Driver Interaction with Temporary Traffic Management
Phase 2 Report: Simulator Study

by N. Reed, A. Dale & B.F. Sexton

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by N. Reed, A. Dale & B.F. Sexton (TRL)

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Driver Interaction with Temporary Traffic Management

Client: Highways Agency, SSR Corporate Health & Safety
(Paul Mitchell)

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Executive summary

Structure of the project
Road worker safety is a key priority for the Highways Agency. It has recently introduced the ‘Aiming for Zero’ initiative to address this issue directly. Road worker activity during temporary roadworks carries a high risk of injury due to the exposure to ‘live’ traffic, particularly during short-term works at night. Contractors have suggested that the number of signs used in a closure could be reduced to risk exposure when deploying the signs.

This project was commissioned to examine driver behaviour and response to changes in the configuration of the signs used for temporary traffic management (TTM). The objective was to examine whether it was possible to use an effective TTM configuration that reduces the number of carriageway crossings necessary to deploy the TTM measures. The TTM configurations were tested in a controlled environment using 81 participants in a driving simulator trial. The recommended layout will move forward to a limited area roll-out.

The simulator trial
The use of a driving simulator allowed the research team to develop a driving scenario that provided a safe, realistic and consistent environment in which to assess driver behaviour when travelling through the different TTM configurations that were developed for this study.

During the simulator trial, the computer systems logged data from the driven vehicle 20 times a second throughout each trial drive. The recorded data was separated into vehicle control measures and visual behaviour measures. Vehicle control measures include information on the speed of the vehicle driven by the participant, when and how drivers change lane, the way in which a driver brakes and the movement of the vehicle within the lane or related to other vehicles in the simulation.

The measures of visual behaviour enabled an assessment of the duration and frequency with which participants looked at the signs present when driving through the roadworks and their distance from each sign when they chose to look at it. These measures help to identify the information the participants used to make decisions when approaching the roadworks and what to determine what information tended to be ignored.

Modified TTM layouts
Four TTM configurations were created in the simulator and each participant drove through all four configurations. The Chapter 8 TTM layout DZB6 (Lane-change zone for a single lane closure on a dual carriageway road for which the national speed limit applies) was used and three variants on this standard layout were created for the purposes of comparison. The three modified layouts are shown in Figure 1.
Figure 1: Modified Chapter 8 TTM layouts tested in the simulator

Modified Chapter 8 TTM Layouts

All are based on the current Chapter 8 design but have changes to the number of signs and sign designs. There are also differences in placement of the distance signs.

**Layout 1 (top left)**
- Removal of 600 yd wicket
- Removal of Detail A signs

**Layout 2 (top right)**
- Removal of 800, 600, 400 wickets
- Use of Hooked arrow sign and “NOW” board

**Layout 3 (bottom left)**
- Further use of Hooked arrow and “Now” board
- Removal of one 610 from taper
Results

The results of the simulator trial showed that driver behaviour was relatively consistent across the four TTM configurations under test; statistical results indicated that for each of the modified layouts, behaviour did not differ significantly from that observed in the standard DZB6 configuration.

Overview of simulator results:

- Drivers maintained a similar following times to the vehicle in front regardless of whether they were in a road works section or not.
- All drivers present in the lane to be closed (lane 3) on approach to the roadworks had merged into lane 2 at least 200 metres before the cone taper, suggesting that in all layouts drivers understood the TTM measures and what they had to do in response.
- Drivers reduced speed when in a roadwork environment.

The result of this study is inconsistent with the findings of previous work in this area. However, this study developed a more robust methodology and examined a number of areas that the previous work was unable to consider (due to technological advancement in the TRL simulator).

When examining drivers’ visual behaviour, it is clear that:

- Few drivers looked directly at TTM signs, regardless of the TTM configuration used.
- Glance durations were typically short (less than 0.5s).

In addition to the physical measures of behaviour:

- No consensus emerged when participants were asked which if any of the roadworks they encountered had “too many signs”.
- Participants asked to rate the clarity of the four TTM configurations indicated that Layout 1 was significantly clearer than all other layouts (including the Chapter 8 layout).
- Some drivers commented on the lack of a speed limit sign, expecting a 50mph limit to be applied (and enforced).
- The results of the post-trial questionnaire suggested that drivers are not fully aware of the number of signs in a temporary closure.
- The results also suggest that drivers are unable to distinguish differences in TTM configuration while travelling through the works area.
- An interesting finding, apparent in the simulator and questionnaire data, was the tendency for drivers to travel at a slower speed through roadworks.
**Recommendations**

The results of this research project indicate drivers behaved in a safe and consistent manner in the four different TTM configurations presented. There were no significant changes in any safety critical behaviour on the approach to roadworks. This suggests that any of the three alternate TTM designs could safely be used on the network.

To ensure that all the objectives of this task are achieved and that driver safety is protected, an on-road trial to test the use of Layout 1 is recommended. The use of Layout 1 involves the removal of two features from the standard configuration (600 yard wickets, Detail A). After approaching traffic management contractors regarding the on-road trial of an alternate TTM configuration, it is clear that the changes made in Layout 1 are considered relatively superficial and could be covered by the current risk assessment procedures.

The use of Layout 1 on the network will help to reduce some of the risk workers are exposed to during operations but further studies should look to use the information provided by this study and make more substantial changes to TTM where possible. This change is a first step, with the 600 yard wicket being removed. Following a discussion with contractors, the next sign to be examined should be the 200 yard wicket. This would be a further step to reducing the number of signs in a closure, which if deemed safe would help further reduce the risk to road workers.

The findings provide support for more radical sign designs and techniques for informing the driver during traffic management operations, particularly in areas that have previously challenged designers, such as wider motorways and managed motorways. The consistent behaviour that was shown across the different configurations in the simulator trial suggest that it may be possible to develop a suite of dynamic TTM configurations that are tailored to suit the demands of the particular roadworks site, rather than having a more rigid configuration that is applied in all circumstances.
1 Introduction

Road worker safety is a key area of network operations and recently the Highways Agency introduced the ‘Aiming for Zero’ initiative to address this issue directly. Road worker activity during roadworks carries a high risk of injury due to the exposure to ‘live’ traffic, particularly during short-term works at night. Contractors have suggested that the number of signs used in a closure could be reduced to lessen risk exposure when deploying or removing the signs.

Although reducing the number of signs used for temporary traffic management (TTM) would lower risk exposure for operatives, there would also be a reduction in the information available to vehicles approaching the roadworks. The Highways Agency must therefore consider risk to both the road-worker and the travelling public when considering any change in current policy or practices.

Previous work (Baguley, 1996) has identified that there was scope to reduce the number of signs and simplify TTM. This project aims to provide the Agency with a data-led case for any recommended changes. This will be based on objective measurements of driver behaviour using TRL’s high fidelity driving simulator to present participants with current and simplified sign layouts. The results of the study are to inform an on-road trial of TTM elements shown to reduce risk without compromising safety.

1.1 Structure of the project

This Highways Agency task (593) consists of three phases:

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This report covers Phase 2, examining how drivers interact with TTM and whether there is scope to simplify the DZB6 TTM layout currently used on the network.

1.2 Findings from Phase 1

The aim of the first phase of this project was to engage with stakeholders, and develop three alternative TTM designs that could be used in place of the current relaxed Chapter 8 layouts. In addition, a literature review was conducted to inform further decisions on the TTM layout designs.

It was suggested that in the current TTM configuration, there may be more signs than are required for a driver to understand how they are required to behave in order to pass through roadworks safely. There is little reliable evidence on driver behaviour through roadworks or the effect of changing the current sign configuration in any way. Therefore, the stakeholder group felt that Phase 2 of this project (simulator study) would produce useful information on driver behaviour in roadworks. This will also give the first reliable data on drivers’ visual behaviour with regard to TTM signs. With the assistance of stakeholders, three alternative TTM layouts for use in this phase of the project have
been developed. It was important that these new designs were operationally valid alternatives to the current Chapter 8 TTM layout.

The first two layouts for the simulator study were developed with direct involvement from stakeholders during the workshop. The third was developed subsequently by TRL using information gained from within the workshop. Each layout reduces the number of signs on approach to the roadworks, while still informing drivers about the upcoming road configuration and the required behaviour. The first layout removes a small number of signs from the standard configuration; the second layout removes some signs and uses different sign content with the intention of improving compliance; the third layout uses a minimal signage configuration. The three designs move progressively away from the standard Chapter 8 layout, permitting investigation as to the safe minimal signage level.

The layouts developed all have theoretical benefits to their use, either in terms of reducing visual clutter or improving the clarity of instructions given to drivers. However, there needs to be conclusive evidence before changes to the current Chapter 8 configuration can be considered. The simulator trial will provide useful insight into driver behaviour with the new layouts. If driver behaviour were shown to be at least as safe as that observed for the current Chapter 8 configuration for any of the new layouts, they may be considered preferable due to their reduction in exposing road workers to risk in deploying/removing the signs. If driving behaviour improves, then there would be a strong case for change.

Prior to the study being approved, stakeholders were given the opportunity to examine the trial and comment on the roadworks that were to be presented to participants in the study. When results are available, they will be circulated to stakeholders to gain further insights into the implications of the results.

### 1.3 Approach to Phase 2

The decision to use a full mission, high fidelity driving simulator was based on the premise that such a system provides:

- The controlled presentation of motorway and roadworks environments
- A scientifically robust method for examining driver behaviour:
  - Conditions for traffic, weather etc are repeatable across participants
  - Data on driver behaviour is captured accurately and at high frequency
  - Eye movement data is captured by the eye tracking system
  - Participants’ subjective attitudes and awareness of the configurations could be assessed after each drive.
- A safe environment in which to test potentially high risk road conditions.

The project used a bespoke motorway simulation to examine four TTM layouts. One of these was the Chapter 8 layout, included for reference. The other three were new configurations, varying in the degree to which they were changed compared to the Chapter 8 layout.

This report seeks to ensure that any changes in driver behaviour associated with the change in TTM configuration are discovered; highlighting whether the change is a positive or negative safety issue.
2 Method

2.1 TRL car driving simulator

The study employed the TRL car simulator running SCANeR II™ software provided by Oktal. The simulator is based on a real vehicle with motion system and is surrounded by display screens onto which are projected the images that represent the external environment to the driver. The simulator provides 210° forward field of view using three flat screens. A rear screen gives a 60° rearward field of view with a display that is adjusted to appear correct for each of the driving mirrors.

An integrated, non-intrusive SmartEye™ eye tracking system was used to measure the frequency and duration with which participants looked at the road work signs. Further details about the simulator and facilities are provided in Appendix A.

2.2 Participants

The TRL participant database comprises more than 1,200 members of the public in the local area. From this database, 81 participants were recruited to take part in the study. All possessed a current driving licence and there were no particular inclusion/exclusion criteria. Participants were selected to cover a wide range of ages. Approximately equal numbers of participants were recruited across age (younger group: 17-44 years; older group: 45+ years) and gender criteria to incorporate different experience levels and driving styles. There were therefore twenty participants in each age-gender group (with one additional participant in the Older-Male group).

2.3 Protocol

Following a 10 minute familiarisation drive to acquaint participants to the controls of the simulator vehicle and to allow them to settle into their normal driving behaviour, participants were required to drive the test route for approximately 30 minutes. In the route, they encountered the four TTM configurations. The total duration of an experimental session for one participant was one hour and included introduction, eye tracker calibration, familiarisation drive, test drive, questionnaire and debriefing.

2.4 Route design

The test route created for this trial consisted of 42 km of simulated three-lane motorway environment. All trials were driven in a simulated night-time environment and the vehicle headlights operational. Objects within the simulated environment (such as cones, signs, road-workers’ high visibility clothing) were given appropriate levels of illumination and reflectance. Figure 2 shows a screenshot of a driver entering the roadworks section. Clearly visible are the headlight pattern of the simulated vehicle, the traffic cones and signs illuminated by the headlights and the position lights of the autonomous vehicles in the simulation.

Participants experienced all four variations of the TTM layout in their one test drive. The four designs used were:

- Chapter 8 (control) layout
- Layout 1: minor change
- Layout 2: moderate change
- Layout 3: large change

The four different TTM configurations are shown in Appendix D. Each roadworks section was separated from the next by 10km of standard generic three lane motorway. Four
different variants of the test route were created with the four TTM configurations present in a different order within each variant.

Using these four different variants of the route allowed the design to be counterbalanced to control for order effects on behaviour. The route included the current standard design of TTM and the three modified configurations.

The traffic conditions were designed to encourage the use of the outside lane of the carriageway. Each autonomous vehicle within the simulation was programmed to follow the vehicle ahead at a reasonably close distance with gaps to allow merging when necessary.

![Figure 2: Screenshot of simulated roadworks](image)

2.5 Participant instructions

Participants were delivered standardised instructions before driving the simulator. They were told “drive as you would normally do” and that their “driving was not being judged”. They were also told that they “should not treat the simulator like a computer game”.

Following the familiarisation drive participants were instructed “For the trial today you are asked to drive on a motorway under night time conditions”. No information was given as to driving conditions that they would encounter during the simulated drive.

2.6 Questionnaire

Participants’ subjective responses to the simulator drive and the specific TTM configurations were recorded in a questionnaire. The questionnaire can be found in Appendix C.
2.7 Data analysis

Simulator data was collected at 20Hz throughout each simulator drive. The data streams collected are shown in Appendix B.

Data was processed and analysed using Microsoft Excel 2007; statistical analyses were conducted using SPSS 14.0. Unless otherwise stated, all graphs within the results section of this report display the 95% confidence interval for each mean.
3 Results

3.1 Questionnaire results

The questionnaire used in this study was designed to assess three main areas with reference to roadworks:

- Are drivers able to distinguish a difference in road work types having driven through a works area?
- Which temporary traffic management (TTM) configuration sends the clearest message to drivers?
- What feedback do drivers have when faced with a change in TTM layout or the current Chapter 8 relax configuration?

3.1.1 Did drivers feel overloaded by signs?

Participants’ responses to the questions discussed in this section were based on their experience of the drive only. Following these questions, participants were given a sheet with the four TTM configurations on for the second part of the questionnaire.

Figure 3 shows that only 24% of the 81 participants tested felt that there were ‘too many’ signs in the roadworks present in the simulated motorway scenario.

![Figure 3: Percentage of participants who felt they were overloaded by signs](image)

However, among the participants who reported feeling overloaded, there was no consensus as to which TTM configuration was responsible, as shown in Figure 4.

![Figure 4: If yes, which set of roadworks did you find had too many signs?](image)
Five of the nineteen drivers who reported feeling overloaded suggested Layout 3 was responsible. This is a counterintuitive result since Layout 3 had the fewest signs. The largest proportion of the drivers who felt overloaded by signs reported the Chapter 8 layout as the most overloading design.

The results indicate that the majority of drivers did not feel overloaded by the number of signs that were present to implement TTM. For the nineteen that did, the Chapter 8 layout was most commonly reported as overloading. This is perhaps unsurprising since the modified designs all reduced the number of signs present. However, no firm conclusions can be drawn with inconsistent results from a small sample of participants.

### 3.1.2 Understanding the TTM configuration

For the questions that followed, participants were given a schematic diagram of each TTM configuration for reference. This ensured that all participants had the same information regarding the configuration of each TTM design and the participants’ ability to remember the designs from the simulator drive was not a confounding factor in the analysis.

#### 3.1.2.1 Easiest to understand

The first question asked which design was the easiest to understand, the results of which are shown in Figure 5.

![Bar Chart](image)

**Figure 5: In which set of roadworks were the signs easiest to understand?**

Figure 5 shows Layout 1 was thought to be the easiest to understand by almost half the drivers who took part in the study. The results also show that an equal proportion of participants found Layout 3 and the current Chapter 8 standard closure were the easiest to understand. This is notable since Layout 3 was the most dramatic change in TTM configuration that was applied in the trial.
3.1.2.2 Hardest to understand

Participants were then asked in which set of roadworks were the signs hardest to understand. Results are shown in Figure 6.

![Figure 6](image)

**Figure 6: In which set of roadworks were the signs the hardest to understand?**

Figure 6 shows that Layouts 2 and 3 were most commonly rated as the hardest to understand and the Chapter 8 layout was rated difficult by a significant minority. An informative comparison is, for each layout, to subtract the percentage of participants who rated it the hardest to understand from that who rated it the easiest to understand. This is shown in Figure 7 where a positive bar suggests that a configuration was easier to understand and a negative bar suggests that a configuration was harder to understand.

![Figure 7](image)

**Figure 7: Relative rating of understanding of each layout ([% rating layout as easiest] – [% rating layout as hardest])**

Figure 7 shows that Layout 1 can be shown to have been the easiest to understand, with the Chapter 8 layout trailing in second place and layouts 3 and 2 placed lower still.
3.2 Simulator data

The objective measures of driver behaviour recorded by the simulator are presented in three areas:

- Speed
- Merging
- Following time

These three areas cover the most important aspects of driver behaviour in roadworks. As this study is concerned primarily with safety, the issue of journey time reliability has not been considered.

In presenting results, the term ‘works area’ is used. This area is defined as starting 1,500m prior to the start of the cone taper and finishing at the end of the road works.

3.2.1 Speed

![Graph showing mean speed through each works area across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%).](image)

Figure 8: Mean speed through each works area across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%)

Figure 8 shows the average speed that drivers passed through the works area for each of the four configurations tested during this study. The results indicate that the TTM configuration had little effect on drivers’ mean speed passing through the works area, supported by no statistically differences between layouts (p>0.05).
Figure 9: Mean speed at the start of each works area across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%)

Figure 9 shows the mean speed of drivers at the start of the works area. As with the mean speed through the works area (Figure 8), no significant difference is seen in speed under the four conditions \((p>0.05)\). This suggests that drivers entered the roadworks at a very similar speed, irrespective of the signs they saw ahead.

The sign configuration may have influenced drivers’ perception of appropriate speed through each works area. A lack of information may cause a driver to drive faster – unaware of the risks or slower – seeking more information as to the road conditions. Either behaviour may compromise safety. Consequently, each participant’s maximum (Figure 10) and minimum (Figure 11) speeds within each works area were recorded.

Figure 10: Mean of maximum speeds recorded within each works area across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%)
Figure 10 and Figure 11 show that the difference in speed behaviour between each layout was small and indeed no comparisons reached statistical significance ($p > 0.05$).

The conclusion in terms of speed behaviour is that drivers in the simulated scenario were consistent across the four layouts in the speeds that they chose to adopt through the works area.

### 3.2.2 Merging

In this section, participants merging behaviour and lane position when approaching the roadworks area is analysed. This is to assess whether drivers can process the information presented on the signs and move over safely within adequate time relative to the start of the cone taper. Only six participants were found to be in lane 3 of the motorway, 2000 metres from the cone taper start for each of the four TTM configurations. In this section, graphs are presented showing the percentage of participants in lane 3 (the lane to be closed) on approach to the cone taper that marked the start of the roadworks for each of the four TTM configurations. The X-axis on each graph represents the distance from the cone taper and the ‘0’ at the far right of the X-axis is where the cone taper starts.
Layout 1 – Minor change

Figure 12: Percentage of participants in lane 3 on approach to the roadworks in layout 1

Layout 2 – Moderate change

Figure 13: Percentage of participants in lane 3 on approach to the roadworks in layout 2
Figure 14: Percentage of participants in lane 3 on approach to the roadworks in layout 3

Chapter 8 control layout

Figure 15: Percentage of participants in lane 3 on approach to the roadworks in the Chapter 8 layout

Figure 12-Figure 15 show that for all configurations of TTM, only a small proportion (less than 10%) were in lane 3 on approach to the roadworks. There is a consistent pattern across the four configurations in that less than 5% of participants were in lane 3 when closer than 1000 metres from the cone taper and that all participants were out of lane 3 before 200 metres from the cone taper. This suggests that the sign information and location in each layout is sufficient in instructing drivers of the upcoming lane closure and roadworks, as all participants moved over in a good distance before the cone taper commenced. If comparisons are to be drawn between layouts, Layout 3 seemed most effective in encouraging participants to change lanes early as there were no participants
in lane 3 after 1000 metres from the cone taper. However taking into account the small sub-sample of participants in lane 3 on approach to the roadworks, the reliability of this assertion is uncertain.

3.2.3 Following time

Following time for a vehicle is the time it would take that vehicle at its current speed to cover the distance from the front of the vehicle to the rear of the vehicle immediately ahead. For reference, this was calculated when participants were driving through the stretch of standard motorway in between each roadworks. The values are shown in Figure 16.

Figure 16: Mean following time when over 1 mile from the roadworks across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%)

As would be expected, differences between layouts were minimal. A very small difference of 0.2 seconds was recorded between layout 1 (the smallest figure) and the Chapter 8 layout (the largest figure).
Figure 17 above shows the mean following time within the works area for each of the four layouts.

![Bar chart showing following time for each layout]

**Figure 17: Mean following time when within the works area across TTM configurations. Error bars indicate the 95% Confidence Interval (CI 95%)**

All layouts produced similar following times showing that all drivers maintained a safe gap when within each of the different roadwork layouts. The slight difference between layouts was not found to be statistically significant. Comparing Figure 17 to that of Figure 16 there was very little difference in following time observed in the normal motorway environment to that observed when driving through the different TTM conditions; following times of between 5-6 seconds is maintained throughout the drives and safety is not compromised.

### 3.3 Eye Movement Results

Table 1 shows the number of people who looked at each sign in each layout. The sign that was most looked at was the hook over arrow placed at 300 yards in Layout 3. This is likely to be because it is a sign that participants are unused to seeing. The signs looked at by the fewest participants were the 610 arrows placed in the cone taper. Only one participant looked at the 610 arrow at the start of the taper in Layouts 1 and 3; no participants looked at it in Layout 2 or the Chapter 8 layout. Note that for each table 'RW' is an abbreviation used to refer to the 7001 roadworks warning triangle; cells that are greyed out indicate that the sign was not present in the relevant layout.
Table 1: Number of people who looked at each sign (the figure in brackets shows the mean number of glances at each sign per participant observing each sign)

<table>
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<td>5 (1.20)</td>
<td>7 (1.14)</td>
</tr>
<tr>
<td>800yds</td>
<td>4 (1.00)</td>
<td>4 (1.00)</td>
<td>5 (1.20)</td>
<td>3 (1.33)</td>
</tr>
<tr>
<td>700yds</td>
<td></td>
<td></td>
<td>4 (1.25)</td>
<td></td>
</tr>
<tr>
<td>600yds</td>
<td></td>
<td>6 (1.00)</td>
<td>3 (1.33)</td>
<td>9 (1.11)</td>
</tr>
<tr>
<td>400yds</td>
<td>3 (1.00)</td>
<td>6 (1.33)</td>
<td>4 (1.50)</td>
<td>9 (1.44)</td>
</tr>
<tr>
<td>300yds</td>
<td></td>
<td></td>
<td>4 (1.00)</td>
<td>13 (1.00)</td>
</tr>
<tr>
<td>200yds</td>
<td>5 (1.40)</td>
<td>6 (1.00)</td>
<td>5 (1.00)</td>
<td>3 (1.33)</td>
</tr>
<tr>
<td>610S</td>
<td>1 (1.00)</td>
<td>0 (0)</td>
<td>1 (1.00)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>610E</td>
<td>4 (1.00)</td>
<td>4 (1.00)</td>
<td></td>
<td>3 (1.00)</td>
</tr>
</tbody>
</table>

When a person did look at a sign they tended to do so only once, as can be seen from the values shown in brackets in Table 1. This implies that people are able to get all the information they require from one glance at the sign.

The mean glance duration is the mean length of time that the participant's gaze fell onto a specific sign. The longest mean glance was 0.59 seconds (this was for the nearside 200 yard sign in Layout 2). The signs that people looked at for the shortest length of time were the 610 arrows in the taper.

Table 2: Mean glance duration for each sign (s)

<table>
<thead>
<tr>
<th>Sign</th>
<th>Layout 1</th>
<th>Layout 2</th>
<th>Layout 3</th>
<th>Chapter 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>RW</td>
<td>0.32</td>
<td>0.58</td>
<td>0.33</td>
<td>0.32</td>
</tr>
<tr>
<td>800yds</td>
<td>0.39</td>
<td>0.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700yds</td>
<td></td>
<td></td>
<td>0.30</td>
<td>0.34</td>
</tr>
<tr>
<td>600yds</td>
<td>0.27</td>
<td>0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400yds</td>
<td>0.42</td>
<td>0.46</td>
<td>0.38</td>
<td>0.33</td>
</tr>
<tr>
<td>300yds</td>
<td></td>
<td></td>
<td>0.39</td>
<td>0.45</td>
</tr>
<tr>
<td>200yds</td>
<td>0.55</td>
<td>0.33</td>
<td>0.59</td>
<td>0.33</td>
</tr>
<tr>
<td>610S</td>
<td>0.25</td>
<td>n/a</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>610E</td>
<td>0.33</td>
<td>0.44</td>
<td></td>
<td>0.27</td>
</tr>
</tbody>
</table>
For the configurations of prime importance within this study (Layout 1 and Chapter 8), an additional analysis was conducted to establish in which lane the simulated vehicle was present when each glance to the lane merge signs at each distance was taken. This was to assess whether the participants’ viewing of the sign was critical to their eventual lane choice in driving through the TTM configuration. The results are shown in Table 3 (Chapter 8 layout) and Table 4 (Layout 1).

**Table 3: Number of participants viewing each of the wicket signs in the Chapter 8 layout separated by the lane in which the driven vehicle was travelling**

<table>
<thead>
<tr>
<th>Sign</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>800yds</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>600yds</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>400yds</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>200yds</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3 shows that the only participants to look at the 400 yard and 200yard wicket signs were travelling in lanes 1 and 2.

**Table 4: Number of participants viewing each of the wicket signs in Layout 1 separated by the lane in which the driven vehicle was travelling**

<table>
<thead>
<tr>
<th>Sign</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>800yds</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>600yds</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>400yds</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4 shows that only participants in lanes 1 and 2 looked at the wicket signs.
The mean distance at which participants looked at signs varied greatly (Table 5). The shortest mean distance at which a sign was viewed was 28.0m (offside 610 arrow, Layout 3). The furthest mean distance at which a sign was viewed was 354.4m (offside 400yard wicket board in the Chapter 8 layout).

**Table 5: Mean view distance from each sign (m)**

<table>
<thead>
<tr>
<th>Sign</th>
<th>Layout 1</th>
<th>Layout 2</th>
<th>Layout 3</th>
<th>Chapter 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>MAW</td>
<td>96.4</td>
<td>80.6</td>
<td>136.2</td>
<td>296.9</td>
</tr>
<tr>
<td>800yds</td>
<td>322.3</td>
<td>353.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700yds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600yds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400yds</td>
<td>124.2</td>
<td>281.2</td>
<td>121.0</td>
<td>233.9</td>
</tr>
<tr>
<td>300yds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200yds</td>
<td>117.7</td>
<td>158.3</td>
<td>147.3</td>
<td>180.6</td>
</tr>
<tr>
<td>610S</td>
<td>94.6</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>610E</td>
<td>86.4</td>
<td>179.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The eye tracker results suggest that (if at all) participants tended to observe signs in their peripheral vision, which would not be detected by the eye tracker. It is likely that they were aware of the presence of signs ahead but did not look at them directly. Drivers could also use the movement of the other traffic and the presence of cones ahead as visual cues to help them decide on the appropriate behaviour to take.
4 Conclusion

The simulator study has demonstrated that in all of the configurations tested:

- Few participants (<10%) were present in the lane to be closed by TTM at a distance closer than 1000m from the cone taper
- No participants were present in the lane to be closed by TTM any closer than 200m from the cone taper.

This suggests that each of the configurations was successful in guiding participants away from the lane closure. In all configurations, the 200 yard sign was only examined directly by six or fewer participants. Furthermore, only one participant was in lane 3 any closer than 400m from the cone taper (this was in the Chapter 8 layout) and so the extra information provided by the 200 yard sign was only relevant for a very small proportion of participants (unless one considers the unlikely possibility that a driver in lane 2 may consider moving out into lane 3 to overtake slower moving vehicles at a distance closer than 400m from the start of the cone taper).

The questionnaire results suggest that of the new layouts under test, participants had a subjective preference for Layout 1. There was a tendency to report that the number of signs in Layout 1 was appropriate and it was easy to understand the information being presented.

The very small number of participants for whom the 200 yard sign is relevant suggest that the TTM configurations as presented in the simulator were successfully conveying the information to participants that they needed to merge into lane 2 from lane 3 in good time before the lane closure and before they reached the 200 yard sign. This suggests that the 200 yard sign did not play a significant role in ensuring participants changed lane to avoid the closure of lane 3.

4.1 Implications for deployment of TTM

The most significant change with Layout 1 is the removal of the 600 yard sign. The use of this layout on the network would reduce exposure to risk for workers due to a 20% reduction in the number of carriageway crossings required to deploy the TTM. Based on the results achieved in this study, removal of the 200 yard wicket sign could now be considered since all participants had merged into lane 2 before this sign. This would further reduce the risk to road workers in deploying the TTM.

4.2 Summary

The results of this research project indicate that regardless of the design of TTM, drivers behave in a safe and consistent manner. The findings show there were no significant changes in any safety critical behaviour on the approach to roadworks with the proposed alternate layouts. This suggests that any of the three alternate TTM designs could be used on the network safely.

To ensure that all the objectives of this task are achieved and that driver safety is protected, an on-road trial to test the use of Layout 1 is recommended. The use of Layout 1 involves the removal of two features from the standard configuration (600 yard wickets, Detail A). After approaching traffic management contractors regarding the on-road trial of an alternate TTM configuration, it is clear that the changes made in Layout 1 are considered relatively superficial and could be covered by the current risk assessment procedures. Future studies could consider the removal of the 200 yard sign as the driver behaviour and eye tracking results suggest that its absence would not adversely affect road safety.
Acknowledgements

The work described in this report was carried out in the Human Factors and Simulation group of the Transport Research Laboratory. The authors are grateful to Iain Rillie who carried out the technical review and auditing of this report.

References


ARTSM & RSMA (1998) Cosmetic or crucial? The case for good signing and lining Association for Road Traffic Safety and Management & Road Safety Markings Association: Teddington, UK.


Bourne, N; Gillan, W; Notley, S; Taylor, N and Webster, D (2008) A review of literature on the nature of the impact of road works on traffic movement and delay Published Project Report PPR348 TRL: Crowthorne, UK.


Cairney, PT (1981a) An analysis of wrong responses to some proposed symbols for traffic signs ARRB Internal Report AIR 1106-2 Australian Road Research Board Ltd: Victoria, Australia.

Cairney, PT (1981b) Knowledge of road signing ARRB Internal Report AIR 1106-1 Australian Road Research Board Ltd: Victoria, Australia.

Cairney, PT (1989) Understanding traffic control devices ARRB Special Report 44 Australian Road Research Board Ltd: Victoria, Australia.

Cameron, C and McGill, A (1968) A competitive evaluation of speed control signs ARR 3(8) Australian Road Research: Victoria, Australia.


Dewer, RE and Ells JG (1982) *Techniques for the design and evaluation of traffic signs* RTAC Forum 4(2) Regional Transportation Advisory Committee: Duluth, MN, USA


Institute of Transportation Engineers (1997) Traffic Signing Handbook ITE: Washington D.C., USA

Jacobs, RJ (1977) Mixed use of alphabetic and symbol messages Letter to the Editor ARR 7(3), pp.52-54 Australian Road Research: Victoria, Australia.

Jacobs, RJ; Johnson, AW and Cole, BL (1975) The visibility of alphabetic and symbolic traffic signs ARR 5(7) Australian Road Research: Victoria, Australia.


Mackie, AM (1967) Progress in learning the meanings of symbolic traffic signs Research Report LR91 RRL: Crowthorne, UK.

McCarthy, JV and Hoffmann, ER (1977) The difficulty that traffic signs present to poor readers Department of Mechanical Engineering, University of Melbourne: Parkville, Australia.


RRL (1965) Research on Road Traffic HMSO: London

Standards Australia (1992) Development, testing and implementation of information and safety symbols and symbolic signs Australian Standard 2342 Standards Australia: North Sydney, Australia.


Appendix A  TRL Car Driving Simulator

A.1 TRL Driving Simulator

TRL has successfully operated a driving simulator for more than 15 years and in that time the simulator has seen a number of different incarnations to keep pace with improvements in vehicle, projection, computing, and simulation technologies and as such is one of the most advanced simulators in the UK. The latest iteration uses a Honda Civic family hatchback (see Figure A.1). Its engine and major mechanical systems have been replaced by a sophisticated electric motion system that drives rams attached to the axles underneath each wheel. These impart limited motion in three axes (heave, pitch, and roll) and provide the driver with an impression of the acceleration forces and vibrations that would be experienced when driving a real vehicle. This significantly enhances the realism with which drivers approach the driving task and reduces the incidence of simulator sickness (a condition with symptoms similar to those of motion sickness) among participants. All control interfaces have a realistic feel and the manual gearbox can be used in the normal manner (automatic gears can be simulated).

![Figure A.1 TRL Car Driving Simulator](image)

Surrounding the simulator vehicle are large display screens onto which are projected the graphic images that represent the external visual environment to the driver. The level of environmental detail includes photo-realistic images of buildings, vehicles, signing, and markings, with terrain accurate to the camber and texture of the road surface. We have also recently added the capability to simulate night-time driving scenarios. The driving environment is projected at a resolution of 1280x1024 onto three forward screens to give the driver a 210° horizontal forward field of view. The presence of the two flat side screens adjacent to the driver gives a very strong impression of other vehicles travelling alongside of the vehicle. A rear screen provides a 60° rearward field of view, thus enabling normal use of all mirrors.
Surveillance video cameras are mounted in the car and participants can be recorded during their drive. There is also an intercom facility for communication between the vehicle and the control room. An in-car colour LCD display can also be used to give instructions or provide other task-related information.

Figure A.2 TRL Car Driving Simulator: Control Room

More than one hundred autonomous traffic vehicles can be programmed to participate in the simulation. TRL has a library of different vehicle types to choose from including cars, trucks, buses, emergency vehicles, bicycles, and pedestrians. Each obeys specific driving rules to behave in a normal manner with respect to other traffic vehicles. However, these can be overridden causing them to perform specific manoeuvres e.g. emergency stop, sudden lane change etc. The autonomous vehicles also have dynamic properties of their own – they appear to pitch realistically under acceleration and braking, and vehicle graphics include body tilt and roll under braking, acceleration and turning; speed dependent rotating wheels and fully working brake, indicator, fog, and head lights. These provide additional cues to the driver and greatly enhance the realism of a scene. To generate scenarios with a heavy traffic load (> 1700 vehicles per lane per hour) we can generate a vehicle ‘swarm’. The swarm function allows us to define a region around the driver where vehicles will be placed and controlled. A vehicle moving out of the visible range of the driver is replaced by a new vehicle positioned to maintain the desired traffic density. This gives the impression of very high volume of traffic while maintaining the performance of the simulator.

A stereo sound system with speakers inside and outside the vehicle generates realistic engine, road, and traffic sounds to complete the representation of the driving environment. The software used to implement the simulation is called SCANeR II and was created by OKTAL to provide a flexible and powerful simulation with a highly advanced traffic model. It is employed by more than twenty research institutes across the globe and TRL leads the user group with access to OKTAL expertise for trial set-up and integration, if required.

The dynamics of the vehicle are modelled using a validated vehicle model that is used for product development by Renault. The model interprets the driver’s control inputs, relates
them to the current vehicle status and computes a prediction of how a real vehicle would behave in the given circumstances. The system then responds to present to the driver its optimal representation of how this behaviour would be perceived through the visual, sound, and motion sub-systems. The vehicle dynamics are updated at 100Hz whilst the visuals are refreshed at 60Hz so that the driver perceives a seemingly continuous driving experience. Data is then recorded relating to all control inputs made by the driver, including steering, pedals, gear, indicators; vehicle parameters such as speed, RPM; and parameters to assess behaviour in relation to other vehicles such as distance and following times. The data recording rate is fully controllable dependent upon the trial demands, up to a rate of 100Hz.

The simulator also includes a full integrated SmartEye eye-tracking system for the analysis of driver visual behaviour. This system, in addition to being able to report the driver’s gaze direction, is integrated with the 3D environment presented in the simulation, such that the eye-tracker can report in the simulator data the specific element on which the participant is fixating – a specific road sign, traffic light, the road ahead, or interior items such as the instrument panel or infotainment system. This dramatically improves the accuracy and efficiency of post-trial data analysis.

Participants for trials are recruited from a dedicated database of over 1000 members of the public. This comprises drivers from a wide range of ages and backgrounds, all of whom are familiar to TRL such that participants from particular demographic bands or driving experience/ability ratings can be selected to suit the trial requirements. The simulator facilities include a medical room for taking any physiological measures and trials management staff are trained in Good Clinical Practice. There is an interview room for questionnaire completion and debriefing and an information room for conducting computer based test or training tasks. Data management procedures are well established and compliant with the Data Protection Act 1998 to ensure security, confidentiality, and integrity of all records.
Appendix B  Simulator data

*Error! Reference source not found.* shows the measures collected from the simulator trial at 20Hz throughout each simulator drive.

Table 6: Data collected by the simulation computers at 20Hz

<table>
<thead>
<tr>
<th>Measure</th>
<th>Unit of measurement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Number of Glances</em></td>
<td>Count of glances at target</td>
<td>Number of times a driver has glanced at a sign</td>
</tr>
<tr>
<td><em>Total Glance Duration</em></td>
<td>Seconds</td>
<td></td>
</tr>
<tr>
<td><em>Mean Glance Duration</em></td>
<td>Seconds</td>
<td>The average amount of time that a person has spent looking at a sign</td>
</tr>
<tr>
<td><em>Mean Distance</em></td>
<td>Metres</td>
<td>The average distance that a driver is from a sign when they glance at it</td>
</tr>
<tr>
<td><em>Maximum Brake Position</em></td>
<td>0-1; where 0 = no pressure, 1 = maximum braking</td>
<td>The maximum depression of the brake pedal by the driver when braking in the roadworks zone</td>
</tr>
<tr>
<td><em>Mean Speed</em></td>
<td>Miles per hour</td>
<td>The average speed of the vehicle during the roadworks zone</td>
</tr>
<tr>
<td><em>Maximum Speed</em></td>
<td>Miles per hour</td>
<td>The maximum speed of the vehicle during the roadworks zone</td>
</tr>
<tr>
<td><em>Minimum Speed</em></td>
<td>Miles per hour</td>
<td>The minimum speed of the vehicle during the roadworks zone</td>
</tr>
<tr>
<td><em>Standard Deviation of Speed</em></td>
<td>Miles per hour</td>
<td>The standard deviation of vehicle speed during the roadworks zone</td>
</tr>
<tr>
<td><em>Mean speed at start</em></td>
<td>Miles per hour</td>
<td>Mean speed at the start of the roadworks zone</td>
</tr>
<tr>
<td><em>Speed at lane change</em></td>
<td>Miles per hour</td>
<td>Mean speed at the time the participant changed lane in the roadworks zone</td>
</tr>
<tr>
<td><em>Distance from taper</em></td>
<td>Metres</td>
<td>Distance from the taper when the lane change occurred</td>
</tr>
<tr>
<td><em>Lane change gap</em></td>
<td>Seconds</td>
<td>The gap to the vehicle in front when the lane change occurred</td>
</tr>
<tr>
<td><em>Headway Far</em></td>
<td>Seconds</td>
<td>The headway to the vehicle in front when over 1 mile from the roadworks zone</td>
</tr>
<tr>
<td><em>Headway Near</em></td>
<td>Seconds</td>
<td>Headway to the vehicle in front when less than 1 mile from the roadworks zone</td>
</tr>
</tbody>
</table>
Appendix C   Trial Questionnaire

To be completed by TRL
Participant Number: ___________________  Date of Trial: ______/_____/_______

Driving Simulator Study: Temporary Traffic Management

SECTION A
DRIVER PROFILE

Note:
- All information on this form is confidential.
- It will be stored securely at TRL.
- No information will be used by other projects at TRL.
- No individuals will be identified.

A1.   Name

A2.   What was your age at your last birthday?

A3.   Are you Male or Female (tick)?

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
</table>

A4.   How many years have you held a full driving licence?

A5.   Approximately how many miles have you driven in the last year?

A6.   What type of vehicle(s) do you drive (tick all those that apply)?

<table>
<thead>
<tr>
<th>Motorcycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
</tr>
<tr>
<td>Light Goods Vehicle</td>
</tr>
<tr>
<td>Heavy Goods Vehicle</td>
</tr>
</tbody>
</table>
SECTION B
YOUR DRIVING

(Please circle the number that you feel is most appropriate)

<table>
<thead>
<tr>
<th>B1. In general, do you enjoy driving?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely dislike driving</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B2. How many days in a typical week do you drive?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B3. How confident do you feel when driving generally?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unconfident</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B4. How confident do you feel when driving on motorways?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very unconfident</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>
### SECTION C
#### ROADWORKS SIGNS

In the simulator drive, you passed through four sets of roadworks. Each differed in the configuration of signs used to give information to the driver.

The following questions relate to your experience in driving through the roadworks and the effectiveness of the signs in giving you information.

| C1. In which set of roadworks were the signs **EASIEST** to understand? |
|---|---|---|---|---|
| First | Second | Third | Fourth |

(Please select one answer)

| C2. For the roadworks in your answer to question C1, how clear was the information provided? |
|---|---|---|---|---|---|---|---|---|
| Completely unclear | Completely clear |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| C3. In which set of roadworks were the signs **HARDEST** to understand? |
|---|---|---|---|---|
| First | Second | Third | Fourth |

(Please select one answer)

| C4. For the roadworks in your answer to question C3, how clear was the information provided? |
|---|---|---|---|---|---|---|---|---|
| Completely unclear | Completely clear |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| C5. Through the simulated drive you came across the different signs below: |
|---|---|---|
| (a) | (b) | (c) |

Please state below what each sign means:

(a)
### Signs giving instructions about lane use were present through the simulator drive. For the following questions please refer to the picture provided.

**C8(a).** Imagine you were on the motorway shown in the picture provided. If you saw this sign, which lanes does it suggest would be available ahead for normal traffic?

(Select one or more as appropriate)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

**C8(b).** How confident are you that your answer to C8(a) is correct?

<table>
<thead>
<tr>
<th>Very unconfident</th>
<th>Very confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

**C9(a).** Imagine you were on the motorway shown in the picture provided. If you saw this sign, which lanes does it suggest would be available ahead for normal traffic?

(Select one or more as appropriate)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

**C9(b).** How confident are you that your answer to C9(a) is correct?

<table>
<thead>
<tr>
<th>Very unconfident</th>
<th>Very confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

**C10.** The number of signs varied between each set of road works. Which set or road works had a sufficient number of signs to understand what you had to do?

(Please select one answer)
- **C11.** In the drive did you ever feel overloaded by the number of signs?
  - Yes
  - No

- **C12.** If Yes, which set of road works did you find had too many signs?
  (Please select one answer)
  - 1
  - 2
  - 3
  - 4

- **C13.** Did you ever feel that there were too many signs such that you felt overloaded by the number of signs that were present or unable to take in all the information they provided?
  - Yes
  - No

  - **Road works 1**
  - **Road works 2**
  - **Road works 3**
  - **Road works 4**

- **C14.** Did you completely understand what you were meant to do when driving through each set of road works?

<table>
<thead>
<tr>
<th>Road works 1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road works 2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Road works 3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Road works 4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

- **C15.** How safe did you feel when following the instructions given on the signs whilst approaching the road works?

<table>
<thead>
<tr>
<th>Not at all safe</th>
<th>Completely safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

- **C16.** Did you change lanes when approaching the road works?
  - Yes
  - No

- **C17.** If yes, How safe did you feel when changing lanes on the approach to the road works?

<table>
<thead>
<tr>
<th>Not at all safe</th>
<th>Completely safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
C18. How safe did you feel when the traffic merged from three lanes to two?

<table>
<thead>
<tr>
<th>Not at all safe</th>
<th>Completely safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
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<tr>
<td>5</td>
<td>6</td>
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<td>7</td>
<td>8</td>
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<tr>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>


| C19 | If you have any other thoughts about the signs used to manage traffic at motorway roadworks or have any other views about the simulator trial, please write your comments below |

**End of questionnaire**

Thank you very much for your participation
Appendix D  Alternative TTM configurations tested in Phase 2

D.1 Chapter 8 control layout

Below is an example of the control layout for this trial. This configuration is from the Traffic Signs Manual Chapter 8 and is the basis for relaxed closures on dual-carriageway roads:

![Figure 18: Chapter 8 layout – control layout for this study](image)

The proposed approach was to use this current layout as a template, and adjusts the signage in various ways. Maintaining a familiar overall layout of TTM is of benefit; drivers are more likely to except changes that are based on an existing layout.
D.2 Layout 1: Minor change

Within this proposed layout (shown in Figure 19) the Detail ‘A’ has been removed from the hard shoulder since under normal circumstances traffic should not use the hard shoulder and removing the Detail ‘A’ improves access for vehicles that have broken down and for emergency vehicles attempting to respond to any incident. A Keep left/right arrow sign and two lane closure signs have been removed from within the taper. The 600 yard “wicket board” sign has also been removed on both sides of the carriageway.

Figure 19: Layout 1: Minor change – Simple sign reduction
D.3 Layout 2: Moderate change

For the moderate change shown in Figure 20, the changes in and around the taper remain the same. The 800 yard “wicket board” sign is removed, replaced by a “road works” (Diagram 7001) triangular warning sign. The 1 mile supplementary plate underneath it is also removed. The 600 yard and 400 yard “wicket board” signs are replaced with “hooked arrow” signs. The distance information on these signs is removed completely; however at the 400 yard position the distance information has been replaced with a bottom panel containing the advisory message ‘Now’.

Replacing the “wicket board” signs with “hooked arrow” signs is a move towards harmonisation with permanent road signs. It may also provides the driver with a clearer message of what they have to do unlike a standard “wicket board” sign that shows that the lane ahead is closed, but gives the driver no instruction.

![Diagram of Layout 2: Moderate change – Use of hooked arrows](image-url)
**D.4 Layout 3: Large change**

This change did not come out of the workshop directly but was developed by TRL using a number of concepts from the literature and the workshop. The changes within this layout build on the use of a “hooked arrow” sign and removal of signage. Only one Keep left/right arrow sign and lane closure sign is used in the taper; this is located approximately in the middle of the taper (subject to clearance/road space availability). This change in position brings the sign into the driver’s direct sightline, which research suggests (Wilkie and Wann, 2002) will increase the chances that a driver will detect the sign from a greater distance.

Based on research into conspicuity, there is a change to the men at work warning triangle, which gives the driver their first indication they are travelling into a roadworks area. The distance plate has been removed and synchronous amber flashing lights attached to the corners of the sign face. The intention is that the lighting would aid the conspicuity of the sign, communicating the triangular “hazard” shape to approaching drivers and thus ensuring that drivers would not pass the sign without looking at it. The removal of the supplementary distance plate is intended to cause the driver to seek...
information on how far away from the roadworks they are, looking past the signs to the roadworks, taper and cone. This may focus a driver’s attention on the traffic conditions and may lead to drivers merging earlier. The distances have been altered slightly, moving the 200 yard “wicket board” sign to 300 yards and moving the 600 yard “wicket board” sign to 700 yards. It is anticipated that giving information earlier to drivers would encourage earlier decisions to change lane in some drivers who follow the advance merge sign.