Advance testing of trial MS4s to identify potential faults/issues in response to requests from TRL.

• A Dedicated Operator who, on each trial night, had sole responsibility for setting, monitoring and clearing the MS4s being used in that night's trial.

3.3 Site selection criteria

Initially, the full length of the M4 within Agency Area 3, i.e. from junction 5 to junction 15, was considered for use in the trials. The section between junction 5 and junction 7 (both carriageways) was quickly ruled out due to the absence of regular MS4s. Similarly, the section between Membury Services and junction 15 was ruled out because the MS4s on this section are not controlled by the same RCC as the rest of those on the M4 in Area 3.

Lit sections of motorway were also excluded as lighting would have been an additional explanatory variable that would have required additional data to be collected to ensure that the results were robust.

The section exclusions listed above resulted in the sections between junction 8/9 and junction 10, and between junction 12 and junction 14 being chosen for the on-road trials.

Given the experimental layout, as described in Section 2, various constraints applied to:

• The position relative to the closest MS4.

• The position of upstream MS4s.

• The position relative to junctions.

• Safe taper locations.

• Scheduled works.

All of these conditions applied to the location of the first cone of the taper.

Position relative to the closest MS4

There had to be 400m between the last MS4 before the first cone and the first cone of the taper itself. (Consideration was given to whether this distance might be varied between 300m and 450m, as described in Appendix D, but the other criteria identified meant that
this flexibility would not have provided any additional suitable collection of three consecutive MS4s, or ‘triplet’.)

**Positions of upstream MS4s**

The adjacent MS4 upstream had to be between 1,600m and 2,000m from the first cone of the taper; the preceding MS4 had to be between 2,800m and 3,600m from the first cone of the taper.

**Position relative to junctions**

The works had to be positioned sufficiently far in advance of the next off-slip, and sufficiently far after the end of the previous on-slip, to ensure that the lane-changing behaviour observed during the analysis could be attributed to the signing of the lane closure rather than the presence of the junction. As part of a previous road worker safety project, TRL used Motorway Incident Detection And Signalling (MIDAS) loop data to investigate the lane-changing behaviour of vehicles in relation to junctions. This analysis used loop data from a range of sites which had no road works operational at the time. The analysis examined at what distance the ‘weaving’, where vehicles change lanes after they enter from an on-slip or prepare to exit from an off-slip, could be observed. The aim was to determine the distance it takes for vehicles to ‘settle down’ into the appropriate lane. The results concluded that the separation distances required were

- at least 1.0 km from the end of the previous upstream on-slip or dedicated slip road to the 1 mile sign in the control trials, or to the most upstream of the three MS4s in use in the experiment (signing 50 / 'Workforce in road – Slow'), and

- at least 1.5 km from the first cone of the taper to the start of the next downstream off-slip or dedicated slip road.

These distances are illustrated in Figure 3.1 and these criteria were applied to this trial.
Use of MS4s to Sign Road Works

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Figure 3.1: Positional criteria for trial locations relative to junctions

Safe taper locations

Locations suitable for the trial had to comply with EM Highways’ criteria for safe taper locations. EM Highways therefore assessed each of the suitable locations as part of its site-specific risk assessment to ensure that no unsafe taper locations were proposed. EM Highways made the final decision of whether a location was appropriate based on an appraisal of the safety of their operatives and of road users.

Table E.1 in Appendix E presents the suitable safe taper experimental trial locations on the eastbound carriageway and locations of the associated three MS4s; Table E.2 identifies the suitable safe taper experimental trial locations on the westbound carriageway.

Scheduled works

Traffic management cannot normally be used solely for a trial. EM Highways therefore continually reviewed its Schedule of Road Works (SRW) to identify planned works which could be used for the experiment, with the taper located in accordance with all of the criteria described above. The use of any single location was dependent on the availability of
scheduled works at an appropriate location to allow a suitable lane closure to be put in place.

### 3.4 Operational methodology during the installation and removal of TTM

Within this project, the assessment of the effectiveness of MS4s as the sole means of signing works (reported in Section 4) was achieved primarily by analysing traffic behaviour during the period between completing the installation of the TTM associated with the trial closure and commencing removal of the TTM once the associated works had been completed.

The Trials Delivery Team agreed to adopt a phased approach to the experimental trials to allow the investigation to gain some understanding of road worker risk during the installation and removal of TTM. This phased approach was as follows:

- The trial signals on the MS4s were activated prior to the installation of any temporary traffic management (TTM).
- Conventional signs on A-frames at ground level were installed on the nearside of the carriageway prior to the installation of the taper and longitudinal run, using the OSSR layout shown in Figure 2.1.
- **Phase 1**: The closure was installed and removed using both conventional signs on A-frames at ground level and MS4s to inform road users of the closure. Once the closure was in place, it was signed by the MS4s only (i.e. the conventional signs were concealed such that they could be reinstated promptly in the event of a failure of the MS4s).
- **Phase 2**: The closure was installed and removed using only the MS4s to inform road users of the closure. Once the closure was in place, it was signed by the MS4s only, and works were performed in the closure.

The switches from Phase 1 to Phase 2 occurred only when all parties were content to proceed to the next phase.

The phased approach enabled operatives to migrate from the current approach to the envisaged approach gradually. Feedback was gathered from the operatives on both the installation and removal of TTM when only the MS4s were in use to inform road users of the lane closure. This feedback was supported by video footage, though this was not analysed systematically in the same way as footage from the closure was when in situ.

### 3.5 Data capture criteria and methodology

The sampling design created for the trial was based around experience gained from previous signing trials and involved the proposed collection of 15 nights of data for single lane nearside (lane 1) closures and 15 nights of data for single lane offside (lane 3) closures for both control and experimental conditions. A balanced design was proposed to ensure that variations in traffic flow, composition and driver behaviour throughout the week were controlled as far as possible.
Covert video recording, using camera systems provided by TRL, allowed the measurement of traffic flows and the effect of signing the works using MS4s on driver lane choice and behaviour.

Cameras mounted on nearside sign frames were positioned as follows:

- **Control conditions** (Figure 3.2a): Cameras were mounted at 1,600m, 800m and 400m before the start of the taper, corresponding to these three sign points. A camera was also positioned in line with the first cone of the taper.

- **Experimental conditions** (Figure 3.2b): Cameras were mounted at the three MS4s upstream of the taper, corresponding to these three sign points. Cameras were also mounted at 800m before the start of the taper and in line with the first cone of the taper as for the control conditions. An additional camera was sited 200m before the start of the taper; this was intended solely as a back-up for observing driver behaviour in the vicinity of the Impact Protection Vehicle (IPV) in the event of an incident during the installation of the traffic management under MS4s only (Phase 2; see Section 3.4).

![Figure 3.2: Video imaging locations used for control lane closures](image)
Typical camera images are shown in Figure 3.3 and Figure 3.4 from control and experimental trials respectively.

![Figure 3.3: Camera view from the 1,600 yards advanced sign position (control)](image)

![Figure 3.4: Camera view from the 1,600-2,000 yards MS4 position (experiment)](image)

Each camera system was uniquely identified corresponding to an A-frame sign measurement distance. TRL provided labelled storage cases to assist with the accurate return of camera data.
4 Outcome 1 – trials data analysis

The camera systems placed through the approach to the works site, as described in Section 3.5, provided video footage which was reviewed by trained analysts.

For closures for which the relevant video footage was successfully obtained, video footage was available for between 45 and 120 minutes for each trial night. This allowed driver behaviours such as traffic flow and lane occupancy to be quantified throughout the advance sign zone. While reviewing the video, the following variables were recorded:

- Vehicle count, by lane.
- HGV percentage (of total flow).
- Details of taper running.
- Details of any incidents or occurrences.

‘Taper running’ was defined as any vehicle remaining within a closed lane beyond (downstream of) the first cone placed as part of the closure of that lane.

An ‘incident or occurrence’ was defined as:

- A vehicle impact with TM equipment, or any other collision.
- Evasive action by a vehicle or because of action by others.
- Swerving, an extreme direction change.
- Dangerous driving, e.g. racing, blocking, lane hogging, obvious excess speed.
- Braking, in particular sustained brake lights, possibly with obvious change of speed.
- Late/poor merge, i.e. forcing into traffic in adjacent lane.
- Excessive traffic within 200m of the taper in the experimental condition relative to the control condition.

When incidents or occurrences were observed during the video analysis following each trial night, the Trials Delivery Team was informed of what was observed. This enabled the Team to decide whether its protocols needed to be modified before proceeding with future trial nights.

4.1 Taper running

4.1.1 Offside (lane 3) closure results

Video data for taper running were collected from 15 control and 13 experimental closures.

- During the 15 control closures, a total of 116 taper runs were identified. This equates to 0.7% of the total vehicles studied during the trials running the taper.
- During the 13 experimental closures, a total of 17 taper runs were identified, which equates to 0.2% of all vehicles.

The proportion of vehicles taper running experienced in the experimental condition was slightly lower than in the control. The difference in these proportions may be explained by
the slightly smaller proportion of vehicles still in the closed lane, lane 3, 400m from the taper in the experimental condition (see Table 4.5).

4.1.2 Nearside (lane 1) closure results

Video data for taper running were collected from 14 control and 12 experimental closures.

- During the 14 control closures, a total of 300 taper runs were identified. This equates to 2.1% of the total vehicles studied during the trials running the taper.
- During the 12 experimental closures, a total of 119 taper runs were identified, which equates to 1.0% of all vehicles.

The proportion of vehicles taper running experienced in the experimental condition was slightly lower than in the control. The difference in these proportions may be explained by the slightly smaller proportion of vehicles still in the closed lane, lane 1, 400m from the taper in the experimental condition (see Table 4.10).

4.2 Incidents or occurrences

For both offside (lane 3) and nearside (lane 1) closures, as described above, there were several instances of taper running in both the control and experimental conditions. However, there were no reported taper strikes during any of the trials.

No other incidents or occurrences were noted during video analysis of either control or experimental closures. No incidents were reported by TTM crews or supervisors, or by an RCC operator.

4.3 Research questions

Two main research questions were considered within the analysis of driver behaviour in the on-road trials.

1. Was there a difference in the locations at which drivers chose to change lane, relative to where the road works were, between when works were signed using only conventional signs on A-frames at ground level (control conditions) and using only MS4s (experimental conditions)?

This was the primary research question and considered driver behaviour in the last 800m before the taper i.e. within the ‘normal’ advance sign zone for relaxation works. The change in the position of the lane closure information between the control and experimental conditions was not relevant to this research question.

Figure 4.1 shows the comparison points (camera pairs) between the control and experimental conditions for this research question.
2. Was there a difference in the locations at which drivers chose to change lane, relative to where drivers received information about the lane closure, between when works were signed using only signs on A-frames at ground level (control conditions) and using only MS4s (experimental conditions)?
This was the secondary research question and considered whether drivers changed lane earlier in the experimental condition as a result of receiving lane closure information further in advance of the taper.

Figure 4.2 shows the comparison points (camera pairs) between the control and experimental conditions for this research question.
4.4 Method

The statistical technique used to test both research questions was a repeated measures ANOVA. An ANOVA tests whether there is a statistically significant difference between a number of mean values. A repeated measures analysis is required in this case as the same vehicles, broadly speaking, were counted at four different points.

For research question 1: There were a number of different factors in the statistical model created for this analysis – lane closed (L1 or L3), trial type (control or experimental) and distance from the taper (800m or 400m). The repeated measures ANOVA detects statistically significant differences within each factor, for example whether the change in the number of vehicles in each lane varied by trial type.

To answer this research question, the three-way interaction between lane, distance from the taper and trial type was examined to identify whether the pattern of vehicles changing lanes relative to the location of the road works differed between the experimental and control groups.

For research question 2: Although two factors used in the model were the same as for the first research question, i.e. lane closed (L1 or L3) and trial type (control or experimental), the third factor was the information point. This compares the relative position at which drivers are provided with specific sets of information regarding the lane closure, namely the information that there are road works ahead, and the points at which information about which lane is closed is provided. The analysis used data collected as follows:

- Within the control condition, data were collected at the signs at 1,600m (the ‘1 mile road works’ sign), 800m (the ‘800 yards’ wicket sign) and 400m (the ‘400 yards’ wicket sign) from the first cone of the taper.
- Within the experimental condition, data were collected at the three MS4 positions, i.e. the most upstream MS4, the middle MS4 and the MS4 400m from the first cone of the taper.

The 1,600m control data and most upstream MS4 data were used as the baseline values for the volume of traffic in each lane – the road works were assumed to have had no effect on lane choice at these points because road users did not receive any information about which lane was closed until downstream of these points.

To answer the research question, the interaction between the three factors (lane, sign number and trial type) was examined to identify whether the pattern of lane-changing differed between the experimental and control groups relative to where the lane closure information was provided to drivers.

4.5 Lane occupancy data

The main control and experimental data were the counts of vehicles in each of the three lanes at each measurement point before the start of the lane closure. Vehicles were counted for between 45 minutes and two hours at each site (dependent on the video footage available) for each trial night for which the relevant video footage was successfully obtained.
4.5.1   Offside (Lane 3) Closure Results

4.5.1.1   Research Question 1

The full results for the single factor and two way interactions in relation to offside (lane 3) closures are presented in Appendix F.1. However, the main interaction of interest was the three factor interaction presented below.

\[ \text{Distance from taper} \times \text{trial} \times \text{lane} \text{ is not significant (p}>0.10) \]

Taking into account all other factors and interactions the interaction between distance from taper, trial and lane was not significant. That is, the distribution of vehicles changing lanes between the 800m to 400m distances did not differ between the experimental and control groups.

Figure 4.3 shows the proportions of vehicles at each distance from taper in the control and experimental conditions in lanes 1, 2 and 3 for offside (lane 3) closures.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.3.png}
\caption{Proportion of vehicles in each lane by distance from taper and trial for offside (lane 3) closures}
\end{figure}

At 800m, the proportion of vehicles in lane 1 was already slightly lower in the experimental condition than the control (2% compared to 5%); this indicates that receiving information earlier and via MS4s rather than conventional ground-level signs led to a slightly higher proportion of drivers moving out of this lane prior to the 800m marker. At 400m, the same pattern was maintained with a slightly smaller proportion of vehicles in lane 1 in the experimental condition than the control (2% compared to 3%).

---

1 Statistical significance is classified into two categories within this report. A p-value of <0.05 indicates a 95% confidence that this result is significantly different. A p-value <0.10 indicates that the result is significantly different, but only at the lower 90% confidence level.
each pair of lines is very similar which indicates that, during the last 800m before the taper, lane changing behaviour was very similar between the control and experimental conditions.

Table 4.1 shows the proportion of vehicles in each lane 400m from the taper for the offside (lane 3) control and experimental conditions. At this distance the effect of the taper on driver lane choice should have been the same for both control and experimental conditions. This was also the last point at which drivers received information about which lane was closed in both the control and experimental conditions. Therefore, it is likely that the slightly lower proportion of vehicles in the closed lane in the experimental condition was attributable to the effect of the MS4s compared to the conventional advance signs.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>56.8%</td>
<td>63.2%</td>
</tr>
<tr>
<td>Lane 2</td>
<td>40.0%</td>
<td>35.2%</td>
</tr>
<tr>
<td>Lane 3</td>
<td>3.2%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Table 4.1: Proportion of vehicles in each lane 400m from the taper, offside (lane 3) closures

**Traffic flows**

The sites had a good mixture of traffic flows from 173 to 1096 per hour in all lanes 400m from the taper. High, medium and low flows were shared across experiment and control sites as shown in Table 4.2. The unbalance is discussed below and controlled for in Table 4.5.

<table>
<thead>
<tr>
<th>Traffic flow (vehicles per hour)</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-300)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Medium (300-550)</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>High (550+)</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 4.2: Number of control and experimental trials by traffic flow, offside (lane 3) closures

In order to determine if there was a significant difference in the distribution of flows across control and experimental conditions, a Mann-Whitney test was carried out. The Mann-Whitney test was significant (p<0.10), hence there was a statistically significant difference in the median flows for the control and experimental groups for the offside (lane 3) closures. By removing a selection of the sites (Table 4.5) the flow could be balanced between the two groups.
Day of the week

During the trial, control and experimental data were collected from relaxation closures on Monday to Friday nights. Data were not collected from closures at the weekend as the majority of closures occur on weekdays and the data collected needed to be representative of typical closures across the network.

Although every effort was made to ensure the day of the week on which experimental and control trials were conducted was the same in both cases, there were slight differences. The distribution of trials by day of the week is given in Table 4.3. The slight unbalance is controlled for in Table 4.5.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Tuesday</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Wednesday</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Thursday</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Friday</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

Table 4.3: Number of control and experimental trials by day of the week, offside (lane 3) closures

HGV count

Heavy goods vehicles may have an effect on lane changing behaviour under control conditions, since they may obscure nearside signs from other road users.

The number of heavy goods vehicles was also recorded for both experimental and control sites to determine if there was a significant difference in the number of heavy goods vehicles between the two groups.

The sites had a range of HGV flows from 43 to 130 per hour in all lanes at the taper. High, medium and low rates were shared across experimental and control sites as shown in Table 4.4. The unbalance is discussed below and controlled for in Table 4.5.

<table>
<thead>
<tr>
<th>HGV flow (vehicles per hour)</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-75)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Medium (75-90)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>High (90+)</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

Table 4.4: Number of control and experimental trials by HGV flow, offside (lane 3) closures
In order to determine if there was a significant difference in the distribution of HGV flows across control and experimental conditions, a Mann-Whitney test was carried out. The Mann-Whitney test was not significant (p>0.10); hence, there was no difference in the median HGV flows for the control and experimental groups for the offside (lane 3) closures.

**Site selection**

The ANOVA results described above were based on 15 control sites and 13 experimental sites. In order to corroborate these results, the analysis was rerun several times removing a selection of sites (shown in Table 4.5) for different reasons. The result of the analyses with each selection of sites was stable to small unbalances to the study design.

<table>
<thead>
<tr>
<th>Extra analysis type</th>
<th>Remove sites</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly flow rates</td>
<td>n/a</td>
<td>As the counts were based on vehicle counts of between 1 and 2 hours, each count was divided by the number of hours surveyed to give an hourly flow rate.</td>
</tr>
<tr>
<td>Balanced traffic flow</td>
<td>1, 2, 3, 6, 7, 13, 15, 17, 18, 19, 20, 22, 23 &amp; 25</td>
<td>A random selection of sites were removed in order to have 2 experiment and control sites in the low traffic banding (0-300), 3 of each in the medium band (300-550) and 2 of each in the high band (550+).</td>
</tr>
<tr>
<td>Balanced day of the week</td>
<td>23 &amp; 25</td>
<td>A random selection of sites was removed in order to balance the day of the week on which experimental and control trials were conducted. This analysis was conducted with 3 trials on Monday, 3 on Tuesday, 4 on Wednesday, 2 on a Thursday and 1 trial on a Friday for both experiment and control.</td>
</tr>
<tr>
<td>Balanced HGV flow</td>
<td>3, 5, 15, 23, 27 &amp; 28</td>
<td>A random selection of sites were removed in order to have 3 experiment and 3 control sites in the low (0-75), 3 of each in the medium (75-90) and 4 in the high (90+) hourly HGV rate bands.</td>
</tr>
</tbody>
</table>

Table 4.5: Selection of sites for additional analyses, offside (lane 3) closures

**4.5.1.2 Research Question 2**

The full results for the single factor and two way interactions are presented in Appendix F.2. However, the main interaction of interest was the three factor interaction presented below.

*Information point * trial * lane* significant (p<0.05)

Taking into account all other factors and interactions the interaction between information point, trial and lane was significant. That is, the distribution of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign differed between the experimental and control groups.

Figure 4.4 shows the proportions of vehicles at each sign in the control and experimental conditions in lanes 1, 2 and 3 for the offside (lane 3) closures.

2 After traffic flow was balanced for, the Mann-Whitney test was not significant (p>0.10), hence there was no difference in the median flows for the control and experimental groups.
The significant difference arose because the proportion of vehicles in lane 2 increased across the three sign points in the control condition, whereas the proportion decreased in the experimental condition. For this analysis, however, the crucial lane was the closed lane, lane 3; the proportion in this lane decreased across both control and experimental conditions.

At the most upstream sign, the proportion of vehicles in lane 3 was lower in the experimental condition than the control (3% compared to 6%). At this point, no information about which lane was closed had been presented and the legibility distance of MS4s and wicket signs was far less than the distance to the next sign, thus drivers were unable to see far enough downstream to read the wicket symbol on the next sign. Hence, the difference between the proportion of vehicles in lane 3 between the control and experimental conditions at this sign was likely to be due to chance.

A similar pattern was seen at the middle sign (which displayed the first wicket sign) where 2% of drivers remained in the closed lane, lane 3, in the experimental condition compared to 5% in the control condition.

The crucial measurement point from a safety point of view was the measurement taken close to the taper, as drivers remaining in the closed lane at this point were likely to represent the biggest risk to road workers. As was seen in Figure 4.3, at the 400m sign, fewer drivers were in lane 3 in the experimental condition than in the control condition, i.e. the risk to road workers was potentially less for the experimental offside (lane 3) closures.

Site selection

The ANOVA results described above was based on 15 control sites and 13 experimental sites. As for research question 1, in order to corroborate these results the analysis was rerun several times removing a selection of sites (shown in Table 4.5) for different reasons. The
result of the analyses with each selection of sites was stable to small unbalances to the study design.

4.5.2 Nearside (Lane 1) Closure Results

4.5.2.1 Research Question 1

The full results for the single factor and two way interactions in relation to nearside (lane 1) closures are presented in Appendix G.1. However, the main interaction of interest was the three factor interaction presented below.

Distance from taper * trial * lane not significant (p>0.10)

Taking into account all other factors and interactions the interaction between distance from taper, trial and lane was not significant. That is, the distribution of vehicles changing lanes between the 800m to 400m distances did not differ between the experimental and control groups.

Figure 4.5 shows the proportions of vehicles at each distance from taper in the control and experimental conditions in lanes 1, 2 and 3 for nearside (lane 1) closures.

![Figure 4.5: Proportion of vehicles in each lane by distance from taper and trial for nearside (lane 1) closures](image)

At 800m, the proportion of vehicles in lane 1 was already slightly lower in the experimental condition than the control (36% compared to 38%); this indicates that receiving information earlier and via MS4s rather than conventional ground-level signs led to a slightly higher proportion of drivers moving out of this lane prior to the 800m marker. At 400m, the same pattern was maintained with a slightly smaller proportion of vehicles in lane 1 in the experimental condition than the control (27% compared to 30%).
The slope of the lines for each pair of lines is very similar which indicates that, during the last 800m before the taper, lane changing behaviour was very similar between the control and experimental conditions.

Table 4.6 shows the proportion of vehicles in each lane 400m from the taper for the nearside (lane 1) control and experimental conditions. At this distance the effect of the taper on driver lane choice should have been the same for both control and experimental conditions. This was also the last point at which drivers received information about which lane was closed in the experimental condition and second to last point in the control (as there was also a wicket sign at 200m). Therefore, it is likely that the slightly lower proportion of vehicles in the closed lane in the experimental condition was attributable to the effect of the MS4s compared to the conventional advance signs.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>30.0%</td>
<td>27.3%</td>
</tr>
<tr>
<td>Lane 2</td>
<td>58.1%</td>
<td>58.7%</td>
</tr>
<tr>
<td>Lane 3</td>
<td>11.9%</td>
<td>14.0%</td>
</tr>
</tbody>
</table>

Table 4.6: Proportion of vehicles in each lane 400m from the taper, nearside (lane 1) closures

**Traffic flows**

The sites had a good mixture of traffic flows from 258 to 970 per hour in all lanes 400m from the taper. High, medium and low flows were shared across experiment and control sites as shown in Table 4.7. The slight unbalance is discussed below and controlled for in Table 4.10.

<table>
<thead>
<tr>
<th>Traffic flow (vehicles per hour)</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-300)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Medium (300-550)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>High (550+)</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 4.7: Number of control and experimental trials by traffic flow, nearside (lane 1) closures

In order to determine if there was a significant difference in the distribution of flows across control and experimental conditions, a Mann-Whitney test was carried out. The Mann-Whitney test was not significant (p>0.10), hence there was no difference in the median flows for the control and experimental groups for the nearside (lane 1) closures.
Day of the week

The distribution of trials by day of the week is given in Table 4.8. The slight unbalance is controlled for in Table 4.10.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Tuesday</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Wednesday</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Thursday</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Friday</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Table 4.8: Number of control and experimental trials by day of the week, nearside (lane 1) closures

HGV count

The sites had a range of HGV flows from 50 to 115 per hour in all lanes at the taper. High, medium and low rates were shared across experimental and control sites as shown in Table 4.9. The unbalance is discussed below and controlled for in Table 4.10.

<table>
<thead>
<tr>
<th>HGV flow (vehicles per hour)</th>
<th>Control</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-75)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Medium (75-90)</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>High (90+)</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Table 4.9: Number of control and experimental trials by HGV flow, nearside (lane 1) closures

In order to determine if there was a significant difference in the distribution of HGV flows across control and experimental conditions, a Mann-Whitney test was carried out. The Mann-Whitney test was not significant (p>0.10); hence, there was no difference in the median HGV flows for the control and experimental groups for the nearside (lane 1) closures.

Site selection

The ANOVA results described above were based on 14 control sites and 12 experimental sites. In order to corroborate these results, the analysis was rerun several times removing a selection of sites (shown in Table 4.10) for different reasons. The result of the analyses with each selection of sites was stable to small unbalances to the study design.
Extra analysis type | Remove sites | Description
--- | --- | ---
Hourly flow rates | n/a | As the counts were based on vehicle counts of between 45 minutes and 2 hours, each count was divided by the number of hours surveyed to give an hourly flow rate.
Balanced traffic flow | 5, 15, 18 & 23 | A random selection of sites were removed in order to have no experiment or control sites in the low traffic banding (0-300), 5 of each in the medium band (300-550) and 6 of each in the high band (550+).
Balanced day of the week | 7, 13, 16 & 19 | A random selection of sites was removed in order to balance the day of the week on which experimental and control trials were conducted. This analysis was conducted with 2 trials on Monday, 3 on Tuesday, 3 on Wednesday, 1 on a Thursday and 2 trials on a Friday for both experiment and control.
Balanced HGV flow | 6, 10, 12, 18, 22 & 25 | A random selection of sites were removed in order to have 3 experiment and 3 control sites in the low (0-75), 4 of each in the medium (75-90) and 2 in the high (90+) hourly HGV rate bands.

Table 4.10: Selection of sites for additional analyses, nearside (lane 1) closures

4.5.2.2 Research Question 2

The full results for the single factor and two way interactions are presented in Appendix G.2. However, the main interaction of interest was the three factor interaction presented below.

Information point * trial * lane not significant (p>0.10)

Taking into account all other factors and interactions the interaction between information point, trial and lane was not significant. That is, the distribution of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign did not differ between the experimental and control groups.

Figure 4.6 shows the proportions of vehicles at each sign in the control and experimental conditions in lanes 1, 2 and 3 for the nearside (lane 1) closures. At the most upstream sign, the proportion of vehicles in lane 1 was higher in the experimental condition than the control (56% compared to 47%). At this point, no information about which lane was closed had been presented and the legibility distance of MS4s and wicket signs was far less than the distance to the next sign, thus drivers were unable to see far enough downstream to read the wicket symbol on the next sign. Hence, the difference between the proportion of vehicles in lane 1 between the control and experimental conditions at this sign was likely to be due to chance.

A similar pattern was seen at the middle sign (which displayed the first wicket sign) where 44% of drivers remained in the closed lane, lane 1, in the experimental condition compared to 38% in the control condition. This indicates that the combination of the wicket sign and view of the taper in the control condition may have encouraged more road users to move out of the closed lane at this sign compared to the experimental condition when the taper would not have been in view. The extra distance over which the MS4s would have been visible in the experimental condition (192m compared to 64m for conventional ground level signs - from Clark et al, 2009) was not sufficient to offset the benefit of having the taper in view in the control condition.
The crucial measurement point from a safety point of view was the measurement taken close to the taper, as drivers remaining in the closed lane at this point were likely to represent the biggest risk to road workers. As was seen in Figure 4.5, at the 400m sign, fewer drivers were in lane 1 in the experimental condition than in the control condition, i.e. the risk to road workers was potentially less for the experimental nearside (lane 1) closures.

The slope of the lines suggests that more lane changing took place between the middle sign and the sign at 400m in the experimental condition than in the control condition. However, the distance between signs was greater in the experimental condition than in the control condition (typically 800m-1,600m between MS4s compared to 400m between the 800 yard and 400 yard wicket signs); therefore this lane changing took place over a longer distance.

![Graph showing proportion of vehicles in each lane by sign and trial for nearside (lane 1) closures](image)

Figure 4.6: Proportion of vehicles in each lane by sign and trial for nearside (lane 1) closures

**Site selection**

The ANOVA results described above was based on 14 control sites and 12 experimental sites. As for research question 1, in order to corroborate these results the analysis was rerun several times removing a selection of sites (shown in Table 4.10) for different reasons. The result of the analyses with each selection of sites was stable to small unbalances to the study design.

**4.6 Outcome 1 conclusion**

The first research question investigated whether there was a difference in the locations at which drivers chose to change lane, relative to where the road works were, between control and experimental conditions. This question considered driver behaviour in the last 800m prior to the taper i.e. within the ‘normal’ advance sign zone for relaxation works. The results show that the three way interaction was not significant i.e. the pattern of vehicles changing
lanes between the 800m to 400m distances did not differ between the experimental and control groups.

At 800m, the proportion of vehicles in the closed lane was already slightly lower in the experimental condition than in the control condition (2% compared to 5% for the offside closure, and 36% compared to 38% for the nearside closure); this indicates that receiving information from MS4s earlier in the experimental condition led to a slightly higher proportion of drivers moving out of the closed lane prior to the 800m point. At 400m, the same pattern was maintained with a slightly smaller proportion of vehicles in the closed lane in the experimental condition than in the control condition (2% compared to 3% for the offside closure, and 27% compared to 30% for the nearside closure).

The second research question investigated whether there was a difference in the locations at which drivers chose to change lane, relative to where drivers received information about the lane closure, between the control and experimental conditions. This was a secondary question which determined whether drivers moved over earlier in the experimental condition because they received lane closure information further from the taper. The results showed that the three way interaction was not significant for the nearside (lane 1) closure, but that it was significant for the offside (lane 3) closure i.e. the pattern of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign differed between the experimental and control groups.

The significant difference for the offside (lane 3) closure) appears to have been attributable to the proportion of vehicles in lane 2 increasing across the three sign points in the control condition, but decreasing in the experimental condition. For this analysis, however, the crucial lane was the closed lane, lane 3; the proportion in this lane decreased across both control and experimental conditions.

In the experimental condition, the first measurement point was at the most upstream sign (located between 2,000m and 3,200m from the taper) which displayed ‘Workforce in Road – SLOW’. In the control condition, the first measurement point was at the ‘Roadworks ahead’ sign (located 1,600m from the taper). At the first measurement point the proportion of vehicles in the closed lane was different in the experimental condition than in the control condition (3% compared to 6% for the offside closure, and 56% compared to 47% for the nearside closure). At this point, no information about which lane was closed had been received and the distance to the next sign was far greater than the legibility distance of MS4s and wicket signs; thus drivers were unable to see far enough downstream to read the wicket symbol on the next sign. Hence, the difference between the proportion of vehicles in the closed lane between the control and experimental conditions at this sign was probably due to chance.

In the experimental condition, the final measurement point was the MS4 400m upstream of the taper. In the control condition, the last measurement point was at the 400 yard wicket sign. This was the crucial measurement point from a safety point of view as drivers remaining in the closed lane at this point were likely to represent the biggest risk to road workers. As was seen above, at this point fewer drivers were in the closed lane in the experimental condition than in the control condition i.e. the risk to road workers was potentially reduced.

Removing a selection of sites in order to test the stability of the results indicated that the results were stable to small imbalances in the study design.
The proportion of vehicles taper running was slightly lower in the experimental condition than in the control condition (0.2% of vehicles compared to 0.7% for the offside closure, and 1.0% compared to 2.1% for the nearside closure); this slight difference may be explained by the slightly smaller proportion of vehicles still in the closed lane 400m from the taper in the experimental condition.

No other incidents or occurrences were noted during video analysis of either control or experimental closures for either the offside or the nearside closures. No incidents or taper strikes were reported by TTM crews or supervisors.
5 Outcome 2 – using MS4s to routinely sign road works: Evaluation of the risk benefits to road workers

The Measurement of Injury Risk (MIRi) Index was developed by TRL for the Highways Agency to measure the relative risk of different TTM operations. The index applies to the deployment and retrieval of TTM for relaxation closures, considering the risk to road workers only.

The MIRi tool implements the MIRi Index, quantifying the risk using three factors:

- Likelihood of collision.
- Duration of exposure.
- Severity of injury in such collisions.

The MIRi tool has been used to provide evidence of the potential risk reduction associated with TTM techniques such as Sign Simplification and Off Side Signs Removal (OSSR). The risk mitigation hierarchy in IAN 150/14 Revision 2 (Highways Agency, 2014) was generated using the MIRi tool and this hierarchy has been widely used by Asset Support Contractors (ASCs) / Managing Agent Contractors (MACs) / Design Build Finance Operate (DBFO) contractors across the industry to support their risk assessments when using these techniques.

As documented in the MIRi project report (Morgan, Reeves, Fowler, Lawton, & Smith, 2012), the principles of the MIRi Index can be applied to a number of the Agency’s high priority projects under the Aiming for Zero programme. These scores generated by the tool provide an indication of the relative risk to road workers when installing and removing TTM using these innovative techniques, compared to techniques already in widespread use by the Traffic Management (TM) industry.

The omission of conventional signs on A-frames at ground level in advance of the works was examined using the principles of the MIRi Index. In terms of the risk to road workers, this replicates the scenario in which suitable advance signing for drivers is provided by Variable Signs and Signals (VSS) instead.

Table 5.1 presents the relevant figures for the following methods to examine how the relative risk to road workers differs depending upon the technique used to provide advance warning of road works:

- The use of MS4 signs.
- The use of ground level signs as set out in the supplementary guidance to Chapter 8 (Off Side Signs Removal and Sign Simplification); these were the typical methods used at the time of the trials reported here.
- The use of ground level signs as set out in Chapter 8.

MIRi Index values have been quoted for both single nearside (lane 1) and single offside (lane 3) closures. Note that the MIRi Index scores quoted are for the full process of installation and removal of the closure as a whole, including advanced signing (when applicable), detail A (when applicable), taper, and longitudinal run, and that the MIRi Index takes no account of the effect of any of the techniques on driver behaviour. Using the tool quantifies the risk to road workers associated with installing and removing TTM only and does not take into account differences to the risk associated with working within a closure.
### Table 5.1: MIRi index values for road workers when installing and removing TTM for a single lane closure

<table>
<thead>
<tr>
<th>Risk hierarchy</th>
<th>Technique</th>
<th>MIRi value for a nearside (lane 1) closure</th>
<th>MIRi value for an offside (lane 3) closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technique with higher relative risk</td>
<td>Chapter 8</td>
<td>252,601</td>
<td>299,804</td>
</tr>
<tr>
<td>Decreasing Risk</td>
<td>TTM Sign Simplification</td>
<td>218,367</td>
<td>252,014</td>
</tr>
<tr>
<td></td>
<td>Off Side Signs Removal</td>
<td>188,605</td>
<td>208,696</td>
</tr>
<tr>
<td>Technique with lower relative risk</td>
<td>Use of MS4 signs</td>
<td>155,429</td>
<td>175,520</td>
</tr>
</tbody>
</table>

Based upon the figures in Table 5.1, Table 5.2 summarises the relative risks to road workers for the four TTM techniques relative to the Off Side Signs Removal technique for nearside closures and the Sign Simplification technique for offside closures.

### Table 5.2: Risk in terms of MIRi index values, relative to a closure using Off Side Signs Removal (nearside closure) and Sign Simplification (offside closure), for road workers when installing and removing TTM for a single lane closure

<table>
<thead>
<tr>
<th>Risk hierarchy</th>
<th>Technique</th>
<th>MIRi value relative to a nearside (lane 1) OSSR closure</th>
<th>MIRi value relative to an offside (lane 3) sign simplification closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technique with higher relative risk</td>
<td>Chapter 8</td>
<td>134% (an increase of 34%)</td>
<td>119% (an increase of 19%)</td>
</tr>
<tr>
<td>Decreasing Risk</td>
<td>TTM Sign Simplification</td>
<td>116% (an increase of 16%)</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Off Side Signs Removal</td>
<td>100%</td>
<td>83% (a reduction of 17%)</td>
</tr>
<tr>
<td>Technique with lower relative risk</td>
<td>Use of MS4 signs</td>
<td>82% (a reduction of 18%)</td>
<td>70% (a reduction of 30%)</td>
</tr>
</tbody>
</table>

---

3 MIRi Index values were calculated using MIRi tool Version 1 and were the combined scores for the installation and removal of a TTM closure on a three lane carriageway with a hard shoulder. All figures quoted were based on using a combined TMIPV, signs secured with sandbags. The longitudinal run was assumed to be 500m long with no cone lamps, a single entry, a single exit and no inner boundary. In addition the calculations assumed that, once the advanced signing was in place, the Detail A was set out at the start and end of the taper, the TM operatives then drove round to the start of the TTM and positioned the TM vehicle in lane 3 for the taper installation; the TMIPV enters the closure to install the taper and the taper is built upstream of the vehicle; after installation of the advance signing, detail A (when required), the taper and longitudinal run, the vehicle drove round and the Workforce in Road sign was laid flat, this sign being reassembled before the TTM was removed.
The risk to road workers when installing and removing TTM using only MS4s to provide advance signing is 18% lower for nearside closures than when using Off Side Signs Removal, and 30% lower for offside closures than when using Sign Simplification. It is safer still relative to the risk to road workers when installing and removing a full Chapter 8 relaxation layout.

The risk reduction arises from the reduction in total time it takes to install/remove the closure and, in the case of offside closures, the elimination of carriageway crossings to install/remove the advance signs on both sides of the carriageway.

5.1 Outcome 2 conclusion

The Measurement of Injury Risk Index estimates that the risk to road workers when installing and removing TTM using only MS4s to provide advance signing is 18% lower for nearside closures than when using Off Side Signs Removal, and 30% lower for offside closures than when using Sign Simplification techniques. It is safer still relative to the risk to road workers when installing and removing a full Chapter 8 relaxation layout.

The risk reduction arises from the reduction in total time it takes to install/remove the closure and, in the case of offside closures, the elimination of carriageway crossings to install/remove the advance signs on both sides of the carriageway.
6 Outcome 3 – operational requirements

An understanding of the likely implications for – and the impacts on – the Traffic Officer Service (TOS) which is responsible for the management of Variable Signs and Signals (VSS) is required, namely the availability of both the technology infrastructure and staffing resources. This section considers these through an analysis of data and feedback from East Regional Control Centre (ERCC) staff. The views of EM Highway Services, the Asset Support Contractor (ASC) for Area 3, are also presented as indicative of the views of on-road staff that have experienced this signing regime. The feedback reported here may not necessarily be representative of the views of the wider TOS, ASCs, Managing Agent Contractors (MACs), or Design Build Finance Operate (DBFO) contractors.

6.1 Availability of technology infrastructure

There are two main reasons that affect the availability of the technology infrastructure:

1. The electronic sign is required to support an unplanned incident or event
2. The electronic sign is not functioning i.e. it has a fault

Over the duration of the on-road trials, the availability of the MS4s was found to be significantly lower than had originally been expected exclusively due to the sign not functioning. This section summarises the observations from the trials, and examines the causes of MS4 availability.

6.1.1 Availability due to faults – Observations from the 1C3 trials

The faults on the MS4s that occurred during the trials resulted in complete loss of pictogram and/or message aspects or the loss/distortion of individual characters within a message aspect. They can be categorised into two types:

- **Intermittent faults:** The display set on an MS4 unexpectedly changed or disappeared for a period of time, but was then reinstated either automatically or on the intervention of the RCC Dedicated Operator.

- **Unrecoverable faults:** The display set on an MS4 unexpectedly changed or disappeared, and could not be reinstated even with the intervention of the RCC Dedicated Operator. All faults identified during testing by the RCC in advance of the trial which caused it to be postponed were categorised as being unrecoverable, since there was inadequate time for the fault to be repaired.

A total of 35 experimental trials were planned, as summarised in Table 6.1. Twenty-five of these were completed, i.e. an adequate period of behavioural monitoring data was able to be obtained.
Of the completed trials, 52% (thirteen trials) were affected by some kind of technical fault occurring on at least one MS4 during the course of the trial night, as shown in Table 6.2.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Trials cancelled due to unrecoverable faults with one or more MS4s.</th>
<th>Trials aborted during TTM installation due to unrecoverable faults with one or more MS4(s).</th>
<th>Successful trials</th>
<th>Total trials planned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westbound</td>
<td>5</td>
<td>4</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Eastbound</td>
<td>---</td>
<td>1</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Combined</td>
<td>5</td>
<td>5</td>
<td>25</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 6.1: Number of cancelled, aborted and successful trial nights

<table>
<thead>
<tr>
<th>Direction</th>
<th>Number of successful trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No faults observed</td>
</tr>
<tr>
<td>Westbound</td>
<td>1</td>
</tr>
<tr>
<td>Eastbound</td>
<td>11</td>
</tr>
<tr>
<td>Combined</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 6.2: Number of successful trial nights with faults observed

The majority of failures were intermittent and required direct intervention from the RCC Dedicated Operator in order to reset the MS4s to the trial settings.

For the three trials on the westbound carriageway in which MS4s exhibited intermittent and unrecoverable faults:

- two trials involved both intermittent and unrecoverable faults on the same MS4, i.e. there were a series of intermittent faults following which the RCC Dedicated Operator was able to reinstate the trial settings, before a final fault occurred which the RCC Dedicated Operator was unable to resolve; and
- one trial involved one MS4 with intermittent faults and one MS4 with an unrecoverable fault. The latter was out of service for the duration of that night’s trial, but the on-road staff decided to proceed with the trial as the MS4 concerned was the one furthest upstream from the works.

A top level analysis of the number of MS4s that exhibited unrecoverable or intermittent faults during the trials programme is presented in Table 6.3. This does not consider the number of different MS4s used but, rather, the number of MS4s required to successfully sign the works according to trial protocols, i.e. three MS4s per trial.
### Table 6.3: Summary of number of MS4s exhibiting faults within the 1C3 trials

<table>
<thead>
<tr>
<th>Direction</th>
<th>Total trials planned</th>
<th>Unsuccessful trials</th>
<th>Successful trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of trials</td>
<td>No. of MS4s used*</td>
<td>No. of MS4s exhibiting unrecoverable faults</td>
</tr>
<tr>
<td>Westbound</td>
<td>22</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td>Eastbound</td>
<td>13</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Combined</td>
<td>35</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

* This is the number of MS4s required to sign the trials and not the number of different MS4s used
** In two of these three cases, the MS4s had also exhibited intermittent faults prior to the unrecoverable fault

Ten trials were unsuccessful; that is, they were cancelled in advance or aborted at the start because an MS4 was displaying an unrecoverable fault. 33% of the total number of MS4s which would have been required to sign these trials (10 of 30) exhibited unrecoverable faults. For the 25 successfully completed trials, 27% of the total number of MS4s required to sign the trials (20 out of 75) exhibited either unrecoverable or intermittent faults.

A more detailed analysis in terms of the individual MS4s is presented in Appendix H.

### 6.1.2 Availability due to faults – assessment of the wider strategic network

In addition to investigating the specific MS4s used in the trial, a wider sample of MS4s was investigated, using the HALOGEN fault logs, in order to ascertain if the difficulties experienced during the trial were commonplace. The sample used was the wider M4 in the Eastern region (roughly aligning with Area 3 on the M4), as this area contains a number of MS4s and no gantries.

The HALOGEN fault logs provide an indication of the likely frequency of faults on MS4s across the strategic road network. The sample studied was from the 10th March 2013 until the 19th February 2014 inclusive. As MS4s can be considered as both signals and signs by HALOGEN, depending on the aspect set, both datasets were included in this analysis.

During the 337 days, 98 MS4s registered as faulty (regardless of whether it was the sign or signal aspect), out of a total of 116 MS4s, with between 55 fault entries on the least faulty MS4 and 8208 fault entries on the most faulty MS4 within this timeframe.

Table 6.4 shows the ten MS4s with the highest fault counts. It can be seen that the signal aspects of the MS4s registered faults more frequently than the message aspects.

While this is a small sample of the results, this does not necessarily indicate that these are the MS4s that are most likely to fail on the M4 in the Eastern region in terms of effectively/accurately displaying information. This is because HALOGEN does not appear to align easily with on-road faults as discerned by the RCC operators – specifically faults that would disrupt road works solely signed with MS4s due to the MS4 being incapable of satisfactorily displaying the necessary aspects such as shown in Figure 2.2 and Figure 2.3.

The HALOGEN fault logs could therefore not be used to ascertain on-road faults, or the percentage of time the VSS was unavailable, in this specific case and therefore could not be
used to assess the availability of VSS on the wider strategic road network. However, the number of registered HALOGEN faults emphasises the apparently high chance of a failure occurring on MS4s in general.

<table>
<thead>
<tr>
<th>Geographical Address</th>
<th>SIG Aspect Faults</th>
<th>MSS Aspect Faults</th>
<th>Total Faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>M4/2928A</td>
<td>6955</td>
<td>1253</td>
<td>8208</td>
</tr>
<tr>
<td>M4/2522B</td>
<td>4770</td>
<td>3086</td>
<td>7856</td>
</tr>
<tr>
<td>M4/2460A</td>
<td>6046</td>
<td>1624</td>
<td>7670</td>
</tr>
<tr>
<td>M4/2955B</td>
<td>5280</td>
<td>747</td>
<td>6027</td>
</tr>
<tr>
<td>M4/2969B</td>
<td>4582</td>
<td>835</td>
<td>5417</td>
</tr>
<tr>
<td>M4/2785B</td>
<td>3438</td>
<td>712</td>
<td>4150</td>
</tr>
<tr>
<td>M4/2628B</td>
<td>3241</td>
<td>504</td>
<td>3745</td>
</tr>
<tr>
<td>M4/2590B</td>
<td>2014</td>
<td>868</td>
<td>2882</td>
</tr>
<tr>
<td>M4/2940A</td>
<td>1610</td>
<td>1179</td>
<td>2789</td>
</tr>
<tr>
<td>M4/2747B</td>
<td>1947</td>
<td>820</td>
<td>2767</td>
</tr>
</tbody>
</table>

Table 6.4: Top equipment faults on the Eastern M4 over 337 days

A technology report from August 2014 was reviewed to gain further understanding of the overall availability of VSS as reported by the Technology Performance Management Service (TPMS).

TPMS shows that the message signs managed by the East RCC had an availability of 95.79% and the signals managed by the East RCC had an availability of 95.83%. These figures are applicable to all VSS, rather than MS4s alone. In the case of both signs and signals, these figures represent the lowest availability across all of the RCCs. Across the Agency’s network as a whole, the availability of VSS appears to have been increasing from month-to-month, though this overall trend may mask regional differences.

While an availability of approximately 96% suggests that a typical VSS is available for 23 hours out of every 24 hours, it implies that three successive VSS (i.e. at least one of the three successive VSS) would typically be unavailable for approximately one hour out of every eight hours. That is, during any relaxation works, a VSS triplet is highly susceptible to faults and is not suitably robust.

6.1.3 Availability due to incident management

The Agency’s Command and Control (C&C) database logs incidents identified from Traffic Officer reports, CCTV or public reports. This database is maintained by the RCC as an operational database, i.e. to keep track of the progress of incidents, so as to inform other parties such as breakdown assistance and the emergency services.

C&C data include incident types such as breakdowns, injury accidents, non-injury accidents, debris, and pedestrians. Information about traffic management is also reported, for example, details of any lanes closed and VSS used.
A sample of the C&C dataset was analysed to investigate if this could be used to identify the frequency with which VSS might currently be used to inform drivers of incidents near or alongside road works.

There were substantial variations in the number of incidents that would have been likely to use VSS, assuming they were available, that were recorded as occurring in road works, both between different areas and between different months in the same area. In addition, the number of occurrences of road works was much smaller than had been anticipated. While some variation had been expected, the extent of the variation raised questions about the reliability of using C&C data for this purpose.

The aim of this had been to identify the potential impact on normal operations of an incident within road works, while constrained by the Agency’s current systems and processes. However, a future way of working should not be constrained by the Agency’s current systems and processes. If VSS are to be used regularly to provide drivers with advance warning of road works, the Agency would require a system which is intelligent enough and flexible enough to allow simultaneous signalling. For example, if lane 1 of a four lane carriageway is closed for road works and this is signed by VSS, the system should treat it as if it is a three lane carriageway. If an RCC operator then uses the same VSS devices to set, say, a lane 4 closure due to an incident, the system should recognise the existing setting and propose a setting that allows for the two to co-exist. This would remove any potential conflict or impact on normal operations while also providing real-time accurate information to motorists.

6.2 Impact on RCC resources

Specific protocols were put in place during the trials to manage risk and thereby ensure that the trials could be undertaken as safely as possible (see the Safety Report (TRL, 2014) for further details).

One of these protocols was the inclusion of an RCC Dedicated Operator to manage and operate the signs and signals specific for the trial. However, this level of dedicated staff input required by these protocols is potentially unmanageable/unachievable on a routine basis. It was therefore necessary to seek feedback from all of the involved parties within the trials on current operational models, practices and processes, and how these might be adapted or improved if VSS were to be routinely used as the sole method for providing advance signing of road works.

This section considers the likely impacts on RCC resources. This is a key consideration, based on the experiences with the trial MS4s reported in Section 6.1.1.

6.2.1 TRL observations from attended trial nights in the ERCC

TRL staff were present in the ERCC for the first four nights of the experimental trials, with the objective of observing both current RCC working practices and the trials protocols as defined within the Safety Report. The observations reported below were from this limited period of time in a single RCC and therefore may not be representative of all of the Traffic Officer Service’s RCCs.

RCC staff resources: The attended nights identified that general RCC operator workload can vary dramatically across the duration of a single shift. For example, workload is high in the
period around 21:00-22:00 when all of the scheduled road works are called into the RCC and then decreases significantly; the occurrence of unforeseen incidents on the network can also dramatically increase workload depending upon the severity and the number of RCC staff involved.

In addition, it was observed that the number and scale of interventions by the RCC Dedicated Operator to react to faults on the MS4s being used within the trials varied considerably. This was further supported by the trials safety sheets completed by the RCC Dedicated Operator over all of the trial nights.

Therefore, if a single operator were to combine the monitoring of VSS used to sign road works and their existing normal duties within a shift, this could potentially delay the operator responding to faults/failures on safety-critical VSS, thereby leaving road workers temporarily unprotected, even if the system provided sound alerts to the RCC to warn that safety-critical VSS had failed and hence required immediate action. Without additional staffing to monitor safety-critical VSS, this risk may not be acceptable; on the other hand, it may be disproportionate to make available a dedicated resource to monitor safety-critical VSS at all times. Ensuring that this risk is managed proportionately will therefore be challenging.

**RCC staff competency:** Whilst all RCC operators undergo foundation training on joining the TOS, this training is designed to develop the newly recruited operator to a base level of competency. The RCC Control Office Base System (COBS) which is used to manage and operate the VSS is a complex system with many elements of functionality. Of particular note, it was observed that operators have varying levels of understanding regarding the functionality of the system relating to the notification of faults and alerts.

Within the COBS:

- RCC operators are notified of System Alarms by the 'lightning bolt' indicator on the COBS icon bar (see Figure 6.1). For example, an alarm is raised if one of the sub-systems becomes faulty.
- RCC operators are notified of System Alerts by the 'bell' indicator on the COBS icon bar (see Figure 6.1). For example, an alert is raised to make the operator aware of events that may need them to take some action.

![Figure 6.1: Icon bar on SERCO COBS display](image)

Both system alarms and system alerts are accompanied by an audible warning, although it appears that this has been disabled for all RCC operators other than the RCC Team Manager.
There did not appear to be a defined process for responding to such faults and alerts as they occurred, possibly due to their high frequency; rather, they were addressed when an operator was available to do so. The action which would then be taken was unclear.

The safety-critical nature of VSS used as the sole measure to sign road works means that such notifications would be of greatly increased significance, especially if an RCC operator does not have the VSS device in question displayed on screen using the detailed maps view.

**Fault reporting and repair of roadside equipment:** When RCC operators identify an MS4 fault, there is an established procedure for them to report this. The fault then becomes the responsibility of the technology maintainer (RTMC or TechMAC). The RCC operators spoken to for this research do not appear to be aware of the process, and likely timescale, for the repairs to take place or of ensuring that repairs have been undertaken. It subsequently appeared that, because VSS are not categorised as safety-critical, faulty VSS frequently remain unfixed for long periods of time.

MS4s are understood to have no requirements for direct testing by the technology maintainer since they designed to constantly self-test. If, during this self-testing sequence, the system identifies a fault that is not self-rectified after 15 minutes, the system sends an alert to the national fault reporting system (TPMS) and a fault ticket is raised. This acts as the initiator for the technology maintainer to commence their processes for diagnosing the fault and putting in place an action plan to rectify as part of the technology maintainer’s Asset Management Plan (AMP), the technology maintainer will have a detailed testing regime for VSS in place, but this does not guarantee that the VSS will always be working. This approach merely serves to react to faults as they occur rather than put in place measures to prevent faults occurring in the first place.

### 6.2.2 Feedback from interviews with RCC staff

Following the completion of the 1C3 trials, interviews were conducted with RCC staff. The purpose of these interviews was to:

- understand how the RCC currently operates, particularly in relation to the use of Variable Signs and Signals (VSS) in support of road works;
- gain feedback on the trial from the RCC dedicated operator; and
- understand how the operational model may need to change if VSS were to be regularly used as the sole method for providing advanced signing for road works.

The interview guide for these interviews is presented in Appendix J. Interviews were conducted with three groups of staff as follows:

- **RCC operators** (including the 1C3 trial-specific 'RCC Dedicated Operator'): The interviews used the questions from Section A as a basis for discussion – these questions related to the current use of VSS to support road works in the RCC (i.e. outside of the trial). A total of four RCC operators (including the RCC Dedicated Operator) participated in the interviews.

- **The 1C3 trial-specific 'RCC Dedicated Operator'**: The interview used the questions from Section B as a basis for discussion – these questions related to the 1C3 experimental trials and to the use of VSS as the sole method for signing road works if
this approach were to be used regularly in the future. A single member of RCC staff acted as the RCC Dedicated Operator throughout the whole trial period.

- **RCC Managers/Team Leaders**: The interviews used the questions from Section C as a basis for discussion – these questions relate to the use of VSS as the sole method for signing road works if this approach were to be used regularly in the future. A total of five Managers/Team Leaders participated in the interviews.

The key findings from the interviews are summarised below:

**RCC operations with respect to the use of VSS**: The reliability of VSS was considered to be one of the primary issues affecting their current and future use by all interviewees.

Whilst there was a consensus that failures need to be addressed as soon as possible, both in terms of acknowledgement and response, it was acknowledged that this is often not possible, due to one or more of the following:

- The frequency with which faults occur on the network as a whole (potentially meaning a high density of alerts registering on COBS within any given shift).
- The availability of appropriate technical support in the RCC control room; this was considered to be a particular issue outside of normal working hours when no such support is present in the room and technical support is provided from a call centre where operators are less familiar with the technology. (However, the need for this is unclear as the technical support staff should be aware of VSS faults without requiring RCC operators to inform them, testing them routinely if necessary.)
- The need for a suitable road space booking and traffic management to ensure that a technician can access the VSS in person if a fault cannot be corrected simply by resetting the VSS.
- The lack of transparency to RCC operators in whether faults have been logged by the maintainer, the absence of any hierarchy of which technology/location is of greater importance to another, and the end-to-end mean time to repair the fault, which often appears to be not in-line with the performance requirements expected by the Agency.

Analysis of the interview data indicates a lack of consistency in how operators respond to fault alerts on COBS. If road works were to be signed more frequently using VSS alone, improved protocols would be required to ensure faults are responded to promptly and consistently by RCC operators and technicians. Some frustration was expressed by RCC staff that operators are frequently unaware of a fault on an individual VSS until they come to use it, and that they are often unable to tell whether a fault has been registered by the maintainer, and the timescale for ensuring it is resolved.

A further concern highlighted by the interviewees was associated with the timing of the first call under the existing ‘four-call’ system (as described in Traffic Officer Procedure CCF302 – The Use of Signals, VMS and MIDAS at Short Duration Static Road Works). Due to the high level of calls received by the RCC in the period between 21:00-22:00 when works are typically going out, on-road teams frequently call in earlier to reduce the likelihood of their call being queued. This means that VSS are sometimes being set to warn road users significantly before traffic management is ready to be placed, so that road users are being advised of a closure that is not physically present. During the trials, radio (Airwave) was
sometimes used by the RCC Dedicated Operator and the on-road workers to ensure the VSS were switched on at the appropriate time and to avoid the delays associated with queuing. However, interviewees felt that it would not be appropriate to use radio for communication routinely, given that this would require a dedicated operator, but that the use of radio could be beneficial in an emergency.

Furthermore, it was reported that works are not always called off by on-road teams, i.e. the fourth call of the four-call system, again resulting in VSS signing closures that are no longer in place. (The RCC Dedicated Operator observed this latter behaviour twice during the 1C3 trials themselves.) Routine use of VSS as the sole means to sign works might require a more robust enforcement of communications procedures. The use of VSS as the sole means to sign road works could reduce the current four-call system to a two-call system since the VSS would be required for the duration of the works (though there may still be a benefit to the RCC being aware of when TTM installation has been completed, and of when the TTM removal is about to start, as this information may affect how an incident near the works is signed).

Depending upon the type of closure, the time required to set the signals and inform affected parties varies considerably. It was considered that it would be advantageous if jobs were set up within COBS well in advance of the time of the works, e.g. based on information in the Schedule of Road Works (SRW). However, it was recognised that the SRW is not always accurate, and that this approach cannot take account of emergency, short notice works.

**Feedback on the trials:** It was considered that the trials had minimal impact upon RCC operators due to the provision of an RCC Dedicated Operator. It was recognised that the reliability of the VSS was the biggest issue affecting the undertaking of the trials. All interviewees recognised the potential benefits of using VSS as the sole method to sign road works, but that the approach used within the trials was not practicable for wider, routine application. This included feedback on the reliability of COBS itself, which does not always accurately reflect what is on the VSS on road, and appears to ‘freeze’ occasionally, sometimes then reverting to previous settings.

**Changes to operational models:** The view was firmly expressed that any RCC-centred operational model for future routine use of VSS as the sole method for signing road works could not practically include an RCC operator permanently monitoring the specific VSS in use by constantly observing the specific VSS in use on COBS and/or CCTV. This is due to the level of resource that might be required and the typical number of road works on the network on a nightly basis (typically 70 to 80 for the ERCC).

Instead, it was considered most likely that the VSS would be managed by responding quickly and effectively to fault alerts, whereby COBS makes an operator aware of a fault when it occurs, when they are performing another task. The requirements of such an operating model are discussed later.

### 6.3 Impact on ASC/MAC/DBFO processes

Interviews were conducted with ASC staff who had been involved with the 1C3 trials, in order to seek feedback on current processes, the success of and/or issues with the 1C3 trials and the feasibility of using VSS as the sole means of signing road works. The interview guide
for these interviews is presented in Appendix J. A total of five ASC staff took part in the interviews.

The ASC staff recognised that the MS4s are not always reliable, though these are normally used only during installation and removal of TTM. During the 1C3 trials, the on-road staff were notified by the RCC staff when the MS4s failed, and were content with the arrangements for managing these faults during the trials themselves.

The ASC staff emphasised that the normal telephone system for ringing through to the RCC would not be adequate if VSS were used to sign road works, given that there can be significant delays in getting through to the RCC. The Airwave radio system was used during the 1C3 trials and this worked very well, but this is unlikely to be practical if VSS were used to sign road works regularly given the number of RCC operators this would be likely to require.

Overall the experience of the 1C3 trials for the on-road staff was very positive – the ASC staff were of the view that drivers pay little attention to the conventional ground-level signs. While some taper running did take place during the 1C3 trials, to their knowledge, there were no taper strikes; the staff involved would normally have expected three or four taper strikes given the number of closures trialled.

In their view, the on-road role is necessarily dangerous, but they felt that the job was no more dangerous when the closures were signed with MS4s only. They commented that the traffic appeared to move out of the closed lane earlier in the trials.

If this approach were to be used regularly, there was clearly a great deal of concern about the reliability of the technology, and concern that, as a back-up, ground level signs would have to be placed regardless, albeit potentially on the near side only. They also recognised that there would be some challenges around obtaining road space bookings for lane closures where these are required to repair the VSS promptly.

Their experience in the 1C3 trials suggested that better planning of their works would be required than is currently the case. This planning would include, for example, ensuring the relevant VSS were tested in advance, as was the case during the 1C3 trials, whether by RCC operators or by traffic management staff. In addition, the on-road staff’s view was that the information that their colleagues enter into the Schedule of Road Works needs to be more accurate, and shared with the RCC more effectively in advance, with the additional benefit that this could save them time at the side of the road when communicating with the RCC.

6.4 Outcome 3 conclusion

Faults were exhibited on 30 of the 105 MS4s (29%) that were intended to be used during the experimental trials. Subsequently, of the 35 planned experimental trials, ten had to be cancelled in advance or aborted before the closure was set out, and a further thirteen were affected by some kind of technical fault occurring on at least one MS4 during the course of the trial night. That is, only 34% of trial nights went ahead without a fault.

The routine availability of fully functional MS4s (i.e. ones not exhibiting faults) is currently likely to be insufficient for them to be used as the sole method for signing relaxation works, irrespective of whether this approach is comparable to using ground level signing in terms of road user behaviour.
Assuming these technological issues can be resolved, other changes to the current way of working would also be required to ensure that MS4s can be used to provide drivers with suitable advanced warning of road works. For example, the Agency would require a system which is intelligent enough and flexible enough to allow simultaneous signalling of incidents and road works. A dedicated system alarm for any VSS in use as the sole method for signing road works would be beneficial.

Other approaches that would represent a more significant shift from the current approach to managing VSS could mitigate the risk associated with this approach. For example:

- Management of VSS used to sign road works from a centralised unit, so that all RCC operators are able to operate all VSS across the network. This would make it more likely that an RCC operator would be available to deal with a VSS failure immediately that this is alerted.

- Providing on-road staff with alerts directly when the VSS relevant to their works fails. This would remove the risk of a delay in an RCC operator informing on-road staff of the failure.

- Providing the maintainer with the ability to set the relevant VSS for road works purposes. This would ensure that the maintainer retains responsibility associated with signing road works settings. This could also include testing of the relevant VSS in advance. This approach would require appropriate technology changes, and the development of protocols and hierarchy of settings for the simultaneous management of VSS between the maintainer, NTIC and the RCC, so that no party can unwittingly overwrite the VSS.
7 Summary, Conclusions and Recommendations

A programme of work has been initiated to investigate the feasibility of using electronic Variable Signs and Signals (VSS), installed across the network and currently used to manage incidents and events, in place of conventional signs on A-frames at ground level to display lane closure information. The research task presented in this report has specifically sought to evaluate the use of MS4 Variable Message Signs (VMS) for this purpose.

The outcomes sought by Highways Agency from this task were:

- **Outcome 1**: to assess whether lane closure information displayed on MS4 VMS for advance warning of road works on relaxation scheme works are as effective as (or better than) existing methods when considered in terms of driver behaviour.

- **Outcome 2**: to evaluate the risk benefits to road workers associated with the elimination of the placement, maintenance and removal of temporary advance signing.

- **Outcome 3**: to gain an understanding of the likely implications and impacts on the Traffic Officer Services (TOS) if road works were to be routinely signed using MS4s.

7.1 Influence on driver behaviour (Outcome 1)

Driver lane change behaviour was analysed to understand the difference between the ways in which drivers approach works signed with conventional ground-level signs compared to works signed with MS4s. Driver behaviour was evaluated on the basis of two measures: distance in advance of the works and location relative to where lane closure information was presented.

Based on the location where drivers received information, the results for nearside (lane 1) closures showed that the pattern of vehicles changing lanes between the most upstream sign containing lane closure information and the 400m sign did not differ significantly between the experimental and control groups, even though drivers in the experimental condition received lane closure information further from the taper. The results for offside (lane 3) closures showed that the proportion of vehicles in lane 2 in the experimental condition decreased between the most upstream sign and the 400m sign whereas, in the control condition, this proportion increased. However, this was not the crucial lane in respect of safety: in the closed lane, lane 3, the pattern of vehicles changing lanes was similar in the control and experimental conditions, with the proportion in this lane decreasing between the signs.

For distance in advance of the works, driver behaviour was considered in the last 800m prior to the taper i.e. within the ‘normal’ advance sign zone for relaxation works. The results showed that the differences in driver lane change behaviour were not significant for either offside (lane 3) or nearside (lane 1) closures i.e. the pattern of vehicles changing lanes between the 800m to 400m distances did not differ between the experimental and control groups.

However, in the experimental condition a slightly higher proportion of drivers moved out of the closed lane prior to the 800m point. This may have been due to the earlier presentation of lane closure information in the experimental condition. Subsequently, fewer drivers were
in the closed lane 400m upstream of the taper in the experimental condition than in the control condition.

The proportion of vehicles identified as taper running for both offside (lane 3) and nearside (lane 1) closures was slightly lower in the experimental condition than in the control condition and may be explained by the slightly smaller proportion of vehicles still in the closed lane 400m from the taper. A smaller proportion of vehicles in the closed lane close to the taper is likely to represent a reduction in risk to workers as vehicles are less likely to incur into the closure in which the road workers would be working.

The analysis of driver behaviour was based upon lane occupancy vehicle counts once all of the Temporary Traffic Management (TTM) was in place and the TTM crew were clear of the works. It therefore takes no account of driver behaviour during the installation and removal of TTM, though no specific incidents occurred during these periods in the trials.

Based on the findings from these on-road trials, it can be concluded that, for nearside (lane 1) closures, driver behaviour on the approach to road works using MS4 VMS to display the advance warning of closures is comparable to road works using approved TTM techniques. For offside (lane 3) closures, using MS4 VMS results in comparable driver behaviour within the last 800m (i.e. within the ‘normal’ advance sign zone) to using approved TTM techniques, but the way in which lane changing occurs relative to the position of the signs differs.

7.2 Evaluation of the risks to road workers (Outcome 2)

The Measurement of Injury Risk (MIRi) Index was used to estimate the risk to road workers when installing and removing TTM in various scenarios. This indicated that the risk to road workers when using only MS4s to provide advance signing is 18% lower for nearside closures than when using Off Side Signs Removal, and 30% lower for offside closures than when using Sign Simplification. It is safer still relative to the risk when installing and removing a full Chapter 8 relaxation layout.

The risk reduction arises from the removal of risk associated with installing/removing the advanced signs and, in the case of offside closures, the elimination of carriageway crossings to install/remove advance signs on both sides of the carriageway.

This supports the observations from the on-road trials that the risk to road workers is potentially reduced by using MS4 VMS as the sole means of advance signing.

7.3 Operational requirements (Outcome 3)

The reliability of the MS4 triplets (the three MS4s used to sign the relaxation works closure) used in the trial was found to be relatively poor, with 29% of the MS4s failing, and subsequently 66% of the trial nights being affected by at least one MS4 within a triplet displaying either an intermittent and/or an unrecoverable fault. Analysis of data from the Technology Performance Management Service (which is not limited to MS4s but covers all types of Variable Signs and Signals) also suggested that, during any relaxation works, a triplet would be highly susceptible to faults.

The routine availability of fully functional MS4s (i.e. ones not exhibiting faults) is therefore currently likely to be insufficient for them to be used as the sole method for signing
relaxation works, irrespective of the evidence from the on-road trials that this approach is comparable to using ground level signing in terms of road user behaviour.

The level of dedicated resource in place and the manner in which the trial MS4s were monitored for the duration of the trial would not be practicable if VSS were to be routinely used as the sole measure to sign road works.

No specialist training would be required for Regional Control Centre (RCC) operators to understand the requirements of this approach, as the use of VSS as the sole method for signing road works is merely a different application of existing RCC operator skills. However, briefings or some form of refresher training would be required to ensure that protocols are clear to all involved, with more comprehensive introductions for team coaches and team managers.

7.4 Recommendations

The reliability of VSS needs to be improved to ensure that MS4s can be used routinely as the sole means of providing drivers with suitable advanced warning of road works. The system would also need to be intelligent enough and flexible enough to allow simultaneous signalling of incidents and road works. Changes to the current way of working would be required to ensure that this approach becomes feasible. The following are seen as essential requirements:

- Identifying which aspects and legends are critical for VSS to be used for this purpose and what precisely has failed on a VSS when a fault is displayed on the COBS (for example, whether it was the sign or signal element). These are seen as key to identifying when on-road teams would need to implement any form of back-up signing to ensure road users remain aware of the closure (See Section 7.4.1).

- Implementation of an appropriate, distinguishable method for alerting RCC operators when faults occur on safety-critical VSS. On-road teams would be reliant on the VSS for their safety; therefore it would be imperative that RCC operators are made aware of faults as soon as possible and that these are responded to promptly and appropriately. Any alert would need to be clearly distinguishable, and should be identified on the Control Office Base System (COBS) display separately from any existing alerts/alarms (see Section 6.2.1). This should be coupled with an audible alert that would be heard by all operators in the room who are assigned to managing the VSS, not merely by the RCC Team Manager.

- Gaining agreement from all affected Asset Support Contractors (ASCs) that the approach of system alerts rather than permanent observation, as was the case during the trial, would be acceptable. This would be imperative as safety-critical signs would not be individually monitored by a human being, meaning that road workers might be left unprotected for slightly longer following the occurrence of a VSS fault before the on-road team would be notified.

- Improving communication mechanisms between the ASC and the RCC. This would need to address two aspects:
  - Having an appropriate, permanent line of communication with on-road teams irrespective of their work/activities. Present communication methods
can sometimes be unsuccessful if, for example, road workers are using noisy equipment.

- Ensuring that any specified communication protocols are followed for occasions when communication is required, e.g. calling on and calling off works.

- Addressing the **perceived transfer of liability from the road workers to RCC staff**: some operators might feel unduly responsible if VSS were to fail given that on-road teams would be reliant on the VSS for their safety.

- Development of robust protocols to manage **signing conflicts**:
  - *when VSS in use for signing road works are required for incident management* in the vicinity of the works, and
  - between VSS and any other on-road signs, such as verge-mounted or central reservation-mounted signs controlled directly by the on-road teams.

The following would also be beneficial to the efficiency and reliability of a revised operational model:

- Configuration of COBS to allow VSS upstream of the VSS closest to the works to be set via **automated secondary settings**.

- Being taken to the appropriate location on the network maps within COBS when a fault notification is clicked on, so that the position of the sign within the VSS triplet can be easily identified.

- Being able to enter a log number when the operator sets the works proposal on COBS so that, when COBS shows a signal as set, the job it relates to is clear.

Other approaches representing a more significant shift from the current approach to managing VSS might also mitigate the risk associated with this approach. However, these might be harder to introduce or be deemed impractical/unacceptable. For example:

- Management of VSS used to sign road works from a centralised unit, so that all RCC operators are able to operate all VSS across the network. This would make it more likely that an RCC operator would be available to deal with a VSS failure immediately following an alert.

- Providing on-road staff with alerts directly when the VSS relevant to their works fail in some way. This would remove the risk of a delay in an RCC operator informing on-road staff of the failure.

- Providing traffic management staff with the ability to control the relevant VSS in full, whether temporarily or otherwise. This would ensure that on-road staff fully own the risk to road workers that would be associated with VSS failure, and could include testing of the relevant VSS in advance. This approach would require appropriate protocols for control of the VSS to be handed over temporarily from NTIC and the RCC to traffic management staff, so that they do not unwittingly overwrite the VSS. Traffic management staff would be less likely to be aware of what is occurring on adjacent sections of the network, so this might introduce the risk that an incident close to the works is not signed.
7.4.1 Managing VSS faults: Options for back-up signing

VSS technology is unlikely to ever be 100% reliable, such that no VSS used to sign road works will ever exhibit a fault whilst in use. A back-up mechanism for signing works in the event of a VSS exhibiting a critical, unrecoverable failure may therefore be required.

Within sections of the network where there is no hard shoulder, for example on some Smart motorway sections, the placement of conventional ground-level signs, and locating signing on the verge may not be possible due to local topography, levels of roadside vegetation, etc. Therefore a standard fall-back protocol that can be implemented independently of local site conditions might be required or the ASC will need to formulate an appropriate protocol on a works-by-works basis.

One possibility for this might be to use an Impact Protection Vehicle (IPV), perhaps with a high level sign, to substitute temporarily for a faulty VSS. This could mean parking the IPV in a live lane, though there would clearly be a risk associated with this approach. Another option may be to locate this IPV in the nearest upstream suitable location, such as an Emergency Refuge Area (ERA), though there is no guarantee that there would be such a location available within an appropriate distance.

If one of the three MS4s were to fail temporarily, this may not substantially increase the risk. However, those closer to the closure are likely to be more critical. This might mean the presence of an ERA within a mile upstream of a closure would be beneficial, so that there is a place of relative safety for a back-up IPV to be parked to sign the closure should one of the MS4s fail.
1C3 Use of MS4s to Sign Road Works

Acknowledgements

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- Richard Moore and Tony Francis of EM Highways, and
- Paul Hobday of the East Regional Control Centre

whose experience and dedication enabled the 1C3 experimental trials to take place successfully.

References


## Glossary of abbreviations and acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AfZ</td>
<td>Aiming for Zero (Highways Agency Programme)</td>
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<td>ANPR</td>
<td>Automatic Number Plate Recognition</td>
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<td>ASC</td>
<td>Asset Support Contractor</td>
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<td>CCIL</td>
<td>Command and Control Incident Log</td>
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<td>COBS</td>
<td>Control Office Base System</td>
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<td>DBFO</td>
<td>Design Build Finance Operate</td>
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<tr>
<td>ERCC</td>
<td>East Regional Control Centre</td>
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<tr>
<td>HALOGEN</td>
<td>Highways Agency LOGging ENVironment</td>
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<tr>
<td>HATMS</td>
<td>Highways Agency Traffic Management Systems</td>
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<tr>
<td>IAN</td>
<td>Interim Advice Note</td>
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<td>IPV</td>
<td>Impact Protection Vehicle</td>
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<td>JTI</td>
<td>Journey Time Information</td>
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<td>LMCC</td>
<td>Lorry Mounted Crash Cushion</td>
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<td>MAC</td>
<td>Managing Agent Contractor</td>
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<td>MIDAS</td>
<td>Motorway Incident Detection And Signalling</td>
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<td>Off Side Signs Removal</td>
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<td>RCC</td>
<td>Regional Control Centre</td>
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<td>Schedule of Road Works</td>
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<td>TM</td>
<td>Traffic Management</td>
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<td>TOS</td>
<td>Traffic Officer Service</td>
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<td>TPMS</td>
<td>Technology Performance Management Service</td>
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<td>Traffic Signs Manual</td>
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<td>TTM</td>
<td>Temporary Traffic Management</td>
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<td>VMS</td>
<td>Variable Message Sign</td>
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<td>VSS</td>
<td>Variable Signs and Signals</td>
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Appendix A Comprehension of MS4s

This document summarises previous TRL research into the use of MS4s, specifically focusing on drivers’ comprehension of these signs and how driver behaviour changes as a result of their use. Project 1C3 aims to evaluate the use of MS4s as advanced warning of road works; the literature reviewed here has been used to inform the experimental phase of this project.

Section A.1 summarises the main points from the relevant literature and Section A.2 details the implications for Project 1C3. Appendix B provides short extracts from the reports used in this review; these are useful if the reader would like more information on the methodology used, or a wider overview of the results obtained.

A.1 Summary of Evidence

A number of studies have shown that drivers do respond to safety messages (e.g. ‘slow down’) on Variable Message Sign (VMS) panels. However, this change in behaviour can be short term: these messages often reduce speeds close to the VMS but, further along the carriageway, speeds increase again. Other studies which examined the effect of other information (e.g. ‘1 minute delay to end of works’ or ‘keep your distance’) showed that the VMS had no effect on drivers’ speed choice/headway distance. [Appendices B.1, B.3, B.4, B.5 and B.6]

VMS response studies based on data from diversion route messages show that less than 20% of drivers respond to messages where reading and responding are required. However, it is suggested that this is equally applicable to the ‘workforce in road – slow’ message where drivers that respond to the message should reduce speed and be aware of the presence of road workers. [Appendix B.9]

The complexity of the message displayed has an effect on the time it takes for a driver to respond; a simulator study showed that a significant increase was observed between messages containing the lane closure aspect and one or two text elements, with messages including the speed limit as well. [Appendix B.7]

Most drivers understand the wicket symbol to mean ‘lane closed ahead’ and view the instruction as either mandatory or compulsory. [Appendix B.7]

Supplementary information displayed on MS4s is likely to influence driver behaviour; in surveys, drivers indicate that they would like to receive additional information relating to the lane closure such as how far ahead it occurs and why it is in place. [Appendix B.8]

Road users’ views of the usefulness of a sign (and potentially on the behaviours they exhibit as a result) are likely to be influenced by their perception of its accuracy. [Appendix B.5]

VMS does not just affect road users; road workers are also influenced by its presence. The perceived effectiveness of VMS by road workers is much higher than the actual effectiveness. This could lead to risk compensation behaviours and thus an increase in risk to road workers. [Appendix B.9]
A.2 Implications for Project 1C3

Research has shown that VMS do affect driver behaviour; however, this change can be short term and limited to a small proportion of drivers. Given that Project 1C3 aims to trial MS4s as advance signing of road works, the extent to which VMS are effective at achieving the desired road user behaviour is a concern. However, the reports covered in this review do not consider the effect of other visual stimuli, such as the taper, on driver behaviour: previous research (Safe Temporary Traffic Management Operations Initiative, Trial Report: Sequential Flashing Cone Lamps) has shown that the sequential flashing cone lamps on the taper encourage drivers to change lanes more quickly than lamps with a static light. As a result, the advance signs and taper are likely to be more effective in combination than either in isolation. In addition, the research confirms that drivers understand the meaning of the wicket symbol and hence are likely to recognise the required action.

While research suggests that drivers would like to receive supplementary information including how far ahead and why the works are in place, simulator studies have shown that drivers take longer to read and respond to messages with more content. Therefore, minimising the content of the message displayed on the MS4, whilst still providing sufficient information to the approaching driver, is key to ensuring that drivers in the trial understand the required action. The proposed trial layout has been designed with these criteria in mind, for example the planned experimental layout for Project 1C3 does not incorporate distance information on the MS4s.

This review has highlighted the need to inform and advise operatives involved in the experimental trial that MS4s do not necessarily affect driver behaviour. This will help to eliminate risk compensation behaviours which may develop due to incorrect assumptions about how drivers might react to the advance warning MS4s.
Appendix B  Detailed Research Evidence – TRL Reports

B.1  Safety and effectiveness of the wider use of VMS – Final report
(B R Cooper and J Mitchell, TRL526)

Cooper and Mitchell conducted a survey of drivers, both in off-road and on-road trials, to identify how people behaved in response to the use of a Variable Message Sign (VMS). This found that:

- There are indications that drivers changed their behaviour, at least in the short term, in response to safety messages such as ‘WATCH YOUR SPEED’, ‘KEEP YOUR DISTANCE’ AND ‘DON’T HOG MIDDLE LANE’.
- The recall of information from VMS depends on the amount of information present. As more information is added there is an increase in the amount recalled but a decrease in the proportion recalled.
- Information is recalled in the order of presentation on a sign (top to bottom).

B.2  MS4 off-road research summary report
(B R Cooper, M Freeman and J C Mitchell, TRL604 (revised version of TRL556))

This report summarises the results of a number of off-road research trials to investigate the legibility (in terms of distance from the sign at which it can be seen) and comprehension (in terms of time taken to understand the message at a set distance) of MS4s. Some tests were dynamic (70mph ‘drive through’) and some were static.

Although this report contains information on legibility and comprehension times it does not relate this to driver behaviour itself: it considers the distances at which drivers see the sign and the time it takes drivers to understand its meaning, but it does not specifically consider how and when drivers react to this information.

Following this work, the Highways Agency planned to conduct an on-road trial on the M4 looking at driver behaviour in response to these signs. If this work was conducted, though, it does not appear to have been made available within the Agency, and has certainly not been published.

B.3  On-road assessment of novel legends displayed on mobile VMS unit in road works
(S Clark, T J Horberry, J C Mitchell and L K Walter, T/127/06)

Motorway Incident Detection And Signalling (MIDAS) flow data were used to determine if there was a change in average speed in response to four different messages displayed on mobile VMS prior to road works compared to no message. This trial was conducted during the day on the M25.
Trial legends used in “novel legends” mobile VMS study on M25

The results showed that:

- For each of the four legends displayed, speed was reduced compared with when no legend was displayed.
- The greatest reduction in average speed occurred at the loop sited immediately adjacent to the VMS unit. The reduction in mean speed ranged from 4.7 km/hour to 7 km/hour (on mean speeds in the range 75.5 km/hour to 80.1 km/hour) and this was statistically significant.
- Although average speeds when the legends were displayed increased slightly from the loop at the VMS unit to the loop 400m after, by between 1 and 3 km/hour, these average speeds were still 4 km/hour lower than when no legend was displayed.
- For this trial, in all but two cases, across all loop and lanes, legends ‘A’ and ‘B’ showed the highest reduction in mean speed.
- Legend ‘C’ showed the highest reduction in mean speed in lane 2 at the loop at the VMS unit and the loop 400m after.
- A limited survey of travelling members of the public at the Service Station showed that drivers generally:
  - Remembered seeing a message shown on the mobile VMS.
  - Understood the message.
  - Thought the message was legible.
  - Thought the sign was effective.

B.4 Use of mobile VMS for warning of road works

(I Rillie and L Walter, UPR T/057/07)

The previous project (see Section B.3) looked at the effectiveness of mobile VMS at reducing speed on motorways during the day. This project looked to use three legends (legends A, B and C from the previous project) to determine if they were effective at reducing vehicle speed at short-term night time works on a trunk road.

The results showed that:

- The use of a mobile VMS showing a legend encouraging speed reduction was an effective means to reduce the speed of traffic approaching temporary night-time road works on two lane dual-carriageway trunk roads.
• The findings of this research were consistent with both the fixed VMS study carried out on the M25 (STTMOI Trials Team, 2004)\(^4\) and the previous study of mobile VMS also on the M25 (see Section B.3)

• All legends trialled in the studies on the M25 and A34 and proven to be effective incorporated an instruction or encouragement to reduce speed. The use of these legends was proven to reduce vehicle speeds, whereas other legends that do not specifically encourage speed reduction may not have the same effect on driver lane choice.

• This research confirmed the finding in the 2006 study (see Section B.3) that all the legends shown on the sign caused a reduction in speed.

• The effectiveness of the mobile VMS was maintained across the whole duration of the works. This suggests that the safety benefits of driver speed reduction are maintained for the entire time that the works are present and that the mobile VMS are used.

B.5 Information for motorists on transit times through long term roadworks

(P Vermatt, J Weekley & J Mitchell, CPR442)

This report considered the potential benefits of providing a Journey Time Information (JTI) system to both motorists and to other stakeholders. The system tested used two Automatic Number Plate Recognition (ANPR) cameras and a transportable VMS unit which displayed the delay to be expected through a set of long-term road works.

[Image: Mobile VMS showing delay through road works message]

Anonymised enforcement data for the enforcement system installed at the site was provided. This system monitored a shorter section of the road, entirely within the 50mph zone. There appeared to be no evidence that the presence of the JTI system influenced motorist’s tendency to speed.

Data collection, in the form of interview surveys, took place during normal working hours on weekdays at Michaelwood Services; this was the first motorway services after the road works. The main conclusions arising from this study were that:

- Road users’ views of the usefulness of the sign were strongly influenced by their perception of its accuracy.
- Use of the sign was likely to result in more people diverting to avoid road works, but only if the information was provided sufficiently far in advance to allow drivers time to make up their mind and think about an alternative route.
- There was a small tendency towards feeling that being informed about impending delays would reduce stress levels.

B.6 Close Following Reduction – driver response to VMS signs
(J Crick, E Delmonte & P Owlett, RPN1747)

For this project, research was undertaken in two areas:

- Driver attitudes to VMS messages.
- On-road effectiveness of existing VMS message.

Road signs designed to act as reminders of the dangers of close-following could be an intervention by which the error-based causes of close-following might be prevented. In particular, the message ‘Keep your distance’ was investigated.

The on-road trial did not identify a statistically-significant change in headway, even on a lane-by-lane basis, when the message was displayed.

B.7 Task 3 MM2 Sign Comprehension Study
(Managed Motorways 2 Concept Development, CPR1062)

This study was mainly carried out using a software tool that measures response time and accuracy of participants to visual stimuli containing images of Managed Motorways On-Road Drivers Information (i.e. in a simulated environment). The trial had a number of different elements:

B.7.1 Comparison of gantry-mounted versus verge-mounted information

- During the static version of the test, participants’ accuracy and speed of comprehension of information presented on a single verge-mounted MS4 was greater than or equal to the same information presented on the combination of a gantry-mounted signal and an MS4 together.
- During the dynamic (simulated motion) version of the test, verge-mounted signs were responded to significantly faster than gantry-mounted signs for ‘Lane closed’ and ‘Move out of lane’ statements.
The addition of supplementary information appeared to affect the response times for both verge-mounted and gantry-mounted signs. There was no evidence to suggest that the addition of supplementary information adversely affected the response times on verge-mounted signs compared with gantry mounted signs.

The verge-mounted option using a speed limit aspect of size 1500mm diameter centred in the position of the MS4 was responded to significantly faster than both the verge and gantry-mounted options which contained a 1300mm speed aspect with additional supplementary information.

In general there was little difference in response times arising from variations in the design of lane closure aspect on a verge-mounted MS4.

The ‘1 red X with lane markings’ and ‘European variant’ lane closure aspects were associated with significantly faster response times compared to the equivalent gantry-mounted options.

### B.7.2 Comparison of responses to different MS4 message configurations

- Speed limit and lane closure information displayed on a verge-mounted MS4 could be comprehended successfully even for the most complex configuration of MS4 message.
- For speed limit instructions, it appeared comprehension was equally good for all MS4 message configurations.
- Response times were higher for the MS4 message configurations when lane closure information as opposed to speed limit instruction was being communicated.
- The addition of elements to an MS4 message containing a single speed limit or lane closure aspect appeared to reduce performance in terms of sign comprehension.
• Significant differences in mean response times to lane closure information were noted between the simplest MS4 message configuration and more complex configurations including a second aspect, pictograms and/or text elements. However, performance did not significantly reduce when comparing the further addition of a pictogram and one or two lines of text. But a significant increase was observed between messages containing just the lane closure aspect and one or two text elements, with a message including the speed limit as well.

• Comprehension of lane closure information was more likely to be affected by surrounding elements. Speed limit information was less affected by additional information displayed within it proximity due to the ‘pop-out’ effect that occurs for speed roundels.

B.7.3 Comprehension of aspect design

• Participants demonstrated a high level of understanding of lane closure aspects, particularly those communicating single lane closures and containing a red X or wicket symbol.

• There was less consistency in interpretation of aspect designs intended to instruct drivers to move out of a particular lane in advance of a lane closure.

• The wicket aspect was more likely to be perceived as communicating lane closure ahead than the aspect involving a red X.

• The hooked arrow aspects appeared to give clearer instruction for the need for traffic to move out of the lane than the European Variant.

• For all lane closure aspect designs (e.g. red X, wicket, hooked arrow) the majority of participants viewed the instruction as either mandatory or compulsory.

• Use of a wicket or red X aspect increased the likelihood of participants interpreting the instruction as mandatory.

• Most participants correctly understood that the aspect incorporating a red ring communicated a mandatory speed limit instruction; participants were less consistent in their interpretation of the aspect displaying the advisory speed limit instruction.

B.7.4 Influence-potential of MS4 message elements

• Different types of MS4 elements had varying degrees of ‘influence-potential’ in terms of perceived likelihood of influencing driver behaviour.
• Whilst the mandatory speed aspect was expected to have the greatest influence on driver speed choice, the addition of supporting information appeared to have a beneficial effect on behavioural response, particularly when the information related to an accident ahead.

B.7.5 **Perceptions of verge-mounted driver information provision**

• Participants were asked to rate how effective verge-mounted MS4s were at a) closing lanes to traffic, b) increasing safety after an accident and c) improving driver behaviour. The results suggested that participants had positive perceptions of the use and effectiveness of verge-mounted driver information provision via MS4s.

B.8 **Tasks 5A MM2 Design Evaluation Simulator Study**

(Managed Motorways 2 Concept Development, CPR1062)

This study was carried out on the TRL driving simulator to investigate driver comprehension and behavioural response to on-road driver information via verge-mounted variable message signs on a stretch of four lane Managed Motorway – All Lane Running (MM-ALR). Participants also answered questionnaires to assess their attitudes to and perceptions of verge-mounted VMS.

Participants experienced two drives in the simulator; one with the gantry layout and one with verge signing – see below. For the verge signing section, half the participants experienced the verge red X layout, and the other half experienced the wicket layout. There were two test areas as shown in the following diagrams.
B.8.1 Driver behaviour – speed and lane choice

- Participants’ mean speeds were slightly higher in the verge signing layout compared to the gantry signing layout for each speed limit section.
- Use of different message designs in the verge Red X and Wicket layouts did not have a significant effect on participants’ mean speed.
- Participants’ spot speeds under signs in the verge layout were consistently higher in the verge signing layout than in the gantry layout.
- In most sections, participants exceeded the speed limit plus 10% for a greater proportion of time in the verge layout compared to the gantry layout.
- There was little difference in the surfing magnitude (variability in speed in relation to signs/gantries) between gantry and verge signing layouts.
- There was slightly more compliance with the lane closure aspect by participants in the gantry signing layout than verge signing layout, although compliance levels were high in all layouts. (Out of 102 drives, there were only 11 drives for the Lane Below Signal 1 (LBS1) closure and 19 drives for the Lane Below Signals 3/4 (LBS3/4) closure where participants travelled in the closed lanes.) There was slightly less compliance with the wicket layout than with the Red X. A follow-up questionnaire showed this was unlikely to have been due to poor comprehension.
B.8.2 Questionnaire

- No difference was identified in driver workloads between gantry and verge mounted drives.
- The majority of participants were confident of their knowledge of the speed limit and lane status throughout gantry and verge drives.
- Participants’ perceptions of the mandatory nature of the speed limit and lane closure instructions were almost identical across verge and gantry layouts.
- Participants perceived supplementary information that could be displayed on MS4s as likely to influence driver behaviour, and said that they would like to receive additional information relating to the lane closure such as how far ahead it occurred and why it was in place.

B.9 An Independent Review of VMS effectiveness – Combined Reports

(Prepared at the request of the Highways Agency by TRL, 2013)

The scope of this independent review was to examine questions relating to the use of Variable Message Signs (VMS) on the Highways Agency Strategic Road Network, including:

1. What effect does the use of VMS (in particular the legend 'Workforce in Road – Slow') have on-road worker safety?
2. How does the perceived effectiveness of VMS compare with actual effectiveness (considering both the road worker and road user perspectives)?

The key findings from the review were:

- Overall, the use of “WORKFORCE IN ROAD” VMS was considered to have a neutral to slightly negative effect on-road worker safety.
- Information VMS messages are effective in changing driver behaviour, but actual levels of effectiveness are much smaller than they are perceived to be by road workers.
- There is also a mismatch between perceived effectiveness and actual effectiveness due to psychological factors influencing road users and road workers.
- This is likely to lead to risk compensation behaviours built on subjective belief of the effectiveness of VMS rather than objective knowledge of actual effectiveness.
- These compensation behaviours are likely to increase risk to road workers and so actually decrease their safety where VMS are used.

This report contains references to a large number of studies which consider the effectiveness and driver response to VMS. One interesting comment specifically related to VMS used for road worker safety is:

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5 Information VMS describes VMS set to show information such as “WORKFORCE IN ROAD SLOW” rather than mandatory signals (such as red X signals to diagram 6031.1 of the Traffic Signs Regulations)
“The research evidence examined [...] suggests VMS is only likely to influence the behaviour of up to 20% of road users. The driver type most likely to be affected appears to be the predominantly “compliant” driver who already presents a low level of risk to road workers. This suggests that the overall level of driver response to VMS messages related to road worker safety [e.g. ‘WORKFORCE IN ROAD – SLOW’] will be small and generally limited to drivers who present an already low risk to road workers.”
## Appendix C  Hazard log

### Table C.1: Hazard Log for 'Undesired Events' occurring during the PLANNING of 1C2 and 1C3 trials

<table>
<thead>
<tr>
<th>Description of the 'Undesired Event'</th>
<th>Reason for concern</th>
<th>Acceptability of the 'Undesired Event'</th>
<th>Person(s) at risk</th>
<th>WITH EXISTING CONTROL MEASURES ONLY</th>
<th>TRIAL CONTROL MEASURES (if Party Responsible)</th>
<th>ACTION TO BE TAKEN (if Party Responsible)</th>
<th>WITH TRIAL MEASURES</th>
<th>Likelihood of the 'Undesired Event' occurring and leading to injury</th>
<th>Impact</th>
<th>Residual Risk Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road space booking clashes</td>
<td>The road space to be used for the trial may be double booked</td>
<td>Unacceptable Compliance with trial requirements for road space is critical</td>
<td>Remote</td>
<td>Minor</td>
<td>1. Service Provider: Apply an exclusion zone of at least 5km on the M25/M42 and at least 3km on the M4, either side of the trial road works.</td>
<td>Probable (Likelihood reduced by Trial Control Measures)</td>
<td>Minor</td>
<td>Green</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety issues may arise from inadequate RCC involvement</td>
<td>Unacceptable Adequate RCC staff resources are critical</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>1. RCC Supervisor: Assign an additional resource (the RCC Dedicated Operator) to the trial shift.</td>
<td>Probable (Likelihood reduced by Trial Control Measures)</td>
<td>Very Serious</td>
<td>Amber</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insufficient RCC staffing resources result in poor management of VSS prior to the trial</td>
<td>Unacceptable Road workers must be familiar with trial procedures</td>
<td>Remote</td>
<td>Minor</td>
<td>1. Service Provider: Brief all on-drift staff, including the RCC Dedicated Operator and the SP Staff Member on each individual trial night.</td>
<td>Probable (Likelihood reduced by Trial Control Measures)</td>
<td>Minor</td>
<td>Green</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NOTES: The following are required control measures that should be applied to all 1C2 and 1C3 Experimental Trials:

1. **Service Provider:** Assign a briefed Service Provider Staff Member to the RCC during the trial shift, as a contact point for the TTM Leader.
2. **RCC Team Manager:** Ensure that optimum RCC staff resources are available for the trial shift.
3. **Service Provider:** Undertake the briefing process outlined in the safety report.
4. **RCC:** Undertake the briefing process outlined in the safety report.
5. **RCC Team Manager:** Assign an additional RCC Control Room Staff Dedicated Operator.
6. **RCC Team Manager:** Brief all RCC Control Room Staff (including Dedicated Operator) on each individual night.
## TABLE C.2: Hazard Log for ‘Undesired Events’ occurring DURING THE INSTALLATION OF TRAFFIC MANAGEMENT for individual 1C2 and 1C3 trials

References cited in ‘Trial Control Measures’ column and other key notes will be stated at the end of the table once all trial control measures are agreed.

<table>
<thead>
<tr>
<th>Description of the ‘Undesired Event’</th>
<th>Reason for concern</th>
<th>Acceptability of the ‘Undesired Event’</th>
<th>Person(s) at risk</th>
<th>WITH EXISTING CONTROL MEASURES ONLY</th>
<th>TRIAL CONTROL MEASURES</th>
<th>ACTION TO BE TAKEN</th>
<th>WITH TRIAL CONTROL MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial or total failure of signs prior to setting VSS for trials</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road users may not receive accurate lane closure information</td>
<td>TTM crew may be inadequately protected</td>
<td>Unacceptable Compliance with trial requirements for signing on trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Occasional Very Serious Red</td>
<td>1. RCC Staff: Signal checks on VSS to be used for the closure signing should be carried out on a daily basis (at the request of members of the Trials Delivery Team at the 5 working days prior to and including the day of the trial. Faults will be reported to the RTMC/Technicians and the National Fault Database (NFD) as per normal RCC protocols. Notification of trial cancellation should be given to relevant members of the Trials Delivery Team as soon as it is identified repairs cannot be completed before the trial.</td>
<td>1. RCC Team Leader: Trial should not go ahead.</td>
<td>Improbable [Likelihood reduced by Trial Control Measures]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. TTM Leader: Contact RCC before mobilising the TTM crew to ensure VSS are working in the trial area.</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td>3. RCC Dedicated Operator: Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor of the trial cancellation.</td>
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<td></td>
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<td></td>
<td>4. RCC Dedicated Operator: Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>5. RCC Dedicated Operator: Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.</td>
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<td></td>
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<tr>
<td></td>
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<td></td>
<td>6. RCC Dedicated Operator: Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. RCC Dedicated Operator: Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Partial or total failure of signs prior to setting VSS for trials

- **TTM Supervisor:** Cross-check information from TTM Leader with trial lane closure information/ signal requirements from RCC Supervisor before setting signals.  
- **TTM Leader and RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Team Leader, TRL and RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.

## Incorrect information supplied to RCC

- **TTM Supervisor:** Cross-check information from TTM Leader with trial lane closure information/ signal requirements from RCC Supervisor before setting signals.  
- **TTM Leader and RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Team Leader, TRL and RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.

## Incorrect entry of location information by RCC Dedicated Operator

- **TTM Supervisor:** Cross-check information from TTM Leader with trial lane closure information/ signal requirements from RCC Supervisor before setting signals.  
- **TTM Leader and RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Team Leader, TRL and RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.
- **RCC Dedicated Operator:** Service Provider, SP Staff Member, RCC Dedicated Operator, TRL and the RCC Supervisor to be informed, as appropriate, of trial cancellation.
Table C.2: Hazard Log for ‘Undesired Events’ occurring DURING THE INSTALLATION OF TRAFFIC MANAGEMENT for individual 1C2 and 1C3 trials

References cited in ‘Trial Control Measures’ column and other key notes will be listed at the end of the table once all trial control measures are agreed.

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<tr>
<th>Description of the ‘Undesired Event’</th>
<th>Reason for concern</th>
<th>Acceptability of the ‘Undesired Event’</th>
<th>Likelihood of the ‘Undesired Event’ occurring and leading to injury</th>
<th>Impact of the ‘Undesired Event’ in the person(s) at risk</th>
<th>Residual Risk Rating</th>
<th>Responsible Risk Control Measures</th>
<th>ACTION TO BE TAKEN</th>
<th>IF THE ‘UNDISERED EVENT’ OCCURS EVEN WITH THE TRIAL CONTROL MEASURES IN PLACE</th>
<th>WITH TRIAL CONTROL MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect manual setting of signals by RCC Dedicated Operator</td>
<td></td>
<td>Unacceptable, Compliance with trial requirements for setting of signals via trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>Red</td>
<td>1. RCC Dedicated Operator: Cross-check information from TTM Leader with trial lane closure information/ignal requirements from RCC Supervisor before setting signals.</td>
<td>RCC Dedicated Operator: Reset trial signals in accordance with procedure specified by RCC Supervisor and check COBS display. Note times when error observed and error corrected on Trials Safety Sheet.</td>
<td>RCC Dedicated Operator: Abort trial if faults persist or cannot be corrected. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 6 in Safety Report) for back to standard ground level signing for works.</td>
</tr>
<tr>
<td>Incorrect system generated secondary setting of signals by RCC Dedicated Operator (Independent of operator error)</td>
<td></td>
<td>Unacceptable, Compliance with trial requirements for setting of signals via trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Remote</td>
<td>Very Serious</td>
<td>Red</td>
<td>2. RCC Dedicated Operator: Reset trial signals in accordance with procedure specified by RCC Supervisor and check COBS display. Note times when error observed and error corrected on Trials Safety Sheet.</td>
<td>TTM Leader and RCC Dedicated Operator: Abort trial if faults persist or cannot be corrected. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 6 in Safety Report) for back to standard ground level signing for works.</td>
<td>Arber (Residual Risk Rating reduced by Trial Control Measures)</td>
</tr>
<tr>
<td>Accidental override or cancellation of signals (human error)</td>
<td></td>
<td>Unacceptable, Compliance with trial requirements for setting of signals via trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>Red</td>
<td>3. RCC Dedicated Operator: Continuously monitor VSS.</td>
<td>TTM Leader and RCC Dedicated Operator: Abort trial if faults persist or cannot be corrected. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 6 in Safety Report) for back to standard ground level signing for works.</td>
<td>Remote (Likelihood reduced by Trial Control Measures)</td>
</tr>
<tr>
<td>Interruption or delayed faults occur</td>
<td></td>
<td>Unacceptable, Compliance with trial requirements for setting of signals via trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>Red</td>
<td>4. TTM Leader: Before placing TTM, wait 10 minutes once signals have been set to allow any immediate faults to emerge.</td>
<td>TTM Leader: Contact RCC Dedicated Operator if error is first detected on-road.</td>
<td>Remote (Likelihood reduced by Trial Control Measures)</td>
</tr>
</tbody>
</table>

TRL Road Safety Group

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CPR2000
<table>
<thead>
<tr>
<th>Description of the 'Undesired Event'</th>
<th>Reason for concerns</th>
<th>Acceptability of the 'Undesired Event'</th>
<th>Likelihood of the 'Undesired Event' occurring and leading to injury</th>
<th>Impact of the 'Undesired Event' on the person(s) at risk</th>
<th>Residual Risk Rating</th>
<th>Measures in Place</th>
<th>Action to be Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Execution of the RCC results in a loss of service continuity and the handover of control to another RCC, having no familiarity with the trial</td>
<td>Unacceptable. VSS requires continuous management throughout the trial &amp; continuous communication with on-road team</td>
<td>Remote</td>
<td>Major</td>
<td>Amber</td>
<td>Remote</td>
<td>Major</td>
<td>Amber</td>
</tr>
<tr>
<td>Road users may be unaware of actual risk</td>
<td>Unacceptable Safety of the TTM crew is critical</td>
<td>Improbable</td>
<td>Very Serious</td>
<td>Red</td>
<td>Improbable</td>
<td>Major (Impact reduced by Trial Control Measures)</td>
<td>Amber</td>
</tr>
<tr>
<td>Incident in or near works requiring a change to the VSS identified by the RCC</td>
<td>Unacceptable. Compliance with trial requirements for signing on trial VSS is critical</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>Red</td>
<td>Occasional</td>
<td>Major (Impact reduced by Trial Control Measures)</td>
<td>Amber</td>
</tr>
</tbody>
</table>

**Trial Control Measures**

1. RCC Leader: Handover to another RCC in accordance with standard procedures.
2. SP Staff Member: Inform TTM Leader of evacuation within the RCC.
3. TTM Leader: Abort trial. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 4 in Safety Report) for fall back to standard ground level signing for works.
4. TTM Leader: Standard ground level signing to remain in place at all times but “concealed” as necessary under the trial. Ensure risk assessment, methods statements, etc. address potential TTM crew concerns as far as possible.
5. TTM Leader and RCC Dedicated Operator: Abort trial. Implement Trial Abort Procedure (see 1C2/1C3 Process Flowchart 4 in Safety Report) for fall back to standard ground level signing for works.
6. RCC Leader: Handover to another RCC in accordance with standard procedures.
7. TTM Leader: Move TTM crew to place of safety and reinstate standard procedures.
8. TTM Leader: Reconfirm communication regarding incident and viability of continuing trial.
9. RCC Dedicated Operator: Consult with RCC Dedicated Operator that Step 2 is complete and it is safe to change VSS.
10. RCC Dedicated Operator: Change VSS. którzy

**With Trial Control Measures**

1. RCC Dedicated Operator: Inform TTM Leader of the need to change VSS.
2. RCC Dedicated Operator: Inform TTM Leader of the need to change VSS.
3. RCC Dedicated Operator: Reinstate visual check of reset VSS via drive through and confirm status with RCC Dedicated Operator.
4. RCC Dedicated Operator: Confirm to RCC Dedicated Operator that Step 2 is complete and it is safe to change VSS.
5. RCC Dedicated Operator: Change VSS.
6. RCC Dedicated Operator: Confirm to RCC Dedicated Operator that Step 2 is complete and it is safe to change VSS.
7. RCC Dedicated Operator: Consult with RCC Dedicated Operator that Step 2 is complete and it is safe to change VSS.
8. RCC Dedicated Operator: Confirm to RCC Dedicated Operator that Step 2 is complete and it is safe to change VSS.
Table C.2: Hazard Log for ‘Undesired Events’ occurring DURING THE INSTALLATION OF TRAFFIC MANAGEMENT for individual 1C2 and 1C3 trials

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<th>Person(s) at risk</th>
<th>UNDERSIZED of the ‘Undesired Event’ occurring and leading to injury</th>
<th>IMPACT of the ‘Undesired Event’ on the person(s) at risk</th>
<th>RISK MANAGEMENT RATING Determined using the Highways Agency 5x5 Risk matrix</th>
<th>RESIDUAL RISK RATING Determined using the Highways Agency 5x5 Risk matrix</th>
<th>ACTION TO BE TAKEN</th>
<th>WITH TRIAL CONTROL MEASURES IN PLACE</th>
<th>UNDERSIZED of the ‘Undesired Event’ occurring and leading to injury</th>
<th>IMPACT of the ‘Undesired Event’ on the person(s) at risk</th>
<th>RISK MANAGEMENT RATING</th>
<th>RESIDUAL RISK RATING</th>
<th>WITH TRIAL CONTROL MEASURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident in or near works requiring a change to the VSS (identified by TTM Leader)</td>
<td>Contradictory or overidden VSS may lead to road user error or secondary incidents</td>
<td>Unacceptable, Compliance with trial requirements for signing on trial VSS is critical</td>
<td>TTM crew and road users</td>
<td>Occasional</td>
<td>Very Serious</td>
<td>Red</td>
<td>2. TTM Leader and RCC Dedicated Operator: Ensure that appropriate robust communication systems are in place.</td>
<td>RCC DedicatedOperator: Confirm communication regarding incident and viability of continuing trial.</td>
<td>RCC DedicatedOperator: Ensure that communication regarding incident and viability of continuing trial.</td>
<td>RCC DedicatedOperator: Confirm communication regarding incident and viability of continuing trial.</td>
<td>RCC DedicatedOperator: Ensure that communication regarding incident and viability of continuing trial.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oncoming vehicle(s)</td>
<td>Road users may not receive accurate lane closure information and may be unaware of risks and road workers in the carriageway</td>
<td>Unacceptable Safety of the TTM crew is critical</td>
<td>TTM crew and other road users</td>
<td>Remote</td>
<td>Very Serious</td>
<td>Red</td>
<td>1. RCC DedicatedOperator: Set warning messages on VSS.</td>
<td>RCC DedicatedOperator: Ensure that signals have been changed and are being reset.</td>
<td>RCC DedicatedOperator: Ensure that signals have been changed and are being reset.</td>
<td>RCC DedicatedOperator: Ensure that signals have been changed and are being reset.</td>
<td>RCC DedicatedOperator: Ensure that signals have been changed and are being reset.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of phone system or communication with on-road team resulting in an inability to manage trial conditions effectively</td>
<td>Lack of communication between road workers and RCC</td>
<td>Unacceptable Communication between all parties involved in trial is critical</td>
<td>TTM crew and road users</td>
<td>Improbable</td>
<td>Minor</td>
<td>Green</td>
<td>1. RCC DedicatedOperator: Ensure that respective mobile phone contact details are known.</td>
<td>RCC DedicatedOperator: Ensure that respective mobile phone contact details are known.</td>
<td>RCC DedicatedOperator: Ensure that respective mobile phone contact details are known.</td>
<td>RCC DedicatedOperator: Ensure that respective mobile phone contact details are known.</td>
<td>RCC DedicatedOperator: Ensure that respective mobile phone contact details are known.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description of the 'Undesired Event'</td>
<td>Reason for concerns</td>
<td>Acceptability of the 'Undesired Event'</td>
<td>Percent(s) at risk</td>
<td>UNDESIRED</td>
<td>IMPACT</td>
<td>OCCURRENCE RISK RATING</td>
<td>MEASURES IN PLACE</td>
<td>WITH EXISTING CONTROL MEASURES ONLY</td>
<td>ACTION TO BE TAKEN</td>
<td>WITH TRIAL CONTROL MEASURES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
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<td>----------------------------------</td>
<td>-----------------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical conditions affect the working environment of either the RCC operatives or workers in the closure</td>
<td>RCC operations: high potential for human error due to noise/high levels of distraction in the workplace. Workers in the closure. Physical conditions, e.g., weather, may place workers at risk</td>
<td>N/A</td>
<td>RCC staff and workers in the closure</td>
<td>Occasional</td>
<td>Major</td>
<td>Amber</td>
<td>Monitor safety of works and take appropriate action to protect workforce.</td>
<td>Monitor safety of works and take appropriate action to protect workforce.</td>
<td>Monitor safety of works and take appropriate action to protect workforce.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident override or cancellation of signals (human error)</td>
<td>Trial VSS will display incorrect information. Road users may not receive accurate lane information. Workers in the closure may be inadequately protected</td>
<td>Unacceptable. Compliance with trial requirements for signing on trial VSS is critical</td>
<td>Workers in the closure and road users</td>
<td>Occasional</td>
<td>Major</td>
<td>Amber</td>
<td>1. TTM Leader: Undertake visual check of signals via drive-through every 40 minutes on the M4 and every 30 minutes on the M25/M42.</td>
<td>1. TTM Leader: Undertake visual check of signals via drive-through every 40 minutes on the M4 and every 30 minutes on the M25/M42.</td>
<td>1. TTM Leader: Undertake visual check of signals via drive-through every 40 minutes on the M4 and every 30 minutes on the M25/M42.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategic NTIC settings are applied</td>
<td>Trial VSS may display incorrect information. Road users may not receive accurate lane information. Workers in the closure may be inadequately protected</td>
<td>Unacceptable. Compliance with trial requirements for signing on trial VSS is critical</td>
<td>Workers in the closure and road users</td>
<td>Remote</td>
<td>Minor</td>
<td>Green</td>
<td>1. TTM Leader: Contact RCC Dedicated Operator if error is first detected on-road.</td>
<td>1. TTM Leader: Contact RCC Dedicated Operator if error is first detected on-road.</td>
<td>1. TTM Leader: Contact RCC Dedicated Operator if error is first detected on-road.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermittent or delayed faults occur</td>
<td>Trial VSS may display incorrect information. Road users may not receive accurate lane information. Workers in the closure may be inadequately protected</td>
<td>Unacceptable. Compliance with trial requirements for signing on trial VSS is critical</td>
<td>Workers in the closure and road users</td>
<td>Occasional</td>
<td>Major</td>
<td>Amber</td>
<td>1. TTM Leader: Make-up to 3 attempts to reapply standard ground level signing for works.</td>
<td>1. TTM Leader: Make-up to 3 attempts to reapply standard ground level signing for works.</td>
<td>1. TTM Leader: Make-up to 3 attempts to reapply standard ground level signing for works.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial or complete failure of VSS</td>
<td>Trial VSS may display incorrect information. Road users may not receive accurate lane information. Workers in the closure may be inadequately protected</td>
<td>Unacceptable. Compliance with trial requirements for signing on trial VSS is critical</td>
<td>Workers in the closure and road users</td>
<td>Occasional</td>
<td>Major</td>
<td>Amber</td>
<td>1. TTM Leader: Inform RCC Dedicated Operator of failure of VSS.</td>
<td>1. TTM Leader: Inform RCC Dedicated Operator of failure of VSS.</td>
<td>1. TTM Leader: Inform RCC Dedicated Operator of failure of VSS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Table C.3: Hazard Log for ‘Undesired Events’ occurring DURING WORKS WITHIN THE CLOSURE for individual 1C2 and 1C3 trials

<table>
<thead>
<tr>
<th>Description of the ‘Undesired Event’</th>
<th>Reason for concerns</th>
<th>Acceptability of the ‘Undesired Event’</th>
<th>Person(s) at risk</th>
<th>UNDERSoord of the ‘Undesired Event’ occurring and leading to injury</th>
<th>IMPACT OF the ‘Undesired Event’ on the person(s) at risk</th>
<th>PREVENTATIVE RISK RATING</th>
<th>TRAIL CONTROL MEASURES implemented to prevent or identify an occurrence of the ‘Undesired Event’</th>
<th>ACTION TO BE TAKEN IF THE ‘Undesired Event’ OCCURS EVEN WITH THE TRAIL CONTROL MEASURES IN PLACE</th>
<th>WITH TRAIL CONTROL MEASURES</th>
</tr>
</thead>
</table>
| Execution of the RCC                 | If there is an emergency situation or execution of RCC staff, communication and direction will be terminated | Unacceptable. VSS requires continuous management throughout the trial & continuous communication with on-road team | Workers in the closure and road users | Remote | Major | Amber | None | 1. RCC Team Leader: Handover to another RCC in accordance with standard procedures.  
2. SP Staff Member: Inform TTM Leader of evacuation within the RCC.  
3. TTM Leader: Abort trial. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 4 in Safety Report) for fall back to standard ground level signing for works. | Remote | Major | Amber |
| Incident in or near works requiring a change to the VSS (identified by RCC) | Contradictory or unexpected VSS may lead to road user error or secondary incidents | Unacceptable. Compliance with trial requirements for signing on trial VSS is critical | Workers in the closure and road users | Occasional | Very Serious | Red | 3. TTM Leader and RCC Dedicated Operator: Ensure that appropriate robust communication systems are in place.  
4. RCC Dedicated Operator: Continuously monitor VSS | Occasional | Major | Red |
| Incident in or near works requiring a change to the VSS (identified by TTM Leader) | Contradictory or unexpected VSS may lead to road user error or secondary incidents | Unacceptable. Compliance with trial requirements for signing on trial VSS is critical | Workers in the closure and road users | Occasional | Very Serious | Red | 2. TTM Leader and RCC Dedicated Operator: Ensure that appropriate robust communication systems are in place.  
3. RCC Dedicated Operator: Continuously monitor VSS | Occasional | Major | Red |
| Unexpected congestion affects speed limits displayed on trial VSS | Unexpected congestion may affect critical VSS | Unacceptable. Compliance with trial requirements for signing on trial VSS is critical | Workers in the closure and road users | Remote | Minor | Green | 1. RCC Dedicated Operator: Advise TTM Leader of any changes made to VSS signs by the queue protection algorithm.  
2. TTM Leader and RCC Dedicated Operator: Abort trial if conditions are considered to be unsafe. Implement 1C2/1C3 Trial Abort Procedure (see 1C2/1C3 Process Flowchart 4 in Safety Report) for fall back to standard ground level signing for works. | Remote | Minor | Green |

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**TRL Road Safety Group**

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CPR2000
### Table C.3: Hazard Log for ‘Undesired Events’ occurring DURING WORKS WITHIN THE CLOSURE for individual 1C2 and 1C3 trials

<table>
<thead>
<tr>
<th>Description of the ‘Undesired Event’</th>
<th>Reason for concern</th>
<th>Acceptability of the ‘Undesired Event’</th>
<th>Person(s) at risk</th>
<th>WITH EXISTING CONTROL MEASURES ONLY</th>
<th>TRIAL CONTROL MEASURES</th>
<th>ACTION TO BE TAKEN</th>
<th>WITH TRIAL CONTROL MEASURES</th>
<th>RESIDUAL RISK RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road users may not receive accurate lane closure information and may be unaware of risks and road workers in the carriageway</td>
<td>Workers in the closure and road users in encroaching vehicle</td>
<td>Remote</td>
<td>Major</td>
<td>Amber</td>
<td>1. RCC Dedicated Operator: Continuously monitor VSS.</td>
<td></td>
<td>Remote</td>
<td>Major</td>
</tr>
<tr>
<td>Workforce consider that VSS alone provide inadequate physical protection during the trial</td>
<td>Workers in the closure and other road users</td>
<td>Remote</td>
<td>Minor</td>
<td>Green</td>
<td>1. RCC Dedicated Operator: Continuously monitor VSS.</td>
<td></td>
<td>Remote</td>
<td>Minor</td>
</tr>
<tr>
<td>Loss of phone system or communications with on-road team resulting in an inability to manage trial conditions effectively</td>
<td>Workers in the closure and road users</td>
<td>Probable</td>
<td>Major</td>
<td>Red Hatched</td>
<td>1. Service Provider/TTM Leader: Ensure effective engagement with workforce prior to mobilisation. 2. Service Provider: Ensure risk assessments, method statements, etc address potential worst-case scenarios as far as possible. 3. Service Provider: Only perform works in the trial closures at the discretion of the Service Provider. 4. TTM Leader: Set standard ground level signing to remain in place at all times but with hard signs “concealed” as necessary under each phase of the trial. 5. Service Provider and TTM Leader: Ensure that an appropriate cone impact warning system is used. 6. TTM Leader: Use ‘alternative taper’.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Notes:
- **Likelihood** of the ‘Undesired Event’ occurring and leading to injury
- **Impact** of the ‘Undesired Event’ on the person(s) at risk
- **Residual Risk Rating** determined using the Highways Agency 5x5 risk matrix.

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**References cited in ‘Trial Control Measures’ column and other key notes will be listed at the end of the table once all trial control measures are agreed.**
Appendix D  Location of the last MS4/advance sign relative to the first cone of the taper

D.1  Introduction

The Highways Agency intends to use MS4s, in place of ground level advance signing, to inform drivers when they are approaching road works. When the conventional ground level ‘sign simplification’ layout is used, in accordance with IAN 150/12, the last pair of signs is located 400m upstream of the first cone of the taper. Therefore, the current plans for using MS4s to sign road works locate the last MS4 400m upstream of the first cone of the taper. The Highways Agency believes it would be desirable to be able to vary this distance by up to 100m, i.e. from 400m to 300m, to give Asset Support Contractors (ASCs) / Managing Agent Contractors (MACs) / Design Build Finance Operate (DBFOs) contractors some flexibility in locating road works.

This document considers the following research question:

- Can the position of the last MS4 before the taper be reduced by 100m, whilst still ensuring road users are given the final warning of a lane closure no later than when fixed signs are used?

This document combines research from a number of different sources to inform this issue. In particular, the likely distances in advance of the first cone of the taper at which drivers would receive advice to change lanes, having seen only one advance ground level sign located at 400m or one MS4 located at 300m, have been calculated. The assumptions and relevant reports are detailed below, though an assessment of the robustness of the various findings has not been made.

Even without considering any limitations, the result is no more than indicative as it is not yet known how drivers react to MS4s located 400m upstream of the first cone to sign road works in a real life situation. This is being trialled by the HA’s Aiming for Zero (AfZ) project 1C3.

Figure D.1 displays the control and experimental layouts being compared.

Figure D.1: Control and Experimental layouts
D.2 Control layout

Clark et al (2009) indicates that the legibility distance (i.e. the distance at which a typical driver can read the sign) for a ground-level wicket sign is 64m.

Clark et al (2009) also indicates that a standard wicket sign can typically be read in 0.75 seconds. The Highway Code assumes a typical thinking time of 0.675s. Therefore, it is likely to take a typical driver approximately 1.5 seconds to read the wicket sign, to understand it and to start changing their behaviour as appropriate.

Assuming an approaching vehicle is travelling at 70mph (31m/s), the vehicle will travel 47m in 1.5 seconds.

If drivers first see the wicket sign 64m ahead of it and take 1.5 seconds (47m) to start reacting to it, drivers would typically be 17m ahead of the sign when they first react.

Given that the wicket sign is 400m ahead of the first cone of the taper, drivers would be 417m ahead of the first cone at this point.

D.3 Experimental layout

TRL (2011) indicates that the maximum legibility distance for an MS4 is 192m; the maximum legibility distance is defined as being the maximum distance at which it is possible for someone with 20/60 vision (i.e. a worst-case scenario) to read characters of the height of a speed limit on an MS4.

TRL (2011) also indicates that an MS4 can be read in 0.25 seconds and responded to (i.e. attention is returned to the road) in 1 second. The Highway Code assumes a typical thinking time of 0.675s. Therefore, it takes approximately 2 seconds to understand the MS4 and begin to react.

Assuming the approaching vehicle is travelling at 70mph (31m/s), the vehicle will travel 62m in 2 seconds.

If drivers first see the sign 192m ahead of it and take 2 seconds (62m) to start reacting to it, drivers would typically be 130m ahead of the sign when they first react.

Given that the MS4 is 300m ahead of the first cone of the taper, drivers would be 430m ahead of the first cone at this point.

D.4 Conclusion

In the control and experimental layouts the distances in advance of the first cone of the taper at which drivers travelling at 70mph have the information required to decide to move out of the closed lane is similar: 417m for the control and 430m for the experiment. Table D.1 displays the equivalent distance if the vehicle were travelling at a range of speeds.
Table D.1: Distance in advance of the first cone at which drivers have the information to move out of the closed lane at different travel speeds

<table>
<thead>
<tr>
<th>Speed</th>
<th>Control layout</th>
<th>Experimental layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>60mph</td>
<td>424m</td>
<td>438m</td>
</tr>
<tr>
<td>70mph</td>
<td>417m</td>
<td>430m</td>
</tr>
<tr>
<td>80mph</td>
<td>410m</td>
<td>420m</td>
</tr>
</tbody>
</table>

This does not indicate that drivers choose to change lane at comparable distances: there may be differences in the drivers’ reaction to these two types of sign. For example, if there is a belief that MS4s frequently display incorrect information, this may reduce the likelihood of drivers acting upon the information they receive.

Driver behaviour in response to MS4s is being investigated as part of the 1C3 on-road trial (with the last of the MS4s located 400m upstream of the first cone). This trial might indicate that drivers change lanes in response to MS4s at a different distance upstream of the taper than in response to conventional ground level signs, even when the last MS4 is 400m upstream of the first cone. This issue should therefore be re-examined once the 1C3 trial is complete.

D.5 Other considerations

There are a number of issues which have not been considered in the calculations above:

- The effect of the combination of the taper and signs on the time it takes a driver to understand and decide on their subsequent behaviour.
- The effect of the upstream signs on driver behaviour.
- The effect of the distances between each sign on driver behaviour.
- The effect of the repetition of signs on the offside when using ground-level advance signs on driver behaviour.
- The effect of the advisory speed limit on an upstream MS4 in the experimental condition on drivers’ travel speed - a reduction in speed is likely to increase the distance ahead of the taper at which a driver has enough information to make a decision to change lane.

D.6 Other relevant research

The trial report on sequential flashing cone lamps indicates that drivers choose to change lane earlier when sequential lamps are used compared to when static lamps are used. This effect begins approximately 500m ahead of the taper, and suggests that the inclusion of sequential lamps on the taper has a beneficial effect on driver behaviour.

TRL’s on-road trials show that, although drivers receive enough information to choose to change lanes well in advance of the taper (e.g. advance signs and the presence of the sequential lamps ahead), they often choose to remain in the closed lane until much later. For example, the sequential flashing cone lamps study shows that, even with sequential
lamps, approximately a quarter of the traffic in the closed lane 1.1 km ahead of the taper remains in this lane 200m ahead of the taper.

D.7 Evidence base – referenced reports

The following pages detail the thinking and evidence base for the conclusions. The boxed sections are relevant extracts from the reports concerned.

The MM-ALR simulator study indicated that drivers can read MS4s 192m in advance.

Highways Agency Managed Motorways 2 Concept Development Tasks 2, 3, 4 and 5

Key Findings Report CPR1062 March 2011

Maximum legibility distance of the signal – 192m. This is the maximum distance at which it is possible to read characters the height of a speed limit on an MS4 with 20/60 vision, i.e. this describes a worst-case scenario.

(According to the World Health Organization classifications, when the vision in the better eye with best possible glasses correction is 20:60, it is considered as mild vision loss, or near-normal vision.)

The simulator study also has information on response time. The average response time to an MS4 with a lane closure aspect, a pictogram and message text (i.e. E5 in the diagram below), having seen the MS4 for 0.25s, was approximately 1s.

Average (±SEM) response time(s) for MS4 message configurations in the “Lane closed” statement category, grouped by the number of elements displayed on the message (Session B – Static version, exposure duration = 0.25s)

[SL = Speed Limit, LC = Lane Closure, (S) = 1300mm diameter, (L) = 1500mm diameter]

Note: Each line of text is considered as a separate element
A study on sign sizes indicates that a standard wicket sign can be read in 0.75s.

_Safety Argument for Changes to Temporary Traffic Management Sign Sizes by S Clark, B Lyus, J Mitchell, B Lawton, L Smith, A Weare and L Walter_  
_CPR1108_

The accuracy of recalling lane-closure information only from a wicket sign was over 95% for each of the four exposure times in the range 0.25s to 1.75s.

The accuracy of recalling distance-only information from the supplementary distance plate was over 95% for exposure times equal to or greater than 0.75s.

The accuracy of recalling all of the information shown on a wicket sign, i.e. lane closure and distance to the closure was over 95% for exposures times equal to or greater than 0.75s.

For the combined lane closure and distance information, an accuracy of over 95% was achieved for an exposure time of 0.75s or more. This indicates that the 95th percentile reading time of a wicket sign/distance plate combination is of the order of 0.75s. This would be the time available to read the wicket sign from the moment it first becomes legible to the 10 degree cut-off point where the sign should no longer be viewed when driving.

Appendix E of this report details the legibility distance (64m) required for a wicket sign (7202) and supplementary distance plate (7208) to be seen on a 3 lane motorway with hard shoulder.
The sequential lamps study indicates that, compared to static lamps, sequential lamps encourage more drivers to choose to change lane from 500m before the taper. Prior to this point, the effect of static and sequential lamps is similar.

**Trial Report: Sequential Flashing Cone Lamps**

The average data suggest a strong effect from 600m before the taper, with consistent decreases seen in closed lane occupancy from 500m before the taper.

The sequential flashing cone lamps caused a consistent decrease in closed lane occupancy from a point 500m before the taper.

The effect of the sequential lamps is seen consistently from a point 500m before the taper, but also has an effect at a point 600m before the taper in half the cases.

![Traffic profile (normalised) approaching the cone taper](image)

*Figure 4: Traffic profile (normalised) approaching the cone taper (corrected data)*
Appendix E  Locations for experimental trials

The following tables set out the locations (in terms of marker posts) available for performing 1C3 trials on the M4 based upon the position of the first cone of the taper and the 'triplet' of MS4s that would be used to display the trial signals.

<table>
<thead>
<tr>
<th>Link</th>
<th>First cone of taper</th>
<th>First MS4 (Closest to taper)</th>
<th>Second MS4</th>
<th>Third MS4 (Furthest from taper)</th>
<th>Distance from Third MS4 to first cone of taper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction 13 to Junction 12</td>
<td>85/9</td>
<td>86/3</td>
<td>87/5</td>
<td>89/1</td>
<td>3.2km</td>
</tr>
<tr>
<td></td>
<td>81/2</td>
<td>81/6</td>
<td>83/0</td>
<td>84/6</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>79/6</td>
<td>80/0</td>
<td>81/6</td>
<td>83/0</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>78/1</td>
<td>78/5</td>
<td>80/0</td>
<td>81/6</td>
<td>3.5km</td>
</tr>
<tr>
<td></td>
<td>76/5</td>
<td>76/9</td>
<td>78/5</td>
<td>80/0</td>
<td>3.5km</td>
</tr>
<tr>
<td>Junction 10 to Junction 8/9</td>
<td>51/8</td>
<td>52/2</td>
<td>53/5</td>
<td>54/7</td>
<td>2.9km</td>
</tr>
<tr>
<td></td>
<td>48/7</td>
<td>49/1</td>
<td>50/6</td>
<td>52/2</td>
<td>3.5km</td>
</tr>
</tbody>
</table>

Table E.1: Experimental locations on the eastbound M4

<table>
<thead>
<tr>
<th>Link</th>
<th>First cone of taper</th>
<th>First MS4 (Closest to taper)</th>
<th>Second MS4</th>
<th>Third MS4 (Furthest from taper)</th>
<th>Distance from Third MS4 to first cone of taper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction 8/9 to Junction 10</td>
<td>50/6</td>
<td>50/2</td>
<td>49/1</td>
<td>47/5</td>
<td>3.1km</td>
</tr>
<tr>
<td></td>
<td>53/0</td>
<td>52/6</td>
<td>51/4</td>
<td>50/2</td>
<td>2.8km</td>
</tr>
<tr>
<td>Junction 12 to Junction 13</td>
<td>79/2</td>
<td>78/8</td>
<td>77/3</td>
<td>75/8</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>80/7</td>
<td>80/3</td>
<td>78/8</td>
<td>77/3</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>82/2</td>
<td>81/8</td>
<td>80/3</td>
<td>78/8</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>83/7</td>
<td>83/3</td>
<td>81/8</td>
<td>80/3</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>85/3</td>
<td>84/9</td>
<td>83/3</td>
<td>81/8</td>
<td>3.5km</td>
</tr>
<tr>
<td></td>
<td>86/7</td>
<td>86/3</td>
<td>84/9</td>
<td>83/3</td>
<td>3.4km</td>
</tr>
<tr>
<td></td>
<td>87/9</td>
<td>87/5</td>
<td>86/3</td>
<td>84/9</td>
<td>3.0km</td>
</tr>
<tr>
<td>Junction 13 to Junction 14</td>
<td>97/4</td>
<td>97/0</td>
<td>95/5</td>
<td>94/0</td>
<td>3.4km</td>
</tr>
</tbody>
</table>

Table E.2: Experimental conditions on the westbound M4
Appendix F  Offside (Lane 3) Closure Results

F.1  Research Question 1 - ANOVA results for single factor and two factor interactions

*Distance from taper* not significant (*p*>0.10)

Table F.1 shows the total number of vehicle counts made at each distance from taper at the 28 trial sites. The ANOVA model shows that these two numbers are not statistically different.

<table>
<thead>
<tr>
<th>Distance from taper</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>800m</td>
<td>26,588</td>
</tr>
<tr>
<td>400m</td>
<td>26,588</td>
</tr>
</tbody>
</table>

*Table F.1: Number of vehicles at each distance from taper*

*Lane* significant (*p*<0.05)

Table F.2 shows the total number of vehicle counts made in each lane across the trial sites. Overall, 59% were observed in lane 1, 38% in lane 2 and 3% in lane 3. The ANOVA model confirms that the overall number of vehicles observed in each lane is statistically different.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>31,551</td>
</tr>
<tr>
<td>Lane 2</td>
<td>20,006</td>
</tr>
<tr>
<td>Lane 3</td>
<td>1,619</td>
</tr>
</tbody>
</table>

*Table F.2: Number of vehicles in each lane*

*Trial* significant (*p*<0.05)

Table F.3 shows the total number of vehicle counts at the experimental and control sites; these numbers differ as there were 15 control trials and only 13 experimental completed. The ANOVA model showed that these numbers were statistically different from each other. The control trials were on average higher flow than the experimental trials – this was controlled for in the analysis (Table 4.5).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>32,958</td>
</tr>
<tr>
<td>Experiment</td>
<td>20,218</td>
</tr>
</tbody>
</table>

*Table F.3: Number of vehicles in each trial*
Distance from taper * trial not significant (p>0.10)

Differences in the number of vehicles at each distance are the same across the control and experimental groups. That is, variations in counts between the control and experiment are not deemed to be sufficiently different at different distances to matter.

![Graph showing number of vehicles at each distance from taper in each trial](image)

Figure F.1: Number of vehicles at each distance from taper in each trial

Distance from taper * lane significant (p<0.05)

Differences in the number of vehicles at each distance vary by lane. In this case there is a slight reduction in the proportion of vehicles in lane 3 from the 800m to the 400m point, and a corresponding increase in the proportion of vehicles in lane 2. The proportion in lane 1 remained fairly consistent.
**Figure F.2:** Proportion of vehicles in each lane at each distance from taper

*Trial * lane not significant (p>0.10)*

Figure F.3 shows that there was a slightly lower proportion of vehicles in lanes 2 and 3 in the experimental condition compared to the control condition; this observation was reversed in lane 1 where there was a lower proportion of vehicles in the control condition. However, the results show that the distribution of vehicles across the lanes does not differ significantly between the experiment and control sites.

**Figure F.3:** Proportion of vehicles in each lane in each trial
F.2 Research Question 2 - ANOVA results for single factor and two factor interactions

*Information point* not significant (p>0.10)

Table F.4 shows the total number of vehicle counts made at each sign at the 28 trial sites. The ANOVA model shows that these numbers are not statistically different; slight differences between the counts are due to small differences in the starting times of videos.

<table>
<thead>
<tr>
<th>Information point</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most upstream sign</td>
<td>26,419</td>
</tr>
<tr>
<td>Middle sign</td>
<td>26,609</td>
</tr>
<tr>
<td>400m sign</td>
<td>26,588</td>
</tr>
</tbody>
</table>

*Table F.4: Number of vehicles at each distance from taper*

*Lane* significant (p<0.05)

Table F.5 shows the total number of vehicle counts made in each lane across the trial sites. Overall, 58% were observed in lane 1, 38% in lane 2 and 4% in lane 3. The ANOVA model confirms that the overall number of vehicles observed in each lane is statistically different.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>46,196</td>
</tr>
<tr>
<td>Lane 2</td>
<td>30,365</td>
</tr>
<tr>
<td>Lane 3</td>
<td>3,055</td>
</tr>
</tbody>
</table>

*Table F.5: Number of vehicles in each lane*

*Trial* significant (p<0.05)

Table F.6 shows the total number of vehicle counts at the experimental and control sites. The ANOVA model showed that these numbers were statistically different from each other. The control trials were on average higher flow than the experimental trials – this was controlled for in the analysis (Table 4.10).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>49,309</td>
</tr>
<tr>
<td>Experiment</td>
<td>30,307</td>
</tr>
</tbody>
</table>

*Table F.6: Number of vehicles in each trial*
Information point * trial not significant (p>0.10)

Differences in the number of vehicles at each sign are the same across the control and experimental groups. That is, variations in counts between the control and experiment are not deemed to be sufficiently different at different signs to matter.

![Diagram](image)

**Figure F.4**: Number of vehicles at each distance from taper in each trial

Information point * lane significant (p<0.05)

Differences in the number of vehicles at each sign vary by lane. In this case there is a reduction in the proportion of vehicles in the closed lane, lane 3, from the most upstream sign to the sign at 400m, and a corresponding increase in the proportion of vehicles in lane 1. The proportion of vehicles in lane 2 remains fairly consistent across the three information points.
Figure F.5: Proportion of vehicles in each lane at each distance from taper

Trial * lane not significant (p>0.10)

Figure F.6 shows that there was a slightly lower proportion of vehicles in lanes 2 and 3 in the experimental condition compared to the control condition; this observation was reversed in lane 1 where there was a lower proportion of vehicles in the control condition. However, the results show that the distribution of vehicles across the lanes does not differ significantly between the experiment and control sites.

Figure F.6: Proportion of vehicles in each lane in each trial
Appendix G  Nearside (Lane 1) Closure Results

G.1  Research Question 1 - ANOVA results for single factor and two factor interactions

*Distance from taper not significant (p>0.10)*

Table G.1 shows the total number of vehicle counts made at each distance from taper at the 26 trial sites. The ANOVA model shows that these two numbers are not statistically different; slight differences between the counts are due to small differences in the starting times of videos.

<table>
<thead>
<tr>
<th>Distance from taper</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>800m</td>
<td>25,412</td>
</tr>
<tr>
<td>400m</td>
<td>26,175</td>
</tr>
</tbody>
</table>

Table G.1: Number of vehicles at each distance from taper

*Lane significant (p<0.05)*

Table G.2 shows the total number of vehicle counts made in each lane across the trial sites. Overall, 33% were observed in lane 1, 55% in lane 2 and 12% in lane 3. The ANOVA model confirms that the overall number of vehicles observed in each lane is statistically different.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>16,982</td>
</tr>
<tr>
<td>Lane 2</td>
<td>28,538</td>
</tr>
<tr>
<td>Lane 3</td>
<td>6,068</td>
</tr>
</tbody>
</table>

Table G.2: Number of vehicles in each lane

*Trial not significant (p>0.10)*

Table G.3 shows the total number of vehicle counts at the experimental and control sites; these numbers differ as there were 14 control trials and only 12 experimental completed. The ANOVA model showed that these numbers were not statistically different from each other.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>29,069</td>
</tr>
<tr>
<td>Experiment</td>
<td>22,518</td>
</tr>
</tbody>
</table>

Table G.3: Number of vehicles in each trial
Distance from taper * trial not significant (p>0.10)

Differences in the number of vehicles at each distance are the same across the control and experimental groups. That is, variations in counts between the control and experiment are not deemed to be sufficiently different at different distances to matter.

Figure G.1: Number of vehicles at each distance from taper in each trial

Distance from taper * lane significant (p<0.05)

Differences in the number of vehicles at each distance vary by lane. In this case there is a reduction in the proportion of vehicles in lane 1 from the 800m to the 400m point, and a corresponding increase in the proportion of vehicles in lanes 2 and 3.
Use of MS4s to Sign Road Works

**Figure G.2:** Proportion of vehicles in each lane at each distance from taper

*Trial * lane not significant (p>0.10)

Figure G.3 shows that there was a slightly lower proportion of vehicles in lane 1 in the experimental condition compared to the control condition; this observation was reversed in lanes 2 and 3 where there was a slightly lower proportion of vehicles in the control condition. However, the results show that the distribution of vehicles across the lanes does not differ significantly between the experiment and control sites.

**Figure G.3:** Proportion of vehicles in each lane in each trial
G.2 Research Question 2 - ANOVA results for single factor and two factor interactions

Information point not significant (p>0.10)

Table G.4 shows the total number of vehicle counts made at each sign at the 26 trial sites. The ANOVA model shows that these numbers are not statistically different; slight differences between the counts are due to small differences in the starting times of videos.

<table>
<thead>
<tr>
<th>Information point</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most upstream sign</td>
<td>24,593</td>
</tr>
<tr>
<td>Middle sign</td>
<td>25,900</td>
</tr>
<tr>
<td>400m sign</td>
<td>26,175</td>
</tr>
</tbody>
</table>

Table G.4: Number of vehicles at each distance from taper

Lane significant (p<0.05)

Table G.5 shows the total number of vehicle counts made in each lane across the trial sites. Overall, 40% were observed in lane 1, 51% in lane 2 and 9% in lane 3. The ANOVA model confirms that the overall number of vehicles observed in each lane is statistically different.

<table>
<thead>
<tr>
<th>Lane</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 1</td>
<td>30,563</td>
</tr>
<tr>
<td>Lane 2</td>
<td>38,916</td>
</tr>
<tr>
<td>Lane 3</td>
<td>7,189</td>
</tr>
</tbody>
</table>

Table G.5: Number of vehicles in each lane

Trial not significant (p>0.10)

Table G.6 shows the total number of vehicle counts at the experimental and control sites. The ANOVA model showed that these numbers were not statistically different from each other. Differences in the counts are likely to arise due to the difference in the number of control and experimental sites (14 and 12 respectively).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Vehicle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>43,286</td>
</tr>
<tr>
<td>Experiment</td>
<td>33,382</td>
</tr>
</tbody>
</table>

Table G.6: Number of vehicles in each trial
Information point * trial not significant (p>0.10)

Differences in the number of vehicles at each sign are the same across the control and experimental groups. That is, variations in counts between the control and experiment are not deemed to be sufficiently different at different signs to matter.

Figure G.4: Number of vehicles at each distance from taper in each trial

Information point * lane significant (p<0.05)

Differences in the number of vehicles at each sign vary by lane. In this case there is a reduction in the proportion of vehicles in the closed lane, lane 1, from the most upstream sign to the sign at 400m, and a corresponding increase in the proportion of vehicles in lanes 2 and 3.
Figure G.5: Proportion of vehicles in each lane at each distance from taper

Trial * lane not significant (p>0.10)

Figure G.6 shows that there was a slightly higher proportion of vehicles in lane 1 in the experimental condition compared to the control condition; this observation was reversed in lanes 2 and 3 where there was a slightly higher proportion of vehicles in the control condition. However, the ANOVA shows that the distribution of vehicles across the lanes does not differ significantly between the experiment and control sites.

Figure G.6: Proportion of vehicles in each lane in each trial
Appendix H  Detailed Fault Analysis

H.1 Fault identification

Faults during the trials were identified either

- in advance of experimental condition trials, as a result of the MS4 being tested by the RCC specifically for the purposes of the trial;

- at the beginning of or during the trials themselves, by the RCC Dedicated Operator. These were identified via the Control Office Base System (COBS) display, from a live CCTV feed in the vicinity of the affected signal, or via direct feedback from the Temporary Traffic Management (TTM) crew; or

- during the trials by the trials video cameras which captured many instances when an illuminated MS4 display ‘flashed’ off and then immediately on again. (This phenomenon was also observed directly on several occasions when they were in use, so cannot be attributed to a quirk of the video footage.) These types of occurrence are not logged within the Highways Agency LOGging ENvironment (HALOGEN) and do not show up on the COBS display, so were not investigated further within this project.

H.2 Fault categorisation

Identified faults resulted in complete loss of pictogram and/or message aspects or the loss/distortion of individual characters within a message aspect. They can be categorised into two types:

- **Intermittent faults**: The display set on an MS4 unexpectedly changed or disappeared for a period of time, but was then reinstated either automatically or on the intervention of the RCC Dedicated Operator.

- **Unrecoverable faults**: The display set on an MS4 unexpectedly changed or disappeared, and could not be reinstated even with the intervention of the RCC Dedicated Operator. All faults identified during testing by the RCC in advance of a trial which caused it to be cancelled were categorised as being unrecoverable, since there was inadequate time for the fault to be repaired.

H.3 Analysis of the faults affecting individual MS4s used in the trial

Figure H.1 considers the availability of MS4s on the westbound carriageway in terms of the number of different MS4s that were used or had been planned to be used. Based on the locations of scheduled works that could be used for the trials, and the locations of other works activities, only 11 of the 17 different MS4s covering candidate trial locations were planned to be used. Only seven were actually used during the completed trials; of these seven, two failed to operate successfully on any trial nights at all.

Figure H.2 presents the corresponding analysis for the eastbound carriageway. Based on the locations of actual scheduled works during the trials, only nine of the 15 different MS4s covering candidate trial locations were planned to be used. All nine were used at some stage during the completed trials and, of those, only two exhibited any kind of fault on at
least one trial night. The reliability of the MS4s on the eastbound carriageway was therefore much better than those on the westbound carriageway.

![Graph showing usage and failure data for individual 1C3 MS4s on the westbound carriageway.]

**Figure H.1: Usage and failure data for individual 1C3 MS4s on the westbound carriageway**

![Graph showing usage and failure data for individual 1C3 MS4s on the eastbound carriageway.]

**Figure H.2: Usage and failure data for individual 1C3 MS4s on the eastbound carriageway**
**Number and type of failures on individual MS4s**

Figure H.3 and Figure H.4 look in greater detail at the individual MS4s, on the westbound and eastbound carriageways respectively, distinguishing between whether they exhibited only intermittent faults, only unrecoverable faults, or both fault types. The numerical value appearing above the figure bars for some MS4s corresponds to the total number of intermittent faults exhibited by that MS4 over all the trial nights on which they were to be used.

For this analysis, the number of intermittent and unrecoverable faults was based on the number of faults reported by the RCC Dedicated Operator at the end of each trial night.

The corresponding level of intervention by the RCC Dedicated Operator to reinstate the trial settings each time an intermittent failure occurred, particularly for the MS4s at 81/8 and 78/8 on the westbound carriageway, is validation of the effort taken to develop robust safety protocols for the trials.

---

**Figure H.3: Failure types for individual 1C3 MS4s on the westbound carriageway**
To complement the observations of the RCC Dedicated Operator, the HALOGEN fault log files for a selected number of trial nights were reviewed and compared with the corresponding data entries in the Command and Control Incident Log (CCIL) for the trial (as created and edited by the RCC Dedicated Operator). HALOGEN is the central source for the Highways Agency Traffic Management Systems (HATMS) logged data. It records setting, state change and fault information for signals, signs and emergency roadside telephones on England’s motorway network. There was generally a good correlation between the two datasets regarding the number of times that the MS4s demonstrated faults. However, what was often reported as a single fault by the RCC Dedicated Operator often comprised multiple entries within the HALOGEN fault log files. Table H.1 shows an example in which the RCC Dedicated Operator reported that the MS4 failed once but the HALOGEN data identified the occurrence (‘HARD’ fault status) and resolution (‘CLEAR’ fault status) of multiple faults. The rows in the table highlighted in orange indicate where the RCC Dedicated Operator took action to address the fault that had been identified from the COBS display in order to reinstate the trial settings.

Table H.2 shows a further example of an MS4 exhibiting multiple faults on a trial night; in this instance, the faults that resulted in the initial failure of the MS4 at 21:43 were actually the last ones to be resolved at 22:19, i.e. several other faults occurred and were resolved within that time period.
### Table H.1: Comparison of MS4 fault data as reported by the RCC Dedicated Operator and recorded in the HALOGEN fault log

(RCC Dedicated Operator actions also indicated by orange highlighted rows)

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Fault ID</th>
<th>Fault Status</th>
<th>Equipment</th>
<th>Equipment Ref</th>
<th>Clearance Method</th>
<th>Fault Type</th>
<th>Fault Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>25/04/2014 00:37</td>
<td>45389</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>STATUS REPLY - CRC INCORRECT</td>
<td>Lane 1 closed-SLOW</td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:07</td>
<td>45390</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>STATUS REPLY - MESSAGE FAIL</td>
<td>Lane 1 closed-SLOW</td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:07</td>
<td>45391</td>
<td>HARD</td>
<td>SIG</td>
<td>M4/2833A</td>
<td>ASPECT FAILED</td>
<td>TII</td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:07</td>
<td>45392</td>
<td>HARD</td>
<td>SIG</td>
<td>M4/2833A</td>
<td>AMBER FLASHER FAILED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:08</td>
<td>45391</td>
<td>CLEAR</td>
<td>SIG</td>
<td>M4/2833A</td>
<td>F</td>
<td>OIF Initiated Equipment Setting: 'TII' (Reason: Road works - coning)</td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:08</td>
<td>45392</td>
<td>CLEAR</td>
<td>SIG</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:09</td>
<td>45394</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>STATUS REPLY - POWER FAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:09</td>
<td>45396</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>STATUS REPLY - LANTERN/DIM/BRIGHT FAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:09</td>
<td>45395</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>STATUS REPLY - LAMP OR LED FAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td></td>
<td></td>
<td>MSS</td>
<td>M4/2833A</td>
<td>OIF Initiated Equipment Setting: 'SYMBOL 4 - (Workforce in road) Workforce in road-SLOW' (Reason: Clear)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td>45389</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td>45394</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td>45390</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td>45395</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:35</td>
<td>45396</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2833A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/04/14 00:37:55</td>
<td></td>
<td></td>
<td>MSS</td>
<td>M4/2833A</td>
<td>OIF Initiated Equipment Setting: 'Lane 1 closed-SLOW' (Reason: Road works – Coning)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### SINGLE fault as reported by RCC Dedicated Operator

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Fault ID</th>
<th>Fault Status</th>
<th>Equipment</th>
<th>Equipment Ref</th>
<th>Clearance Method</th>
<th>Fault Type</th>
<th>Fault Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/03/14 21:43:50</td>
<td>15227</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - MESSAGE FAIL</td>
<td>SYMBOL 4 - (Workforce in road) Workforce in road-SLOW</td>
</tr>
<tr>
<td>12/03/14 21:43:50</td>
<td>15225</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - CRC INCORRECT</td>
<td>SYMBOL 4 - (Workforce in road) Workforce in road-SLOW</td>
</tr>
<tr>
<td>12/03/14 21:43:50</td>
<td>15228</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - LAMP OR LED FAIL</td>
<td></td>
</tr>
<tr>
<td>12/03/14 21:43:50</td>
<td>15229</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - LANTERN/DIM/BRIGHT FAIL</td>
<td></td>
</tr>
<tr>
<td>12/03/14 21:43:50</td>
<td>15226</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - POWER FAIL</td>
<td></td>
</tr>
</tbody>
</table>

**MS4 set to display a 'road works' pictogram, a 'Workforce in road-SLOW' message aspect and a '50' speed aspect**

Fault types not specified

### Corresponding MULTIPLE faults as reported in the HALOGEN fault log

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Fault ID</th>
<th>Fault Status</th>
<th>Equipment</th>
<th>Equipment Ref</th>
<th>Clearance Method</th>
<th>Fault Type</th>
<th>Fault Text</th>
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<tr>
<td>12/03/14 21:44:14</td>
<td>15222</td>
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<td>SIG</td>
<td>M4/2788A</td>
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<td>ASPECT FAILED</td>
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<td>15233</td>
<td>CLEAR</td>
<td>SIG</td>
<td>M4/2788A</td>
<td></td>
<td>ASPECT FAILED</td>
<td>50</td>
</tr>
</tbody>
</table>

**OIF Initiated Equipment Setting: '50' (Reason: Road works – Coning)**
### Table H.2: Comparison of MS4 fault data as reported by the RCC Dedicated Operator and recorded in the HALOGEN fault log
(RCC Dedicated Operator actions also indicated by orange highlighted rows)

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Fault ID</th>
<th>Fault ID</th>
<th>Equipment</th>
<th>Equipment Ref</th>
<th>Clearance Method</th>
<th>Fault Type</th>
<th>Fault Text</th>
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<tr>
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<td>SIG</td>
<td>M4/2788A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03/14 22:02:25</td>
<td>15293</td>
<td>CLEAR</td>
<td>SIG</td>
<td>M4/2788A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03/14 22:19:20</td>
<td></td>
<td></td>
<td>MSS</td>
<td>M4/2788A</td>
<td>Auto initiated equipment setting: 'Lane closure SLOW DOWN' (Reason: Road works Coning)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03/14 22:19:19</td>
<td>15227</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2788A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03/14 22:19:19</td>
<td>15226</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2788A</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03/14 22:19:19</td>
<td>15228</td>
<td>CLEAR</td>
<td>MSS</td>
<td>M4/2788A</td>
<td>F</td>
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<td></td>
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<td>MSS</td>
<td>M4/2788A</td>
<td>F</td>
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<tr>
<td>12/03/14 22:19:19</td>
<td>15229</td>
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<td>MSS</td>
<td>M4/2788A</td>
<td>F</td>
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<tr>
<td>12/03/14 22:19:38</td>
<td></td>
<td></td>
<td>MSS</td>
<td>M4/2788A</td>
<td>OIF initiated equipment setting: SYMBOL 4 - (Workforce in road) Workforce in road-SLOW (Reason: Road works – Coning)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix I presents an example of the full CCIL and the corresponding HALOGEN data for the full duration of another trial night in which a total of 14 faults were observed across two MS4s. As an additional output, an Excel workbook was prepared containing CCIL and HALOGEN data for all completed trial nights on which MS4 faults occurred to assist in any further investigative work into these issues.

The information presented in Table H.1 and Table H.2 requires additional expertise to readily understand faults as reported by HALOGEN; such investigation was considered to be outside of the scope of the current project. In some cases, the fault might simply have been a communications fault and the MS4 concerned may have been unaffected; however, the RCC Dedicated Operator confirmed that the MS4 concerned was affected whenever it was possible to verify this using CCTV.
Appendix I  Example files from the Command & Control Incident Log and HALOGEN

This Appendix presents a sample Command & Control Incident Log (as completed by the RCC Dedicated Operator) and the associated HALOGEN Signal Change Log and Fault Log from a single trial night within the 1C3 programme. On the night in question (15-16 April 2014), the RCC Dedicated Operator reported a total of 14 faults on the MS4s being used for that night's trial. Three of these faults occurred on the MS4 at marker post 2818A closest to the closure, and eleven occurred on the MS4 at marker post 2788A furthest upstream from the closure.

I.1  Command & Control Incident Log

Incident Header Section

Incident Number: 1453  Incident Creation Date and Time: 15/04/2014 20:56:25
Incident Status: CL  Priority: Y
Call Origin: HA CONTRACTOR
Phone No:
Alarm URN:  Alarm Confirmation:
Alarm Activation Type:
Scheduled:
Type Code: RW  Type: 1C3 - TRIALS - ROADWORKS
Source Supplied: LANE 3 - WORKS EMPTY
Location: P82/2A, J12/13, AREA3, M4, THAM
Postcode: XX99 9XX
Grid Ref: 4570310E 1737690N Beat Id: HEC1 Reported Incident Date: 15/04/2014 Reported Incident Time: 20:56:25 Control Area: 5RW
Sector Id: HEC  Sector Type: U
Sector Name: CHIEVLEY
Grade: NON-ATTENDANCE

Incident Source Section
Incident Closure Section

Summary:
Final Classification Code:          RW1
Final Classification Code Description: ROADWORKS PLANNED NOTIFICATION
Qualifier:  SS1  Qualifier Description: SIGNAL / SIGN SETTING
Qualifier:  L01  Qualifier Description:  1 LANE CLOSED
Contact Performed:   N     HA Worker Reference Number:
External Reference:

Incident Log Lines Section

Log entry types included when this print was generated.

ALM AMB ASD ATT BDN CCH CLT CMC CPL CPS DUP EVT FCH FNL HAA HAB HAC HAD HAZ HHB IED IEF IES IEX IUP LCH LXI LXS MSG MTI MTR NMS OLI PNC PRE PSR RED RES RHV RMK RVA RBV RVC RWK SCH SDS SPO SRS SYS TAG VLU VRD

Log lines
1C3 Use of MS4s to Sign Road Works

15/04/2014 20:56:25 - MSG - HAS101 - EOPC014 13744, 15/04/2014 20:56:25, Created INCIDENT REGISTERED:
15/04/2014 20:56:25 - MSG - SYSTEM - SYSTEM 13744, 15/04/2014 20:56:25, Activated INCIDENT REGISTERED:
15/04/2014 20:57:15 - MSG - HAS101 - EOPC014 13744, 15/04/2014 20:56:25, Closed By HAS101, INCIDENT REGISTERED:
15/04/2014 20:57:15 - CPS - HAS101 - EOPC014 Contingency Plan search results

12 ROADWORK CONTINGENCY PLAN
15/04/2014 20:57:16 - MSG - HAS101 - EOPC014 13751, 15/04/2014 20:57:16, Created INCIDENT NOT ACKNOWLEDGED:
15/04/2014 21:00:06 - RMK - HAS101 - EOPC014

Name       BRIAN
Tel. No     07525968091
Company     EM HIGHWAYS
SRW No.     2548538

Start Date  15/04/2014
Start Time   21:00
End Date    16/04/2014
End Time    05:00

Motorway     M4
Carriageway A
Marker post for start of first sign 80/6
Marker post for start of taper 82/2
Marker post for end of roadworks 85/4
Description of lane closures to be set out? L3 - 1C3
Slip road closure Y/N N
If Y is emergency access available
Will temporary speed restrictions be in place Y/N? N
If yes, what speed will be in place?
Did the contractor request TO assistance Y/N? N
If yes, details of assistance required
Contractor asked to call back when cones laid out Y/N? N
Have you informed the contractor of the incident no. Y/N? Y
Other relevant information (including reason for the roadworks)
RCC Roadwork Contingency Plan to be invoked Y/N? N

15/04/2014 21:00:16 - MSG - HAS101 - EOPC014 13751, 15/04/2014 20:57:16, Closed By HAS101, INCIDENT NOT ACKNOWLEDGED:
Incident [1453] logged: 15/04/2014 20:5...
15/04/2014 21:00:16 - SYS - HA5101 - EOPC014 Acknowledged by Controller
15/04/2014 21:00:23 - CCH - HA5101 - EOPC014 Passed to new Control Area The contents of field Control Area have changed from HE to 5RW
15/04/2014 21:00:23, 15/04/2014 21:00:23, Created INCIDENT NOT ACKNOWLEDGED:
15/04/2014 21:00:26 - MSG - HA5101 - EOPC014 13792, 15/04/2014 21:00:23, Created INCIDENT NOT ACKNOWLEDGED:

Incident [1453] logged: 15/04/2014 20:5:
15/04/2014 21:00:26 - SYS - HA5101 - EOPC014 Acknowledged by Controller
15/04/2014 21:00:33 - SCH - HA5101 - EOPC014 Priority changed to High
15/04/2014 21:02:54 - RMK - HA5101 - EOPC014 MIDAS DISABLED - 2823A - 2853A
15/04/2014 21:04:05 - RMK - HA5101 - EOPC014 HDS SET 2788A - 2833A
15/04/2014 21:07:38 - RMK - HA5101 - EOPC014
    2788A - 50 MPH - WFIR-SLOW
    2803A - LANE 3 WICKET - LANE CLOSURE SLOW DOWN
    2818A - LANE 3 WICKET - LANE 3 CLOSED-SLOW
15/04/2014 21:28:13 - ASD - HA5101 - EOPC014 Bookmarking added for incident(s)/event(s):
    818 15/04/2014
Reason: IN 1C3 TRIAL AREA
15/04/2014 21:29:12 - RMK - HA5101 - EOPC014 SPOKEN TO BRIAN - NO ONE IS ALLOWED IN OUR CLOSURE - AREA 3 ARE AWARE AND WILL BE WORKING ON THE B TRACK
    - AS THEY WILL HAVE A LANE 3 THERE TOO
15/04/2014 21:44:45 - RMK - HA5101 - EOPC014
C52863 - SHOWS AREA TEM ON B TRACK
15/04/2014 21:48:52 - RMK - HA5101 - EOPC014
    2788A - FAIL - RESET 1
15/04/2014 22:01:20 - RMK - HA5101 - EOPC014
    2788A - FAIL - RESET 2
15/04/2014 22:05:55 - RMK - HA5101 - EOPC014
    2788A - FAIL - RESET 3
15/04/2014 22:26:24 - RMK - HA5101 - EOPC014 BRIAN - CLOSURE IS OUT NOW GOING ROUND TO PUT CAMERAS OUT AND DROP SIGNS
15/04/2014 23:10:17 - RMK - HA5101 - EOPC014
    CH39 - TESTED OK EU26 - LOUD AND CLEAR
16/04/2014 00:04:03 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 4
16/04/2014 00:15:07 - RMK - HA5101 - EOPC014
   2818A - FAIL - RESET 1
16/04/2014 00:16:32 - RMK - HA5101 - EOPC014
16/04/2014 00:17:01 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 5
16/04/2014 00:38:59 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 6
16/04/2014 00:45:35 - RMK - HA5101 - EOPC014
   2818A - FAIL - RESET 2
16/04/2014 00:47:19 - RMK - HA5101 - EOPC014
   EU26 - WE ARE IN THE CLOSURE REPLACING SOME OF THE LAMPS THAT HAVE FAILED I HAVE ADVISED EU26 OF SIGN FAILURE - ALL WORKING CURRENTLY
16/04/2014 01:11:02 - RMK - HA5101 - EOPC014
   EU26 - FINISHED LAMPS - ONTO TO DEPOT NOW
16/04/2014 01:14:51 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 8
16/04/2014 01:15:17 - RMK - HA5101 - EOPC014 RESET 7 CORRECTION
16/04/2014 01:47:43 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 8
16/04/2014 02:48:45 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 9
16/04/2014 03:00:10 - RMK - HA5101 - EOPC014
   2818A - FAIL - RESET 3
16/04/2014 03:10:17 - RMK - HA5101 - EOPC014 BRIAN - WE ARE GOING TO COLLECT CAMERAS NOW AND PUT UP THE HARD SIGNAGE THE AREA TEAM ARE STILL WORKING IN THE CLOSURE - SO WE WON'T REMOVE TM YET
16/04/2014 03:26:57 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 10
16/04/2014 03:42:41 - RMK - HA5101 - EOPC014
   2788A - FAIL - RESET 11
I.2 HALOGEN Signal Change Log

<table>
<thead>
<tr>
<th>Date And Time</th>
<th>Equipment Type</th>
<th>Equipment Ref</th>
<th>Equipment Setting</th>
<th>Initiator Id Type</th>
<th>Initiator Id</th>
<th>Implementation Reason</th>
<th>Setting Status</th>
<th>Requested Setting</th>
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<tbody>
<tr>
<td>15/04/2014 21:04</td>
<td>MSS</td>
<td>M4/2788A</td>
<td>SYMBOL 4 - (Workforce in road) Workforce in road-SLOW</td>
<td>OIF</td>
<td>20</td>
<td>ROAD_WORKS-CONING</td>
<td></td>
<td></td>
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<tr>
<td>15/04/2014 21:04</td>
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<td>M4/2818A</td>
<td>SYMBOL 4 - (Workforce in road) Workforce in road-SLOW</td>
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<td>15/04/2014 21:46</td>
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<td>AUTO</td>
<td>SIG</td>
<td>ROAD_WORKS-CONING</td>
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<td>Initiator Id Type</td>
<td>Initiator Id</td>
<td>Implementation Reason</td>
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<td>OIF</td>
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<td>CLEAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16/04/2014 00:13</td>
<td>MSS</td>
<td>M4/2818A</td>
<td>Lane 3 closed-SLOW</td>
<td>OIF</td>
<td>20</td>
<td>ROAD_WORKS-CONING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16/04/2014 00:15</td>
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<td>M4/2788A</td>
<td>Lane closure SLOW DOWN</td>
<td>AUTO</td>
<td>SIG</td>
<td>ROAD_WORKS-CONING</td>
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<tr>
<td>16/04/2014 00:15</td>
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<td>M4/2788A</td>
<td>SYMBOL 4 - (Workforce in road)</td>
<td>OIF</td>
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</tr>
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<td>OIF</td>
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<td>ROAD_WORKS-CONING</td>
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<td>AUTO</td>
<td>SIG</td>
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<td>M4/2788A</td>
<td>SYMBOL 4 - (Workforce in road)</td>
<td>OIF</td>
<td>20</td>
<td>ROAD_WORKS-CONING</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Date And Time | Equipment Type | Equipment Ref | Equipment Setting | Initiator Id Type | Initiator Id | Implementation Reason | Setting Status | Requested Setting
--- | --- | --- | --- | --- | --- | --- | --- | ---
16/04/2014 02:57 | MSS | M4/2818A | SYMBOL 4 - (Workforce in road) Workforce in road-SLOW | OIF | 20 | CLEAR | --- | ---
16/04/2014 02:58 | MSS | M4/2818A | Lane 3 closed-SLOW | OIF | 20 | ROAD_WORKS-CONING | --- | ---
16/04/2014 03:25 | MSS | M4/2788A | Lane closure SLOW DOWN | OIF | 20 | CLEAR | --- | ---
16/04/2014 03:25 | MSS | M4/2788A | SYMBOL 4 - (Workforce in road) Workforce in road-SLOW | OIF | 20 | ROAD_WORKS-CONING | --- | ---
16/04/2014 03:41 | MSS | M4/2788A | Lane closure SLOW DOWN | AUTO | SIG | ROAD_WORKS-CONING | --- | ---
16/04/2014 03:41 | MSS | M4/2788A | SYMBOL 4 - (Workforce in road) Workforce in road-SLOW | OIF | 20 | ROAD_WORKS-CONING | --- | ---
16/04/2014 04:05 | MSS | M4/2788A | OFF | OIF | 20 | CLEAR | --- | ---
16/04/2014 04:05 | MSS | M4/2818A | OFF | OIF | 20 | CLEAR | --- | ---

### 1.3 HALOGEN Fault Log

| Date And Time | Fault Id | Fault Status | Equipment Type | Equipment Ref | Clearance Method | Fault Type | Fault Text | SubSystem |
--- | --- | --- | --- | --- | --- | --- | --- | ---
15/04/2014 21:29 | 49986 | HARD | SIG | M4/2788A | | AMBER FLASHER FAILED | | SIG |
15/04/2014 21:29 | 49985 | HARD | SIG | M4/2788A | | ASPECT FAILED | 50 | SIG |
15/04/2014 21:29 | 49986 | CLEAR | SIG | M4/2788A | F | | | SIG |
15/04/2014 21:29 | 49985 | CLEAR | SIG | M4/2788A | F | | | SIG |
15/04/2014 21:34 | 50014 | HARD | MSS | M4/2788A | | STATUS REPLY - POWER FAIL | | MSS |
15/04/2014 21:34 | 50012 | HARD | MSS | M4/2788A | | STATUS REPLY - CRC INCORRECT | SYMBOL 4 - (Workforce in road) Workforce in road-SLOW | MSS |
15/04/2014 21:34 | 50016 | HARD | MSS | M4/2788A | | STATUS REPLY - LANTERN/DIM/BRIGHT FAIL | | MSS |
<table>
<thead>
<tr>
<th>Date And Time</th>
<th>Fault Id</th>
<th>Fault Status</th>
<th>Equipment Type</th>
<th>Equipment Ref</th>
<th>Clearance Method</th>
<th>Fault Type</th>
<th>Fault Text</th>
<th>SubSystem</th>
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<td>50015</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
<td></td>
<td>STATUS REPLY - LAMP OR LED FAIL</td>
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<td>MSS</td>
</tr>
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<td>50013</td>
<td>HARD</td>
<td>MSS</td>
<td>M4/2788A</td>
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<td>STATUS REPLY - MESSAGE FAIL</td>
<td>SYMBOL 4 - (Workforce in road) Workforce in road-SLOW</td>
<td>MSS</td>
</tr>
<tr>
<td>15/04/2014 21:46</td>
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Appendix J  RCC Interview Guide

A. General RCC operations

RCC operator overview

- How does the RCC operate?
  - Who does what in the room?
- What RCC systems/programmes do you use? What are each of these used for?
- On shifts where you are responsible for traffic management, how many sets of road works do you typically deal with during a shift? Early, lates, nights.
  - How is responsibility for VSS associated with an individual road works assigned - are individual RCC operators assigned responsibility for specific sections of the network or is the operator who takes the call responsible regardless of location on the network?
  - Do you find your workload too low, about right, or too high?

Staff training

- What refresher training on using VSS have you received?
  - When does the training happen? E.g. on a regular basis, only when changes are made to a system or programme?
  - Are you familiar with the Highways Agency Policy for the use of VSS (RCC Advice Note 52)

Use of COBS (Control Office Base System) for monitoring and managing VSS

- In your opinion, how suitable is COBS specifically for monitoring and managing VSS used to sign road works?
- In your experience, how often are signs and signals overwritten by the National Traffic Information Centre (NTIC) or other RCC operators without warning?
- How frequently do you have to deal with notifications, alarms etc. on COBS? How do you respond to these?

Reliability of COBS

- Does the COBS terminal ever exhibit technical problems, e.g. freezing or fail completely?
  - What is the impact on you as an operator if COBS fails on you? Are your responsibilities then delegated?

Communication with road workers

- What are the existing communication mechanisms between the RCC and road workers?
  - How could these be improved, specifically in relation to the setting of signs and signals for road works/managing incidents?
VSS functionality

- Please describe any test procedures/protocols in place for the routine and/or pre-works testing of VSS.

Notification of VSS failures

- What mechanisms are available for you to check the status of the VSS?
  - How are RCC operators notified of VSS failures?
  - If COBS indicates that a VSS has failed, how is this verified (e.g. by CCTV/Traffic Officer), if at all?
    - If it is verified, is the information presented by COBS found to be accurate?

Responding to VSS failures

- How should VSS failures be responded to?
  - Is this what happens in practice?
  - Is there a process for prioritising different types of VSS failure?
  - How could the process for responding to VSS failures be improved?

- In what circumstances is the failure of a VSS considered to pose a risk to road users and/or road workers? How frequently do they occur and what are the response processes?

Reporting VSS failures for repair

- How do you report a fault on a VSS?
- What follow-up procedures do you use to check progress on the reported faults?
- How effective is the process for repairing VSS faults once they have been reported?
  - How could this process be improved?

B. 1C3 trial-specific issues

General view of the trials

The objective of the 1C3 trials was to evaluate the effectiveness of using MS4s to provide road users with advance warning of a relaxation scheme single lane closure.

- Do you think the trial signing was successful?
  - Why?

- Various processes were put into place to ensure, as far as practicable, that the trials could be undertaken in as safe a manner as possible. How suitable do you think these processes were?
  - What changes would you recommend, if any, for future trials involving collaboration between on-road teams and the RCC?

Staff competency
Based on the trials experience what do you consider to be the minimum level of competency, above basic knowledge, for RCC operators to be able to monitor and manage VSS when these are the sole method used to sign road works?

- What, if any, specialist skills are required for the task?

**Suitability of COBS for monitoring and managing VSS**

- Based on 1C3 trial experiences, how suitable is the existing COBS for monitoring and managing VSS when this is the sole method used to sign road works?

- What modifications could be made to COBS to improve the monitoring and management of VSS when these are the sole method used to sign road works?

**VSS functionality**

- What type of test procedures/protocols, if any, should be put in place for the routine and/or pre-works testing of VSS used to sign road works?

**Notification of VSS failures**

- In your opinion, is the change in colour of the VSS graphic on the COBS display an effective way of monitoring failures on VSS used to sign road works?

  - If no: How could it be improved?

**Reporting VSS failures for repair**

- Are current procedures for reporting/repairing faults on VSS fit for purpose where those VSS are used to sign road works?

  - If no: What would improve the process?

**Communication with on-road operatives**

- Based upon trial experiences, what standard communication mechanisms or protocols do you consider necessary to allow road works to be safely signed using only VSS?

**The future of VSS for road works**

- If VSS were to be used regularly as the sole means of providing drivers with advance warning of road works, how could this be managed most effectively?

**C. Future considerations for wider rollout**

**Resource levels**

- Based on the trials experience, how do you think the regular use of VSS to sign road works would need to be managed?

- What do you think would be required in terms of resource levels to monitor/manage VSS used to sign road works?

**Staff competency and training**
Based on the trials experience what do you consider to be the minimum level of competency, above basic knowledge, for RCC operators to be able to monitor and manage VSS when these are the sole method used to sign road works?

- What, if any, specialist skills are required for the task?

What, if any, additional training would be required to ensure that RCC operators can monitor and manage VSS when these are the sole method used to sign road works so as to minimise the risk to road workers and road users?

If, instead of providing information only, MS4s became critical for road worker safety, what would be the best way to ensure that RCC staff [understand the requirement to] react promptly to faults/problems?

**Modification/improvement to COBS**

- What modifications could be made to COBS to improve the monitoring and management of VSS when these are the sole method used to sign road works?

**Workload pressures**

- How do you think RCC operators would react to using only VSS to sign road works?
  - What is your view on the increased level of responsibility?

- How many closures signed using VSS could an RCC operator safely oversee, as part of their normal activities?

- If using only VSS to sign road works, do you think workloads during normal and/or busy periods would prevent RCC operators from reacting to faults on those VSS in adequate time to minimise the potential risks to road users and road workers?

**The future of VSS for road works**

- If VSS were to be used regularly as the sole means of providing drivers with advance warning of road works, how could this be managed most effectively?
Appendix K  ASC Interview Guide

A. Current operational practices (i.e. those used outside of the 1C3 trials)

- How do you currently use VSS for signing road works during
  a) the installation and removal of temporary traffic management?
  b) the undertaking of works within temporary traffic management?
- Where/if VSS are currently used to sign road works, are your on-road teams notified if a VSS fails? If yes: What is the protocol for this and what, if any, action is taken by the on-road team as a result?
- Where VSS failures are detected by your on-road teams, what are the protocols for reporting these failures so that the signs can be repaired?
- What are the existing communication mechanisms between the RCC and on-road operatives? Are these adequate? If not, why not?

B. 1C3 experimental trials

- The objective of the 1C3 trials was to evaluate the effectiveness of using MS4s to provide road users with advance warning of a relaxation scheme single lane closure. Following the trials, do you consider the use of MS4s to display the advance signing of road works to be effective? Why/why not?
- Did your on-road teams feel safe when using VSS as the sole advance signing for road works during
  a) the installation and removal of temporary traffic management?
  b) the undertaking of works within temporary traffic management?
- Did any incidents occur during the trial that put the safety of the on-road teams in jeopardy? If yes, what mitigations would need to be implemented to avoid this in future?
- Is there any feedback from the EM Highways Staff Member from observations in the RCC which have the potential to improve operational practices/ procedures?
- Do you have any additional comments related to the trial?

C. Signing of road works using only VSS

- Before and during the trials, there were issues with MS4 faults in the required locations. Do you have any comments on MS4 fault frequency and how this might affect the use of VSS for the advance signing of road works being taken forward more widely?
- It is understood that road space booking clashes sometimes occur or that works are moved at short notice. Currently, how often do these occur and what are the protocols in place for avoiding them?
Would this be an issue if VSS were regularly used to sign road works? For example, would the RCC need to be notified of the works location in advance so they could pre-set the VSS?

- What type of test procedures, if any, should be put in place for the routine and/or pre-works testing of VSS used to sign road works?

- If VSS were regularly used as the sole advanced signing for road works, what back-up mechanisms (signing and/or processes) would you wish to be in place for signing the works if the gantries failed? What other safety resources (e.g. additional staff members), if any, do you think would be necessary?

- Based upon trial experiences, what standard communication mechanisms or protocols do you consider necessary to allow road works to be safely signed using only VSS?

- Do you have any additional comments about the signing of road works using only VSS?